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Editorial.

The Marconi Licensing Settlement.

IN our July issue, on page 368, we reported briefly that the Marconi Company had won a High Court appeal against a decision of the Comptroller-General of the Patent Office, under which royalties in respect of the use of Marconi patents for the construction of broadcast receiving apparatus were to be reduced from the usual basis of 12s. 6d. per valve stage to 10 per cent. on the wholesale selling price of a receiver, subject to a minimum charge of 5s. on the first valve and 2s. 6d. on each additional valve stage.

The success of the appeal in the High Court entitled the Marconi Company to claim the full royalty on the old basis of 12s. 6d. per stage on all apparatus sold by licensees since the case for a reduction came up before the Comptroller-General of the Patent Office in August of last year. Since many manufacturers had been over-confident that the decision of the Comptroller would stand, they had not made provision for the possibility of having to pay royalties on the old basis, and the Radio Manufacturers' Association, as representing the licensees, got into touch with the Marconi Company immediately the High Court decision was made known, with the object of trying to arrive at some compromise to relieve the trade of the burden of having to pay the full royalties retrospectively.

As we go to press we understand that the Marconi Company has agreed to a new licence on a five years' basis under which royalties will be 5s. per valve stage on all apparatus, whether such apparatus includes Marconi patents or not, and in respect of mains eliminator apparatus as a battery substitute for use with broadcast receiving apparatus the royalty to be 5s. The main heads of the new agreement are given on page 485.

Such an arrangement is, we consider, a compromise in every sense of the word. It is distinctly to the advantage of the Marconi Company that they should be able to guarantee a revenue over five years from patents which have already earned substantial revenue and some of which are due to expire during this period of five years or have already expired. The trade, on the other hand, also gains substantially, since they are relieved of the burden of having to pay at the rate of 12s. 6d. per valve stage as from August of last year up to the time that their present agreement would be due to expire. The present royalty of 5s. per valve-holder will, in many instances, be more advantageous to the licensee than the terms laid down in the decision of the Comptroller-General of the Patent Office, against which the Marconi Company appealed.

The Frequency Departure of Thermionic Oscillators from the "LC" Value.

By Instructor-Lieutenant S. W. C. Pack, A.C.G.I., M.Sc., R.N.

SUMMARY.

The article gives an account of work carried out at the City and Guilds (Engineering) College under the supervision of Professor C. L. Fortescue, M.A., and Professor E. Mallett, D.Sc., during 1927. It describes investigations in the departure of the frequency of valve oscillators from the " LC " value under varying conditions of grid coupling, grid bias, filament current, anode voltage and added resistance in the oscillatory circuit, the investigations being made by a new method. The work is divided into the following sections :—

Section I.—Introduction and general outline of the scheme with comparison of previous work on measurements of frequency variation of thermionic oscillators.

Section II.—Exact procedure and various refinements in the proposed method of investigation.

Section III.—The comparison of the maintained tuning fork frequency against standard time as given out by Greenwich time signals.

Section IV.—The frequency departure from the " LC " value is here dealt with fully. The theory of the frequency of oscillations is given first neglecting and then considering grid current. The expected accuracy of results is estimated and it is found that while the frequency variation is measurable to a very high degree of accuracy, about 1 in 40,000, the measurement of the actual departure from the " LC " value is somewhat uncertain owing to the smallness of this term in comparison with the possible error obtained in measuring the values of L and C. Curves of results obtained with varying conditions such as grid coupling filament current, anode voltage, etc., are given and are explained in the light of the theory. The frequency departure on the average varied between about 110 beats per minute to 160 beats per minute below the " LC " frequency, *i.e.*, the frequency variation was 50 beats per minute (almost 1 cycle per second), about an average departure of 2½ cycles per second below the " LC " frequency. In most cases the variation was much smaller than this, about ½ cycle per second, but in the case of adding resistance to the " L.C." circuit the frequency departure increased from 150 beats per minute to 260 beats per minute below the " LC " frequency, *i.e.*, a frequency variation of about 2 cycles per second. The " LC " frequency was about 640 cycles per second. In a practical case with a combination of small variations in the conditions due to batteries running down, etc., the frequency would probably increase by about ½ cycle per second, *i.e.*, about 8 parts in 10,000 or 0.08 per cent.

Section V.—Criticism of the research work in general. The method has proved to be effective and the results obtained form a good groundwork for further research on the subject. Arising from experience gained in the work, various suggestions are put forward for further research on the frequency variation of valve oscillators.

I. Introduction.

THE thermionic valve adapted as a generator of oscillations has the advantage of being able to give any desirable frequency within limits; these oscillations are controllable to a fair degree of accuracy by variations of the values of the inductance L and the capacity C of the oscillatory circuit. To a very much smaller extent the frequency of these oscillations also depends on the ohmic resistance of the oscillatory circuit, the anode resistance of the valve, the filament current, the anode voltage, and the coupling between the grid and anode coils. It is our purpose in the present investigation to keep L and C of the oscillatory circuit constant and thus fix what we will henceforth refer to as the " LC " frequency, f_0, at a constant value

$$f_0 = \frac{1}{2\pi\sqrt{LC}},$$

and by changing the conditions such as anode voltage or grid coupling whose effects we want to investigate, to vary slightly the actual frequency f of the oscillator. It is these variations that we want to determine

In previous experiments in the frequency variation of thermionic valve oscillators

(i) and (ii), the exact frequency departure has not been measured. Instead, the frequency has been kept constant at some value by making small changes in the capacity of the oscillatory circuit as the conditions are varied. The advantage of the present method is that the frequency differences themselves are actually measured, the capacity and inductance of the oscillatory circuit being kept constant as in a practical case. The usual trouble underlying the determination of small frequency differences is the sudden tendency for two frequencies to "lock" into one frequency as they approach a common value. This tendency to lock is avoided in these experiments, as explained later.

The actual frequency f of the oscillator will differ from f_0 by an amount depending on the factors mentioned above, viz., grid coupling, grid bias, anode voltage, filament current, and resistance. To determine $(f_0 \sim f)$, the departure of frequency from the "LC" value, we must determine f experimentally and calculate f_0 from the known L and C values. To determine f the oscillator frequency, we must produce beats between it and a known frequency and so deduce f by counting the beats: whether f is above or below the known frequency can easily be determined by slight capacity increases in the oscillator, thus reducing f and indicating whether beats should increase or decrease. In the present case, the "LC" values were arranged to give an f_0 which was exactly equal to the known frequency (*i.e.*, a tuning fork harmonic) and so the beats between the known frequency source (of frequency f_0) and the oscillator (of frequency f) gave the frequency departure $(f_0 \sim f)$ direct.

II. Proposed Method of Investigation.

Before we can make any satisfactory measurement on frequency variation, we require to have some reliable source of constant frequency. The smaller our measurement of frequency drift is to be the more nearly constant must our frequency source be. We naturally turn then for our frequency standard to the tuning fork. To maintain it, it is proposed to adopt the method first suggested by Eccles (iii), *i.e.*, by using a thermionic triode and connecting up as described in a previous article (iv). From some part of the tuning fork circuit it is proposed to take a supply to an amplifier employing fairly high grid bias so as to introduce many harmonics and then produce in a loud speaker or telephone a note rich in harmonics of a fundamental frequency exactly equal to the tuning fork frequency. We now have our constant frequency supply, but the frequency so far is not accurately known. To determine the frequency, a synchronous motor or phonic wheel is to be synchronised with the tuning fork frequency through a system of amplifiers from the fork circuit, and by running for a long period of time with a train of dials recording the revolutions, will indicate relatively to some scale the frequency of the maintained tuning fork. The exact procedure and various refinements for ensuring accuracy have been dealt with in a previous article mentioned above.

We will now suppose we have developed our known constant frequency source and are ready for our oscillator experiments. If a loud speaker is inserted in the oscillator circuit we can beat the oscillator frequency against the tuning fork frequency or one of its harmonics. The conditions in the circuit of the valve oscillator may now be varied as required, L and C being kept constant, and the variation in the frequency determined by the alteration in the number of beats. The fact that the oscillator circuit and tuning fork circuit are isolated from one another prevents any locking into a common frequency which might otherwise occur.

The foregoing method appears to be quite straightforward, but actually the constant frequency source gave more trouble and waste of time than one would expect. In the first place maintaining a low-frequency fork by a thermionic valve is no easy matter and requires careful study and design of the operating circuit. Assuming the fork to be maintaining satisfactorily, the next problem is to synchronise the phonic wheel, and there is a large degree of uncertainty in accomplishing this feat.

(i) *Royal Soc. Proc.*, 96, pp. 455–465.
(ii) *Royal Soc. Proc.*, 108, pp. 216–231.

(iii) *Phys. Soc. Proc.*, Vol. 31, 1919.
(iv) *E.W. & W.E.*, Sept., 1927, "A Constant Frequency Source."

III. The Exact Frequency of the Maintained Fork.

(a) *Comparison with Greenwich time signal.*

After much preliminary work the tuning fork maintained strongly, and the synchronous motor pulled into step satisfactorily, so preparations were made to determine accurately the frequency of the maintained tuning fork. The number of vibrations made by the fork were recorded by the dials to a known reduced scale as already referred to, and it was only required therefore to determine the exact number occurring during some definite known period of time. The standard of time used was the College electric clock (checked up by Greenwich time signals). During the test the eye of the observer had to be kept on the dials of the synchronous motor, so it was essential therefore to convey by sound, to the observer, the exact instant at which to make his observation. To accomplish this, two leads were connected across the series coil of one of the electric clocks and connected to the high-resistance side of a small telephone transformer to safeguard against shorting the series coil. The other side of the transformer was taken to a pair of phones in the room where the observations were being made, and here one could listen to the half-minute ticks of the electric clock, while watching the synchronous motor dials. A stop watch set at the same time as the electric clock gave some indication of the approach of the tick of the clock, and also indicated the particular minute of the hour at which the reading was taken. The stop watch acted as a sort of rough adjustment, and the click in the phones provided the fine adjustment. The fork and motor were run for several hours so that an accurate measurement could be made. Five consecutive readings at minute intervals were taken at the commencement of the trial so as to get a good mean figure for the dial reading corresponding to a given instant. Similarly at the end of the trial five consecutive readings were taken and the mean value obtained. Actually intermediate readings were taken in the same way during the whole of the trial at various periods, for it was never certain when the motor would not pull out of step and slow down. Graphs were plotted of the initial readings and the final readings with the idea of getting the initial and final mean reading quite accurately, but it was found that the dial readings themselves had been taken really accurately and could be relied upon to $\frac{1}{20}$ of a unit after some practice. From this we can get some idea of the accuracy in a five-hour test. There is an initial and final reading, the latter to be subtracted from the former. This figure we can rely upon to about $2 \times \frac{1}{20} = \frac{1}{10}$ of a unit.

According to the scale of reduction, on the dial $\frac{1}{10}$ unit corresponds to $20 \times 12 \times \frac{1}{10}$ vibrations of fork, *i.e.*, the possible error in five hours is 24 vibrations of fork.

The total number of vibrations in five hours is about $5 \times 60 \times 60 \times 128$, so our error is of the order

$$\frac{24}{5 \times 60 \times 60 \times 128} \times 100\,\% = 0.001\,\%$$

or 1 in 100,000 approx.

The readings at various instances were tabulated and initial and final mean readings obtained for calculation.

Temperature of room = 67.5 deg. F.
Temperature of fork = 64.1 deg. F.

Our initial mean reading is 275.84 at 11.16 a.m.

Our final mean reading is 9,696.75 units at 4.11 p.m. By subtraction we get 9,420.91 units in 295 minutes.

Hence vibrations per second $= \frac{9{,}420.91 \times 4}{295}$

Frequency of maintained fork

$= 127.741_{15} \ldots$ at 64.1 deg. F.

(*b*) *Remarks.*

We have seen that the resultant frequency value could be relied upon to within 1 part in 100,000. This was borne out in the actual result for it was found that all values estimated over a three-hour period gave the figure 127.741. . . Over a three-hour period we should expect an accuracy of 2 in 100.000 and over a one-hour period 5 in 100.000. The following figures were actually deduced :—

Three-hour period (11.33 a.m. to 2.14 p.m.) . . . 127.7396 . . .

One-hour period (2.14 p.m. to 3.14 p.m.) . . . 127.7445 . . .

We may, therefore, assume that at a

constant temperature the frequency of the fork varied a negligible amount, so we may rely upon the frequency as determined, 127.741 . . . at 64.1 deg. F.

It would have been interesting to determine the frequency variation with temperature variation, but so much time had already been taken up with the constant frequency source that it was considered advisable to proceed with the oscillator experiments. Additional apparatus would have been necessary for varying temperature, and much time taken up. Hence in the absence of any further investigation on valve maintained tuning forks (especially low-frequency forks), we must accept the results established by D. W. Dye for a high-frequency fork (1,000 cycles), viz., 1 deg. C. increase in temperature causes a decrease in frequency of 1.15 parts in 10,000.

and ran all right, but, unfortunately, no time was left available in which to investigate and explain the cause of this change in conditions. A frequency reading was taken which lasted $2\frac{1}{2}$ hours, and following that the research work ended. It is mentioned here, however, in view of the large frequency change probably brought about by removing the earth connection.

The result of the $2\frac{1}{2}$ hours' trial gave a frequency of 127.968_{44}..at temperatures :— Fork temperature 68.65 deg. F. Room temperature 69.72 deg. F.

Expected decrease in frequency from the previous measurement due to increase of fork temperature would have been, according to Dye's figure, as follows :—

$$\frac{100\ (68.65 - 64.1)}{180} \times 1.15 \text{ parts in } 10{,}000,$$

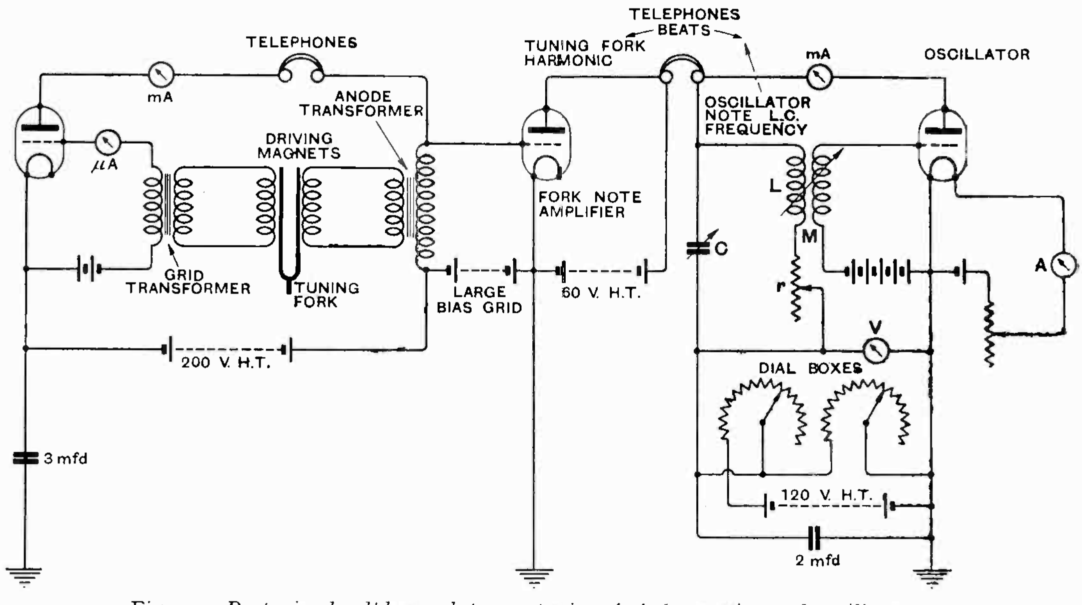

Fig. 1.—*Beats in headphones between tuning fork harmonics and oscillator note.*

Actually, about six weeks later, when the normal temperature was much higher, a frequency determination was made after the oscillator work had been done. It was then found, however, that the motor would not synchronise under the previous conditions, and the measurement was taken with the earth connection to the fork circuit disconnected. The motor then synchronised

i.e., 2.9 parts in 10,000, or 3.7 parts in 12,774, and we should expect a frequency of

$$127.741_{15} \ldots - 0.037$$
$$= 127.704 \sim$$

We may look, therefore, upon the difference between the unearthed and earthed conditions, in the absence of further information, as being responsible for a frequency change of $127.968_{44}..- 127.704$, *i.e.*, 2.64 parts in 1,000, which shows that we must be extremely careful to keep the earthing arrangements of the constant frequency source always the same. It would be interesting to see the results of experiments in this direction made at constant temperature, that is using a maintained fork of non-expansible alloy and a really constant temperature cell.

IV. Frequency Departure from the Theoretical "LC" Value.

(a) *Arrangement of Oscillator and Constant Frequency Source.*

The diagram of connections in Fig. 1 indicates the arrangement for obtaining beats between the oscillator and the constant frequency source.

The oscillator used in these experiments was a low-frequency tuned anode oscillator, with tappings on the anode coil, and may be seen in the photograph in Fig. 2. The grid coil, which also has tappings, can be seen supported on the central wooden shaft and is capable of sliding on this shaft to regulate the coupling between it and the anode coil. The anode coil is in sections, the taps at each section being brought out to the row of brass terminals seen on the side of the box. The valve holder and grid bias batteries were housed inside the box; the remaining apparatus, including condensers, coils, meters, and additional apparatus for the test, were arranged outside the box in the most accessible manner. The wooden shaft, on which slides the grid coil, is marked in cms., commencing from the right-hand end at zero. The position of the grid coil relative to the fixed anode coil can then be noted by referring to these figures on the shaft. The figure quoted is that which is flush with the right-hand end of the cylinder on which the grid coil is wound. When the grid coil is just clear of the anode coil the figure is 0 cms., and when the grid coil is completely within the anode coil the reference figure is 23.8 cms. The oscillator was connected up as indicated in Fig. 1. The valve used was a Marconi D.E.R. The high-resistance dial boxes across the 120-volt H.T. supply were for the purpose of varying the anode voltage. The resistance "*r*" was a special variable high-frequency non-inductive resistance box of the plug-in type made by Gambrell, for the purpose of inserting resistance in the oscillatory circuit. The condensers were a 1,000 jar, 8 jar, and 1 jar, Navy pattern, all in parallel. These all had to be calibrated in position.

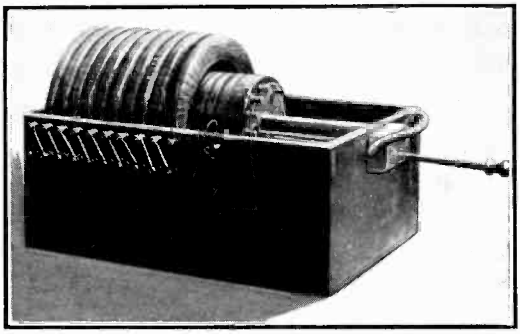

Fig. 2.—*L.F. oscillator under test.*

A filament resistance was inserted for the purpose of reducing the filament current, an ammeter inserted recording the latter. One headphone of a pair of headphones was connected in the anode circuit. The whole of this apparatus was on a different bench from that of the constant frequency source, and all the batteries were entirely distinct.

The connections to the constant frequency source may also be seen in Fig. 1. As in the case of the frequency determination supply was taken from across the transformer winding in the anode circuit of the maintaining valve, to an amplifier. The amplifying valve used was a D.E.5B., so that with a good grid bias the steep slope and cut-off characteristic of this valve could be made to distort the wave form, and produce a note rich in harmonics. The other headphone of the pair of headphones recently mentioned was now connected in the anode circuit of the amplifier, and thus produced a note whose fundamental frequency was exactly that of the maintained tuning fork and whose harmonics were exact multiples. The observer can now listen to beats between the oscillator and tuning fork by wearing the headphones, and in this way he is able to determine accurately the frequency of the oscillator at any time by comparison of known frequency of the constant frequency source.

The procedure in detail is described in sub-section (*c*). We now turn to the theoretical side of valve oscillator frequencies.

(*b*) *Theory of Valve Oscillator Frequencies.*

List of Symbols :—

L = Inductance of anode coil in oscillatory circuit.
C = Capacity of anode coil in oscillatory circuit.
R = Resistance of anode coil in oscillatory circuit.
L_1 = Inductance of grid coil.
R_1 = Resistance of grid coil.
μ = Amplification factor.
R_a = Anode resistance of valve.

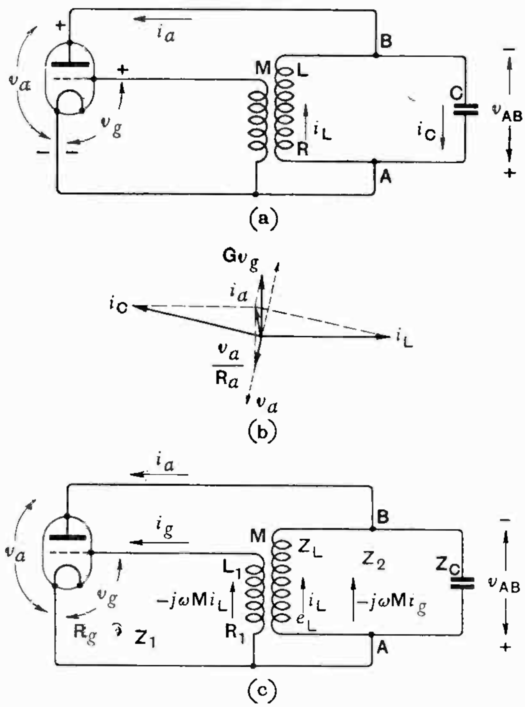

Fig. 3.—*Anode circuit oscillator theory.*

G = Grid conductance.
M = Mutual inductance between grid and anode coils.
I_a = Steady anode current.
V_a = Steady anode potential.
V_g = Steady grid potential.
i_a = Oscillating component of anode current.
v_a = Oscillating component of anode potential.
v_g = Oscillating component of grid potential.
i_L = Oscillating component of current in L.
i_C = Oscillating component of current in C.

The following theory neglecting grid current is due to Prof. C. Gutton, of Nancy. A further theory which considers grid current due to Prof. C. L. Fortescue will then follow.

Let us consider the sinusoidal variations about the steady values. These may be represented by the vectors, as shown in the vector diagram in Fig. 3 (*b*). The circuit is shown in Fig. 3 (*a*).

$$i_a = i_L - i_C,$$

also $$i_a = \frac{v_a}{R_a} + G \cdot v_g$$

$$i_aR_a = v_a + \mu v_g.$$

Now $$v_a = - v_{AB}$$
$$= i_L R - \frac{di_L}{dt} L$$
$$= - i_L (R + DL), \text{ where } D \equiv \frac{d}{dt}$$
$$v_g = - \frac{di_L}{dt} \cdot M.$$
$$= - MDi_L$$
$$i_C = C\frac{dv_a}{dt}$$
$$= - Ci_L(RD + LD^2),$$

and $$i_a = i_L + Ci_L (RD + LD^2),$$
$$i_aR_a = i_LR_a + CR_ai_L (RD + LD^2),$$

also $$i_aR_a = - i_L(R + DL) - \mu MDi_L$$

$$\therefore \{LCR_aD^2 + (CRR_a + L + \mu M)D + (R_a + R)\}i_L = 0$$

$$\left\{LD^2 + \left[R + \frac{1}{CR_a}(L + \mu M)\right]D + \frac{1}{C}\left(1 + \frac{R}{R_a}\right)\right\}i_L = 0$$

If $a = L$, $b = \left[R + \frac{1}{CR_a}(L + \mu M)\right]$, and $c = \frac{1}{C}\left(1 + \frac{R}{R_a}\right)$.

The auxiliary equation to this may be written :—

$$am^2 + bm + c = 0$$

and the solution of the differential equation is in the form :—

$$i_L = \epsilon^{mt}$$

where $m = -\frac{b}{2a} \pm \sqrt{\frac{b^2 - 4ac}{4a^2}}$.

The roots of m are real if

$$b^2 - 4ac > 0$$

i.e. $\left\{\left[R+\frac{1}{CR_a}(L+\mu M)\right]^2-\frac{4L}{C}\left(1+\frac{R}{R_a}\right)\right\}>0.$

This means that the circuit is aperiodic and is non-oscillatory.

The roots are imaginary if

$$b^2 - 4ac<0$$

i.e. $\left\{\left[R+\frac{1}{CR_a}(L+\mu M)\right]^2-\frac{4L}{C}\left(1+\frac{R}{R_a}\right)\right\}<0,$

and the current i_L is expressed in the form :—

$$i_L = A\epsilon^{-b/2a\,.\,t}\sin\left(\frac{4ac-b^2}{2a}\,.\,t+B\right)$$

$$= A\epsilon^{-at}\sin(\omega t+\theta)$$

$$\omega = \frac{1}{2L}\sqrt{\frac{4L}{C}(1+R/R_a)-\left[R+\frac{1}{CR_a}(L+\mu M)\right]^2} \quad .. \quad .. \quad 1$$

$$a = \frac{1}{2L}\left[R+\frac{1}{CR_a}(L+\mu M)\right]$$

is the damping factor, and when positive the sinusoidal oscillations of i_L are damped, *i.e.*, when M is positive, or when

$$-M<\frac{1}{\mu}(L+CRR_a).$$

A shock on the circuit will produce oscillations of a frequency corresponding to ω, but they will be damped out.

When a is negative, however, we have the important case of sustained oscillations. Not only are the oscillations sustained, but they are increased due to the negative damping until the limits of the characteristic curve of the valve take effect.

When a is negative $\left\{R+\frac{1}{CR_a}(L+\mu M)\right\}<0,$ and hence M must be negative and numerically greater than $\frac{1}{\mu}(L+CRR_a)$.

Hence critical $M = -\frac{1}{\mu}(L+CRR_a)$. Therefore the limit of oscillations occurs when

$$M = -\frac{1}{\mu}(L+CRR_a) \quad .. \quad 2$$

We therefore see that the frequency of oscillations produced is

$$f = \frac{1}{4\pi L}\sqrt{4L/C\left(1+R/R_a\right)-\left[R+\frac{1}{CR_a}(L+\mu M)\right]^2} \quad .. \quad .. \quad 3$$

We must remember, however, that we have deduced this from initial circumstances, and it merely relates therefore to the critical conditions of oscillation without regard to subsequent events. For instance, we must bear in mind that directly the critical value of M is satisfied and the oscillations commence it is likely that the amplitude of oscillations will increase until the saturation part of the characteristic is reached. In all probability the immediate result is that the R_a has changed in value, so we can no longer apply our derived equations to the circuit, for initial conditions are now altered. All we can say is that if M corresponds exactly to the critical value $-\frac{1}{\mu}(L+CRR_a)$, then the circuit will just oscillate at

$$f = \frac{1}{2\pi}\sqrt{1+\frac{R/R_a}{LC}},$$

neglecting grid current; but the slightest increase of M will alter conditions at once.

A slightly different method of treatment due to Prof. Fortescue is now given; here grid current is considered (see Fig. 3c).

R_g is the resistance offered by the grid path of the valve to the flow of i_g.

$$Z_1 = R_1 + j\omega L_1 + R_g$$

$$Z_2 = Z_L + Z_C$$

$$Z_L = R + j\omega L$$

$$Z_C = \frac{1}{j\omega C}$$

Now $v_g = i_g R_g = R_g\,.\,\frac{-j\omega M i_L}{Z_1}$

and $v_{AB} = -v_a = i_L Z_L - e_L + j\omega M i_g$

also $v_a = (i_L - i_a)Z_C$

i.e. $i_a = \frac{i_L Z_C - v_a}{Z_C}$

but $i_a = Gv_g + \frac{v_a}{R_a}.$

Combining these equations and eliminating i_a, v_a, v_g, we get i_L in terms of e_L, from which follows the effective impedance of the oscillatory circuit: *i.e.*, (e_L/i_L)

$$i_L\left(Z_2 + \frac{\omega^2M^2}{Z_1} + \frac{Z_C}{Z_1}\cdot GR_g j\omega M + \frac{Z_CZ_L}{R_a} + \frac{Z_C}{Z_1}\cdot\frac{\omega^2M^2}{R_a}\right) = e_L\left(1 + \frac{Z_C}{R_a}\right)$$

For oscillations we must have "effective Z" $= 0$, and if we equate the vertical component (j terms) of $Z_{eff.}$ to zero, we get:—

$$\omega L - \frac{1}{\omega C} - \frac{\omega^2M^2\omega L_1}{[(R_1+R_g)^2+\omega^2L_1^2]} - \frac{\omega ML_1GR_g}{[(R_1+R_g)^2+\omega^2L_1^2]C} - \frac{R}{\omega R_aC} - \frac{\omega^2M^2(R_1+R_g)}{\omega R_aC[(R_1+R_g)^2+\omega^2L_1^2]} = 0$$

i.e.,

$$\omega^4\cdot\frac{M^2L_1C}{[(R_1+R_g)^2+\omega^2L_1^2]} - \omega^2\left\{LC - \frac{ML_1GR_g + \dfrac{M^2(R_1+R_g)}{R_a}}{[(R_1+R_g)^2+\omega^2L_1^2]}\right\} + \left(1+\frac{R}{R_a}\right) = 0$$

(say) $$\alpha\omega^4 - \beta\omega^2 + \gamma = 0$$

then $$\omega^2 = \beta/2\alpha \pm \beta/2\alpha\sqrt{1-\frac{4\alpha\gamma}{\beta^2}}.$$

LC is the important term, all the others being small compared to it, hence $\frac{4\alpha\gamma}{\beta^2}$ is small, and we may say approximately

$$\omega^2 = \beta/2\alpha\left\{1 \pm \left(1 - \frac{2\alpha\gamma}{\beta^2}\right)\right\} = \frac{\gamma}{\beta} \text{ or } \frac{\beta}{\alpha} \text{ approx.}$$

γ/β will give the value which is nearly equal to ω_0, where $\omega_0 = 2\pi f_0$, f_0 being the "LC" frequency.

$$\omega^2 = \frac{1 + R/R_a}{\left\{LC - \dfrac{ML_1GR_g + M^2\left(\dfrac{R_1+R_g}{R_a}\right)}{[(R_1+R_g)^2+\omega^2L_1^2]}\right\}} \quad \ldots 4$$

This equation indicates to what extent grid current modifies the oscillator frequency. If $R_g = \infty$, then there is no grid current and we have as before

$$\omega^2 = \frac{1 + R/R_a}{LC} \quad \ldots \quad \ldots \quad \ldots 5$$

It is difficult to estimate the value of R_g in the present case, but if we put it at 10^5 ohms, then $R_1 = 226$ ohms (see next subsection) and $\omega L_1 = 2\pi \cdot 640 \cdot 0.142 = 562$ ohms are both negligible compared to R_g and our equation is reduced to:—

$$\omega^2 = \frac{1 + R/R_a}{\left\{LC - \dfrac{M^2}{R_aR_g}\left(1 + \mu\dfrac{L_1}{M}\right)\right\}} \quad \ldots 6$$

$$f^2 = \frac{1 + R/R_a}{2\pi LC\left\{1 - \dfrac{M^2}{LCR_aR_g} - \dfrac{\mu}{R_a}\cdot\dfrac{ML_1}{R_g}\cdot\dfrac{1}{LC}\right\}}$$

$$f^2 = f_0^2\,\frac{1 + R/R_a}{\left\{1 - \dfrac{M^2}{LCR_aR_g} - \dfrac{\mu}{R_a}\cdot\dfrac{ML_1}{R_g}\cdot\dfrac{1}{LC}\right\}} \quad \ldots 7$$

Upon equating the horizontal terms:—

$$R + \frac{\omega^2M^2}{R_g}\left(1 - \frac{L_1}{R_aR_gC}\right) + \frac{\mu M}{CR_a} + \frac{L}{CR_a} = 0.$$

By neglecting the small terms this reduces to:

$$\frac{M^2R_a}{LR_g} + \mu M + (CRR_a + L) = 0.$$

When grid current is negligible, R_g is ∞ and we have the usual critical

$$M = -\frac{1}{\mu}(CRR_a + L).$$

For small grid currents we may write

$$M = -\frac{1}{\mu}\left(CRR_a + L + \frac{M^2R_a}{LR_g}\right) \quad \ldots 8$$

(c) *Procedure.*

The inductance of the anode coil (also the grid coil) was first measured using a Campbell Inductometer in a Maxwell Bridge arrangement. The mean of several readings gave

Anode Coil $\begin{cases} L = 484.5 \text{ millihenrys.} \\ R = 19 \text{ ohms.}\end{cases}$

Grid Coil $\begin{cases} L_1 = 141.9 \text{ millihenrys.} \\ R_1 = 226 \text{ ohms.}\end{cases}$

The mutual inductance M between the grid and anode coil was next determined for various positions of the grid coil, again using the Campbell Inductometer as a standard. The calibration curve is given in Fig. 4.

When the apparatus had been set up, various trial tests were made obtaining beats between the oscillator frequency and the tuning fork harmonics. The beats were easily distinguishable and the whole arrangement seemed quite satisfactory, as there was no tendency for the notes to lock. At first only 60 volts H.T. and $1\frac{1}{2}$ volts grid bias were used, but these were altered later to more suitable values.

Oscillator Frequency.—The condensers C were arranged to give a frequency of approximately 256 cycles to beat with the second harmonic of the fork note. The oscillator, however, did not seem to oscillate very easily at this frequency. Similarly at 384 cycles (the 3rd harmonic of the fork note), so the frequency was increased to about 640 cycles to beat against the 5th harmonic of the fork note. Touching various parts of the oscillator circuit with the hand was found to alter beats considerably, so the circuit was earthed. Close proximity (without touching) of the hand or body to the circuit made no difference at all. Inserting a milliammeter into the anode circuit made a slight difference, so it was decided to include everything in the circuit that would be necessary for all subsequent tests, so that the conditions would not be changed. Therefore, the dial boxes, filament resistance, and meters were all connected up. The effect of varying grid coupling was found to be considerable.

"LC" Frequency. Having decided upon the oscillator frequency, about 640 cycles, we must settle upon an exact value for the capacity C to give us the theoretical

$$f_0 = \frac{1}{2\pi\sqrt{LC}}.$$

We want f_0 to be fixed so f_0 will be made equal to $5 \times 127.741_{15}$ . . . cycles, *i.e.*, 638.706 . . . cycles, which is the 5th harmonic of the maintained tuning fork frequency.

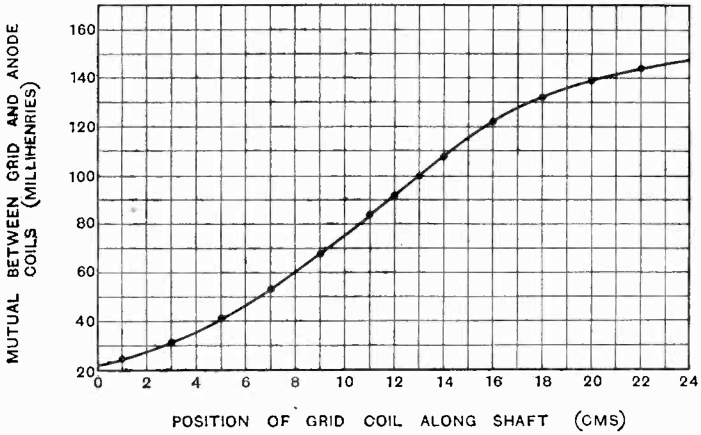

Fig. 4.—*Grid coupling calibration curve for position of grid coil.*

$$C = \frac{10^3}{4\pi^2(638.706)^2 \ . \ 484.5} \text{ farads.}$$
$$= 128{,}165. \ . \ . \ . \ \mu\mu\text{fds.}$$
$$= 116.51 \ . \ . \ . \text{ jars.}$$

Hence using all the coils of L and a capacity C of 116.51 jars the theoretical "LC" frequency is $f_0 = 638.706$ cycles.

Owing to various practical conditions, however, the frequency of the oscillator will not equal f_0, but some frequency f. f will beat against f_0 the 5th harmonic of the tuning fork, and our frequency departure is given direct by the number of beats.

(*To be concluded.*)

Potential Difference and Electromotive Force.

By E. A. Biedermann, B.Sc., A.M.I.E.E.

Introduction.

THE question of the exact meanings to be assigned to the terms "potential difference" and "E.M.F." has been recently discussed in this journal in editorials by Prof. Howe* and in an article by Mr. R. M. Wilmotte.† The subject is one of more than academic interest since, as Mr. Wilmotte points out, the definition of potential difference is involved in a number of other definitions of fundamental importance, such as those of impedance, capacity, self-inductance, etc.

Mr. Wilmotte in his very interesting paper proposed certain definitions for the above terms, and the purpose of this article is to discuss these suggested definitions with a view to showing that on close examination they cannot really be said to satisfy the conditions which Mr. Wilmotte has rightly pointed out must be satisfied by any such definitions, namely, that they shall not only be mathematically rigorous, but also be in accord with generally accepted ideas as to the meanings of the terms.

In the case of an electrostatic system there is no difficulty, because no ambiguity, in defining the potential at any point as the work done in bringing a unit positive charge from an infinite distance to the point, since this work is quite independent of the particular path chosen. Mr. Wilmotte therefore suggests that in the general case of any electrical system it would appear simplest to define potential difference as the work done on the unit charge in bringing it from an infinite distance by a path so selected that no E.M.F. due to electromagnetic induction acts along it. Actually his method of procedure is not directed to finding such a path, but consists in an analytical separation of the different force components which together constitute the resultant electric intensity. Probably this latter method is really the only practicable one, since it is difficult to see how a specification could be given of a path along which no E.M.F. is induced which would be of general applicability.

* March and April, 1928.

† Some Fundamental Definitions, by Raymond M. Wilmotte, B.A., A.M.I.E.E., November, 1928.

Effect of Finite Velocity of Transmission.

Mr. Wilmotte analyses the electric intensity as the resultant of two electric force components, one derived from the scalar potential and the other from the vector potential of classical electromagnetic theory —the so-called *retarded* potentials.

The scalar potential is given by the expression

$$\phi = \Sigma \frac{[q]}{r}$$

and the rectangular components of the vector potential by

$$A_x = \frac{1}{c^2}\Sigma\frac{[i_x]}{r},\ A_y = \frac{1}{c^2}\Sigma\frac{[i_y]}{r},\ A_z = \frac{1}{c^2}\Sigma\frac{[i_z]}{r},$$

q denoting an element of charge, i_x, i_y, i_z conduction current components, and r the distance from the element of charge, or current, to any point P at which it is desired to evaluate the potentials.

The symbols denoting the charge elements and current components have been enclosed in square brackets, in accordance with a convenient practice usually adopted in dealing with these potentials, to denote that the values of these quantities are not those existing at the instant t at which it is required to evaluate the potentials, but at instants $t_0 = \left(t - \frac{r}{c}\right)$, in consequence of the fact that all electromagnetic disturbances are propagated with a constant velocity c whose magnitude depends on the dielectric constant and permeability of the medium. Hence the term *retarded* potentials.

Mr. Wilmotte draws attention to this in a footnote in which he states that it may *sometimes* be necessary to take this effect into account at *high frequencies*. The italics are mine, because I believe that, in seeking to frame definitions of potential difference and E.M.F. which shall be of general applicability, it is absolutely essential to take this factor into account. The omission to do so really obscures the whole subject. One immediate consequence of this omission in Mr. Wilmotte's paper is that he is led in the first place, when considering an electrical system as a whole, to identify "potential," as ordinarily understood, with the scalar potential ϕ, and to refer to the force derived from it as the *electrostatic* force. On taking into account, however, this factor of the finite velocity of transmission it will be found that, whenever the system involves a varying current, the force derived from the scalar potential is not merely an electrostatic force, but includes also a component which is essentially an *electromagnetic* force, just as much so as the force derived from the vector potential. As a consequence, I think it must be admitted that we cannot identify "potential" as commonly understood, with the scalar potential without departing radically from accepted ideas as to what is meant by potential difference.

Electric Force Component Derived from the Scalar Potential.

To make this clear it will be necessary to make use of a little mathematics. The component, along any element of path ds at the point P, of the force derived from the scalar potential is given by

$$E_s = -\frac{d\phi}{ds} = -\frac{d}{ds}\Sigma\frac{[q]}{r} = -\Sigma\frac{d}{ds}\left(\frac{[q]}{r}\right)$$
$$= -\Sigma[q]\frac{d}{ds}\left(\frac{1}{r}\right) - \Sigma\frac{1}{r}\frac{d[q]}{ds}$$

Now, in the case of an electrostatic system $\frac{d[q]}{ds}$ vanishes, because $[q]$ is not varying with time. At first sight it might be thought that the same is true when the system involves varying currents, and therefore varying charges, since we are only differentiating with regard to space at a given instant. Actually $\frac{d[q]}{ds}$ then has a finite value. If P_1, P_2 denote the extremities of a small element of path δs at the point P, then $\frac{d[q]}{ds}$ denotes the limit of $\{[q_2] - [q_1]\}/\delta s$ and there is a change in the value of $[q]$ due to the fact that $[q_1]$ is the value of $[q]$ at the instant $t_1 = \left(t - \frac{r_1}{c}\right)$, while $[q_2]$ denotes the value of $[q]$ at the instant $t_2 = \left(t - \frac{r_2}{c}\right)$, where r_1, r_2 denote respectively the distances from the element of charge to the points P_1, P_2. If, then, $[q]$ is varying at the rate $\left[\frac{dq}{dt}\right]$, there is a change in the value of $[q]$ of amount

$$\left[\frac{dq}{dt}\right](t_2 - t_1) = -\left[\frac{dq}{dt}\right]\left(\frac{r_2}{c} - \frac{r_1}{c}\right)$$
$$= -\left[\frac{dq}{dt}\right]\frac{\delta r}{c}$$

where δr denotes the difference in the values of r for the points P_1, P_2, assuming the position of $[q]$ to remain unaltered. Hence, in the limit

$$\frac{d[q]}{ds} = -\frac{1}{c}\left[\frac{dq}{dt}\right]\frac{dr}{ds}.$$

Substituting this value of $\frac{d[q]}{ds}$ in the expression for E_s above, and writing $\frac{1}{r^2}\frac{dr}{ds}$ for $-\frac{d}{ds}\left(\frac{1}{r}\right)$, we obtain

$$E_s = \Sigma\frac{[q]}{r^2}\frac{dr}{ds} + \Sigma\frac{1}{cr}\left[\frac{dq}{dt}\right]\frac{dr}{ds}.$$

Obviously the part $\Sigma\frac{[q]}{r^2}\frac{dr}{ds}$ corresponds closely to a true electrostatic force, though it should be noted that it is not quite the same thing as the electrostatic force which would exist if the charge distribution were imagined to become suddenly fixed, because the distribution represented by $\Sigma[q]$ is not a distribution existing at any *one* instant, the values of $[q]$ being those of the charges each taken at a different instant depending on the distances of the individual charges from the point P. Still this part of the electric intensity does depend on every element of charge at its appropriate instant, and on its distance, in exactly the same way as a true electrostatic force, so that it is, I think, quite legitimate, and certainly convenient, to refer to it as the electrostatic component of the electric intensity. If we wish to be very accurate we might term it the *retarded* electrostatic force.

The other part of the force E_s derived from the scalar potential, namely, the part whose component parallel to ds is represented by $\Sigma \frac{1}{cr}\left[\frac{dq}{dt}\right]\frac{dr}{ds}$ is essentially a force of an electromagnetic nature, because varying charges on a system are necessarily dependent on the existence of varying currents, as Mr. Wilmotte has emphasised in his article. In fact, as is well known, if q denote the charge on an element of circuit ds', $\left[\frac{dq}{dt}\right] = -\left[\frac{di}{ds'}\right]$, so that the above force component may be written

$$-\Sigma \frac{1}{cr}\left[\frac{di}{ds'}\right]\frac{dr}{ds}.$$

It is, of course, quite true that the line integral of the whole force E_s derived from the scalar potential vanishes when integrated round any closed path, and a definition of "potential" as being the same thing as the scalar potential ϕ therefore satisfies the condition that the work done in bringing a unit charge to the point against the whole force derived from that potential shall be independent of the path followed. On the other hand, I submit, it does not satisfy the other requirement that the definition shall be in accordance with what is generally understood by the term "potential." I doubt if forces of an essentially electromagnetic nature are ever associated with potential difference. Such forces are invariably thought of as E.M.F.'s.

Comparison of Electromagnetic Forces Derived from Scalar and Vector Potentials.

It may be thought that in practice the electromagnetic part of the force derived from the scalar potential will in general be negligible, and in the case of *closed* circuits this may well be the case, except under the special conditions referred to by Mr. Wilmotte in his footnote, but in the case of *open* circuits this is not so. It is true that at points not very distant from an open circuit this force may be negligibly small compared with the *electrostatic* force, but the point I wish particularly to emphasise is that in such cases, with a non-magnetic medium, it is always in some directions comparable with the electromagnetic force derived from the *vector* potential, *no matter how low the frequency.*

That this must be so is easily appreciated if we think for a moment of that part of the resultant electric intensity which constitutes what is usually referred to as the *radiation* field, the only part which is appreciable at large distances from the radiating system. It is well known that the contribution of each current element of a circuit to this radiation field is an element of force proportional to the rate of change of the current, varying inversely as the distance from the element of circuit, and that it is *perpendicular to the radius vector from the element of circuit to the point considered.*

Now, it is obvious that the radiation component derived from the *vector* potential is *parallel* to the current element. There must be, therefore, some corresponding *radial* component of electric intensity produced by the same current element. This radial component is derived from the *scalar* potential. At points in the line through the current element the two force components are actually equal but oppositely directed, so that the contribution of the current element to the radiation intensity is nil.

It is not at first sight very clear how a force component proportional to $\left[\frac{di}{dt}\right]$ can be accounted for by the electromagnetic force $-\frac{1}{cr}\left[\frac{di}{ds'}\right]$ which we have seen is derived from the scalar potential due to the charge on an element of circuit, but it must be remembered once again that the current can only vary from point to point of the circuit in virtue of the fact that it is also varying with time, and consequently $\left[\frac{di}{ds'}\right]$ must essentially depend on $\left[\frac{di}{dt}\right]$. It may be shown, in fact, that the electromagnetic force derived from the scalar potential due to the whole circuit includes a part which is the resultant of contributions from each element of circuit of a radial component proportional to $\left[\frac{di}{dt}\right]$ and varying with distance and direction in exactly the required manner.

Thus the scalar potential due to an open circuit gives rise, in a non-magnetic medium, to an electromagnetic force which is in general comparable with that which is derived from the vector potential. In view of this is it not rather an arbitrary procedure to associate the former force with potential, or potential difference, in its commonly understood sense?

Mr. Wilmotte, I think, does not really contemplate this, but, by omitting to take account of the fact that the scalar potential is a *retarded* potential, he has not brought to light the fact that other forces than electrostatic forces are derived from the scalar potential.

System Consisting of Transmitting and Receiving Antennæ.

It is really on account of this omission that, having tentatively identified "potential" with the scalar potential when considering a system as a whole, he is at once confronted with the difficulty that the commonly accepted meaning of the E.M.F. induced in a distant antenna includes forces represented by the "$\frac{d\phi}{dx}$ terms." Of course it does, because these terms represent forces which are partly *electromagnetic* and therefore properly to be regarded as giving rise to an E.M.F. rather than a potential difference. As a matter of fact, the purely electrostatic part of the forces represented by the "$\frac{d\phi}{dx}$ terms" in the case of a distant antenna may be considered as being for all practical purposes negligible, for the simple reason that the resultant charge on the whole of the transmitting system is nil, and that the dimensions of the system are very small compared with the assumed large distance of the receiving antenna. For all practical purposes, therefore, we could quite satisfactorily define the E.M.F. induced in the distant antenna as the line integral of all the *electromagnetic* forces induced in it.

When, however, the two antennæ are brought close together, as Mr. Wilmotte proceeds to consider, the electrostatic forces are no longer negligible and may exceed the electromagnetic forces. Nevertheless, there is still no reason, as far as I can see, why the electrostatic forces should be regarded as contributing to the E.M.F. induced in the receiving antenna.

Mr. Wilmotte says that in these circumstances the reaction of the one antenna on the other is commonly called the mutual induction, but I think this term is usually taken to denote only the mutual *electromagnetic* induction. The whole reaction of one antenna on the other comprises the effects of *electrostatic* induction in addition to those of mutual induction, and it is precisely when the *electrostatic* forces become appreciable that electrostatic induction occurs, and potential differences, not E.M.F.'s, are produced thereby. This, I think, is the generally accepted view.

Mr. Wilmotte's Proposed Definitions of Potential Difference.

The position with regard to Mr. Wilmotte's suggested definitions of potential difference appears to be this. His first definition, when considering an electrical system as a whole, appears at first sight to accord with generally accepted ideas as to the meaning of the term only because it has not been treated rigorously. When considering the E.M.F. induced in a distant antenna, however, the definition *is*, in effect, rigorously treated, for it is only by so treating it that the E.M.F. would be found to involve the "$\frac{d\phi}{dx}$ terms" appreciably, and then it is at once seen that the definition is not in accordance with generally accepted ideas. He is therefore forced to revise his definition of potential difference and take it to mean the effect arising from the charge distribution only on the part of the system considered, *i.e.*, the distant receiving antenna in that particular instance. He even goes so far as to suggest that this revised definition can be applied to any selected part of a single circuit. Consider for a moment what this leads to. A definition, to be valid, must be so under all circumstances, and it must therefore apply to a circuit carrying a steady current. Mr. Wilmotte's revised definition then asserts that the potential difference between the extreme points A and C of any selected section ABC of the circuit is that arising from the charge distribution on the section ABC alone. But the generally accepted meaning of the potential difference between A and C in such circumstances is unquestionably a quantity equal to the product of the resistance of the section ABC and the current flowing through its assuming, of course, that no sources of E.M.F. are connected in that section. If this is equal to the potential difference arising from the charges on ABC alone, then the effect on ABC of the charge distribution on the remainder of the circuit must be nil, which cannot possibly in general be the case. In this simple case it is quite certain that the accepted meaning of the potential difference between A and C is that arising from the charge distribution on the *whole* circuit. It is certainly not considered that the effect on ABC of the charge distribution on the remainder of the circuit is to be regarded as an E.M.F., as Mr. Wilmotte's revised definition requires us to regard it. It appears very unlikely, therefore, that this particular definition will receive general acceptance. One is forced to the conclusion, therefore, that any attempt to generalise the meaning of potential difference by associating potential, as commonly understood, with the scalar potential of electromagnetic theory must fail, because it will not satisfy the second condition enunciated by Mr. Wilmotte that any definition must submit to the generally accepted meaning of the term.

Possible Alternative Definitions.

As a possible alternative may I suggest that the term potential difference be generalised to mean always the line integral of only that force which depends on the charge distribution, the force represented by $\Sigma \frac{[q]}{r^2} \frac{dr}{ds}$, which corresponds very closely to a true electrostatic force and forms a part in all circumstances of the force derived from the scalar potential.

It is easily shown that the line integral of this particular force in all cases vanishes round a closed path and this definition therefore meets the requirement that the work done on a unit charge in moving it between two points against this force shall be independent of the particular path followed. The line integral of all other forces, whether derived from the scalar or vector potential, would then define the E.M.F., and it is to be noted that these other forces are all electromagnetic forces, depending directly on the distribution of *currents* not on the distribution of *charges*.

After all, is it not more satisfactory to base our definitions of P.D. and E.M.F. on a classification of forces, which have an actual physical existence, rather than on a classification of potentials, which can hardly be regarded as more than mathematical conceptions in spite of the great help they afford in mathematical investigations of electrical phenomena?

The only disadvantage that would appear to arise from such definitions is that we cannot express the potential in the general case in a convenient mathematical form, but only as the line integral from an infinite distance of the force $\Sigma \frac{[q]}{r^2} \frac{dr}{ds}$.

The Marconi Company and Licensees.

Under the term of the proposed new Licence Agreement between the Marconi Company and manufacturers of broadcast receiving apparatus which has been negotiated on behalf of licensees of the Marconi Company by the Radio Manufacturers' Association, the following main heads indicate the general terms under which the new licence will be issued. The A.2. Licence referred to below is, of course, the present general Licence Agreement issued by the Marconi Company.

(*a*) A new Agreement dating from 28th August, 1928, to 28th August, 1933, covering patented and non-patented goods for the field of broadcast reception.

(*b*) The new Licence shall cover the existing patents set out in the schedule to the A.2. Licence, the Eliminator Patent (148,129 at present the subject of their D Licence), all other present and future patents controlled by the Marconi Co. and their Associates the Gramophone Co. in the field as defined in Clause (*a*).

(*c*) Licensees shall give to the Marconi Co. (and to its Associate Company the H.M.V.) the free use of any patents they may possess dealing with the field as defined in Clause (*a*). In respect of the eliminator patent the actual royalty in respect of this patent shall be 5/– per apparatus when embodied in a receiving set. The charge when the apparatus is not so included shall be 6 per cent. of the retail list price.

(*d*) The Radio Manufacturers' Association will call the attention of the Marconi Company to any cases of infringement of the patents, with a request that such infringers shall be prosecuted. Should the Marconi Company not be prepared to undertake such prosecution, the question of the prosecution shall be referred to the arbitration of the President of the Law Society whose decision shall be binding on both sides.

(*e*) The royalty to be 5/– per valve-holder, the term valve-holder to have the meaning attached to it in the A.2. Licence.

The Triode Valve Equivalent Network.

By F. M. Colebrook, B.Sc., D.I.C., A.C.G.I.

1. Introduction.—Assumptions, Scope and Object of the Paper.

THE analysis of the valve equivalent network as usually presented is not in the form best adapted either for numerical application or for the deduction of the general character of the variation of the important quantities of the network with the load in the anode circuit. Even the simplest triode network contains so many possible variables that unless these are grouped in such a way as to give due prominence to the important terms the resulting formulæ are so complicated that it is difficult to "see the wood for the trees."

The following presentation of the subject is an attempt to reduce the formulæ to their simplest form. It is based upon the assumptions made by Miller in his original treatise,* with the complementary modifications introduced by Hartshorn† (i.e., the inclusion of a conductance term in the admittances of the inter-electrode condensers). These assumptions have already received a sufficient degree of experimental confirmation to establish their utility as the basis of design and as a guide to further experimental work.

The analysis is confined to the network equivalent to a single valve and to the study of :

(*a*) The input admittance.

(*b*) The voltage amplification.

The means of extending the analysis to multi-valve networks in which all stray couplings are eliminated by screening and other suitable precautions, are implicit in the analysis and are pointed out in the course of it. For convenience the total range of frequency is divided into (*a*) audible frequencies, (*b*) radio frequencies, the line of division being in the neighbourhood of 20 kilocycles per second.

* Miller : *Bull. Bur. Stand.*, Vol. 15, p. 367 (1919).

† *Proc. Phys. Soc.*, Vol. 39, Part 2, 1927.

It is hoped that the paper will serve the following purposes :

(*a*) Elucidation of experimental data already obtained.

(*b*) Indication of useful lines of future investigation.

(*c*) Guidance in design, particularly in relation to very high radio frequencies.

2. The Network and Notation.

The network considered is illustrated in Fig. 1. It represents a valve having a voltage factor μ and internal A.C. resistance R_a. The grid-filament, grid-anode and anode-filament capacities are represented by the small condensers C_1, C_2 and C_3.

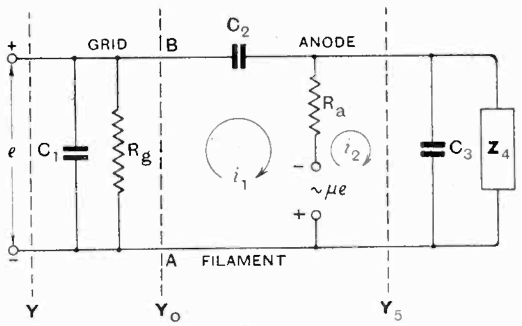

Fig. 1.

The analysis relates throughout to simple harmonic currents and potential differences of frequency $\omega/2\pi$. These are represented in vector form, the circuit characteristics being in consequence "vector operators," or two-dimensional numbers. Any impedance is thus expressible as the two-dimensional number $R + jX$, without assumption as to the form of the numbers R and X, where j obeys the same formal rules as $\sqrt{-1}$. As a single letter it is written **Z**, the magnitude being $Z\,(=\sqrt{R^2 + X^2})$. The corresponding admittance is $\mathbf{Y} = G + jS$, i.e.,

$$\frac{1}{\mathbf{Z}} = \frac{1}{R + jX} = \mathbf{Y} = G + jS$$

Thus the admittances of the inter-electrode capacities are:

$$\mathbf{Y}_1 = G_1 + jS_1 = G_1 + j\omega C_1, \text{ etc., etc.}$$

The anode circuit load is $\mathbf{Z}_4$. For completeness a resistance R_g $(= 1/G_g)$ is introduced to represent possible grid-filament conductivity (e.g., as in cases involving grid-circuit rectification).

3. A Simplification of the Network.

From the point of view of voltage amplification the resultant load in the anode circuit is the actual load $\mathbf{Z}_4$ (admittance $\mathbf{Y}_4$) shunted by the anode-filament capacity of admittance $\mathbf{Y}_3$. It will, therefore, be convenient to combine these two elements in a single symbol $\mathbf{Y}_5$, i.e.,

$$\mathbf{Y}_5 = \mathbf{Y}_4 + \mathbf{Y}_3$$

4. Extension to a Multi-valve Network.

If the valve considered is followed by another, the input admittance of the following valve, modified in some calculable manner by the coupling elements, will appear as a further shunt path to the anode circuit load. Writing $\mathbf{Y}_x$ for this additional admittance, the resultant anode circuit load is now

$$\mathbf{Y}_5 = \mathbf{Y}_4 + \mathbf{Y}_3 + \mathbf{Y}_x$$

In all that follows the symbol $\mathbf{Y}_5$ will be taken to have the above inclusive significance.

5. Elimination of Known Terms from the Input admittance.

The total input admittance $\mathbf{Y}$ is given by $\mathbf{Y} = \mathbf{Y}_1 + G_g + \mathbf{Y}_0$, where $\mathbf{Y}_0$ is the admittance of the remainder of the network (to the right of the dotted line AB in Fig. 1). Of these the only unknown term is $\mathbf{Y}_0$, the other terms being determinable constants for the valve, not affected by $\mathbf{Y}_5$. This term $\mathbf{Y}_0$ is therefore the one that will be investigated, the total input admittance being obtained merely by including the simple additive terms $\mathbf{Y}_1$ and G_g.

The above simplifications reduce the equations to two only. It may, however, be as well to point out that an assumption is involved at this point. It is assumed that the input admittance of the valve is independent of the manner in which the potential difference $\boldsymbol{e}$ is produced between the grid and the filament, i.e., that it is quite independent of the input circuit. The usual network representation necessarily involves this conclusion. The practical aspect of the assumption is that the input circuit has no external coupling to the output circuit, a condition which can easily be obtained by screening.

6. The Circuit Equations.

The currents $\mathbf{i}_1$ and $\mathbf{i}_2$ are given by the equations

$$\mathbf{i}_1\left(\frac{1}{\mathbf{Y}_2} + \frac{1}{G_a}\right) - \frac{\mathbf{i}_2}{G_a} = (\mu + 1)\mathbf{e} \quad \ldots \quad (1)$$

$$\mathbf{i}_2\left(\frac{1}{\mathbf{Y}_5} + \frac{1}{G_a}\right) - \frac{\mathbf{i}_1}{G_a} = -\mu\mathbf{e} \quad \ldots \quad \ldots \quad (2)$$

the solutions of which are

$$\mathbf{i}_1 = \left\{\frac{(\mu + 1)\, G_a + \mathbf{Y}_5}{G_a + \mathbf{Y}_5 + \mathbf{Y}_2}\right\}\mathbf{Y}_2\mathbf{e} \quad \ldots \quad (3)$$

$$\mathbf{i}_2 = \left\{\frac{\mathbf{Y}_2 - \mu G_a}{G_a + \mathbf{Y}_5 + \mathbf{Y}_2}\right\}\mathbf{Y}_5\mathbf{e} \quad \ldots \quad (4)$$

Thus the input admittance term $\mathbf{Y}_0$, i.e., $\mathbf{i}_1/\mathbf{e}$, is

$$\mathbf{Y}_0 = \left\{\frac{(\mu + 1)\, G_a + \mathbf{Y}_5}{G_a + \mathbf{Y}_5 + \mathbf{Y}_2}\right\}\mathbf{Y}_2 \quad \ldots \quad (5)$$

and the voltage amplification $\mathbf{M} = \frac{\mathbf{v}}{\mathbf{e}} = \frac{\mathbf{i}_2/\mathbf{Y}_5}{\mathbf{e}}$ is

$$\mathbf{M} = \frac{\mathbf{Y}_2 - \mu G_a}{G_a + \mathbf{Y}_5 + \mathbf{Y}_2} \quad \ldots \quad (6)$$

7. Representation for Analytical Purposes.

A great gain in generality is obtained by expressing the above formulæ in terms of a new variable

$$\mathbf{r} = a + jb = \frac{G_a}{G_a + \mathbf{Y}_5} = \frac{\mathbf{Z}_5}{\mathbf{Z}_5 + R_a}$$

The justification for this substitution and its significance are discussed below. This quantity will be referred to as the "load factor."

An additional convenient group symbol is

$$\boldsymbol{p} = \frac{\mathbf{Y}_2}{G_a} = \mathbf{Y}_2 R_a$$

It will appear that this ratio is more important than the individual terms $\mathbf{Y}_2$ and G_a.

Making these substitutions, the Equations (5) and (6) become

$$\mathbf{Y}_0 = \left(\frac{1 + \mu\mathbf{r}}{1 + \boldsymbol{p}\mathbf{r}}\right)\mathbf{Y}_2 \quad \ldots \quad (7)$$

$$\mathbf{M} = -\left(\frac{1 - \boldsymbol{p}/\mu}{1 + \boldsymbol{p}\mathbf{r}}\right)\mu\mathbf{r} \quad \ldots \quad (8)$$

8. The Variable r.

The principal reason for the use of the load factor **r** is that this quantity is the real variable of the problem. It is this ratio that matters, rather than the individual quantities $\mathbf{Z}_5$ and R_a. It has the further advantage of restricted variation of a comparatively simple character.

Suppose first that $\mathbf{Z}_5$ is a pure resistance, of magnitude R_5. Then

$$\mathbf{r} = \frac{R_5}{R_a + R_5}$$

and is wholly "real." Further, as R_5 is varied from 0 to ∞, **r** varies from 0 to 1, so that every possible value of R_5 is included in the range 0 to 1 of **r**.

Now suppose $\mathbf{Z}_5$ to be a pure reactance, jX_5, then

$$\mathbf{r} = \frac{jX_5}{R_a + jX_5}$$

$$= \tfrac{1}{2}\left\{1 - \frac{R_a - jX_5}{R_a + jX_5}\right\}$$

Now whatever the magnitude of X_5, the

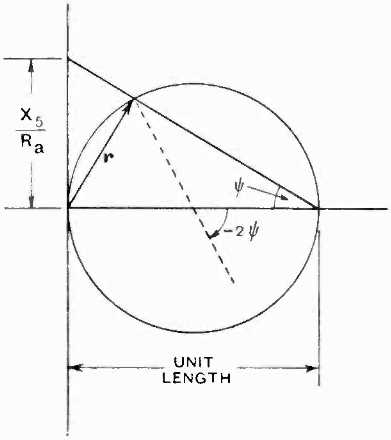

Fig. 2.

fraction inside the bracket is of magnitude 1 and represents a pure rotation. In fact

$$\mathbf{r} = \tfrac{1}{2}\{1 - \epsilon^{-2j\psi}\}$$

where $\tan\psi = X_5/Ra$.

As X_5 varies from $-\infty$ to $+\infty$, 2ψ varies from $-\pi$ to π, and the end of **r** simply moves round a circle of unit diameter as shown in Fig. 2. Thus for any pure reactance load, whether positive or negative (inductive or capacitative), **r** will terminate somewhere on the diameter of the circle shown in Fig. 2. For pure resistance loads, **r** will be wholly "real" and will terminate somewhere on the diameter of this circle. For any load whatever (excluding the special case of negative resistance components in the load) **r** must terminate somewhere on or inside the limiting circle. (Further circular loci for **r** are discussed in Appendix I.)

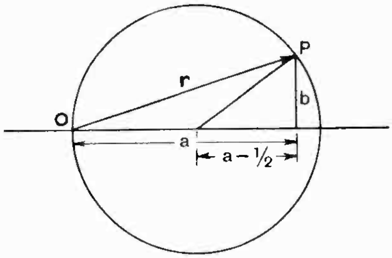

Fig. 3.

This leads to a simple means of making a complete survey of the possible variation of the input impedance and the voltage magnification of a valve. For points on the circumference of the limiting circle (i.e., for pure reactance loads)

$$\mathbf{r} = a + jb$$

and also $(a - 1/2)^2 + b^2 = 1/4$ (see Fig. 3)
i.e., $r^2 = a^2 + b^2 = a$ or $b = \pm\sqrt{a - a^2}$ (9)

Thus for a complete survey of the variation for the important case of pure reactive loads it is only necessary to calculate for convenient points on the diameter of the circle. Such points are

(a)	0	.1	.2	.3	.4	.5
(b)	0	± .3	± .4	± .46	± .49	± .5

(a)	.6	.7	.8	.9	1
(b)	± .49	± .46	± .4	± .3	0

to convert back to actual reactance values if desired we have

$$\frac{X_5}{R_a} = \frac{b}{1 - a}$$

or alternatively the graphical construction of Fig. 2.

For pure resistance loads it is only necessary to calculate for the points $b = 0$

$a = .1, .2, .3$, etc., etc., with the reversion, if desired

$$\frac{R_5}{R_a} = \frac{a}{1 - a}$$

The more general case for any value of **r** whatever lying within the circle is considered in the Appendix.

The following general deductions with regard to the variation of the load factor **r** should be noted. Putting

$$\mathbf{r} = a + jb \; (r = \sqrt{a^2 + b^2})$$

(i) The limits of a are 0 and 1; of $b \pm \frac{1}{2}$; of **r**, 0 and 1.

(ii) The limiting values of b correspond to finite values of the load ($Z_5 = |X_5| = R_a$). The limiting values of a and **r** will never be reached in practice, except by some special artifice, since they correspond to an infinite value for Z_5 (resistive or reactive).

(iii) Positive values of b correspond to positive values of X_5 (i.e., inductive loads), negative values of b to capacitative loads.

9. Deductions from the Network Formulæ at Audible Frequencies.

The formulæ are re-stated here for convenience

$$\mathbf{Y}_0 = \frac{1 + \mu\mathbf{r}}{1 + \boldsymbol{p}\mathbf{r}} \mathbf{Y}_2 \quad \ldots \quad (7)$$

$$\mathbf{M} = -\frac{1 - \boldsymbol{p}/\mu}{1 + \boldsymbol{p}\mathbf{r}} \mu\mathbf{r} \quad \ldots \quad (8)$$

where $\boldsymbol{p} = \mathbf{Y}_2 R_a$

These will be considered in relation to a typical valve having the characteristics

$$R_a = 3 \times 10^4$$
$$\mu = 10$$
$$C_2 = 5 \times 10^{-12}$$
$$G_2/\omega C_2 = 0.1$$

At audible frequencies $\boldsymbol{p}$ is very small. Thus at

$$f = 10{,}000$$
$$\boldsymbol{p} = 0.0009 + 0.0094\,j.$$

This means that $\boldsymbol{p}/\mu$ and $\boldsymbol{p}\mathbf{r}$ can be neglected by comparison with unity. Under these conditions we have the very simple formulæ

$$\mathbf{Y}_0 = (1 + \mu\mathbf{r})\,\mathbf{Y}_2 \quad \ldots \quad (10)$$

$$\mathbf{M} = \mu\mathbf{r} \quad \ldots \quad (11)$$

(1).—*Limiting Input Admittance Locus at Audible Frequencies.*

From the form of Equation (10) it is easily seen that the *total* range of variation of $\mathbf{Y}_0$ is the area of the curve corresponding to the limiting circle for **r**. This circle can be represented vectorially by the equation

$$\mathbf{r} = \frac{1}{2}(1 + \epsilon^{j\theta})$$

where θ can have any value from 0 to 360 deg. From Equation (10) the corresponding locus for $\mathbf{Y}_0$ is the circle

$$\mathbf{Y}_0 = \mathbf{Y}_2 \left(1 + \frac{\mu}{2} + \frac{\mu}{2}\epsilon^{j\theta}\right)$$

which is illustrated in Fig. 4 for the representative valve at a frequency of 10,000 cycles, for which

$$\omega C_2 = 3.14 \times 10^{-7}$$
$$G_2 = 3.14 \times 10^{-8}$$
$$Y_2 = \sqrt{G_2^2 + \omega^2 C_2^2} = 3.30 \times 10^{-7}$$

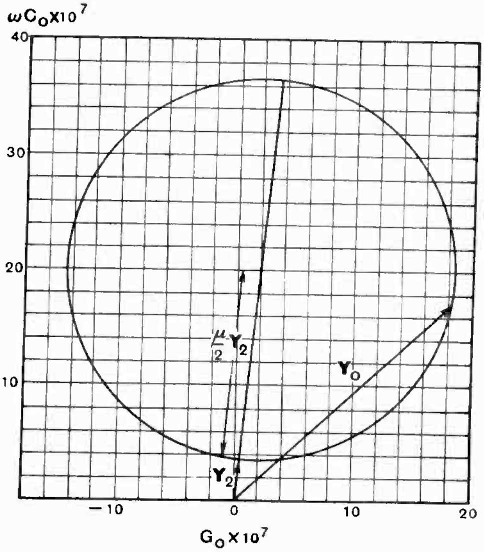

Fig. 4.—*The circular locus for* $\mathbf{Y}_0$ *for pure reactive loads at audible frequencies* ($f = 10{,}000$).

From Fig. 4 it follows at once that the limits of $\mathbf{Y}_0$ are

$$\mathbf{Y}_0\,(\text{min.}) = \mathbf{Y}_2$$
$$\mathbf{Y}_0\,(\text{max.}) = (1 + \mu)\,\mathbf{Y}_2$$

or, putting $\mathbf{Y}_0 = G_0 + j\omega C_0$

G_0 being the input conductance and C_0 the input capacity, it follows from Fig. 4 that

$$G_0\,(\text{max.}) = \left(1 + \frac{\mu}{2}\right) G_2 + \frac{\mu}{2} Y_2$$

$$G_0 \text{ (min.)} = \left(1 + \frac{\mu}{2}\right) G_2 - \frac{\mu}{2} Y_2$$

$$C_0 \text{ (max.)} = \left(1 + \frac{\mu}{2}\right) C_2 + \frac{\mu}{2} \frac{Y_2}{\omega}$$

$$C_0 \text{ (min.)} = \left(1 + \frac{\mu}{2}\right) C_2 - \frac{\mu}{2} \frac{Y_2}{\omega}$$

The numerical values of these limits in the case illustrated are

G_0 (max.) $= 1.84 \times 10^{-6}$ ($1/G_0 = 544{,}000$ ohms).

G_0 (min.) $= -1.46 \times 10^{-6}$ ($1/G_0 = -685{,}000$ ohms).

C_0 (max.) $= 56.5\ \mu\mu$F. (cf. $1 + \mu C_2 = 55\ \mu\mu$F.).

C_0 (min.) $= 3.5\ \mu\mu$F. (cf. $C_2 = 5\ \mu\mu$F.)

(Remember that the *total* input admittance quantities can be obtained from G_0 and C_0 by the simple addition of certain valve constants, as shown in para. 5.)

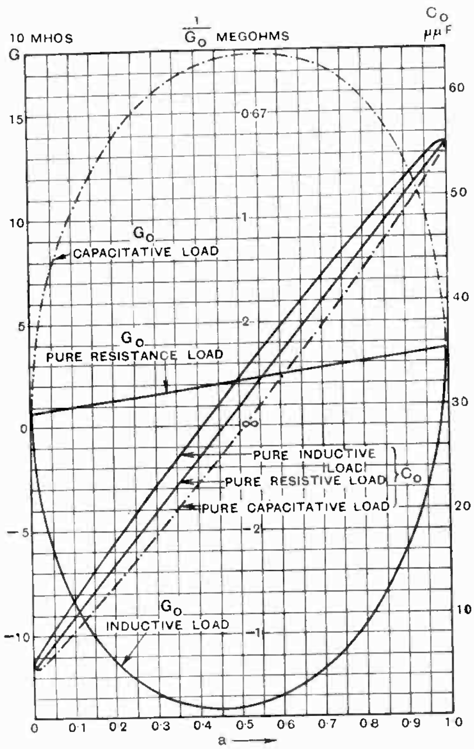

Fig. 5.—C_0 *and* G_0. *Audible frequency* ($f = 10{,}000$).

9 (2).—*Variation of Input Conductance and Input Capacity at Audible Frequencies.*

Putting $\mathbf{r} = a + jb$ and $\mathbf{Y}_2 = G_2 + j\omega C_2$

then $\mathbf{Y}_0 = \{1 + \mu(a + jb)\}(G_2 + j\omega C_2)$

i.e., $G_0 = (1 + \mu a)\, G_2 - \mu b \omega C_2$ .. (12)

and $C_0 = \dfrac{\mu b}{\omega} G_2 + (1 + \mu a)\, C_2$ .. (13)

Putting $b^2 = a - a^2$, corresponding to points on the limiting circle for $\mathbf{r}$ (pure reactance loads), it is easy to see that the curves connecting G_0 and C_0 with a are 2nd degree curves. They are, in fact, ellipses, and are shown in Fig. 5 for the representative valve.

The values of G_0 and C_0 corresponding to pure resistance resultant loads are also shown in Fig. 5.

The principal deductions from these curves will be listed at the end of this section.

9 (3).—*Amplification at Audible Frequencies.*

Since $\mathbf{M} = \mu \mathbf{r}$

the locus of $\mathbf{M}$ is a simple multiple of that of $\mathbf{r}$. Actually the magnitude M, given by

$$M = \mu r$$

is the important quantity.

For pure reactance loads

$$r = \sqrt{a} \text{ (see Equation 9)}$$

and for pure resistance loads

$$r = a.$$

The variation of M with a is thus as shown in Fig. 6, which illustrates the general superiority of reactance over resistance loads from the present point of view. The total range of variation of M is the area enclosed by the lines $M = \mu\sqrt{a}$ and $M = \mu a$.

Note particularly that the amplification given by any single valve is not affected by its own inter-electrode capacities except in so far as C_3 *affects* $\mathbf{Z}_5$ (which effect is, in general, very small).

It is the inter-electrode capacities of the following valve, giving rise to a comparatively low admittance shunt across $\mathbf{Z}_4$, which limit the amplification given by the valve.

Note further, that the maximum amplification is μ, but that this requires $\mathbf{Z}_5$ = infinity, a condition which cannot be realised.

It will be shown later that at radio frequencies, the maximum value of M exceeds

μ and corresponds to a load condition which can be realised.

9 (4).—*Principal Deductions (Audible Frequencies).*

(*a*) *Input Admittance.* (Not including that of the actual grid-filament capacity.)

(i) The input capacity is always positive and depends more on the magnitude of the load than its phase angle. Its limits are very approximately the grid-anode capacity and $(1 + \mu)$ times this capacity. (The limits may exceed these by a few per cent. on account of the power factors of the inter-electrode capacities.)

(ii) The input conductance is positive for capacitative loads and negative for inductive loads. Its limits are approximately $\pm\mu/2$ times the magnitude of the grid-anode capacity admittance, and are thus approximately proportional to frequency.

(iii) Plotted against the "real" part of the load ratio the curves showing the variation of the input conductance and input capacity are ellipses for pure reactance loads and straight lines for pure resistance loads.

(*b*) *Voltage Amplification.*

(i) The only effect of the inter-electrode capacities on voltage amplification, for a given input voltage, is the shunt effect of the actual anode-filament capacity on the load.

(ii) For a given load magnitude the amplification is higher for a pure reactance load than for a pure resistance load.

(iii) The upper limit of the voltage amplification is the voltage factor of the valve, but this cannot be attained as it implies an infinite load impedance (load factor unity).

10. Deductions from the Network Formulæ at Radio Frequencies.

At radio frequencies the terms in the formulæ are none of them negligible, so that no general approximations are permissible. On general grounds, however, it might be anticipated that at radio frequencies the conductance term in $\mathbf{Y}_2$ becomes unimportant, and there is a certain amount of experimental confirmation of this view.* On this assumption the formulæ take the slightly simpler form

$$\mathbf{Y}_0 = \frac{1 + \mu\mathbf{r}}{1 + j\rho\mathbf{r}} j\omega C_2 \quad .. \quad (14)$$

$$\mathbf{M} = \frac{1 - j\rho/\mu}{-1 + j\rho\mathbf{r}} \mu\mathbf{r} \quad .. \quad (15)$$

where $\rho = \omega C_2 R_a$

10 (1).—$\mathbf{Y}_0$ *at Radio Frequencies.*

Note first as a confirmation of the formula that when $\mathbf{r} \rightarrow 1$

$$\mathbf{Y}_0 \rightarrow (1 + \mu) \frac{j\omega C_2}{1 + j\rho} = (1 + \mu) \frac{1}{R_a + 1/j\omega C_2}$$

i.e., $\mathbf{Y}_0$ tends to the limit $(1 + \mu)$ times admittance of C_2 and R_a in series, a conclusion which is obvious from an inspection of Fig. 1.

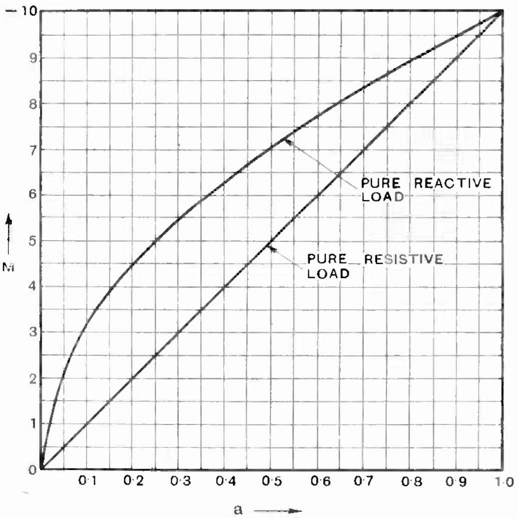

Fig. 6.—*Voltage amplification. Audible frequency* (f = 10,000).

For a circular locus of $\mathbf{r}$, both numerator and denominator of the expression for $\mathbf{Y}_0$ represent circular loci, and it can easily be shown that $\mathbf{Y}_0$ has also a circular locus. The equation of the circle is rather complicated in form, however, and in the present

* *Proc. Phys. Soc.*, Vol. 40, p. 14 (G. W. Sutton).

instance it will be preferable to take the general case

$$\mathbf{r} = a + jb$$

and analyse $\mathbf{Y}_0$ in terms of its components G_0 and C_0,

i.e.,

$$\mathbf{Y}_0 = G_0 + j\omega C_0 = \frac{1 + \mu\,(a + jb)}{1 + j\rho\,(a + jb)}\,j\omega C_2 \quad (16)$$

from which $G_0 = \dfrac{\mu\rho r^2 + \rho a - \mu b}{(1 - \rho b)^2 + \rho^2 a^2}\,\omega\, C_2 \quad (17)$

$$C_0 = \frac{(1 - \rho b) + \mu a}{(1 - \rho b)^2 + \rho^2 a^2}\,C_2 \quad (18)$$

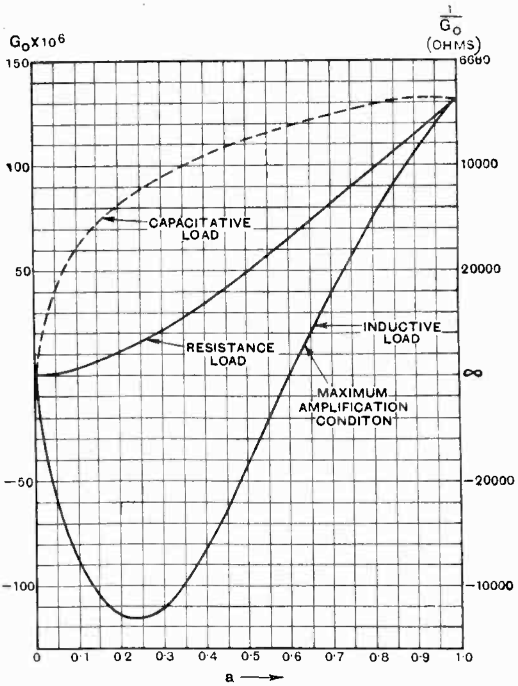

Fig. 7.—G_0 *at* 376.8 *metres* ($\omega = 5 \times 10^6$, $\rho = .75$).

10 (2).—*Input Capacity and Conductance at a Medium Wavelength* ($\lambda = 377$ m.).

At audible frequencies the input capacity and conductance for any given value of a increase or decrease uniformly with b up to the limiting value on the circumference of the load factor circle. In other words, the area of the curve plotted for pure reactance loads includes the total range of values of the input admittance terms. This is no longer true for radio frequencies, though it remains true down to fairly short wavelengths (100 metres or so). However, it appears that in every case the maximum values of G_0, C_0 and M are associated with pure reactance loads. These are the most interesting features of the variation, and pure reactance loads will therefore be considered. The short-wave cases in which the input admittance and voltage amplification have maxima and minima for a given value of a corresponding to points *inside* the limiting circle will be considered in Appendix II.

The variation of C_0 and G_0 with a for pure reactive loads can be calculated from the appropriate forms of Equations (17) and (18), i.e.,

$$C_0 = \frac{(1 - \rho b) + \mu a}{1 - 2\rho b + \rho^2 a}\,C_2 \quad .. \quad (19)$$

$$G_0 = \frac{(\mu + 1)\rho a - \mu b}{1 - 2\rho b + \rho^2 a}\,\omega C_2 \quad (20)$$

For pure resistance resultant loads ($b = 0$) the appropriate formulæ are

$$C_0 = \frac{1 + \mu a}{1 + \rho^2 a^2}\,C_2 \quad .. \quad .. \quad (21)$$

$$G_0 = \frac{\rho a\,(1 + \mu a)}{1 + \rho^2 a^2}\,\omega C_2 \quad .. \quad (22)$$

(Remember that these imply loads which are purely resistive when combined with the anode-filament capacity, e.g., tuned circuits. They would not apply exactly to actual resistances in the anode circuit, since the resultant load would not then be purely resistive.)

The variations of G_0 and C_0 for pure reactance and pure resistance resultant loads are shown in Figs. 7 and 8, for a wavelength of 377 metres ($\rho = .75$).

The principal points to note in these curves are listed below :—

(i) The input capacity varies considerably both with the magnitude and the phase of the resultant load, being greater for inductive than for capacitative loads.

(ii) The input capacity reaches a maximum value (slightly greater than $(1+\mu)C_2$ for a *finite* inductive load. It will appear later that this maximum is associated with the maximum amplification condition.

(iii) The input conductance can be positive or negative. It is negative for a certain range of inductive loads reaching a maximum negative value for a finite inductive load. In the case illustrated the negative input shunt resistance becomes as low as 8,700 ohms. For large effective impedance loads the input shunt resistance is positive but may reach a low figure (about 8,000 ohms in the case illustrated). The input shunt conductance is always positive for a capacitative load.

It would, of course, be possible to calculate the actual critical (maximum and minimum) values of C_0 and G_0 from Equations (19) and (20), but it is found that the analysis becomes

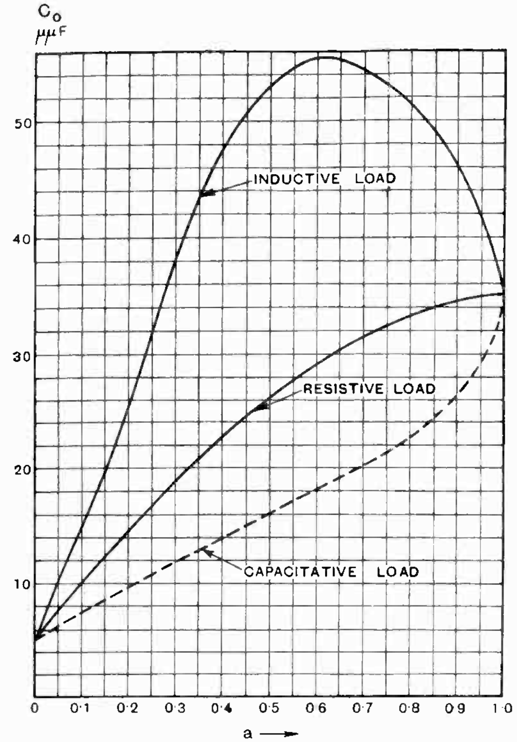

Fig. 8.—C_0 *at* 376.8 *metres* ($\omega = 5 \times 10^6$, $\rho = .75$).

very cumbersome in form and exceedingly difficult to elucidate by a physical interpretation. This step is therefore not given in detail.

10 (3).—*Input Admittance at Short Wavelengths.*

The behaviour of the equivalent network at very short wavelengths (30 metres and less) presents some very peculiar features, which are due to the fact that if ρ is large enough, the denominator $(1 - 2\rho b + \rho^2 a)$ can assume a range of exceedingly small values. For $\lambda = 28.3$, $\rho = 10$ for the representative case chosen. The variations of G_0 and C_0 for this value of ρ are shown in Figs. 9 and 10.

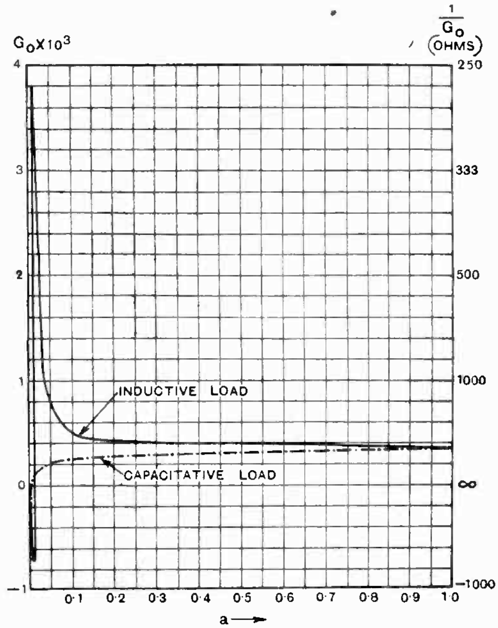

Fig. 9.—G_0 *at* 28.3 *metres* (*pure reactance load*).

Note that for a small value of a (in the neighbourhood of .01) and b positive (i.e., inductive) both input capacity and input conductance show very rapid fluctuations. The input conductance swings from a negative value (corresponding to a negative input resistance of only 1,400 ohms or so) to a large positive value (corresponding to an input shunt resistance of about 260 ohms). Apart from this rapid fluctuation the input shunt resistance remains fairly constant in the neighbourhood of about 5,000 ohms, both for inductive and capacitative loads.

The input capacity shows a similar fluctuation, actually becoming negative, i.e., effectively an inductance, over a small range of values. It must be remembered, however, that C_0 is not the *total* input capacity (*see* para. 5), which is never likely to be negative.

In the absence of experimental confirmation, which is not at present available, the above conclusions are put forward with a certain reserve, though an examination of the input admittance formulæ makes the mechanism of these fluctuations quite clear. It is at least reasonable to anticipate that if a triode valve is adequately represented by the usual equivalent network at short wavelengths, those or similar peculiarities in the variation of the input admittance with load may be looked for. Similar irregularities could presumably be produced artificially by increasing the grid-anode capacity so as to obtain a similar high value for ρ at a longer wavelength.

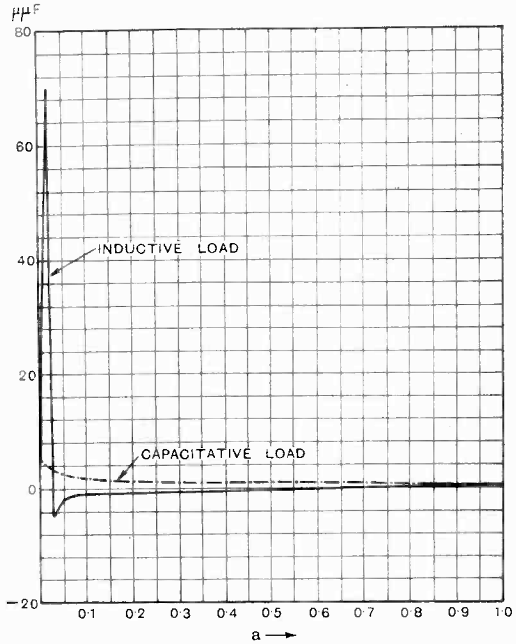

Fig. 10.—C_0 *at* 28.3 *metres* ($\rho = 10$).

10 (4).—*Amplification at Radio Frequencies.*

The formula for the voltage amplification becomes

$$\mathbf{M} = -\mu r \frac{1 - j\rho/\mu}{1 + j\rho r}$$

where $\rho = \omega C_2 R_a$ .. .. (23)

The magnitude of **M** is given by

$$M^2 = \frac{r^2}{1 + \rho^2 r^2 - 2\rho b}(\mu^2 + \rho^2) \qquad (24)$$

The first point to notice is that, as distinct from the audible frequency behaviour of the valve, **M** is considerably affected by C_2.

The important thing to know about the voltage amplification is its maximum value (if any) and the conditions under which it can be obtained.

First, it may be stated (for a fuller explanation, *see* Appendix III) that the maximum value of M will be associated with a pure inductive load. Attention will therefore be confined to this type of variation.

10 (5).—*Maximum Amplification Condition.*

For a pure inductive load formula (24) becomes

$$M^2 = \frac{a}{1 + \rho^2 a - 2\rho b}(\mu^2 + \rho^2) \qquad (25)$$

with $b^2 = a - a^2$.

It is easily shown by the usual differentiation method that this reaches a maximum value (with respect to a) given by

$$M^2 = \mu^2 + \rho^2 \text{ or } M = \sqrt{\mu^2 + \rho^2} \quad (26)$$

when $a = 1/(1 + \rho^2)$ and $b = \rho a$ .. (27)

These conditions can always be fulfilled, since $1/(1 + \rho^2) < 1$.

It is interesting to state this result in terms of the actual resultant anode circuit reactance X_5. From paragraph 8 :

$$\frac{X_5}{R_a} = \frac{b}{1 - a} = \frac{\rho a}{1 - a} = \frac{1}{\rho} = \frac{1}{\omega C_2 R_a}$$

i.e., $$X_5 = \frac{1}{\omega C_2}$$

This indicates that the maximum amplification condition is of the nature of a resonance in which the grid-anode capacity plays a part.

From Equation (26) it appears that the voltage amplification can actually *exceed the voltage factor*, this condition being reached with a finite resultant anode circuit load. This should be compared with the behaviour of the valve at audible frequencies, where the voltage factor is the upper limit of the voltage amplification, and this is only attainable with an infinite resultant anode circuit load.

It is only at rather short wavelengths that the excess of the possible amplification over the voltage factor becomes appreciable. At 283 metres, for instance, $\rho = 1.0$, so that the maximum value of M is 10.05 when μ is 10. On the other hand, for $\lambda = 28.3$, $\rho = 10$ and the maximum value of M is 14.14 for the same value of μ.

The variation of M with a for purely inductive loads is shown in Fig. 11 for wavelengths of 283 and 28.3 metres.

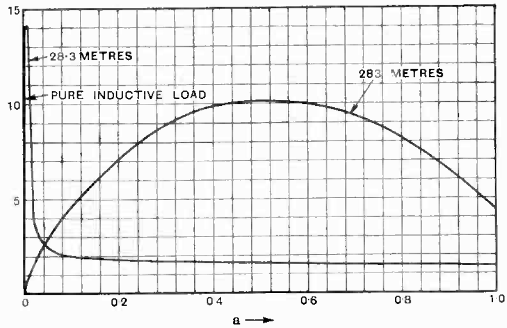

Fig. 11.—*Amplification at 283, and at 28.3 metres.*

It is important to realise that this calculated value of the voltage amplification refers to a maintained applied input potential difference between the grid and the filament, and takes no account of the manner in which the input potential difference is produced. If, as usually occurs in practice, the input P.D. is the resonance voltage across a tuned circuit a much more complicated state of affairs obtains, for this resonant voltage will depend on the input shunt resistance, which itself depends on the anode circuit load. The data for a full analysis of this case are given in this paper, but the matter is not discussed in detail as the paper is confined to the valve network itself without reference to associated input apparatus. In connection with this aspect of the matter, however, the following points should be noted.

10 (6).—*Voltage Amplification and Input Admittance.*

The optimum voltage amplification condition is defined by

$$a = 1/(1 + \rho^2)\ ;\ b = \rho a$$

which implies a pure inductive load. For such a load

$$G_0 = \frac{(\mu + 1)\,\rho a - \mu b}{1 + \rho^2 a - 2\rho b}\,\omega C_2$$

$$C_0 = \frac{(1 + \mu a) - \rho b}{1 + \rho^2 a - 2\rho b}\,C_2$$

For the values of a and b defining the maximum voltage amplification condition these reduce to

$$G_0 = \rho\omega C_2 = \rho^2 G_a = \omega^2 C_2{}^2 R_a$$

and $\quad C_0 = (1 + \mu)\,C_2$

Thus the maximum voltage amplification load gives approximately the maximum input capacity and a fairly low input shunt conductance.

The maximum amplification point is marked on the input capacity and conductance curves for $\lambda = 377$ metres. It is similarly situated on the 28.3 metre curves, but cannot conveniently be shown. It is marked, however, on Fig. 14 (Appendix II). Notice that in both cases the maximum voltage amplification value of a is near the point where the input conductance crosses the axis from negative to positive values, which fact is the probable explanation of the instability associated with tuned circuit H.F. amplification. The actual maximum voltage amplification for a given input voltage is associated with a positive input resistance,

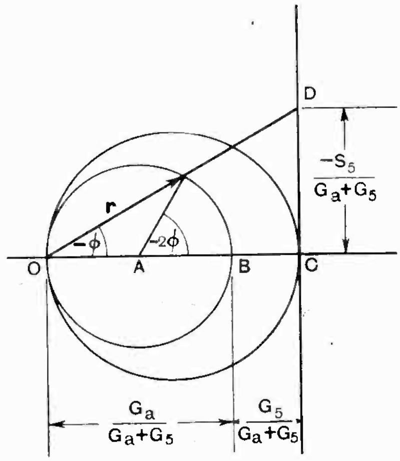

Fig. 12.

i.e., with a stable condition. With a tuned input circuit, however, the resonant P.D. would increase as the input conductance was reduced by making the load inductive reactance smaller, so that the actual response might increase right up to the instability condition.

At short wavelengths the input conductance associated with the maximum amplification condition becomes very high indeed. For instance, at 28.3 metres $\rho = 10$, and for the representative valve, with $R_a = 3 \times 10^4$, the input shunt conductance is $100/(3 \times 10^4)$, corresponding to an input shunt resistance of only 300 ohms. From this it would appear probable that the difficulty of realising high frequency amplification at short wavelengths is not due to the failure of the amplification process itself, but rather to the low input resistance associated with the amplification condition. This aspect of the matter is recommended to the attention of those who are engaged on development work in this sphere.

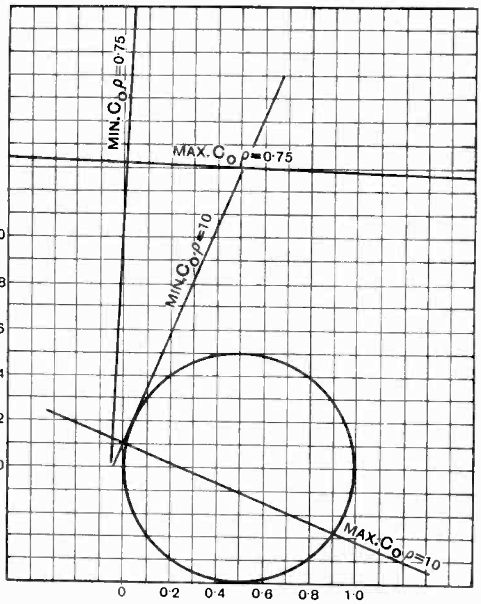

Fig. 13.

APPENDIX I.

Circular Loci of the Load Factor r.

Suppose the load to consist of a variable reactance in parallel with a fixed resistance (e.g., a condenser-tuned " rejector " circuit).

Then $\mathbf{Y}_5 = G_5 + jS_5$

where G_5 is constant.

$$\mathbf{r} = \frac{G_a}{G_a + \mathbf{Y}_5} = \frac{G_a}{G_a + G_5 + jS_5}$$

$$= \frac{G_a}{G_a + G_5} \frac{1}{2}\left\{1 + \frac{1 - jS_5/(G_a + G_5)}{1 + jS_5/(G_a + G_5)}\right\}$$

$$= \frac{1}{2} \frac{G_a}{G_a + G_5} (1 + \epsilon^{-2j\phi})$$

where $\tan \phi = \dfrac{S_5}{G_a + G_5}$

Referring to Fig. 12, the locus of $\mathbf{r}$ is therefore the circle on OB as diameter, becoming the limiting circle when G_5 is zero.

Similarly, if

$$\mathbf{Z}_5 = R_5 + jX_5$$

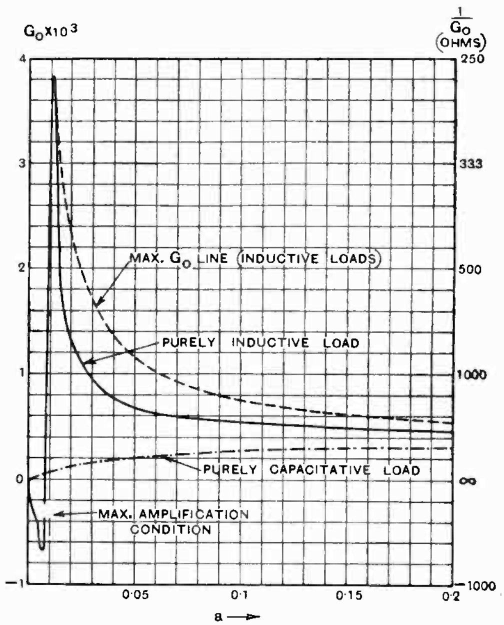

Fig. 14.—*G_0 for 28.3 metres (pure reactance load).*

where R_5 is constant, the circular locus of $\mathbf{r}$ is given by

$$\mathbf{r} = \frac{R_5}{R_a + R_5} + \frac{1}{2}\frac{Ra}{R_a + R_5}(1 - \epsilon^{-2j\psi})$$

where $\tan \psi = \dfrac{X_5}{R_a + R_5}$.

APPENDIX II.

Optimum Input Admittance Lines.

For any given value of a it can be shown by differentiation of 18 with respect to b that C_0 is a maximum or minimum when

$$1 - \rho b = (-\mu \pm \sqrt{\mu^2 + \rho^2})\, a$$

This defines two straight line relationships between a and b, which are shown plotted in Fig. 13 for

$\rho = .75$ ($\lambda = 377$ metres) and $\rho = 10$ (28.3 metres). In the former case neither line cuts the limiting circle, so that the initial values cannot be realised and the maximum realisable values of the input admittance terms correspond to points on the limiting circle. In the latter case the lines do actually cut the circle. For certain values of a, therefore, critical values of the input admittance will be associated with loads that are not purely reactive. The point of intersection of the optimum lines is obviously some kind of discontinuity. This point lies near the circumference of the limiting circle, and accounts for the rapid fluctuation in C_0 observed in this region.

Precisely similar observations can be made with respect to G_0, the optimum lines being

$$1 - \rho b = (\rho \pm \sqrt{\mu^2 + \rho^2})(\rho a/\mu)$$

Fig. 14 shows the variation of G_0 with a for pure reactance loads and also for that part of the maximum G_0 line which lies within the limiting circle. As already pointed out, the optimum G_0 line only affects the value of G_0 over a region which does not include the highest practically attainable value of G_0, which latter is associated with a pure reactance load. This point is of mathematical rather than practical interest, and for that reason is not elaborated in the text.

APPENDIX III.

Optimum Voltage Amplification Lines.

Since $$M^2 = \frac{r^2}{1 + \rho^2 r^2 - 2\rho b}(\mu^2 + \rho^2)$$

it is easily shown that for any given value of a, m^2 reaches a maximum when

$$b = \frac{1 + \sqrt{1 + 4\rho^2 a^2}}{2\rho}$$

increasing with b up to this limit. As in the input admittance cases, the optimum line does not cut the circle for longer wavelengths (i.e., smaller values of ρ) and for such cases the maximum of M corresponds to the highest realisable value of b for a given value of a (i.e., pure inductance loads). For $\lambda = 28.3$ m. ($\rho = 10$) the line actually cuts the circle, as shown in Fig. 15. As before, however, it is found that although for values of a corresponding to the included part of the maximum M line a load which corresponds to the maximum M line (i.e., not purely inductive) gives a higher voltage amplification than a purely inductive load, a higher amplification is obtained for a purely inductive load corresponding to a value of a for which the maximum M line gives an unrealisable value of b just outside the circle. The effect of the maximum M line is, in fact, similar to that shown in Fig. 15 for the input conductance.

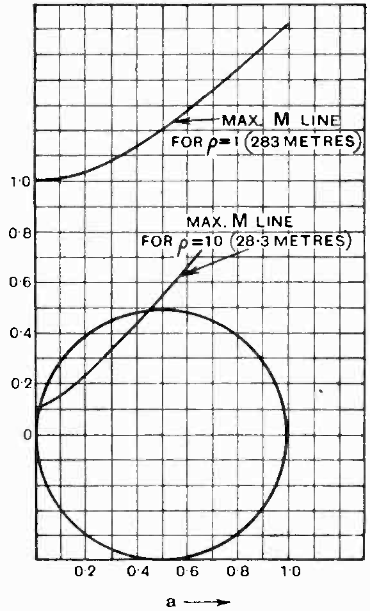

Fig. 15.

Book Review.

DER BAU VON ANODEN — UND HEIZSTROM — NETZANSCHLUSSGERÄTEN. By Manfred von Ardenne. 72 pp., with 78 Figures. Rothgiesser and Diesing, Berlin.

This is a fourth edition, largely rewritten and enlarged. It describes the principles of operation and gives instructions for the construction of practically every known type of apparatus for supplying anode and filament current from the supply mains whether D.C. or A.C. After a general introduction, there are five sections dealing with choke-coils, condensers, resistances, transformers and rectifiers, respectively. Having thus discussed the various components in detail the remainder of the book is devoted to the construction of complete sets of apparatus for D.C. and A.C. mains supply, a subject to which the author has devoted considerable attention. Except for two or three poor photographs the book is well printed and well illustrated and can be recommended to those interested in supplying their receiving sets from the mains—and who is not ?

G.W.O.H.

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.

The Definition of Selectivity.

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

SIR,—I am much indebted to Professor Howe for his comments in the Editorial of *E.W. & W.E.* for August on my proposals with regard to the specification of selectivity and sharpness of tuning, contained in the same issue. He suggests that what he calls the "anomaly" of a two to one ratio between selectivity and sharpness of tuning should be avoided by making the variable circuit element in the latter case one having an approximately linear relation with the frequency (*e.g.*, the square root of the capacity in the simple series resonant circuit), and he supports this suggestion with the statement that the square root of a capacity is, in such a connection, just as fundamental an idea as a capacity.

In reply :—

(1) Selectivity and sharpness of tuning are quite definite and distinct ideas. As pointed out in my article, it is only in certain special and very simple cases that there is any simple numerical relation between them at all, and the two to one relationship which holds in such cases is not really a "highly undesirable anomaly," but, on the contrary, a useful emphasis of the distinction.

(2) It could no doubt be maintained quite logically that the square root of a capacity is just as fundamental an idea as a capacity, but the very words used to describe it show that in the way things have actually developed it is a derived and not a primary idea.

(3) The proposed modification obtains an apparent simplification in some special cases at the expense of complicating the general definition.

Having said this much in legitimate self-defence, I would like to make it clear that I am really quite open to conviction in the matter and would welcome further comment, either from Professor Howe or from anyone else who is interested in this subject. There is no doubt that the term selectivity is somewhat loosely used at present, and my views were put forward mainly with the idea of stirring up comment and suggestion.

F. M. COLEBROOK.

Teddington.

Measurement of Wavelengths of Broadcasting Stations.

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

SIR,—With reference to the illuminating account of wavelength measurements by R. Braillard and E. Divoire in *E.W. & W.E.*, p. 412, August, 1929, where the heterodyne note of 1000 cycles per sec. is made to beat with a tuning fork of like frequency, the following may be of interest: If the audio frequency circuit of my modulated C.W. wavemeter (see *W.W.*, p. 107, January 23rd, also *E.W. & W.E.*, p. 83, February, 1929) is replaced by a constant audio E.M.F. injected from a valve driven fork (say) the radio frequency will be modulated by a constant audio frequency of 1000 cycles. The modulated radio frequency from the meter is heterodyned by the incoming signals until a note of 1000 cycles is obtained. The resulting beats between this and the audio note from the wavemeter serve to indicate the constancy of the received station. Such beats can either be recorded or indicated visually on a suitable instrument.

The radio frequency circuit of the meter consists of an inductance and condenser of great accuracy, whilst the potentials applied to the valve are adjusted so that a negligible variation in frequency is introduced by its negative resistance. The valve has preferably a low anode to screen-grid capacity, *e.g.*, 3 micromicrofarads.

Doubtless by injecting the audio E.M.F. at some suitable point in the circuit given by the authors in Fig. 2, similar results could be obtained. The screened valve has, of course, the advantage of greater simplicity.

N. W. MCLACHLAN.

London, 1929.

Anode Rectification.

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

SIR,—In his article on Anode Rectification in your current issue, Mr. A. G. Warren states that the method of approximate integration which I described in *E.W. & W.E.* of August, 1927, is unsuitable for the most desirable type of rectification characteristic. He concludes that there is no satisfactory alternative to actual calculation, by which he means the averaging of eighteen selected ordinates. May I suggest that in this opinion he does less than justice to a labour-saving device of tried merit. Indeed, it will be found that if my method be applied to Mr. Warren's own example, its accuracy for the purpose will be amply vindicated.

The formula which I recommended was (*loc. cit.*),

$$i_r = \frac{1}{n}\left\{ i_{\frac{\pi}{2n}} + i_{\frac{3\pi}{2n}} + \cdots + i_{\frac{(2n-1)\pi}{2n}} \right\}$$

where the phase angles are reckoned from the extreme minimum of the voltage variation, i.e., from $-E$. If, now, n be put $= 3$, a simple calculation shows that, in accordance with Mr. Warren's scheme of reckoning the angles from a central zero,

$$i_r = \frac{2}{3} \times \left(\frac{i_1 - i_2}{2}\right)$$

where the value of the bracket factor is that corresponding to the value $\theta = 60°$ in Mr. Warren's table. To test the accuracy of this result, I tried to interpolate for $\theta = 60°$ from the values there given. It was, however, impossible to do so to four-figure accuracy, as the values do not difference smoothly. This seems to indicate that the accuracy implied in Mr. Warren's example is somewhat illusory, the fourth significant figure being quite untrustworthy. Taking, however, the value of $\frac{i_1 - i_2}{2}$ required as the mean of those given for 55° and 65°, it is found that i_r is .0567 mA. as compared with Mr. Warren's .0565 mA., surely not a bad shot! Indeed, it is difficult to see what more could be required, in view of the uncertainty attaching to the fourth place of the figures given.

It is only fair to my formula to restate the condition under which it applies. This is, that the $2n$th differences of the characteristic function shall be zero. This expressly rules out the ideal "angle" characteristic, but even when $n = 3$ it certainly admits most of the experimental characteristics likely to be met with in practice. The course of such a characteristic over a wide range may well be set out from six experimentally determined points, and thus be represented by a polynomial function of the fifth degree whose sixth differences are zero. (The fact that more than six points may actually be taken only indicates the necessity for "graduating" the data, to which a smooth curve of the fifth degree will then be adequate.)

Should the standard of accuracy required be even higher than this, the value of n may be increased so as to ensure a still more representative arc of the curve. For example, if $n = 6$, we shall have in Mr. Warren's notation

$$i_r = \frac{1}{3}\left\{\left(\frac{i_1 - i_2}{2}\right)_{15°} + \left(\frac{i_1 - i_2}{2}\right)_{45°} + \left(\frac{i_1 - i_2}{2}\right)_{75°}\right\}.$$

These values are given in his table, so that the calculation stands as under

$$\begin{array}{r} .0081 \\ .0600 \\ .1007 \\ \hline 3).1688 \\ \hline .0563 \end{array}$$

Surely the saving of labour even here is considerable, while the accuracy is unimpeachable. Indeed, the error introduced by the approximation is infinitesimal compared with the observational errors in the data to which it is here applied.

It is pertinent to observe that, if we could be assured of the *absolute* accuracy of the data in his table, Mr. Warren's longer method would be justified. Failing this, however, we are entitled to use any method of approximation whose intrinsic error lies well within the standard of error of the data used. I think it will be found that the standard of accuracy obtained by putting $n = 3$ in my formula is considerably superior to that of the determination of most experimental characteristics, while with $n = 6$ the accuracy is beyond all cavil. To put $n = 18$, which is essentially his procedure, is simply to multiply labour for no useful purpose.

In conclusion, may I say that I do not quite see the "obvious simplification" attained by plotting the curve of $\frac{i_1 - i_2}{2}$. To my mind nothing is gained by finding the means of nine pairs of ordinates and then finding the average of the nine means. Why not average the complete set of eighteen from the original curve? Setting out the new graph only introduces a fresh source of error, and there is no reason why the original curve should not be drawn to as large a scale as may be necessary. I cannot help thinking that, working to four-figure accuracy, it would have been better to dispense with this device.

W. A. BARCLAY.

Bieldside, N.B.

Frequency Modulation.

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

SIR,—After consideration of Mr. Holmblad's reply in the August issue, I am forced to the conclusion that my formula for a frequency-modulated wave is an impossible one. It is now clear that in the expression

$$i = a \sin(\omega t + \phi) \quad \ldots \quad (1)$$

for an ordinary sine wave, ω represents the cyclic frequency not because it is the multiple of t but because it is the differential coefficient of the angle $\omega t + \phi$. When ω or ϕ is a function of t, ω ceases to represent the cyclic frequency at the instant t, and the correct expression for this frequency is $\frac{d}{dt}(\omega t + \phi.)$

To deduce the formula then for a frequency-modulated wave, it may first be written in the form

$$i = a \sin\{f(t)\} \quad \ldots \quad (2)$$

The instantaneous frequency $\frac{df}{dt}$ is to vary sinusoidally between limits $\omega + km$ and $\omega - km$, so that

$$\frac{df}{dt} = \omega + km \cos mt.$$

By integration

$$f(t) = \omega t + k \sin mt + \theta.$$

If time is measured from a zero point where $i = 0$, then θ vanishes and (2) becomes

$$i = a \sin\{\omega t + k \sin mt\} \quad \ldots \quad (3)$$

which agrees with the formula employed by Mr. Holmblad.

On comparing (3) with (1) it is seen that the frequency-modulated wave may be regarded as one in which the phase angle ϕ has a slow cyclic variation $k \sin mt$. Methods known as "phase modulation" have been proposed in which a fixed-frequency wave is modulated by a phase-adjusting impedance. It would appear that the wave resulting from such "phase modulation" is of the same form as that produced by "frequency modulation."

Readers interested in the subject should refer to an article by John R. Carson in the Proceedings of the American Institute of Radio Engineers, Vol. 10, page 57. The subject is approached in a somewhat different manner but the conclusions arrived at with regard to the width of the side-bands agree with those of Mr. Holmblad.

G. H. MAKEY.

The Patent Office.

Abstracts and References.

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PROPAGATION OF WAVES.

Sur la Couche Ionisée de la Haute Atmosphère (The Ionised Layer of the Upper Atmosphere).—M. Ponte and Y. Rocard. (*L'Onde Élec.*, May, 1929, V. 8, pp. 179–191.)

Authors' summary :—" In problems relating to the conducting properties of the upper atmosphere, it seems that up to now one has been satisfied with a distinctly summary kinetic theory for calculating fundamental values such as the free paths of the electrons. We attempt in this article to arrive at new values taking more strict account of the interactions between electrons and molecules. It will be seen that we thus reach results differing considerably from those usually admitted, since we find a value for the electron free path which is (other things being equal) 40 to 160 times smaller than that deduced from the elementary theory. It must be understood that these results are only valid for electrons possessing the velocity of thermal agitation, which is the case for the electrons of the higher atmosphere—apart from the influence of the earth's magnetic field. As soon as electrons become accelerated—however little—by an electric field, the interactions with molecules become negligible and the free paths increase."

The next part of the paper will discuss the consequences of the above conclusion as it affects the Heaviside layer and its behaviour towards different wavelengths.

Group Velocity.—D. G. Bourgin. (Summary in *Phys. Review*, June, 1929, V. 33, p. 1072.)

The empirical formula suggested by Tonks (May Abstracts, p. 265), namely, $\mu E = vE_i$, where μ and v are the group and phase velocities and E and E_i are the total and doubled reactive energies per unit length respectively, is examined for validity. The theorem does not hold in general if the characteristic linear differential equation involves higher space derivatives than the second—the physical interpretation is immediate.

Über die Absorption Hertzscher Wellen in ionisierten Gasen (The Absorption of Hertzian Waves in Ionised Gases).—H. Dänzer. (*Ann. der Phys.*, 7th June, 1929, 5th Series, V. 2, No. 1, pp. 27–62.)

An investigation arising from an attempt to imitate on a small scale the effects of the Heaviside layer on electromagnetic waves. 4–4.5 cm. waves were generated by a spark dipole oscillator (after Lebedew) and directed by an optical system of paraffin lenses. Reception was by a bolometer system (balanced bridge), a length of Wollaston wire being reduced at its mid-point, the un-reduced ends acting as the poles of the receiving dipole. The rays were directed against a " layer " of intensively ionised gases (Ne, A, N, H, O and Air) and reflection and absorption measurements were made. Using the absorption effect thus measured as a method of investigation, the writer then measured the life of the free electrons produced by the ionising discharge. Values for the various gases ranged from about 3×10^{-4} sec. (H and N) to 1×10^{-4} sec. (Air and O). The theoretical section of the paper appears to be similar to the treatment of the subject (from considerations regarding the propagation of waves) by H. Lassen (*Zeitschr. f. Hochf. Tech.*, 1926, V. 28, p. 139).

Magnetic Storms and Radio Signals.—I. J. Wymore. (*Nature*, 20th July, 1929, V. 124, p. 109.)

A paragraph quoting the announcement that the Bureau of Standards have discovered the following relation between magnetic storms and radio signals:—when signals from European stations are weaker than usual and those from nearer stations in America are louder than usual, magnetic storms may be expected within a few days. After a magnetic storm, much stronger signals are received from distant stations.

Some Observations of Short Period Radio Fading.—T. Parkinson. (*Proc. Inst. Rad. Eng.*, June, 1929, V. 17, pp. 1042–1061.)

Author's summary :—" The data presented are the product of an investigation started at the beginning of 1928 with the object of studying the short-period fading of radio broadcast transmissions. Particular attention was paid to those intensity changes which take place during periods ranging from a few seconds to several minutes. Various antenna combinations were used in making simultaneous records in order to separate the effects of various causes of fading.

" The data secured partly confirm the conclusions of previous investigations, partly point to other sources of fading. Varying intensity of the indirect ray and interference between indirect and ground rays are evidenced as in earlier experiments, but rotation of the plane of polarisation of the indirect ray is also shown to be a considerable factor and there are suggestions of lateral direction shifts of the indirect rays and of their arrival by multiple paths."

The paper is followed by an appendix giving a summary of the conclusions of other workers from previous investigations.

A New Method of Determining Height of the Kennelly-Heaviside Layer.—C. B. Mirick and E. R. Hentschel. (*Proc. Inst. Rad. Eng.*, June, 1929, V. 17, pp. 1034–1041.)

Field strength measurements of signals from aeroplanes, recorded during the past year at the Naval Research Laboratory, Washington, showed periodic variations of fairly constant frequency over considerable time intervals. The measurements were on frequencies 2,500–6,000 kc. per sec., at distances up to 130 miles; in most cases marked fading was observed at distances beyond 15 or 20 miles.

From data thus obtained (which included velocity of aeroplane over the ground, distance from recording station, and distance between peaks of fading) a determination of the height of the Heaviside layer has been attempted, on the following theory. As the transmitter moves from or toward the receiver, the ratio of the length of the ground path to the sky path is changing, and the phase relation between the two components is also progressively changing; while the aeroplane travels over a distance V/F (V = velocity parallel to ground, to or from recording station; F = frequency of intensity variation), the graphic record goes from peak to peak, and the phase of one component has changed 360 degrees with respect to the other—*i.e.*, the difference between the optical lengths of the two paths has changed by a distance equal to the wavelength of the transmitted wave.

The data from a number of flights have been treated according to this theory. In practically every case the distance between maxima of fading was found to increase with the distance of transmission, which conforms with the theory and its geometrical representation. The values for the layer height varied from 53.4 to 85.0 miles, the mean of 11 tests working out to approximately 70 miles (113 km.). All these tests were in daytime, and were on either 2,725 or 3,000 kc. per sec.

FADING AND SKIP DISTANCE IN THE DUTCH EAST INDIES.—S. G. Langendam. (*Tijds. Ned. Radiogen.*, December, 1928, V. 4, pp. 3–12.)

For average telephonic ranges of 400 km. the best wavelengths were 70–80 m., showing little fading between 11 a.m. and 2 p.m. Skip distance effects seemed completely absent.

THE OZONE IN THE EARTH'S ATMOSPHERE.—D. N. Harrison. (*Nature*, 13th July, 1929, V. 124, pp. 58–61.)

"Ozone observations are now made regularly at least once a day at about half a dozen places in different parts of the world. The results up to the present from these series of observations are the subject of this article."

THERMAL DIFFUSION OF RARE CONSTITUENTS IN GAS MIXTURES.—S. Chapman. (*Phil. Mag.*, January, 1929, V. 7, pp. 1–16.)

THE ATTENUATION OF ULTRA-VIOLET LIGHT BY THE LOWER ATMOSPHERE.—L. H. Dawson, L. P. Granath, and E. O. Hulburt. (*Phys. Review*, 1st July, 1929, V. 34, pp. 136–139.)

Among the results may be mentioned:—The absorption around 2,800–2,900 A.U. was not sufficient to account for the sharp cessation of the solar spectrum in this region (this is in keeping with the belief that the ultra-violet limit of the solar spectrum is due to ozone in the high atmosphere). The absorption in the lower atmosphere at 2,200–2,050 A.U., a spectrum region where ozone is relatively transparent, is great enough to prevent sunlight of these wavelengths from penetrating to sea level.

RECEPTION EXPERIMENTS IN MOUNT ROYAL TUNNEL: DISCUSSION.—C. R. Englund: A. S. Eve. (*Proc. Inst. Rad. Eng.*, May, 1929, V. 17, pp. 892–894.)

Referring to the paper dealt with in May Abstracts, p. 263, Englund mentions that Eve spoke of radio methods of ore prospecting, and points out that the attenuation in the ground which Eve reports as observed for ordinary radio signals is not necessarily the same attenuation as that which the ore prospector would encounter in applying radio to subterranean ore finding. In the latter process it would seem that ordinary transverse waves are the preferable type, such for example as would best be produced and observed by using buried aerials. In these waves the electric and magnetic vectors are not in time phase (because of the earth's conductivity) but are at right angles to the Poynting vector, and the only serious difference from ether waves is the presence of an attenuation factor. Ordinary radio transmission is another type of wave motion, a longitudinal one. The equiphase surfaces no longer coincide with the equiamplitude surfaces, and there is attenuation in directions both along and perpendicular to the ground. That the attenuation perpendicular to the ground in these "hybrid" waves should be the same as the attenuation along the direction of propagation of transverse waves is neither necessary nor evident and a distinction is clearly to be made. He then elaborates this point both mathematically and by quoting experimental results.

RANGE TESTS WITH WAVES UNDER ONE METRE IN LENGTH.—W. Ludenia. (*See* under "Transmission.")

BEAM TELEPHONY ON 14 CM. WAVES.—K. Kohl. (*See* under "Transmission.")

LA PÉNÉTRATION DES DÉPLACEMENTS ÉLECTRIQUES OU MAGNÉTIQUES AINSI QUE DES ONDES ÉLECTROMAGNÉTIQUES À LA SURFACE DE SÉPARATION DE DEUX MILIEUX (The Penetration of Electric or Magnetic Displacements, or of Electromagnetic Waves, at the Surface of Separation of Two Media).—A. K. Kotelnikoff. (*Rev. Gén. de l'Élec.*, 13th July, 1929, V. 26, pp. 53–59.)

Starting with the fundamental equations defining the propagation of any sinusoidal displacement, the writer investigates the modifications which their general solutions undergo at the surface of separation of two unlike media. The expressions thus established are then applied in succession to the cases where the displacements are electric, magnetic, and finally when they are electromagnetic waves. "The resulting simple relations and their graphic representation allow a physical interpretation to be placed on the phenomena under consideration."

A Note on Doppler Effect and the Hypothesis of Radiation Quanta.—D. S. Kothari. (*Phil. Mag.*, July, 1929, V. 8, No. 48, pp. 55–63.)

"The Doppler-Fizeau effect . . . is easily explained if radiation is considered to be propagated in the form of waves. In the present note it is explained on the hypothesis of radiation quanta, *i.e.*, light is considered to be propagated in the form of quanta and not waves. It is further shown that Compton effect is a particular case of Doppler effect." The writer ends his paper by pointing out that the Majorana experiment can now be regarded as proving the constancy of the velocity of light both on the wave theory and on the quantum theory.

Über die kalorimetrische Absolutmessung des elektrolytischen Leitvermögens für hochfrequenten Wechselstrom (On the Calorimetric Absolute Measurement of Electrolytic Conductivity for High-frequency Currents).—E. Justi. (*Ann. der Phys.*, 7th June, 1929, Series 5, V. 2, No. 1, pp. 65–93.)

As an example of the results, the behaviour of a NaCl solution (about 9.2 per cent.) may be given :—The comparative resistance values for various wavelengths were roughly 56 (50 m. wave), 23 (75 m. wave), 13 (100 m. wave) and 8 (120 m. wave). Thus within this range of frequencies there is no large sudden change in conductivity such as might be expected (somewhere between L.F. oscillations and light frequencies) to reconcile the transparency of many electrolytes with Maxwell's theory, which demands opacity as a condition for conductivity. Among results obtained in preliminary experiments, the writer concludes that the increase of resistance caused by surrounding a wire carrying a H.F. current with an insulating coating is probably not due to dielectric loss in that coating (as is usually assumed) but to the latter's higher dielectric constant, causing a more pronounced skin effect.

A Study of Wave Synthesis by Mechanical Means.—A. D. Ladner. (*Marconi Rev.*, June, 1929, No. 9, pp. 1–8.)

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

Cosmical Magnetic Phenomena.—S. Chapman. (*Nature*, 6th July, 1929, V. 124, pp. 19–26.)

The Rouse Ball Lecture delivered at Cambridge on 31st May. It is divided into the following sections :—Lunar and Planetary Magnetism ; Terrestrial Magnetism ; Solar Magnetism ; Origin of the Magnetism of the Earth and Sun ; the Electrical Conductivity within the Earth ; Radial Limitation of the Sun's Magnetic Field ; Terrestrial Drift Currents and other Electromagnetic Phenomena. In this last section, the writer says : "Eastward drift currents will flow at heights where the mean free path is larger than, or comparable with, the spiral-radius of ions and electrons ; in the earth's field, at the equator, the spiral-radius is about 2 cm. for an electron, and 5 metres for an ionised oxygen or nitrogen molecule ; consequently *electronic* drift currents will occur at heights above about 70 km., and *ionic* drift currents above about 150 km. But the number of electrons and ions is much less than would be required to enable the drift currents to shield the outer space from the earth's magnetic field ; less than 5 per cent. of the tubes of force crossing the earth's surface are confined within the atmosphere by the drift currents. This estimate is derived from the spherical harmonic analysis of the earth's field, which shows that only about 3 per cent. of the surface intensity is due to overhead currents ; from this it is possible to infer that there are less than 10^{16} ions per sq. cm. column of atmosphere, above a height of 150 km."

Die radiale Begrenzung des Magnetfeldes der Sonne (On the Radial Limitation of the Sun's Magnetic Field).—J. Bartels. (*Naturwiss.*, 12th April, 1929, V. 17, pp. 243–244.)

A communication on the subject of Chapman's paper referred to in July Abstracts, p. 387.

Variation diurne du Potential Électrique de l'Air et Déperdition Électrique pendant le Mois de Septembre, 1928, à l'Observatoire de Ksara — Liban (Daily Variation of Atmospheric Electric Potential and Electric Dissipation Loss during September 1928, at Ksara, Liban).—J. Chevrier. (*Comptes Rendus*, 13th May, 1929, V. 188, pp. 1306–1307.)

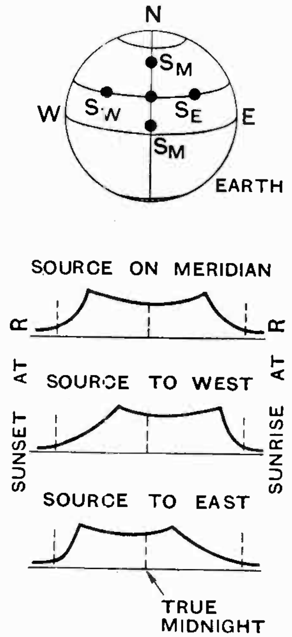
Un Procédé pour déterminer à grande Distance la Position géographique et la Vitesse de certaines Discontinuités ou Perturbations météorologiques à l'Aide des Atmosphériques qu'elles émettent (A Method of Determining from a Great Distance the Geographical Position and the Velocity of Certain Meteorological Discontinuities or Disturbances, by Means of the Atmospherics which these Emit).—J. Lugeon. (*Comptes Rendus*, 24th June, 1929, V. 188, pp. 1690–1692.)

Deductions from 550 days' atmospheric registrations taken at Zurich with the writer's "atmoradiograph," which records the frequency per minute of the disturbances and gives an idea of their intensity by the thickness of the line traced (see *Ac. Soc. Helvétique Sc. Nat.*, 109th Session, Lausanne, 1928, p. 141).

The writer divides atmospherics into the usual two classes—*local*, short range (a few hundred metres to a few kilometres), not susceptible to D.F., almost always attributable to local meteorological causes and thus giving an indication of the quality and geographical origin of the air in circulation there ; and *distant*, capable of being D.F.'d, of range reaching several thousands of kilometres, emanating chiefly from discontinuities where the cold or polar air is "active." The range of these atmospherics is greatest in the dark, least in the illuminated, portion of the atmosphere. Registration is remarkably regular, suggesting a filtering or absorptive effect along the path of the waves. The differing properties of the two classes allow them to be distinguished one from the other in those cases where the two are superposed.

The régime of the distant atmospherics, received in complete darkness, is established gradually after sunset at the place of origin. Their first maximum is reached a little after the end of the astronomical twilight there—when the last solar ray has left the "mirror of reflection of the Hertzian waves." Inversely, from the moment when the first rays of the solar aurora point to the zenith of the place of origin or of the receiver (according to whether the latter is W. or E. of the former), long-distance propagation of atmospherics is progressively diminished and finally annulled when the whole path is in daylight.

A minimum of intensity of distant atmospherics occurs when the sun is opposite to the meridian of the receiver—at midnight. "This is due to the *tide* of the Heaviside layer, which at that time is at its highest point so that the path is at its maximum length, with a consequent weakening of received field."



The next part of the paper deals with the deduction, from the shape of the records, of the position of the source of the distant atmospherics.

Thus in the diagram if S_M is a source on the meridian of the receiver R the recorded curve will be symmetrical with respect to true midnight, since the twilight phases are the same at S and R. If the source is at S_W, west of R and practically on the same parallel of latitude, the cessation of distant atmospherics will occur after sunset at R, with a time-lag equivalent to the time-difference between twilight at R and S: for a source to the east, the curve will be displaced in the reverse direction. The longitude of S is thus given by the last nocturnal maximum, corresponding to the end of the night at the source.

The rest of the paper is devoted to showing how a comparison of these curves, day after day, gives a means of measuring the average velocity of displacement of a source, and an indication of its importance.

COMETS AND TERRESTRIAL MAGNETIC STORMS.—H. B. Maris and E. O. Hulburt. (*Phys. Review*, June, 1929, V. 33, pp. 1046–1060.)

See May Abstracts, p. 265, on the "ultra-violet blast" theory in its relation to comets. Evidence in support is here provided by data concerning 31 comets between 1848 and 1927. In the month preceding each comet's activity there occurred on the average 6, 4, 2.9 and 1.5 times as many magnetic storms of strength 4, 3, 2 and 1 respectively, as should have occurred according to chance.

SUR L'ACCÉLÉRATION DES MASSES D'AIR DANS LES MOUVEMENTS ATMOSPHÉRIQUES (The Acceleration of Masses of Air in Atmospheric Movements).—L. Petitjean. (*Comptes Rendus*, 24th June, 1929, V. 188, pp. 1688–1690.)

By thermodynamic methods, making use of a relation due to Margules, the writer obtains an equation to give the sense of the acceleration in question. Applying this to the air in the northern hemisphere, he finds 4 possible cases, two of which are subdivided into two possibilities (accelerated and retarded motion). An example of these 4 cases is given by the first:—the air rises, turning to the left; the movement is retarded. This case occurs when "passive" warm air is thrown on the left of the "active" cold air following the surface of a cold front.

ELEKTROMAGNETISCHE STORUNGEN II (Atmospherics. Part II).—F. Schindelhauer. (*E.N.T.*, June, 1929, V. 6, No. 6, pp. 231–236.)

Further elaboration of the author's theory dealt with in February Abstracts, pp. 101–102. The final summing-up is as follows:—The available observations lead to a grouping of "ring-stream" disturbance which agrees with the actual direction of the magnetic field. The daily variation of the direction in Aboukir is "in principle" the same as in Potsdam (p. 232, r-h. column). During the day an ionised layer moves between the earth's surface and the "ring-stream" layer, acting as a screen and itself forming a source of disturbance (*cf.* Lugeon, August Abstracts). The electrical equilibrium processes in this layer take place along the lines of magnetic force, since the free paths are short (p. 233, l-h. column). In the afternoon the two layers merge into one another, with the result that as ionisation decreases a gradual rotation of the (magnetic) N-S direction towards the (magnetic) E-W direction takes place, apparently following the course of the sun (p. 234, l-h. column). The ionisation in the day-layer in the morning, and the recombination in the afternoon, take place from below upwards. The influence of the displacement of the earth's magnetic axis relative to the axis of rotation is seen in the daily variation of the direction (p. 234, r-h. column).

ÜBERLAGERUNG DES NEWTONSCHEN FELDES DURCH EIN COULOMBSCHEN FELD (The Superposition of an Electric Field on the Newtonian Field).—G. v. Gleich. (*Zeitschr. f. Phys.*, 13th June, 1929, V. 55, No. 5/6, pp. 378–385.)

Many phenomena, such as the behaviour of comet tails, suggest that the sun is the mid-point not only of a gravitational field but also of an electrical field. The writer sets out to find how great an electric charge the sun must have in order to produce the much-argued-over periheliondisplacement of Mercury. He concludes that a particle of sun- and planet-substance, of the mass of an electron, would have to carry a charge greater than 4.66×10^{-31} e.s.u., which he considers reasonable in comparison with the known charge of an electron.

A final note suggests that the sun's electromagnetic field—if it exists—may undergo variations in strength which perhaps might be connected with sunspot frequency: this idea recalls Ludendorff's work on the dependence of the shape of the solar corona on the sunspot frequency.

DURCHLÄSSIGKEIT DER ABSOLUT REINEN UND TROCKENEN ATMOSPHÄRE FÜR SONNENSTRAHLUNG (Transparency of the Absolutely Pure and Dry Atmosphere for Solar Radiation).—W. Kastrow. (*Meteor. Zeitschr.*, No. 10, 1928, V. 45, pp. 377–381.)

Basing his calculations on the recent determination at Mt. Wilson of the energy-distribution in the solar spectrum, and proceeding by a different mathematical path to that usually followed, the writer obtains values disagreeing quite seriously with those of Linke and Fowle.

BROADCASTING OF SYNOPTIC WEATHER CHARTS.—(*Nature*, 6th July, 1929, V. 124, p. 30.)

A paragraph on the present broadcasting from 5XX of weather charts for reception on picture receivers.

EINE BEMERKUNG ÜBER DIE ABHÄNGIGKEIT DER MAXIMALEN HIMMELSPOLARISATION VON DER SONNENHÖHE (A Note on the Dependence of the Maximum Sky Polarisation on the Height of the Sun).—J. J. Tichanowsky. (*Meteor. Zeitschr.*, No. 12, 1928, V. 45, p. 480.)

SUNSPOTS AND PRESSURE.—M. V. Unakar. (*Nature*, 6th July, 1929, V. 124, pp. 11–12.)

INTERNATIONAL CO-OPERATION FOR AURORAL RESEARCH.—C. Störmer. (*Journ. Roy. Astron. Soc. Canada*, January, 1929, V. 23, pp. 1–7.)

The photographic methods used in the work referred to in April and August Abstracts, pp. 204 and 445, are here described, and a plan for international co-operation is discussed.

PERIODS OF SOLAR AND TERRESTRIAL PHENOMENA.—H. Fritz. (*Monthly Weather Rev.*, October, 1928, V. 56, pp. 401–407.)

VARIATIONS DU CHAMP ÉLECTRIQUE TERRESTRE À LA STATION DU SOMMET DU PUY DE DÔME (Variations of the Terrestrial Electric Field at the Puy de Dôme Summit Station).—E. Mathias and Ch. Jacquet. (*Comptes Rendus*, 1st July, 1929, V. 189, pp. 14–15.)

COMPTE RENDU DES OBSERVATIONS RADIOATMOSPHÉRIQUES FAITES PENDANT L'ANNÉE 1927 (Report on the Observations of Atmospherics during 1927).—D. B. Paolini and G. P. Ilardi. (*L'Onde Élec.*, May, 1929, V. 8, pp. 222–226.)

A paper communicated to the U.R.S.I. Congress in 1928. The observations were based on the Paolini atmospheric-scale, which includes 14 degrees of which 8 distinctly interfere with reception; four of these (group I) represent "distinct" atmospherics which can be easily counted, while the other four (group II) represent the "confused" type. A summarised analysis of the monthly "density" of each of these two groups is given.

DIE ERZEUGUNG WEITGEHEND HOMOGENER MAGNETFELDER DURCH KREISSTRÖME (The Formation of Extensive Homogeneous Magnetic Fields by Circular Currents).—G. Fanselau. (*Zeitschr. f. Phys.*, 4th April, 1929, V. 54, No. 3/4, pp. 260–269.)

A more complex form of the usual Helmholtz coil presents great advantages over the latter and should be useful for measuring terrestrial magnetism.

ZUR FRAGE DES TÄGLICHEN WINDGANGES (The Question of the Daily Variations of Wind).—B. Iswekow. (*Meteorol. Zeitschr.*, No. 1, 1929, V. 46, pp. 1–7.)

PROPERTIES OF CIRCUITS.

ÉTUDE DE LA MÉTHODE DE BEATTY POUR LA MESURE DE L'AMPLIFICATION D'UN ÉTAGE À RÉSONANCE (An Investigation of Beatty's Method of Measuring the Amplification of a Tuned Stage).—F. Bedeau and J. de Mare. (*L'Onde Élec.*, May, 1929, V. 8, pp. 210–221.)

Authors' summary :—"The calculation of the amplification of a tuned stage has been dealt with by a number of writers. Simplifying assumptions are generally made which in spite of their apparent legitimacy considerably affect the accuracy of the results. Beatty's method (*E.W. & W.E.*, January, 1928) although very simple, gives a much more accurate calculation of the amplification. Now that tuned amplifiers with screen-grid valves are being more and more used, it seems of interest to discuss Beatty's paper, which acts as a guide to the choice of valves. . . . We pass over that part of the paper dealing with future progress with screen-grid valves, and have on the other hand developed the paragraph on the study of stability."

Regarding the determination of the valve constants which must be obtained, the writers do not recommend Miller's method of measuring the amplifying power K and internal resistance ρ, but prefer a direct determination of the latter by a Wheatstone bridge. The slope $S (= K/\rho)$ is then measured directly by Barkhausen's method (of which a diagram and summary are given). The grid-plate capacity they find by the method of Hull and Williams (diagram and summary also given).

LA QUESTION DE L'AMPLIFICATION (The Question of Amplification).—P. Olinet. (*QST Franç.*, June, 1929, pp. 12–17.)

In this continuation of the series, the first parts of which were referred to in October Abstracts, 1928, the writer deals with the practical production of negative resistances, taking as examples the two two-triode combinations known as Turner's Kallirotron and Scott-Taggart's Biotron, both of which he analyses.

VERSTÄRKERTRANSFORMATOREN (Amplifier Transformers).—M. Osnos. (*Telefunk. Zeit.*, May, 1929, V. 10, No. 51, pp. 39–58.)

A graphic representation of the functioning of an amplifier transformer is given, and general equations are derived for the ratio input-voltage/output-voltage, for a large number of different circuits. The choice of the most favourable ratio is indicated for each type of circuit, and for the two classes of transformer considered—those with a more or less closed secondary circuit and those whose secondary circuit is a valve grid circuit.

ÜBER VERSTÄRKERTRANSFORMATOREN (On Amplifier Transformers).—R. Gürtler. (*Telefunk. Zeit.*, May, 1929, V. 10, No. 51, pp. 58–61.)

Compares Osnos's treatment (see above) with that of Rukop (Abstracts, 1928, V. 5, p. 343) with a view to the most efficient combined use of both. The writer recommends the use of Rukop's formulæ for the preliminary design of a transformer, particularly the one proceeding from the permissible fall of the frequency curve at the limits of frequency (25 and 10^4 p.p.s.). Osnos's equations are suitable for more exact investigations, showing clearly as they do the influence of the various factors (iron-losses, leakage, etc.) in the various frequency zones.

GRID LOSSES IN POWER AMPLIFIERS.—E. S. Spitzer. (*Proc. Inst. Rad. Eng.*, June, 1929, V. 17, pp. 985–1005.)

Author's summary :—In spite of the widespread use of radio-frequency power amplifiers, apparently no measurements of the power required to drive such amplifiers have ever been made. In this paper, a study of driving power is made at 60 cycles. It is found that the power input to the grid is proportional to the d-c grid current raised to the 1.34 power. The proportionality factor depends on the type of tube and the plate circuit conditions. With constant grid current the grid power input is found to be practically independent of grid bias voltage. A simple theory, based on an assumed relation between grid current and voltage, agrees quite well with the experimental results. Data are then given on six types of commercial air-cooled transmitting tubes showing driving power, a-c driving voltage, gross power output and efficiency as functions of the d-c grid current. Finally, the effects of primary and secondary electron emission by the grid on the driving power are considered.

LOW-FREQUENCY AMPLIFICATION WITH TRANSFORMERS.—P. R. Dijksterhuis and Y. B. F. J. Groeneveld. (*E.W. & W.E.*, July, 1929, V. 6, pp. 374–379.)

A theoretical investigation of the circuit shows the effect of various factors in producing imperfect reproduction. The way in which these influences are avoided in the Philips transformer type 4003 is described :—the core is made of a special nickel-iron alloy which has a much greater permeability than the usual silicon-iron core (so that for a given primary self-induction the transformer can be made one-third of the usual size) and which gives an inductance which is independent of the amplitude, whereas with silicon-iron the inductance may vary as much as from 1 to 5 according to such variation of amplitude. To keep down the resistance of the primary without risking the breaks (and consequent joints) occurring with copper wire, a special silver alloy is used having about the same specific resistance as copper but a high mechanical strength and no tendency to corrode. In the secondary, a nickel alloy wire is employed. Owing to the magnetic properties of this alloy, the secondary resistance increases very much with higher frequencies, so that the amplification keeps nearly uniform at the point (about 8–9 thousand) where there would otherwise be a leakage-resonance peak. This alloy also has good mechanical strength and no tendency to corrode. *Cf.* van Sluiters, June Abstracts, p. 326.

PUSH-PULL AMPLIFICATION : THE USE OF RESISTANCE CAPACITY COUPLING.—F. Aughtie. (*E.W. & W.E.*, June, 1929, V. 6, pp. 307–309.)

Author's summary :—To obviate the need for a transformer, use is made of the phase reversal which takes place in a single resistance capacity coupled stage, to provide a grid feed for the second valve of the output pair. A potentiometer adjustment enables the grid swings of the two output valves to be adjusted to give optimum output power, the correct setting being obtained very easily using only a milliammeter and a pair of telephones.

THEORIE DES GEKOPPELTEN SCHWINGUNGSKREISES MIT SELBSTERREGUNG (Theory of the Coupled Circuit with Self-Excitation).—Y. Watanabe. (*E.N.T.*, May, 1929, V. 6, pp. 194–210.)

The mathematical treatment used by Hecht for the theory of forced oscillations in coupled circuits is here applied to the case of the coupled circuit with self-excitation. The simplicity of the method allows it to be carried through without that neglect of certain terms which has been necessary in former investigations of the subject (*e.g.*, by Rogowski) and which—it is shown—was not always justifiable. The method is then applied to investigating the properties of the magnetically or electrically coupled intermediate-circuit valve transmitter with primary and secondary reaction. The chief results are :—a fundamental formula is obtained for the oscillation amplitude of the magnetically coupled circuit. Since the intensity of oscillation of the valve oscillator is only limited by increase of the internal resistance, the stability of both coupling-oscillations can be investigated by this formula. The critical conditions for the entry of the change-over from one frequency to the other are given by other equations. The electrostatically coupled circuit is similarly treated, and finally verification of the theoretical results is obtained by measuring the "negative admittance" and comparing with the value obtained by Appleton and van der Pol by the static method.

ÜBER DEN ZWISCHENKREISRÖHRENSENDER MIT STARK GEDÄMPFTEM SEKUNDÄRKREIS (On the Intermediate Circuit Valve Transmitter with Strongly Damped Secondary Circuit).—Y. Watanabe. (*E.N.T.*, June, 1929, V. 6, No. 6, pp. 244–248.)

A continuation of the author's investigations into this circuit published in 1925. The present paper deals with the critical value for the secondary resistance, at which the transition takes place from the second to the third type of oscillation.

ZUR THEORIE DES RÜCKGEKOPPELTEN RÖHRENSENDERS (On the Theory of the Reactively-coupled Valve Oscillator).—F. Kirschstein. (*Zeitschr. f. Hochf. Tech.*, June, 1929, V. 33, pp. 201–211.)

"A simple method of dealing with the amplitude-problem," based on characteristic curves obtained by D.C. measurements, combined with a graphical integration process. The treatment resembles Barkhausen's ("self-excitation formula") but differs from it in dispensing with "symbolical" methods of calculation and in the introduction of a control characteristic varying with the working conditions. By this, not only can the effect of various working values on the oscillation amplitude be made particularly clear, but also a simple development of the grid "break-off" diagram is made possible.

DIE NEGADYNSCHALTUNG (The "Negadyne" Circuit).—R. H. Elsner. (*Rad., B., F., für Alle*, July, 1929, pp. 299–306.)

After remarking that this circuit was originated in Holland (Numans-Roosenstein) and that it is generally known in England as the "Newman" circuit, the writer proceeds to describe the general principles of the double-grid valve in space-charge-grid connection, and then deals with the negadyne circuit, its various forms and its uses as receiver and oscillator. The paper ends with a discussion of the literature on the subject.

RECIPROCAL THEOREMS IN RADIO COMMUNICATION.—J. R. Carson. (*Proc. Inst. Rad. Eng.*, June, 1929, V. 17, pp. 952–956.)

Author's summary :—"Two reciprocal theorems, the generalised Rayleigh theorem and the Sommerfeld-Pfrang theorem are of great theoretical importance in radio-communication. A careful analysis of these theorems and their mathematical derivations shows that they are quite distinct and their practical fields of application different. In particular it shows that the Sommerfeld-Pfrang theorem labours under restrictions, implicit in its mathematical derivation, which seriously limit its field of practical applicability."

From the generalised Rayleigh reciprocal theorem deduced by the writer in 1924, however, a form may be obtained which is suitable for immediate application with the single restriction that the current (conduction plus polarisation) must be linear in the electric intensity : otherwise the medium may vary arbitrarily from point to point. This form is as follows :—If an electromotive force is inserted in the transmitting branch of antenna A_1 and the current measured in the receiving branch of A_2, then an equal current (both as regards amplitude and phase) will be received in the transmitting branch of A_1 if the same electromotive force is inserted in the receiving branch of A_2.

Here nothing is stated explicitly about power and efficiency. For the very important case, however, where the impedances of transmitter and receiver are adjusted for maximum output and maximum absorption of energy it can be shown that the ratio of the power output of the generator to the power absorbed by the receiver is the same for transmission in either direction. Thus in the case of transmission between two entirely dissimilar aerials the transmission efficiency is the same in the two directions provided the terminal impedances are properly adjusted.

It is important to note that the single restriction mentioned above implies the failure of the theorem when the waves are propagated in an ionised medium in which the earth's magnetic field has an appreciable effect on the conduction currents. This applies also to the Sommerfeld-Pfrang theorem ; so that the application of either theorem to *short wave* transmission is somewhat doubtful.

RECIPROCITY IN ELECTROMAGNETIC, MECHANICAL, ACOUSTICAL, AND INTERCONNECTED SYSTEMS.—S. Ballantine. (*Proc. Inst. Rad. Eng.*, June, 1929, V. 17, pp. 929–951.)

Author's summary :—Recent criticism by Carson of the statement of the reciprocal relations in a radio communication system given by Sommerfeld is supported by a simple example showing the incorrectness of this statement.

Carson's proof of the extension of Rayleigh's reciprocity theorem to a general electromagnetic system was limited to $\mu = 1$ and to sources consisting of ponderomotive forces on the electricity. A new proof is given under more general conditions, ϵ, μ, σ being merely restricted to be scalars and the impressed forces are of the electric type introduced by Heaviside and Abraham. These may be regarded as impressed charges and currents, including ether displacement current. The theorem is finally stated in terms of volume and surface integrals, and thus combines the view-points of both Lorentz and Carson.

The reciprocity relations in a mechanical system are reviewed.

The interconnection of electrical and mechanical systems is next considered and a "transduction coefficient" is defined. This concept is useful in formulating mechanical problems in electric-circuit form. An example of symmetrical transductance (copper coil in steady magnetic field) is given. The subject of units is taken up and it is proposed that, in order to bring the mechanical quantities into agreement with the electrical ones when the latter are expressed in "practical" units, the mechanical quantities be expressed in "mechanical-volts," amperes, etc., *i.e.*, in "practical-electric units of the mechanical quantities." A table for converting the principal mechanical quantities from c.g.s. to practical-electrical units is given.

Reciprocity is shown to exist in interconnected electro-mechanical systems with reversible transduction.

The equations of sound propagation in a gas are developed, regarding the velocity and excess pressure as the fundamental quantities. An acoustical reciprocity theorem involving these quantities is then proved.

Interconnections of mechanical and acoustical systems are then discussed and reciprocal relations are shown to exist in the composite system. Such relations are also valid for a system comprising electrical, mechanical and acoustical systems in series connection.

The reciprocity relations in a reversible electrophone are applied in a method of determining the frequency characteristic of an electrophone or microphone. This is called the "method of three electrophones." The overall transmission curves of the devices taken two at a time are measured and from these data the frequency characteristic of any one of them can be calculated. Only one of the electrophones is required to be reversible.

THE MATHEMATICAL THEORY OF THE MAGNETIC FIELD ROUND A CIRCULAR CURRENT, AND ALLIED PROBLEMS.—A. Russell. (*Journ. I.E.E.*, May, 1929, V. 67, pp. 655–665.)

Author's summary:—An attempt is made to simplify the theory of the magnetic field round a plane circular current filament. The lines of force round such a filament are identical with the lines of flow round a circular vortex in hydrodynamics. A diagram showing these curves was drawn by Donald Macfarlane under Kelvin's direction in 1869 and has often been reproduced since. The author shows how the curves can be drawn by means of simple bipolar formulæ. He shows that the mutual inductance M between two concentric and coplanar circles the radii of which are a and b is given very approximately by the formula

$$M = \frac{8\pi^2 b^2}{a + 3\sqrt{(a^2 - b^2)}}$$

If b/a is less than 0.5 the maximum inaccuracy of this formula is less than 1 in 40,000. If b/a is less than 0.7 its inaccuracy is less than 4 in 1,000. It is less than 1 per cent. when $b/a = 0.9$. Even when b/a is 0.95 the inaccuracy is less than 2 per cent. A formula is given for the attraction between two coaxial circular filaments. An equation is also given from which the distance between them when their attraction is a maximum can be computed. If b is not greater than about the tenth part of a, the distance y between them, when their attraction is a maximum, is given very approximately by

$$2y = a + b.$$

In a mathematical Appendix a fairly complete list is given of formulæ for the two fundamental elliptic integrals and of formulæ for differentiating them. Some of these formulæ are new and some can only be found in treatises which are out of print and are obtainable in very few libraries. They can be usefully applied in electrical theory.

OVER HET PROBLEEM DER DEMPING IN DE MATHEMATISCHE PHYSICA (On the Problem of Damping in Mathematical Physics).—M. J. O. Strutt. (*Physica*, May, 1929, V. 9, No. 5, pp. 161–174.)

SUR LES PUISSANCES ET HORMANANCES MUTUELLES DES COURANTS ALTERNATIFS NON SINUSOIDAUX (On the Mutual Powers and "Hormanances" of Non-sinusoidal Alternating Currents).—A. Blondel. (*Comptes Rendus*, 27th May, 1929, V. 188, pp. 1351–1355.)

A contribution to the discussion of the subject of power factors of non-sinusoidal A.C. The writer suggests the word "hormanance" in place of "reactive power" to represent the product of a voltage and a current displaced by 90°. For further discussion on the matter, see Iliovici, Budeanu and others in *Bull. d.l. Soc. franç. d. Élec.*, April, 1929.

THE FORCES ACTING ON CONDUCTORS SURROUNDED BY MAGNETIC SCREENS.—J. H. Morecroft and A. Turner. (*Journ. Am.I.E.E.*, January, 1929, V. 48, pp. 25–27.)

A current-carrying wire in a magnetic field has a much smaller force acting on it when it lies inside an iron tube than when it is unscreened; but if, to this smaller force, the force on the iron tube is added, the total equals the force on the unscreened wire. The paper describes experiments showing this, and showing also that each wire in a motor armature-slot contributes the same turning moment on the axle, though the wires at the bottom of the slot transmit their share direct to the core while those at the surface transmit their share by pressure on their insulating envelope.

CIRCUITS COUPLED TO TUNED AND DETUNED AERIALS.—R. Rechnitzer. (*See* two articles under "Aerials.")

UNE CURIEUSE CONSÉQUENCE DE LA RÉSONANCE D'UN CIRCUIT OSCILLANT (A Curious Result of Resonance in an Oscillating Circuit).—A. Curchod. (*Rev. Gén. de l'Élec.*, 15th June, 1929, V. 25, pp. 925–929.)

The "pumping" action of an iron armature partly entering an inductance coil which is in series with a condenser of suitable capacity, when the circuit is supplied with an alternating voltage, is here investigated.

TRANSMISSION.

REICHWEITENVERSUCHE MIT ZENTIMETERWELLEN (Range Tests with "Centimetre" Waves).—W. Ludenia. (*E.N.T.*, June, 1929, V. 6, No. 6, pp. 248–249.)

A preliminary report on experiments backed by the Telefunken Company. With a transmitter of 35 w. primary energy, a range of 3 km. was obtained with a 40 cm. wave and with a 20 cm. wave. Later (July, 1928) this was increased to 10 km. for a 40 cm. wave. For telegraphy, a simple Hertz spark oscillator was used, fed with 500 frequency A.C. For telephony a similar oscillator was fed with a frequency of 10,000 to 100,000. The calculated mean radiated energy was about 10 w. This comparatively high figure was obtained by the use of particularly favourable electrode material, by special design of dipole, by loss-free choke leading-in of the H.T., and by a multiple arrangement of dipole systems with synchronised feed.

Reception was first accomplished, with good success, with a dipole and a galena detector. Later, a triode in Barkhausen-Kurz connection was used, the triode being specially designed for short wave work and the connections being provided with choking coils. Hertzian cylindrical reflectors (dimensions $2\lambda \times \lambda$, focal length $\lambda/2$) were used at transmitter and receiver. With reflectors of focal length 2λ the radiated sector could be brought down to 6 degrees. Paraboloid reflectors also "behaved well." Wavelengths were measured by the production of stationary waves in air.

As regards propagation, only the space wave seems to be effective. Trees, hillocks, etc., act as perfect screens. The height of transmitter and receiver should be not less than 30 wavelengths above the "subterranean water mirror" (grundwasserspiegel), otherwise the range falls off rapidly. No fading or atmospherics were found, but in bright sunlight (especially over water or snow) the waves suffered a certain amount of absorption. They passed unweakened through thick fog, rain or snow-storms. No sign of rotation of the plane of polarisation could be found.

GERICHTETE TELEPHONIE MIT UNGEDÄMPFTEN 14-CM-WELLEN (Beam Telephony on 14 cm. Undamped Waves.)—K. Kohl. (*Naturwiss.*, 5th July, 1929, V. 17, p. 544.)

Long ranges with short waves can only be accomplished with waves down to about 10 m. in length; shorter waves are limited to all intents and purposes to the straight-line path between sender and receiver—as Fassbender has shown with 3 m. [3.7 m.] waves (May Abstracts, p. 264). But the shorter the waves the more do they lend themselves to directive working, and the writer finds no difficulty in generating and receiving a 14 cm. beam, using special valves made by the TKD (Nürnberg). A telephony range of 1,400 metres has been obtained, and since transmitter and receiver are exactly similar, two-way (change-over) communication is given. For purposes hitherto served by light-telephony, these "decimetre" waves seem to possess important advantages.

ÜBER DIE INTENSITÄT UND ZUSAMMENSETZUNG DER STRAHLUNG VON VERSCHIEDENEN PUNKTEN DES MASSENSTRAHLERS (On the Intensity and Composition of the Radiation from Different Points of the "Agglomerate-Radiator").—A. G. Arkadiewa. (*Zeitschr. f. Phys.*, 6th June, 1929, V. 55, No. 3/4, pp. 234–251.)

The writer's work with this apparatus on the generation of very short waves (from a fraction of a millimetre to about 50 mm.) has been known since 1923, and the first part of the present paper was read in 1926. The second part, which deals with the measurement (by means of an interferometer) of the wavelengths emitted from different points, and with the work—on the same lines—of Schardin, was read in 1928. A vertical disc rotates with its lower edge immersed in an agglomerate of metallic granules (aluminium shavings) suspended in machine oil. As the disc rotates, its edge carries with it a coating of the agglomerate; two electrodes, pointing to the centre of this coating but at a little distance from it, conduct a current through it by sparking to its surface. The main body of the oil is kept continuously stirred or "in vibration" by a rotating stirrer.

Concentration of the radiated waves is accomplished by concave metal mirrors 15 cm. in diameter and quartz lenses, and intensity measurement is carried out by a thermoelement at a resulting focus. Results are summarised as follows:—the oscillations are generated at the two points of entry of the "lead-in" sparks and also at the space between them, the greatest energy being at the points of entry. The radiated energy is independent of the nature of the metallic granules. The composition of the radiation varies for different points, the points of entry of the sparks give shorter waves than the space between, which appears to give a mixture of longer waves. The optical system described, being smaller than the one used in the early experiments, brings out the presence of shorter waves previously masked; the latest measurements are of waves going down to 0.07 mm.

EINIGE VERSUCHE MIT DEM ELEKTROLYTISCHEN GENERATOR (Some Experiments with the Electrolytic Generator).—V. M. Schulgin. (*Physik. Zeitschr.*, 15th April, 1929, V. 30, pp. 235–237.)

Continuing his work on the generation of H.F. oscillations by an electrolytic cell (January Abstracts, p. 42) the writer found that the chief generating source was the hydrogen set free at the platinum wire electrode. He therefore now uses a gas electrode as cathode. Using 240 volts, he obtains in an indoor aerial 5 m. long high-frequency currents of 0.15 to 0.4 ampere. The frequency is not actually specified.

1.7–12 METRE GENERATING CIRCUITS.—W. J. Lee. (*QST*, July, 1929, V. 13, pp. 30–31, 88.)

In the course of an article describing physiological experiments with ultra-short waves, the writer illustrates and describes the various generating circuits tried. A push-pull circuit gave good results and has been used for similar tests at the Rockefeller Institute, but the writer prefers the single-valve "Huxford" oscillator. With this circuit, using a UX-852 valve with 1,500 v. on the anode, the current induced in a tuned secondary circuit (between the plates of whose condenser the physiological effects were produced) varied from 1.5 A. for a 1.7 m. wave to 4.0 A. for a 10 m. wave.

BROADCAST POWER AMPLIFIERS.—W. T. Ditcham. (*Marconi Rev.*, May, 1929, No. 8, pp. 12–20.)

ENERGY-TRANSFER IN SHORT WAVE TRANSMITTERS.—(German Patent 473741, Telefunken, pub. 20th March, 1929.)

The separation in space of one stage from the next is desirable to avoid mutual reactions, but is difficult owing to the fact that the inductance must be kept small. An intermediate "coupling" circuit is here proposed, which may possess an electrical length equal to several wavelengths; a point of this is earthed.

FREQUENCY MODULATION.—G. H. Makey. (*E.W. & W.E.*, July, 1929, V. 6, p. 384.)

Referring to Holmblad's letter (July Abstracts, p. 390) the writer says that the conclusions are invalidated by the use of a wrong formula to represent the frequency modulation system specified in the Westinghouse patent. The correct formula cannot be split into a series of side-band terms by any method known to the writer, who however explains that he does not support the claims of the system, and suggests that others may be able to split the correct expression — $i = A \sin(\omega t + kt \sin mt)$—into the sum of a series of simple sine terms.

PREVENTION OF PARASITIC OSCILLATIONS IN SHORT WAVE OSCILLATORS.—(German Patent 472732, Lorenz, pub. 4th March, 1929.)

The use of ohmic resistances (socket-less incandescent lamps are recommended) in grid and anode leads is here specified.

TRANSMISSION ON TWO WAVES FOR THE ELIMINATION OF FADING.—(German Patent 472659, Esau, pub. 4th March, 1929.)

An otherwise symmetrical two-valve oscillator circuit is made to emit two different frequencies simultaneously by connecting a capacity across grid- and anode-connections at a point which is not symmetrical.

ELIMINATION OF DISTURBANCES IN H.F. GENERATORS.—(German Patent 474373, Lorenz, pub. 5th April, 1929.)

Disturbances (*e.g.*, " trill effects ") due to the slight eccentricity of the rotor are here neutralised by inserting in the H.F. lead an iron-cored choke with polarising and auxiliary windings, the latter being fed with carefully adjusted current impulses in time with the disturbances (*e.g.*, by tapping diametrically-opposed points on the armature of the D.C. motor driving the alternator).

CONTROL OF IDLE LOAD IN VALVE KEYING.—(French Patent 651720, Telefunken, pub. 27th Feb., 1929.)

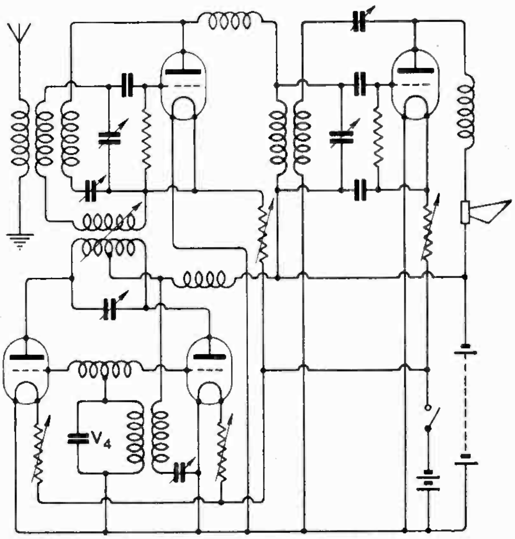
This particular method includes a rectifier valve in a circuit coupled to the generator valve oscillating circuit. The rectifier circuit (which includes a condenser shunted by a resistance) is connected to the grid of the idle-load valve, whose grid bias is thus affected by the strength of the oscillating current. *Cf.* Telefunken patent, August Abstracts.

RECEPTION.

RECHTECKIGE VERFORMUNG VON RESONANZKURVEN NACH EINEM NEUEN PRINZIP, UND IHRE ANWENDUNG BEIM EMPFANG SEHR KURZER WELLEN (The Rectangular Formation of Resonance Curves on a New Principle, and its Use in the Reception of Very Short Waves).—H. E. Kallmann. (*Zeitschr. f. Hochf. Tech.*, June, 1929, V. 33, pp. 212–223.)

Author's summary :—" Undesired frequency fluctuations in work with very short waves demand, just as telephonic modulation demands, a decrease of receiver selectivity. At present, this decrease is usually brought about by higher damping in the receiver oscillating circuit ; but the consequent gradual slope of the damped resonance curve is very undesirable because of the increased liability to interference. For the formation of an approximately rectangular curve of receiver sensitivity, it is here proposed to vary one of the natural frequencies involved over a narrow range at supersonic periodicity, so that the frequency band swept over is broader than the sum of all the [transmitter] fluctuations. . . ."

In practice it would be undesirable to vary the transmitter frequency, and equally undesirable to use some mechanical method of varying the natural



frequency of the receiver circuits. The true application of the method lies therefore in heterodyne reception, the heterodyne generator frequency being varied at supersonic frequency by a method depending on the variation of grid resistance or grid bias. In the actual tests, with a push-pull oscillator (using one double valve) it was found that an A.C. grid voltage of 1 v. was enough to produce the desired effect, and one arrangement successfully employed consisted in connecting a circuit of suitable wavelength in the lead to the grids, with reactive coupling to the anode circuit.

The diagram shows such a local oscillator, of periodically varying frequency, combined with the receiver for which it provides the heterodyne frequency. V_4 represents the frequency-varying circuit. The wavelengths used in all the tests were of the order of $2\frac{1}{2}$ metres.

ON HETERODYNE RECEPTION.—I. Tanimura. (*Electrot. Lab. Tokyo*, Circular No. 58, April, 1929.)

In Japanese. The theories of Hogan, Liebowitz, Howe, Appleton and Taylor are discussed, and some experimental results obtained by the writer are shown, which serve to verify the theory of Appleton and Taylor.

RECEIVER WITH APERIODIC HIGH-FREQUENCY AMPLIFICATION.—M. v. Ardenne. (*E.W. & W.E.*, July, 1929, V. 6, pp. 369–373.)

After discussing the advantages of the aperiodic amplifier with resistance coupling over the tuned-high-frequency amplifier (simplicity, cheapness, and reduced anode current) the writer deals with the construction and employment of the new multiple valve developed by himself and Loewe (2 H.F., single grid only) for a cascade of such amplifiers. *Cf.* same author, April Abstracts, p. 210.

UN RÉGULATEUR ANTI-FADING (An Anti-Fading Regulator).—L. Chrétien. (*T.S.F. Moderne*, April, 1929, V. 10, pp. 201–213.)

In a frequency-changing receiver, the variable P.D. produced by the fading is used to control the amplification of the intermediate-frequency stages. Unlike de Bellescize (who uses a relay), the writer applies the variable P.D. directly across a resistance in the grid-bias battery circuit, so that it adds to or subtracts from the bias of the intermediate-frequency valves. Curves showing practical results are given.

REDUCING NOISE IN BROADCAST RECEIVERS.—R. Wm. Tanner. (*Rad. Engineering*, March, 1929, V. 9, pp. 24–25.)

"Noise" here includes atmospherics, interference from power lines and from nearby wireless stations. The article deals chiefly with the revival of the 1920 "resonance wave coil" in which the aerial is connected to a long helix, the top third of which is surrounded by a closely-fitting metal tube connected to earth through a rejector circuit. The receiver connection is taken from a shorter, split tube sliding over the remaining part of the helix. Results with this device cannot be quite satisfactory when battery eliminators are used unless these are provided with electrostatic shields between primaries and secondaries, to prevent the aerial effect of the supply line.

The use of band-pass filters (for superheterodyne receivers) is dealt with briefly, and the paper ends with a paragraph on the reduction of hum in A.C.-fed receivers by reducing the audio-amplification to one stage—by using a "power" detector valve working direct to the power amplifying valve.

AMPLIFIER NOISES: SETTING A LIMIT TO LONG-DISTANCE FRAME-AERIAL RECEPTION.—A. L. M. Sowerby. (*Wireless World*, 24th July, 1929, V. 25, pp. 75–78.)

ATMOSPHERIC ELIMINATION. (German Patent 466030, Telefunken.)

Two intermediate, aperiodic circuits, taking their energy from two separate coils in the same aerial, act in an opposed sense on a third circuit. One of the aperiodic circuits is coupled to a rejector circuit tuned to the in-coming wave.

REGISTRIERUNG VON RADIOGEGEBENEN ZEICHEN (Recording Wireless Signals).—B. Brockamp. (*Zeitschr. f. Geophys.*, No. 7/8, 1928, V. 4, pp. 404–405.)

Description of an apparatus, suitable for field work, which records very quick signals and notes of very different frequencies, giving sharp beginning and break-off.

SOME USES FOR THE NEUTRALISING CONDENSER.—(*Wireless World*, 22nd May, 1929, V. 24, p. 532.)

Some suggested unorthodox applications for the neutralising condenser in H.F. circuits are:—(1) as variable coupling between two tuned circuits; (2) as the reaction control in a Hartley circuit where the tuning-coil has a centre-tap; (3) for matching various tuning condensers in two or more tuned receiving circuits. In this latter case a neutralising condenser connected in parallel with each of the remaining circuits will compensate for the minimum capacity in the aerial circuit being higher than elsewhere.

AERIALS AND AERIAL SYSTEMS.

DIE ABGESTIMMTE, INDUKTIV GEKOPPELTE ANTENNE (The Tuned, Inductively Coupled Aerial).—R. Rechnitzer. (*Telefunk. Zeit.*, May, 1929, V. 10, No. 51, pp. 62–75.)

Some of the results of this theoretical investigation are as follows:—amplification without reaction has an optimum when $K = \sqrt{d_A d_g}$ (where K is the coupling factor and d_A and d_g are the decrements of the aerial and of the grid circuit). The actual value of maximum amplification is

$$V_{\max.} = \frac{1}{2d_g}\sqrt{\frac{R_g}{R_A}}.$$

The selectivity of the arrangement is given by

$$S = \frac{a^2}{d_A d_g(1 + a^2)}, \text{ where } a = \frac{K}{K_{\text{opt.}}} \text{ and } \alpha = \frac{1}{x} - x,$$

x being the ratio representing the detuning. For a good compromise between selectivity and strength of signal, a may be 0.5 to 0.7.

THE EFFECT OF THE EARTH ON SHORT-WAVE RADIATION FROM VERTICAL AND HORIZONTAL AERIALS.—G.W.O.H. (*E.W. & W.E.*, July, 1929, V. 6, pp. 351–352.)

An editorial note on our more recent knowledge of the subject, and its progress since the nearly twenty-year-old Sommerfeld theory of the radiation from a vertical aerial. Particular attention is given to Strutt's paper (June Abstracts, p. 329). "Perhaps the most important result of the investigation is that the usefully radiated energy of a horizontal antenna, if placed at a proper height, is not less than that from a similar vertical antenna, which agrees with the results of long-distance measurements with both types of aerials."

A REFLECTOR SYSTEM.—(German Patent 460270, Galletti).

The wires forming the reflector are disposed along a closed ellipse so as to form a cylinder of elliptical cross section, which has a radiating antenna at one or both foci, and which is closed at one end; the radiation takes place in the direction of the open end.

Die Selektivität eines mit einer verstimmten Antenne gekoppelten Empfangskreises (The Selectivity of a Receiving Circuit Coupled to a Detuned Aerial).—R. Rechnitzer. (*Telefunk. Zeit.*, May, 1929, V. 10, No. 51, pp. 75–80.)

The writer quotes the work of Zepler (*ibid.*, No. 44, December, 1926) where the theory of one form of this circuit, the conditions for obtaining a good selectivity, and the calculation of the amplification are all gone into. The present paper investigates the increased selectivity of a more complex form of the circuit, in which not only the coupling is variable but also the aerial circuit, which now contains a variable series condenser.

Short Wave Aerial in High Vacuum.—(German Patent 461142, O. Muck.)

The object of enclosing the aerial in a vacuum is to avoid corona.

Directive Aerial System.—(German Patent 474123, Hahnemann, published 27th March, 1929.)

This is a 1924 patent, according to which the best sharpness of beam is obtained by spacing the n aerials so that the distance apart $d = \frac{n-1}{n} \cdot \lambda$.

Influence of Weather Conditions on British Overhead Lines.—G. W. Molle. (Summary in *Science Abstracts*, Sec. B., 25th May, 1929, V. 32, pp. 297–298.)

Feeding of an Extra-high Frequency Power through a Metallic Pipe.—E. Takagishi, E. Iso, and S. Kawazoe. (*Res. Electrot. Lab. Tokyo*, No. 245, January, 1929.)

In Japanese. Two specimens of "beam transmission" feeder systems were tested, one being a copper conductor with a concentric copper pipe, and the other a similar copper conductor with a galvanised iron pipe. Transmission efficiencies (for feeder 55 m. long) were nearly 86 and 82 per cent. respectively.

Short Wave Receiving Aerials.—(French Patent 648548, Radio Corp., published 11th December, 1928.)

To make the propagation velocity in the wires of a Beverage aerial equal to that in space, a number of horizontal wires of length equal to half the wavelength are attached or capacitively coupled to the long horizontal wires.

VALVES AND THERMIONICS.

Further Remarks concerning Thermionic "A" and "b"; a Revision and Extension.—E. W. Hall. (*Proc. Nat. Acad. Sci.*, June, 1929, V. 15, pp. 504–514.)

The work of Du Bridge and Warner and of Bridgman may seem highly unfavourable to the writer's thesis that electric conduction in metals is carried on by electrons in two different states, the "free" electrons or "thermions" which are the ones issuing in thermionic emission, and the "associated" or "valence" electrons which are the ones expelled in photoelectric action. The writer, however, here undertakes to show that all this evidence, both experimental and thermodynamical, is entirely consistent with his thesis.

Contact Potential Measurements with Adsorbed Films.—I. Langmuir and K. H. Kingdon. (*Phys. Review*, 1st July, 1929, V. 34, pp. 129–135.)

The values obtained do not agree with those calculated from the thermionic emission constants.

Thermionic Emission Associated with Electrons belonging to Atoms, not with Free Electrons?—(*See* Ives and Olpin, under "Phototelegraphy.")

Die experimentelle Prüfung des Maxwellschen Geschwindigkeitsverteilungsgesetzes für Elektronen, die aus einer Glühkathode austreten (The Experimental Verification of Maxwell's Law of the Distribution of Velocities for Electrons Emitted by a Hot Cathode).—A. Demski. (*Physik. Zeitschr.*, 15th May, 1929, V. 30, No. 10, pp. 291–314.)

The Interaction of Electron and Positive Ion Space Charges in Cathode Sheaths.—I. Langmuir. (*Phys. Review*, June, 1929, V. 33, pp. 954–989.)

Jaffe's theory rejected: the Theory of the Effect of Ions on Space Charge Currents between Parallel Planes: Potential Distribution and Current Flow resulting from the Production of Ions uniformly throughout the Volume between two Planes: Effect of the Electrons generated by Ionisation: Random Currents and Potential Distribution in the Plasma: Theory of Double-Sheath considering Initial Velocities: the Sheath Edge: Experimental Data on Double Sheaths: Tube with Oxide Coated Cylindrical Cathode: Filamentary Cathodes.

The Rectification of Radio Signals by a Thermionic Tube containing Alkali Metal Vapor.—K. H. Kingdon and E. E. Charlton. (*Phys. Review*, June, 1929, V. 33, pp. 998–1018.)

Authors' abstract:—The cathode of a thermionic triode tube is surrounded by a region of minimum potential caused by electron space-charge. If the cathode is of thoriated tungsten, and the tube contains cæsium vapor, a few positive ions are formed by ionisation of cæsium atoms striking the hot cathode. Some of these ions accumulate around the potential minimum, raise the potential at that point, and allow a larger electron current to flow to the anode. The ions have a natural frequency of oscillation about the potential minimum, which is usually several hundred kilocycles. If an alternating voltage is applied to the tube, of a frequency agreeing with this natural frequency, the ions are set in oscillation about the potential minimum. This oscillation of the ions makes the potential minimum more negative, and decreases the anode current. In addition the amplitude of oscillation may build up by a resonance effect to such a large value that the ions are able to discharge to one of the neighbouring conductors, leading to a still greater decrease in anode current. This kind of rectification is much greater for small alternating voltages than that resulting from curvature of the triode characteristics.

MOTION OF POSITIVE IONS IN A PLASMA.—L. Tonks and I. Langmuir. (*Phys. Review*, June, 1929, V. 33, p. 1070.)

Hitherto it has been assumed that positive ions in a plasma have a "temperature" about one-half the electron temperature, to account for the positive ion currents which flow to electrodes and walls. This assumption causes theoretical difficulties which are overcome by supposing that each new positive ion has the small temperature of a gas atom and accelerates only under the influence of fields arising from the tendency of the high temperature electrons to flow away.

FURTHER STUDIES IN THE EMISSION OF ELECTRONS FROM COLD METALS.—T. E. Stern, B. S. Gossling and R. H. Fowler. (*Proc. Roy. Soc.*, 1st July, 1929, V. 124 A, pp. 699–723.)

An examination of the space charge effect and of the effect of surface films on the emission coefficient, leading also to an explanation of the fugitive temperature effect. The paper begins by an important correction of a numerical mistake in an exponential factor in Fowler and Nordheim's original paper.

DIE THEORIE DER ELEKTRONENEMISSION DER METALLE. ZUSAMMENFASSENDER BERICHT (The Theory of Electron Emission from Metals: a Survey).—L. Nordheim. (*Physik. Zeitschr.*, 1st April, 1929, V. 30, No. 7, pp. 177–196.)

MATHEMATICAL THEORY OF THE FOUR-ELECTRODE TUBE.—J. G. Brainerd. (*Proc. Inst. Rad. Eng.*, June, 1929, V. 17, pp. 1006–1020.)

The work is essentially an extension to the four-electrode valve of Carson and Llewellyn's work on the triode. Author's summary:—"This paper gives the mathematics of the four-electrode tube, including in the most general case expressions for the plate and two grid currents in terms of applied voltages in the two grid circuits and the impedances of all three circuits. The results are exact, variation in the amplification factors being included. Because of the complexity of the general equations, these expressions for the currents have been developed: I, in terms of one grid-filament voltage and external impedances in plate and other grid circuit, assuming no voltage in latter; II, in terms of grid-filament voltages of both grid circuits and external impedance in plate circuit; III, in terms of applied voltages in both grid circuits and external impedances in plate and two grid circuits.

"The results of I show the effect of an external impedance in the non-control grid of a 'screen-grid' or 'space-charge-grid' tube; II covers the approximate theory of a 'double-function' tube; III gives a more exact and comprehensive theory of the tube in any use."

MEASUREMENTS OF ELECTRICAL FLUCTUATION PHENOMENA.—H. A. Wheeler. (*Phys. Review*, January, 1929, V. 33, p. 124.)

Investigations of shot effect, flicker effect and thermal convection in conductors by a method which amplifies the variations and uses them to obtain galvanometer deflections without previous rectification.

HOT CATHODE THYRATRONS: PART II: OPERATION.—A. W. Hull. (*Gen. Elec. Review*, July, 1929, V. 32, pp. 390–399.)

Second and final part of the paper referred to in June Abstracts, p. 330 (*see* also Hull and Langmuir, same page). Various applications are described and the suitable circuits illustrated, *e.g.*:—in connection with photoelectric cells; a circuit for measuring the maximum value of a transient; as an "inverter" for converting D.C. into A.C. By the use of a sensitive rheostat (a pile of thin carbon discs, in series with a resistance and a source of A.C. voltage, the voltage across the resistance being applied to the thyratron grid) a displacement of 1/100,000 inch will start the thyratron, releasing a current of many amperes.

UNE NOUVELLE LAMPE DE PUISSANCE: LA LAMPE "PHILIPS" MINIWATT B.443 (A New Power Amplifier Valve: the Philips Miniwatt B.443).—A. van Sluiters. (*Rev. Gén. de l'Élec.*, 8th June, 1929, V. 25, pp. 901–904.)

After pointing out that with power valves with only one grid the amplification is reduced by the action of the anode on the anode current, the writer shows how the three-grid valve named avoids this trouble; his calculations show that a second grid quadruples the power; the third grid (next the anode) is kept at filament potential so that whatever polarity changes the second grid may undergo, the secondary electrons set free at the anode will return to the anode.

GRID LOSSES IN POWER AMPLIFIERS.—E. S. Spitzer. (*See under* "Properties of Circuits.")

THE MODERN H.F. VALVE: SINGLE STAGE AMPLIFICATION OF TWO OR THREE HUNDRED WITH THE NEW SCREEN-GRID VALVE.—W. I. G. Page. (*Wireless World*, 24th and 31th July, 1929, V. 25, pp. 68–71 and 107–110.)

"It is the purpose of these notes to examine the relative merits of some twenty typical H.F. valves with a view to finding the maximum stage amplification which can conveniently be obtained with them." Among other points:—there are at least two screened valves now available which have anode-grid capacities as small as that in Hull's experimental valve (0.006 $\mu\mu$F.). The regaining of selectivity by using a step-up transformer in place of the 1 : 1 transformer (which is about the best for a screen-grid valve) is discussed, and it is concluded that the consequent loss of amplification is not enough to reduce that type of valve to the level of the cheaper triode.

VALVE SELECTING CHARTS: A NEW CLASSIFICATION OF RECEIVING VALVES.—R. T. Beatty. (*Wireless World*, 17th July, 1929, V. 25, pp. 48–52.)

DIRECTIONAL WIRELESS.

RADIO DEVELOPMENTS APPLIED TO AIRCRAFT.—J. H. Dellinger and H. Diamond. (*Mech. Engineering*, July, 1929, V. 51, pp. 509–514.)

An article chiefly on the "equi-signal" beacons referred to in several past Abstracts. A section on fog landing discusses briefly the various types of altimeters: it is mentioned that the one depending on capacity-change ("the change in capacity between two plates on the airplane as the airplane approaches the ground") suffers from the limitation that at altitudes above 100 ft. the change in capacity is infinitesimal.

ACOUSTICS AND AUDIO-FREQUENCIES.

DER HEULSUMMER UND SEINE VERWENDUNG BEI RAUMAKUSTISCHEN MESSUNGEN (The "Howling" Hummer and its Use in the Measurement of Room-Acoustics).—P. Just. (*Schalltech.*, No. 1, 1929, V. 2, pp. 5–9.)

The conversion of the ordinary glow-lamp hummer or the heterodyne hummer into a "howling" hummer, by means of a continuously rotating condenser, gives an arrangement very useful for intensity measurements in rooms, as it gets rid of interference effects. Oscillograph echo curves are given showing the success obtained.

MEASUREMENTS ON SOUND DAMPING MATERIALS.—E. Meyer and P. Just. (*T.F.T.*, February, 1929, V. 18, pp. 40–45.)

The method described depends on the measurement of the time at which echoes occur after the suppression of the sound.

THE MOVING COIL LOUD SPEAKER.—H. M. Clarke. (*E.W. & W.E.*, July, 1929, V. 6, pp. 380–384.)

A method is described of obtaining a "constant impedance non-inductive instrument which lends itself to damping by suitable filter circuits" (thus avoiding resonance-effects), "which allows of the use of the maximum power output available, and which may be controlled externally to obtain any required response characteristic."

The method is a compensating-winding method: a coil on the inner pole contains half as many turns as the moving coil, and a similar coil is fixed to the outer pole in the air-gap outside the moving coil. The latter is thus evenly flanked by as many fixed turns as it contains itself, the fixed windings being in series in such a way that they magnetically oppose the moving coil. Hysteresis, eddy currents and self-induction can thus be reduced to a negligible quantity. The use of such an instrument with suitable damping circuits is investigated; apart from the production of practically any response curve desired, the improvement of power factor facilitates the rise of current to its full value, while the shunting circuit cuts down the time during which transients are maintained.

THE ACOUSTIC PERFORMANCE OF A VIBRATING RIGID DISK DRIVEN BY A COIL SITUATED IN A RADIAL MAGNETIC FIELD.—N. W. McLachlan. (*Phil. Mag.*, June, 1929, V. 7, No. 46, pp. 1011–1038.)

Author's summary:—The object of this paper is to examine analytically the performance of an arrangement akin to the type of loud speaker used for acoustic reproduction in which the driving agent is a circular coil situated in a strong radial magnetic field.

Accordingly the paper deals with the acoustic performance of a rigid disk, supported at its periphery and driven by a concentric circular coil situated in a radial magnetic field of constant value. Alternating current passed through the coil (which is connected in the anode circuit of a thermionic valve) causes the disk to vibrate axially. The simultaneous differential equations associated with the mechanical and electrical aspects of the problem are solved for the steady and the transient state, with and without elastic constraint at the periphery. Expressions are obtained for the acoustic radiation resistance, the acoustic power radiated, and the current in the moving coil. It is shown that the E.M.F. induced in the coil, due to its motion in the magnetic field, is concomitant with a capacity reactance in quadrature with the acoustic radiation resistance. By virtue of this and the inductance of the coil, the system has an electromechanical resonance frequency. If the damping is adequately small the mechanical system will execute oscillations in the absence of elastic constraint. Electrical circuit diagrams equivalent to the mechanical and electrical systems combined are given for the constrained and unconstrained conditions of the disk. These facilitate the study of transients.

The analysis is illustrated by curves showing the coil current, acoustic output, and axial pressure for three different disks. It is shown that, under set conditions, there is a certain size of disk for which the output is a maximum. A curve is also given by the aid of which the accession to inertia due to the divergence of the waves propagated by the disk can be evaluated.

MOVING COIL LOUD SPEAKERS, WITH PARTICULAR REFERENCE TO THE FREE-EDGE CONE TYPE.—C. R. Cosens. (*E.W. & W.E.*, July, 1929, V. 6, pp. 353–368.)

"Although loud speakers in general are not suitable for simple mathematical treatment, it so happens that the 'moving-coil free-edge cone' is amenable to analysis if we make certain simplifying assumptions; and the results so obtained appear to resemble the results of experiment sufficiently closely to be of value for design purposes." Rayleigh's definition of the "intensity" of sound at a point is used to derive (by integration over a closed surface) a measure of the "output" or volume W. By making two of the above-mentioned assumptions, it is shown that if E_g is the R.M.S. value of the E.M.F. applied to the grid of the receiver power stage, faithful reproduction of the sound in the studio demands that $W \propto E_g^2$ throughout the important frequency-range. Other assumptions made are that the diaphragm is perfectly plane and rigid, with an infinite plane baffle (so that Rayleigh's investigation of such a diaphragm can be used) and that there is no energy-loss in the suspension.

The formulæ arrived at are later applied to the design of a particular loud speaker. Among the various points in design which emerge is the fact that for the sake of the higher frequencies, the coil inductance must be kept down—*i.e.*, the minimum of wire on as large a diameter as possible should be used—so that McLachlan's 2 in. diameter coil should be better from a high-note point of view than the ¾ in. coils of commercial types. Regarding this high-note reproduction, the writer shows that it is accomplished through resonant vibrations of the diaphragm of which his calculations take no account (since they assume a perfect rigidity) so that his equations really apply to the lower frequencies only. Various plans for increasing the high-note reproduction are discussed, but the writer concludes that the elastic vibrations of the diaphragm itself are enough for the purpose—in fact, the use of a stiff varnished paper for the cone sometimes appears to overdo it and to give too much high frequency.

SOUND RADIATION FROM A SYSTEM OF VIBRATING CIRCULAR DIAPHRAGMS.—I. Wolff and L. Malter. (*Phys. Review*, June, 1929, V. 33, pp. 1061–1065.)

" . . . At low frequencies the diaphragms react upon each other to increase the efficiency of radiation. This effect vanishes at high frequencies. . . . In certain cases the combination may result in decreased efficiency over particular frequency ranges. These results are all explainable on the basis of phase differences between motion of a diaphragm and the pressure over the surface of another diaphragm due to the motion of the first."

THE "BREAKING-UP" OF LOUD SPEAKER DIAPHRAGMS.—N. W. McLachlan. (*Wireless World*, 10th and 17th July, 1929, V. 25, pp. 33–35 and 62–64.)

An analysis of the modes of vibration of the diaphragm: how nodal points are traced by means of dust patterns.

THE KYLE CONDENSER REPRODUCER.—C. Kyle. (*Rad. Engineering*, March, 1929, V. 9, pp. 26–29.)

Practical and theoretical discussion of a new electrostatic loud speaker which has a perforated back-plate with "corrugations or other undulated surface," a flexible dielectric diaphragm stretched over this back-plate so as to bridge across the depressions, and a thin flexible conducting coating cemented or otherwise fixed to the inner surface of the diaphragm. The wedge-shaped air spaces thus obtained are said to give a good compromise between sensitivity and good frequency-response.

SILVER SOLDERS IN RADIO LOUD-SPEAKERS.—R. R. Shuman. (*Rad. Engineering*, March, 1929, V. 9, p. 40.)

For the joint between suspension spring and silicon steel armature, soft solder disintegrates under the vibration and hard (or spelter) solder requires too high a temperature. Silver solders are found to be satisfactory.

PHOTOTELEGRAPHY AND TELEVISION.

BILDTELEGRAPHENBETRIEB ÜBER LEITUNGEN (Picture Telegraphy Service over Conductors).—P. Arendt. (*Telefunk. Zeit.*, May, 1929, V. 10, No. 51, pp. 30–39.)

An article on the various services on which the Telefunken-Karolus-Siemens system is used, including the Japanese overhead line and cable network and the England-Scotland-Paris-Berlin press network.

BILDFUNK MOSKAU-BERLIN (Moscow-Berlin Picture Telegraphy).—P. W. Schmakow. (*Telefunk. Zeit.*, May, 1929, V. 10, No. 51, pp. 5–29.)

A detailed and profusely illustrated description of the Telefunken-Karolus system used on this wireless service, and of the tests leading to the successful establishment of communication at the end of 1927. Improvements since that time are only briefly mentioned: *e.g.*, the problem of rendering the Kerr cell controllable by smaller voltages by reducing the gap, without thereby reducing the amount of light passed, was solved by the use of a number of small gaps forming a "multi-cell."

TELEVISION BY THE MIHÁLY SYSTEM: FIRST DESCRIPTION OF A NEW RECEIVER SHORTLY TO BE SEEN IN THIS COUNTRY. (*Wireless World*, 3rd July, 1929, V. 25, pp. 7–9.)

RECEIVING SYSTEM FOR PICTURE TELEGRAPHY. (German Patent 474371, Iszerstedt, pub. 2nd April, 1929.)

Elements of light and shade are produced by the movements of pins with black heads in a white liquid or with white heads in a black liquid, these movements (regulated by electromagnets) bringing the heads right up to, or taking them away from, the surface of the liquid in which they are immersed. In practice the "surface" would presumably be the bounding wall of a transparent container.

PHOTORADIO DEVELOPMENTS.—R. H. Ranger. (*Proc. Inst. Rad. Eng.*, June, 1929, V. 17, pp. 966–984.)

The first part of the paper deals briefly with general developments 1926–1928, including the work of Karolus, Schriever, G. M. Wright, Jenkins and Dieckmann (simple equipments for recording weather maps), Thorne-Baker, Cooley (amateur apparatus recording by corona discharge on photographic paper) and Korn. A fundamental improvement is the use of the dot-dash method of representing picture values instead of depending on signal intensity.

The rest of the paper deals with the recent work of the Radio Corporation of America. Points mentioned are:—the advantage of making gear-ratios even (an odd ratio makes the teeth mesh in a given sequence for one line and in an entirely different sequence for the next); the use of the Push-Pull principle to reduce the inertia of relays; the elimination of reversing clutches by the use of the Reverse Lead Screw; air speed control (air-driven tuning forks working air brakes on the motor; Braman and Nelson's air drive making use of both phase and amplitude of resonance and thus providing a curve of response with a very steep portion); and hot air recording, in which a controlled stream of hot air acts on paper sensitised with chemical salts capable of undergoing an endothermic double decomposition reaction, with the formation of brownish-black products.

PICTURE TRANSMISSION FROM ORIGINALS OF VARYING THICKNESS. (German Patent 473331, Lorenz, pub. 14th March, 1929.)

When such things as manuscripts with stuck-on photographs are being transmitted, the focus may be upset: this is avoided by a pilot-wheel running over the original and regulating, by levers, the position of the lens system.

LIGHT CONTROL. (German Patent 473772, Telefunken, pub. 2nd April, 1929.)

A transparent body is immersed in a transparent medium of "almost" the same refractive index, and a ray of light passed through body and medium. If the indices of refraction are equal, the ray passes straight through without disturbance; if now the control current alters the index of the body, or of the medium, or of both [presumably in opposite senses], almost all the light is blocked out by diffuse reflection and refraction.

HIGH FREQUENCY SUPPLY FOR KERR CELL. (German Patent 473650, Telefunken, pub. 21st March, 1929.)

To avoid difficulties due to the appreciable and varying conductivity of the cell liquid, high frequency potentials are here used: the signals influence, through a modulating valve, an oscillator generating a frequency of 10^6 or more cycles per sec., which is impressed on the Kerr cell.

ÜBER DIE GESETZMÄSSIGKEITEN DER LICHTELEKTRISCHEN GESAMTEMISSION (The Conformity to Law of the Total Photoelectric Emission).—R. Suhrmann. (*Zeitschr. f. Phys.*, 21st March, 1929, V. 54, No. 1/2, pp. 99–107.)

VARIATION OF THE PHOTOELECTRIC EFFECT WITH TEMPERATURE, AND DETERMINATION OF THE LONG WAVE-LENGTH LIMIT FOR TUNGSTEN.—A. H. Warner. (*Phys. Review*, May, 1929, V. 33, pp. 815–818.)

ÜBER DAS LEITVERMÖGEN VON STARKEN ELEKTROLYTEN FÜR HOCHFREQUENZSTRÖME (The Conductivity of Strong Electrolytes for H.F. Currents).—H. Zahn. (*Zeitschr. f. Phys.*, No. 5/6, 1928, V. 51, pp. 350–354.)

Experimental confirmation of Debye and Falkenhagen's deduction that the conductivity must be greater for high than for low frequencies.

TALBOT'S LAW IN PHOTOELECTRIC CELLS.—N. Campbell. (*Phil. Mag.*, July, 1929, V. 8, No. 48, pp. 63–64.)

A criticism of Carruthers and Harrison's paper (July Abstracts, p. 395). A reply from Harrison and Stiles follows.

SUR LA THÉORIE DE L'EFFET PHOTO-ÉLECTRIQUE (On the Theory of the Photoelectric Effect). —P. Auger. (*Comptes Rendus*, 13th May, 1929, V. 188, pp. 1287–1289.)

A paper on the distribution in space of the initial directions of the photo-electrons.

ÜBER DIE HÖCHSTGESCHWINDIGKEIT LICHTELEKTRISCHER ELEKTRONEN IM SELEKTIVEN EMFINDLICHKEITSBEREICH DES KALIUMS (On the Maximum Velocity of Photoelectric Electrons in the Zone of Selective Sensitivity of Potassium).—H. Teichmann. (*Ann. der Phys.*, 7th May, 1929, 5th Series, V. 1, No. 8, pp. 1069–1095.)

PHOTOELECTRIC EFFECT AT LOW TEMPERATURES.—J. C. McLennan, L. A. Matheson and C. D. Niven. (Summary in *Science Abstracts*, Sec. A., 25th May, 1929, V. 32, p. 460.)

THE PHOTO-E.M.F. IN SELENIUM.—R. L. Hanson. (*Journ. Opt. Soc. Am.*, May, 1929, V. 18, pp. 370–382.)

The photo-E.M.F. in a selenium cell over a wide range is found to be independent of the current through the cell and bears a linear relation to the intensity of illumination. The response appears to be practically instantaneous, whereas there often seems to be considerable lag in the change in conductivity caused by illumination. The photo-E.M.F. sensitivity has a maximum for the visible spectrum in the region $\lambda = 490$ mμ. The effect is definitely not a thermal one. No direct relation between it and the photoelectrical conductivity was traced. Many points of agreement were found with Coblentz' "actinoelectric" effect in molybdenite.

SUR LES COURBES CARACTÉRISTIQUES DES CELLULES PHOTOÉLECTRIQUES (Photoelectric Cell Characteristics).—L. Dunoyer. (*Bull. de la Soc. franç. de Phys.*, 3rd May, 1929, No. 278, pp. 89S–90S.)

In the course of this paper, which deals largely with Campbell's work, a new type of cell is described in which the alkali metal is deposited in a thin film on the inner surface of a hemisphere closed by a transparent plate: the anode is a wire close to this plate. Above a certain voltage the current increases suddenly to a value of the same order as that reached in ordinary cells at the inset of the disruptive régime; only in the present case the large current ceases with the illumination. As the voltage is increased, the current increases more slowly, till the voltage for the disruptive condition is reached; but between these two voltages there is a range of about 20 v. in which perfectly stable and remarkably intense photoelectric currents can be obtained. Thus a cell 4 cm. in diameter, illuminated by a carbon filament 50 c.p. lamp at 25 cm. distance will give a current up to 100 microamperes—and therefore can work a relay directly.

MAXIMUM EXCURSION OF THE PHOTOELECTRIC LONG WAVE LIMIT OF THE ALKALI METALS.—H. E. Ives and A. R. Olpin. (*Phys. Review*, 1st July, 1929, V. 34, pp. 117–128.)

Authors' abstract:—Earlier experiments have shown that the long wave limit of photoelectric action in the case of thin films of the alkali metals varies with the thickness of the film. A maximum value is attained greater than that for the metal in bulk, which for the majority of the alkali metals lies in the infra-red. The wavelength of the maximum excursion of the long wave limit was first studied for *Na*, *K*, *Rb* and *Cs*. In each case it was found to coincide with the first line of the principal series, *i.e.*, the resonance potential. If this relation holds for lithium, its maximum long wave limit should be greater than that of sodium. This was tested and confirmed by experiments in which red-sensitive lithium cells were prepared, sensitive to 0.6708 μ. It is suggested that photoelectric emission is caused when sufficient energy is given to the atom, to produce its first stage of excitation. The identity of photoelectric and thermionic work functions suggests that atomic excitation is the initial process in thermionic emission as well.

LIGHT-SENSITIVE CELLS. I.—CONSTRUCTION OF ALKALI METAL CELLS.—J. P. Arnold. (*Rad. Engineering*, March, 1929, V. 9, pp. 21–24.)

The first of a series of four articles dealing with design, development and application of all representative types of light-sensitive cells.

MEASUREMENTS AND STANDARDS.

THE MEASUREMENT OF DIRECT INTERELECTRODE CAPACITANCE OF VACUUM TUBES.—A. V. Loughren and H. W. Parker. (*Proc. Inst. Rad. Eng.*, June, 1929, V. 17, pp. 957–965.)

Authors' summary:—"A method of measuring direct capacitance in the range 10^{-10} to 10^{-15} farad by a charging current at radio frequencies is described. A low resistance current indicator is shunted across one of the direct capacitances. The charging current $I = \omega EC$ is a measure of the direct capacitance provided that ωE is maintained constant. A simple circuit arrangement provides an apparatus giving reliable results measured visually by substitution with a standard.

The method has been practically applied in the measurement of direct capacitances present in vacuum tubes providing data for design purposes and for control of product uniformity. The method is specially advantageous in its ability to measure exceedingly small direct capacitances present in screen-grid tubes."

The method of substitution employed eliminates the need of measuring the absolute value of the current and thus there is no need for calibration of the current indicator. The constancy of the calibration of the standard condenser is all that is required, and the use of coaxial cylinders makes this easily possible. A type shown has a capacity increase of 1.00×10^{-14} farad per turn of micrometer head.

DER GEBRAUCH VON VERSTÄRKERRÖHREN ZUR MESSUNG KLEINER ENERGIEBETRÄGE (The Use of Amplifier Valves for the Measurement of Small Amounts of Energy).—J. Brentano. (*Zeitschr. f. Phys.*, 27th April, 1929, V. 54, No. 7/8, pp. 571–581.)

The writer discusses various bridge-methods evolved by himself for the measurement of very small D.C. currents and potential differences, in which disturbance from external sources is avoided. The work of Müller and Frisch and of Wynn Williams in the same field is referred to and criticised (*cf.* Abstracts, 1929, p. 280, and 1928, V. 5, p. 584).

HIGH GRID RESISTOR AMPLIFIER.—P. J. Mulder and J. Razek. (*Journ. Opt. Soc. Am.*, June, 1929, V. 18, pp. 466–472.)

A study of the increase of slope of the grid-bias/plate-current curve when very high resistances are included in the grid circuit. For a value of 2,710 megohms, the curve has an almost vertical portion, a change of 1/10 volt in bias producing a current change of 12 mA.; but at this extreme value of grid resistance the curve does not repeat if the change is made in the reverse direction. Grid resistances up to 1,800 megohms can, however, be used (with the particular valve employed—CX-312 A), with the advantage of a slope very much steeper than that given by the usual value of grid resistance. The difficulty lies in obtaining constant resistances of these high values; but the use of xylol made sufficiently conductive by the addition of small quantities of alcohol gave resistances which (when equilibrium conditions had been reached after the making) remained constant over periods of months.

USE OF THE THERMIONIC VALVE IN MEASUREMENTS OF IONISATION CURRENTS.—J. A. C. Teegan. (*Nature*, 20th July, 1929, V. 124, pp. 91–92.)

By the use of the voltage drop across a very high resistance (about 10^{11} ohms, from a 10 : 1 mixture of xylol and alcohol—*cf.* Mulder and Razek, above) the writer has used a single triode circuit to indicate ionisation currents, and now hopes to use it for the absolute measurement of such currents (of the order of 10^{-12}A.).

A VACUUM TUBE POTENTIOMETER FOR RAPID E.M.F. MEASUREMENTS.—H. M. Partridge. (*Journ. Am. Chem. Soc.*, No. 1, 1929, V. 51, pp. 1–7.)

A method which does not demand constancy of batteries, etc. The first valve has two grids, the second one; the space-charge grid voltage of the former is simultaneously the anode voltage of the latter. The E.M.F. to be measured is applied to the control grid of the first valve: it is then replaced by a potentiometer E.M.F. (measured by a voltmeter) which is adjusted till the same current is produced in the second valve's anode circuit. The voltmeter then gives the required value of E.M.F.

CURRENT MEASUREMENT WITH A COMPTON QUADRANT ELECTROMETER.—E. E. Watson. (*Proc. Camb. Phil. Soc.*, January, 1929, V. 25, Part I, pp. 67–74.)

With this instrument, using the "rate of deflection" method, currents of 10^{-14} ampere can be measured accurately in less than a minute.

A DIRECT-CURRENT AMPLIFIER FOR MEASURING SMALL CURRENTS.—J. M. Eglin. (*Journ. Opt. Soc. Am.*, May, 1929, V. 18, pp. 393–402.)

Author's abstract:—A direct-current amplifier consisting essentially of a Wheatstone bridge, having the amplifying tube in one arm and a balancing tube in another, has been described by P. I. Wold and by C. E. Wynn-Williams [Abstracts, 1928, V. 5, p. 584]. This circuit has now been developed to give a constant amplification for currents in either direction up to 10,000 times the lowest measurable value. The amplification and the lowest measurable current are alterable together by changing the resistance introduced between the grid and filament of the amplifying tube. With tubes of high insulation, the amplification can be made as large as 10^6; and the measurable current as low as 10^{-14} ampere. Some improvements of the circuit are: (1) the insertion of a resistance in series with the tube in one arm of the bridge to "compensate" for variations in plate and grid battery voltages; (2) the suspension of the tubes to protect them from mechanical vibrations; (3) the use of tubes with pure tungsten filaments to avoid changes in contact potentials, and with plates enclosing the filaments completely to lower the effects of wall charges. In a "null" method of using the circuit the values of the grid resistance and an auxiliary potential introduced in the grid-filament circuit are sufficient to determine the measured current.

DIE VERWENDUNG VON BLITZSCHUTZLAMPEN ALS INDIKATOR-RÖHREN (The Use of Lightning-protector Lamps as Indicator-bulbs).—E. Hiedemann. (*Zeitschr. f. Unterr.*, No. 1, 1929, V. 42, pp. 27–28.)

The writer suggests that the common lightning-protector or over-voltage lamps have longer life and a lower lighting voltage than the special, rare-gas-filled resonance indicators used in wavemeters.

FREQUENCY MEASUREMENTS OF RADIO WAVES RECEIVED, AND CALIBRATION OF WAVEMETERS BY STANDARD FREQUENCIES TRANSMITTED.—S. Ishikawa. (*Electrot. Lab. Tokyo*, Circular No. 59, April, 1929.)

In Japanese.

A MODULATED WAVEMETER: AN AID TO ACCURATE TUNING AND DISTANT RECEPTION.—H. B. Dent. (*Wireless World*, 3rd July, 1929, V. 25, pp. 2–6.)

Description of the construction of a heterodyne wavemeter with modulating valve. *Cf.* "Constancy of Oscillator Frequency," August Abstracts, p. 457.

THE CALIBRATION AND CONSTRUCTION OF A STANDARD FREQUENCY METER.—T. D. Parkin. (*Marconi Rev.*, April, 1929, No. 7, pp. 18–28.)

SHORT WAVE SIGNAL STRENGTH MEASURING APPARATUS.—T. L. Eckersley. (*Marconi Rev.*, May, 1929, No. 8, pp. 1–6.)

BEITRAG ZUR HERSTELLUNG KONSTANTER SCHWINGUNGSFREQUENZEN EINES RÖHRENGENERATORS (A Contribution towards the Production of a Constant Frequency in a Valve Generator).—F. Maske. (*Physik. Zeitschr.*, 1st April, 1929, V. 30, No. 7, pp. 197–201.)

By heterodyning a test circuit with a standard circuit, using a wavelength of 100 metres, the writer investigates the causes of frequency variation in valve oscillators, and particularly the influence of changes in filament current. He concludes that the effect of these changes is to alter the virtual capacity of the valve. This virtual capacity is in parallel with the oscillating circuit, and therefore its alteration changes the frequency of the latter: but it is connected to the oscillating circuit *through an anode condenser*, and from the properties of two condensers in series, therefore, it is possible to render the variations of the virtual capacity of the valve much less important, by making the anode condenser *small*. If, in any particular form of circuit, this condenser is shunted by a H.T. battery, the desired effect can still be obtained by the use of choking coils in the battery leads. The writer has thus obtained, for a 10 per cent. change of filament current, a frequency which was constant to 10^{-5} per cent.

ÜBER DIE KONSTANZ ELEKTRISCH ERREGTER MECHANISCHER SCHWINGUNGEN UND IHRE ANWENDUNG (On the Constancy of Electrically Excited Mechanical Oscillations, and Their Application).—W. Hensel. (*Physik. Zeitschr.*, 1st May, 1929, V. 30, No. 9, pp. 274–278.)

EIN EINFACHER VERSUCH ZUR BESTIMMUNG DER SCHWINGUNGSZAHL EINER STIMMGABEL (A Simple Test for Determining the Frequency of a Tuning Fork).—K. Gentil. (*Zeitschr. f. Math. u. Nat. Unterr.*, No. 10, 1928, V. 59, p. 448.)

A gramophone record is placed upside-down on the turntable, scattered with lycopodium powder, and set to rotate 60 times per minute. The vibrating fork is then drawn slowly from the edge of the disc to the middle [presumably with an attached bristle touching the disc]. From the resulting spiral the frequency can conveniently be counted.

NEUE VERFAHREN ZUR KOINZIDENZVERGLEICHUNG VON PENDELUHREN (New Methods of Coincidence-comparison for Pendulum Clocks).— —. Baltzer. (*E.T.Z.*, 27th June, 1929, V. 50, pp. 933–934.)

The use of the expensive and insufficiently accurate chronograph has recently been superseded by the coincidence method, in which a second clock is used which goes faster than the standard clock, and the number of swings between coincidences of the two pendulums is counted. The article describes the methods of avoiding mechanical contacts devised by Ferrié (photoelectric cell) and by Lejay (change of wavelength or intensity in short waves) and recent variations of these two methods.

OBSERVATIONS ON MODES OF VIBRATION AND TEMPERATURE COEFFICIENTS OF QUARTZ CRYSTAL PLATES.—F. R. Lack. (*Bell Tech. Journ.*, July, 1929, V. 8, pp. 515–535.)

The characteristics of quartz plates of the perpendicular or Curie cut are compared with parallel or 30-degree cut plates with reference to the type of vibration of the most active modes, the frequency of these modes as a function of the dimensions, and the magnitude and sign of the temperature coefficients of these frequencies. One of the various points emerging is that since both modes of the perpendicular cut crystals have a negative temperature coefficient, it is to be expected that it would be impossible to obtain zero temperature coefficient crystals with this orientation, as has been done with the parallel cut plates.

A HIGH PRECISION STANDARD OF FREQUENCY.—W. A. Marrison. (*Bell Tech. Journ.*, July, 1929, V. 8, pp. 493–514.)

Author's synopsis :—A new standard of frequency is described in which three 100,000 cycle quartz crystal-controlled oscillators of very high constancy are employed. These are interchecked automatically and continuously with a precision of about one part in one hundred million. They are checked daily in terms of radio time signals by the usual method employing a clock controlled by current maintained at a submultiple of the crystal frequency. Specially shaped crystals are used which have been adjusted to have temperature coefficients less than 0.0001 per cent. per degree C.

EXPERIMENTS ON MAGNETOSTRICTIVE OSCILLATORS AT RADIO FREQUENCIES.—J. H. Vincent. (*Nature*, 6th July, 1929, V. 124, p. 41.)

A short note on a paper read before the Physical Society on 24th May. An account was given of the behaviour of two oscillators of different length in an oscillating circuit. The frequency of the smaller oscillator was 540 kc. per sec.

PIEZOELECTRIC CONTROL PATENTS. (German, 472549, Lorenz, pub. 4th March, 1929; French, 651817, Soc. Mat. Tel., pub. 28th February, 1929.)

(1) To avoid over-straining the crystal, the latter is connected across a part only of the total capacity or inductance of the oscillating circuit. (2) The internal grid-anode capacity of the oscillator valve is neutralised (anode battery lead goes to mid-point of anode tuned-circuit inductance, and a neutrodyne condenser is connected between anode circuit and grid) in order to protect the crystal from overload.

MAGNETOSTRIKTIVE SCHWINGUNGEN (Magnetostrictive Oscillations).—E. Kopilowitsch. (*Ukr. Phys. Abh.*, No. 1, 1928, V. 2, pp. 19–22.)

A THERMOSTAT CONSTANT TO ONE-THOUSANDTH OF A DEGREE CENTIGRADE.—F. R. Winton. (*Journ. Scient. Instr.*, July, 1929, V. 6, pp. 214–217.)

Author's abstract :—A toluene-mercury thermoregulator, with variable-resistance contact in the grid circuit of a thermionic valve, controls the anode current which passes through a heating coil in the bath. One ten-thousandth of a degree Centigrade change of bath temperature is compensated by 5 to 10 per cent. change in heating current.

MAGNETOSTRICTION : REMARKS ON SCHULZE'S RESULTS.—L. W. McKeehan. (*Zeitschr. f. Phys.*, No. 9/10, 1928, V. 52, pp. 752–754.)

Schulze's discovery that the magnetostrictive null point does not agree exactly with the minimum of hysteresis does not contradict the connection between the two properties.

MAGNETOSTRICTION OF DIAMAGNETIC SUBSTANCES IN STRONG MAGNETIC FIELDS.—P. Kapitza. (*Nature*, 13th July, 1929, V. 124, p. 53.)

Previous attempts to find magnetostriction in bismuth failed (*e.g.*, Van Aubel, 1903, using fields up to 3 kilogauss). The writer, using fields up to 300 kilogauss, obtained with an extruded bismuth rod a contraction only slightly larger than that expected from the "classical" magnetostriction (the stresses produced by the magnetic forces on the magnetic poles of the magnetised body) : but with a bismuth rod grown in a crystal, a larger effect was easily observed, which could be due only to the "atomic" magnetostriction. The writer's deductions from his results include the expectation that larger atomic magnetostriction would occur in substances where the atoms are not symmetrically bound, such as tin, tellurium and graphite.

MEASUREMENT OF ATOMIC DISTANCES BY PIEZO-ELECTRIC VIBRATIONS.—A. Meissner. (*Naturwiss.*, 11th January, 1929, V. 17.)

Lycopodium powder registration of H.F. vibrations of a circular disc of quartz, 15 mm. in diameter, was used to calculate the distances separating the silicon atoms in the quartz ; the results agreed well with those obtained by the use of X-rays. The writer points out the remarkable accuracy (within a few per cent.) of the determination of structural dimensions of the order of 10^{-8} cm. from experiments made on an object of considerable size.

AN OPTICAL LEVER FOR MEASURING THICKNESS CHANGES OF MICA TO AN ACCURACY OF ABOUT 1.5×10^{-8} CM.—W. N. Bond. (*Phil. Mag.*, June, 1929, V. 7, No. 47, pp. 1163–1182.)

In a paper on "Certain Molecular Lengths Measured by an Optical Lever."

ON THE ULTRAMICROMETER OF DOWLING.—S. Ekelöf. (*Journ. Opt. Soc. Am.*, April, 1929, V. 18, pp. 337–341.)

A description of tests carried out during the past year with the Dowling circuit, using the capacity change method. With a tuned anode circuit and separate inductive reaction, it was found that the use of an appropriate grid battery increased the sensitivity considerably, to 0.1 mA. per 1 $\mu\mu$F. variation of capacity. The substitution of a grid-leak condenser combination, in place of the grid battery, increased the sensitivity to the high value of 4 mA./1 $\mu\mu$F. variation, and was particularly convenient as it was little influenced by stray capacities. If it were possible to keep working conditions (filament current, etc.) constant, such accuracy would enable measurements to be made of displacements as small as 10^{-9} mm.—*i.e.*, about 1/100 of the diameter of the hydrogen atom! The writer considers that by using large capacity batteries and by taking other precautions, displacements less than 10^{-6} mm. could be measured, using plates of 4 cm. radius spaced 0.1 mm. He describes the use made of a much less sensitive form of the apparatus, in investigating a hydroelectric engineering problem—the fracture of long steel lamels (forming ice-racks for turbines) from fatigue due to vibration.

AN INSTRUMENT FOR MEASURING SMALL AMPLITUDES OF VIBRATIONS.—W. Bragg. (*Journ. Scient. Instr.*, June, 1929, V. 6, pp. 196–197.)

The use of a simple device by which the small amplitudes are measured by moving away a chattering contact and observing the point at which chattering stops.

BEOBACHTUNG UND REGISTRIERUNG VON DICKENÄNDERUNGEN DÜNNER DRÄHTE (Detection and Recording of Thickness Variations in Thin Wires).—W. W. Loebe and C. Samson. (*Zeitschr. f. tech. Phys.*, October, 1929, V. 9, pp. 414–419.)

An application of the ultra-micrometer principle to the investigation of thin wires (*e.g.*, tungsten filaments).

THE HIGH FREQUENCY ULTRA-MICROMETER.—L. Richtera. (*Elektrot. u. Masch : bau*, 27th January, 1929, V. 47, pp. 76–78.)

Various new applications are discussed, together with the substitution of recording methods for those depending on aural observation.

THE HETERODYNE NULL METHOD OF MEASURING DIELECTRIC CONSTANT.—P. N. Ghosh and P. C. Mahanti. (*Nature*, 6th July, 1929, V. 124, p. 13.)

From their own experiences, the writers suggest two possible sources of error in the process which may account for the discrepancies in the results of various workers. Taking precautions against these, they have obtained the value 1.000579 ± 4 for dry and carbon dioxide-free air at N.T.P.

MESSUNG DER DIELEKTRIZITÄTSKONSTANTEN UND DER SCHEINBAREN LEITFÄHIGKEIT VON ISOLIERSTOFFEN BEI HOCHFREQUENZ (The Measurement of the Dielectric Constant and Apparent Conductivity of Dielectrics for High Frequencies).—H. Kühlewein. (*Zeitschr. f. tech. Phys.*, July, 1929, V. 10, No. 7, pp. 280–288.)

By variation of the capacity of an oscillatory circuit loosely coupled to a transmitter, the resonance curve is taken. The capacity is composed of two condensers, the variable standard condenser and the test condenser (into which the dielectric under test can be introduced) connected in parallel. The dielectric is then introduced into the test condenser and the curve again taken. The two resonance curves show a displacement due to the change of capacity of the test condenser caused by the introduction of the dielectric. From this displacement the dielectric constant can be calculated. From the two curves the two logarithmic decrements can be obtained, and from their difference the apparent conductivity of the dielectric can be reckoned. Two different arrangements are used: for wavelengths greater than 600 m. the indicator is a double-thread electrometer in parallel with the condensers, for shorter wavelengths a hot-wire milliammeter is connected in series with the oscillatory circuit. Typical examples of tests by the method are given.

A TESTING SET FOR TRANSMITTING VALVES.—Y. Kusunose. (*Electrot. Lab. Tokyo*, Circular No. 57, April, 1929.)

In Japanese. The set is capable of testing valves with an input up to 40 kw. at an anode voltage up to 20 kv., on wavelengths from 100 to 5,000 m.

APPAREIL À LECTURE DIRECTE POUR LA MESURE DES CHAMPS MAGNÉTIQUES "GAUSSMÈTRE" (Direct-reading Instrument for the Measurement of Magnetic Fields: the Gaussmeter).—G. Dupouy. (*Bull. d. l. Soc. franç. d. Élec.*, April, 1929, V. 9, pp. 348–370.)

This instrument depends on the torque produced by the field on a magnetically anisotropic crystal (*e.g.*, $FeCO_3$, siderose, or Fe_2O_3, oligiste). This torque is opposed by a spiral spring or by the torsion of a wire. The scale is calibrated by a Cotton balance or other apparatus. Advantages are:—direct reading; the small size of the crystal allows an almost point by point exploration of the field. A disadvantage is a slight variation of the torque with temperature, but this can be compensated for.

SHIELDING AND GUARDING ELECTRICAL APPARATUS USED IN MEASUREMENTS—GENERAL PRINCIPLES.—H. L. Curtis. (*Journ. Am.I.E.E.*, June, 1929, V. 48, pp. 453–457.)

This abridgment of the first part of a symposium of six papers concludes with a bibliography of 18 items.

AN AREA-COMPUTING SCALE. (*Journ. Scient. Instr.*, July, 1929, V. 6, pp. 230–231.)

A transparent scale engraved with a radial arrangement of graduated lines, by which the approximate areas of plane figures of regular or irregular shape can be determined. *See* R. W. K. Edwards (*Proc. Roy. Soc.*, V. 73, 1904) for the principles involved.

COMPENSATING ZERO SHUNT CIRCUIT.—J. Razek and P. J. Mulder. (*Journ. Opt. Soc. Am.*, June, 1929, V. 18, pp. 460–465.)

The stabilisation of the single triode zero shunt circuit voltmeter, by using the same potential divider to supply both anode and balancing voltages, was suggested by Wynn-Williams in 1927. The present paper investigates his circuit mathematically.

SUBSIDIARY APPARATUS AND MATERIALS.

A LOW POWER AUDIO-FREQUENCY CURRENT SUPPLY FOR GENERAL LABORATORY USE.—C. W. Oatley. (*Journ. Scient. Instr.*, July, 1929, V. 6, pp. 217–220.)

This tuning-fork generator derives its power entirely from the 100-volt D.C. lighting mains, and provides 180 cycle A.C. of constant frequency and good wave-form. Current from the mains passes in succession through (*a*) a choke of a few henrys (which has proved sufficient to eliminate all mains hum), (*b*) two magnetising coils around, but not touching, the prongs of the fork near the bend, (*c*) a lamp resistance and a resistance for grid-bias supply, and (*d*) the filament of a 3-electrode valve. Between the prongs of the fork are two soft iron cylinders; one of these has a winding controlling, through a transformer, the grid of the valve; the second has two windings, one carrying the anode supply, the other leading to the output terminals.

In order that there shall be no mutual interference when several observers are using the generator simultaneously, it is essential that each take only a negligibly small amount of power from the source. Each observer therefore (or each laboratory bench) has a separate one-valve amplifier, the input voltage of which is supplied by the fork.

ALTERNATORS AND ROTARY TRANSFORMERS FOR A.C. OF HIGH FREQUENCY.—(French Patent 647166, Bunet, published 1st November, 1928.)

A diagram and short description of the special design of pole face, windings, etc., is given in *Génie Civil*, 15th June, 1929, p. 588.

A NEW ELECTRICAL RECORDING SYSTEM.—B. H. C. Matthews. (*Journ. Scient. Instr.*, July, 1929, V. 6, pp. 220–226.)

Author's abstract:—" This paper describes a new form of moving iron oscillograph, and a valve amplifier designed to work with it, for the recording of very small and rapid fluctuations of E.M.F. Moving systems have been used having natural vibration frequencies of up to 10,000 per sec. The instrument gives fairly accurate records of potential waves of about 30 microvolts [in a circuit of 10,000—500,000 ohms] with a duration of about 2 milliseconds. The system, though rapid and sensitive, is electrically unbreakable. A new form of standing wave camera is also described." The oscillograph is on the telephone-receiver principle, the steady pull of a magnet on an armature being modulated by coils round the pole-pieces.

DAS THERMOELEMENT TE/BI UND SEINE PRAKTISCHEN ANWENDUNGEN (The Tellurium-Bismuth Thermoelement and its Practical Use).—M. A. Lewitsky and M. A. Lukomsky. (*Physik. Zeitschr.*, 1st April, 1929, V. 30, No. 7, pp. 203–205.)

Although this is the most sensitive of all known couples, it has not hitherto been made use of owing to the irregularity of the electrical properties of tellurium, and also to its brittleness. The writers appear to have overcome these difficulties to a great extent in their design, largely by the use of constantin wire as the lead which is fused into the tellurium. See also Lange and Heller, *ibid.*, 1st July, 1929, V. 30, No. 13, pp. 419–425.

VAKUUMTECHNISCHE NEUERUNGEN AN KATHODENOSZILLOGRAPHEN (New Methods of Vacuum Technique for Cathode Ray Oscillographs).—M. Knoll. (*Zeitschr. f. tech. Phys.*, July, 1929, V. 10, No. 7, 294–299.)

The use of rubber or lead washers in the place of the usual fat- or pizein-washers presents many advantages. Elastic metal packing for stuffing-boxes is now used to allow the adjustment of movable parts. High-vacuum taps in metal effect a considerable shortening of the time spent in exhausting. Finally, a vacuum-testing Geissler tube, readily replaceable, acts as an indicator permanently in position.

EIN- UND AUSFÜHRUNG VON PLATTEN UND FILMEN AN KATHODENOSZILLOGRAPHEN OHNE STÖRUNG DES HOCHVAKUUMS (Introduction and Removal of Plates and Films in Cathode-ray Oscillographs without Disturbing the High Vacuum).—P. Hochhäusler. (*E.T.Z.*, 13th June, 1929, V. 50, pp. 860–864.)

After discussing the various systems of external recording (photographing the fluorescent screen; passing the ray out through a Lenard window—of thin metal: no reference is made to the thin glass window referred to in June Abstracts, p. 341) and their disadvantages in reducing the speed of recording and the intensity of the ray respectively, the writer describes the method devised by himself and Schwenkenhagen for combining the advantages of external and internal recording, for continuous records. The film is stored inside the vacuum and is led out through a mercury-filled rectangular-sectioned tube on the barometer principle. It was found that this procedure does not affect the vacuum, nor is the sensitive layer injured by passage through the mercury. The film has to be guided by smooth guiding-rods so that the surface tension of the mercury does not force it against the sides of the tube. An oscillograph made on this principle is described and illustrated. The pointer-length of the ray is only 40 cm., but the sensitivity is kept up to 10 v. per mm. deflection by bringing the deflecting plates very close to the ray by adjustment during a run: this adjustment is by rotating the plates which are mounted on a slant on their spindles. The paper then describes an arrangement for using photographic plates inside the vacuum and releasing them into the open air by means of a trap, without the complications of the "ante-vacuum" used by Rogowski (Abstracts, 1928, V. 5, p. 690). Various other new arrangements are described, such as that for giving the time base, and for leading-in the deflecting plates and anode (plugs comprising copper fused into glass are here used).

On Some Vacuum Recording Gauges.—K. C. D. Hickman. (*Journ. Opt. Soc. Am.*, April, 1929, V. 18, pp. 305–331). *And* A Modified Pirani Vacuum Gauge.—T. De Vries. (*Ibid.*, pp. 333–335.)

Rectification of Alternating Current, especially at High Tension.—(French Patent 653538, Philips' Co., published 22nd March, 1929.)

In discharge-tube rectifiers for high-tension currents, a reverse flow is prevented by separating sufficiently the cathode and anode. This may lead to a difficulty in procuring a current flow in the desired direction. According to the present invention, the main, high-tension tube has one or more auxiliary electrodes between cathode and anode connected to the anode through a small auxiliary rectifier, with suitable resistances in series to limit the current through that rectifier. The connections are such that the auxiliary electrodes of the main tube only facilitate the passage of current when a current is passing in the right direction in the auxiliary tube.

Les Redresseurs au Tantale (Tantalum Rectifiers).—J. Innocenti. (*T.S.F. Moderne*, August, September, November, December, 1928, and January, 1929.)

A New Range of Dry Metal Rectifiers: A Voltage-doubling Bridge Circuit with Full-wave Rectification on Two Rectifier Units.—(*Wireless World*, 17th July, 1929, V. 25, p. 57.)

Suppression of Secondary Frequencies in Static Frequency Multipliers: Comments and Reply.—H. Freese. (*Zeitschr. f. Hochf. Tech.*, June, 1929, V. 33, pp. 223–225.)

Comments by Kramar and Gutzmann on the paper dealt with in May Abstracts, pp. 280–281, with replies by the author.

Les Redresseurs à Oxyde de Cuivre (Copper Oxide Rectifiers).—M. Demontvignier. (*L'Onde Élec.*, May, 1929, V. 8, pp. 192–209.)

The theory of action, calculations of voltage drop and efficiency, construction, and applications to Wireless are here discussed by an engineer of the company manufacturing the Rectox (Hewittic) rectifier.

The Aluminium Electrolytic Rectifier.—W. E. Holland. (*Trans. Am. Electrochem. Soc.*, V. 53, 1928, pp. 195–201.)

Recent improvements and points in operating are described.

Telefunken Glow-discharge Rectifier for A.C. Mains.—(*Rad., B., F., für Alle*, July, 1929, pp. 320–321.)

The Telefunken Company is now making the RGN 1500, a filament-less rare-gas rectifier of the type hitherto chiefly used in the U.S.A.

Die physikalische Natur der elektrischen Vorgänge in homogenen Isolatoren (The Physical Nature of the Electrical Processes in Homogeneous Insulators).—A. Smurow. (*Arch. f. Elektrot.*, 8th May, 1929, V. 22, No. 1, pp. 31–61.)

A lecture under the same title, with a long subsequent Discussion, is fully reported in *E.T.Z.*, 23rd May, 1929, V. 50, pp. 768–773.

The Properties of Dielectrics. I.—Electric Moment and Molecular Structure.—C. P. Smyth. (*Journ. Franklin Inst.*, June, 1929, V. 207, pp. 813–824.)

The Determination of the Dielectric Constants of Imperfect Insulators.—R. L. Lattey and O. Gatty. (*Phil. Mag.*, June, 1929, V. 7, No. 46, pp. 985–1004.)

Carbolite, Its Production and Properties.—P. A. Florensky. (*U.S.S.R. Scientific Tech. Dept.*, No. 238, 1928.)

In Russian with French summary. Carbolite is a dielectric discovered by the Russians: one form of it is made by the condensation of tricresol with formol. It possesses a number of advantages over other similar materials, being very tractable—it can be moulded, turned, etc., etc.

Breakdown of Solid Insulators; of Glass in D.C. and Alternating Fields; of Porcelain; of Impregnated Paper. On the Heat Theory of Electrical Breakdown; etc.—Walther, Kobeko and others. (*Trans. Phys. Tech. Lab. Leningrad*, No. 5, 1928.)

In Russian.

Dielektrizitätskonstante und Leitfähigkeit technischer Isolierstoffe und die Gestaltung der Stromkurve beim Stromdurchgang (The Dielectric Constant and Conductivity of Commercial Insulating Materials, and the Form of the Current Curve).—P. Böning. (*Zeitschr. f. tech. Phys.*, July, 1929, V. 10, No. 7, pp. 288–294.)

Author's summary:—It has been shown (Abstracts, 1928, p. 523, and 1929, p. 405) that the dielectric constant and also the conductivity of commercial dielectrics are apparently dependent on the voltage. The relations are here developed further, particular attention being given to their range of validity. A theoretical and experimental investigation is then made of the shape of the current curve when a circuit containing a condenser with such dielectric is submitted to a sinusoidal voltage.

DESIGN METHODS FOR SOFT MAGNETIC MATERIALS IN RADIO.—J. Minton and I. G. Maloff. (*Proc. Inst. Rad. Eng.*, June, 1929, V. 17, pp. 1021–1033.)

"Radio transformer design is usually complicated by the effect of passing d-c space current through the winding or by the use of an air-gap to prevent saturation of the core by unidirectional current. The procedure to follow when one of these disturbing effects is present is not very difficult, but it becomes somewhat involved if an efficient design is wanted when both are present. In this paper an attempt is made to present a workable method of taking account of these disturbing effects. The method involves the determination of the apparent and maximum obtainable permeabilities of the magnetic materials, so that a proper conclusion may be arrived at by an application of simple engineering methods."

SHADED MAGNETIC FIELD OF A.C. MAGNETS.—N. Andersen. (*Elect. Journ.*, February, 1929, V. 26, pp. 82–85.)

A device for obtaining quiet operation of an A.C. magnet on a closed gap, by which a pull is obtained during the complete cycle.

LES ALLIAGES LÉGERS DE HAUTE CONDUCTIVITÉ : LEUR EMPLOI DANS LA CONSTRUCTION DES LIGNES ÉLECTRIQUES (Light Alloys of High Conductivity : their Use in the Construction of Electric Lines).—H. Chaumat. (*Rev. Gén. de l'Élec.*, 4th May, 1929, V. 25, pp. 687–689.)

CONSTANT SPEED COUPLING.—J. P. Hall & Co. (*Engineering*, V. 126, p. 771.)

A non-electrical, centrifugal-force opposing-spring coupling is described which, when the motor speed was varied from 455 to 760 r.p.m., allowed the speed of the (8 kw.) dynamo to change only from 430 to 455 r.p.m.

AUTOMATIC CONTROL OF FREQUENCY AND LOAD.—H. A. McCrea. (*Gen. Elec. Review*, June, 1929, V. 32, pp. 309–313.)

A description of the Warren Frequency Control Equipment for power stations. Where manual operation results in instantaneous frequency variations of one-tenth of a cycle, this equipment limits them to one-fortieth of a cycle.

"STABILIZZAZIONE" DI ACCENSIONE PER APPARECCHI COMPORTANTI TUBI E VALVOLE TERMOIONICHE (Stabilisation of Filament Current for Thermionic Tube and Valve Apparatus).—E. Pugno-Vanoni. (*Elettrotec.*, 15th May, 1929, V. 16, pp. 339–340.)

A method, for alternating current, depending on a "constant intensity transformer" with an auxiliary primary winding connected in series with the leads to the apparatus carrying the main load, and a secondary which "arranges itself in a suitable position under the opposing influences of gravity and electrodynamic repulsion." This secondary is connected to the primary of an insulating transformer, whose secondary goes to the filament. Excellent test results are given.

A NEW AUTOMATIC A.C. VOLTAGE REGULATOR.—K. Howe. (*Rad. Engineering*, March, 1929, V. 9, p. 40.)

The numerous applications for this device. and some indications of its performance, are given here ; as regards its actual nature, it is stated that "like the conventional transformer, the regulator consists of primary and secondary windings and a special core shape employed to produce regulation. Unlike transformers, the placement of windings in respect to the others and the cross-section of the core have very marked effects. . . ." *Cf.* above, Pugno-Vanoni.

EINE AUSGLEICHSSCHALTUNG MITTELS NORMALER METALLFADENLAMPEN (A Stabilising Arrangement using ordinary Metal-filament Lamps).—H. Roder. (*Telefunk. Zeit.*, May, 1929, V. 10, No. 51, pp. 80–82.)

By making use, through a bridge connection, of the difference between the current-voltage curves of an ordinary resistance and of a metal-filament lamp, a voltage stabiliser is obtained which can be used for A.C. or D.C. For a 33 per cent. change in supply voltage (300 v. $\pm$ 33 per cent.) the greatest change in the working voltage (33 v.) was $\pm$ 1.4 per cent. An application suggested is in providing grid-bias in transmitters. The method is in theory applicable also to the stabilisation of power, but in this case its efficiency is very low (smaller than 2 per cent.).

STATIONS, DESIGN AND OPERATION.

KURZWELLENVERSUCHE BEI DER AMERIKAFAHRT DES LUFTSCHIFFES "GRAF ZEPPELIN" (Short-wave Tests on the American Flight of the Airship "Graf Zeppelin.")—(*E.T.Z.*, 3rd January, 1929, V. 50, pp. 16–18.)

Report of the Wireless Division of the DVL. Among the results mentioned the following may be noted :—On the outward journey the airship signals, from a set giving 2 watts to the (dipole) aerial, were received in Berlin practically without a break up to 4,000 kms., using wavelengths of 27–37 m. Short transmissions at irregular intervals (owing to airship trouble) gave good reception on about 20 m. up to 5,000 km. and weaker reception up to 5,500 km. Temporary breakdown of communication occurred during the twilight hours, for which period no special wave had been provided. It is concluded that work still needs to be done (*a*) in finding the suitable waves for various distances, and (*b*) in developing more powerful transmitters, up to the limits suitable for the various aircraft ; "this limit, for an airship of the size of the LZ.127, should be about 100–200 w." [to aerial ?] While the breakdown of communication is attributed to the use of the wrong wavelength for the twilight hours, the frequent insufficient strength of signal was due to the power being too small. The short-wave receiver on board the airship (push-pull "audion" with 3 L.F. stages) was much less affected by atmospherics than the long-wave receiver; but it was troubled by local disturbances which however can be guarded against.

DUPLEX ARRANGEMENTS.—(German Patents 471143, Telefunken; 464724 and 475535, Lorenz.)

(1) The same valve is used for transmission and reception, the reaction coupling only allowing oscillation to take place when the microphone is in action. (2) deals with the use of a directive, rotatable aerial for transmission and another independent one for reception: the direction of duplex communication can thus be altered by swinging the two aerials. (3) A bridge arrangement with one aerial only; the transmitted and received waves are so nearly equal in wavelength that their interference wave can be used in the receiver. Talking and calling switching arrangements are described.

DRAHTLOSES GEGENSPRECHEN (Duplex Wireless).—W. Hahn. (*E.T.Z.*, 11th July, 1929, V. 50, pp. 1019–1024.)

Author's summary:—"After mentioning the earlier experiments carried out by the German Post Office in conjunction with private firms, the fundamental circuits and the necessary steps for joining up to the telephone systems are discussed, special attention being given to the doubly- and singly-actuated reaction-stopper circuits. A description is given of the stability measurements carried out over the test service Berlin-Hamburg, on short waves, and of the fading effects within the speech-frequency band [selective fading] found during those tests. The equipments for the Germany-Argentine service, and its tests, are [briefly] described. [See also *E.T.Z.*, 20th June, 1929, p. 907.] The conclusion of the paper glances at future developments in duplex radiotelephony."

LA NOUVELLE CONVENTION RADIOÉLECTRIQUE DE PRAGUE ET LA SUPPRESSION DES INTERFÉRENCES ENTRE LES ÉMISSIONS DE RADIODIFFUSION (The New Prague Radio-electric Convention, and the Suppression of Interference between Broadcasting Stations).—M. Adam (*Rev. Gén. de l'Élec.*, 13th July, 1929, V. 26, pp. 61–72.)

TELEPHONY WITH AUSTRALIA.—(*Electrician*, 19th July, 1929, V. 103, p. 69.)

An editorial paragraph on the re-broadcasting of the Westminster Abbey Thanksgiving Service throughout Canada by the Marconi-Mathieu multiplex (beam) system; the re-broadcasting was so good that the service was passed on to Australia over the Canada-Australia beam and was successfully re-broadcast in Australia. On the same day two-way telephony was conducted between England and Australia, using the same route. The paragraph remarks: "One would have thought that such an event, unique in the history of telephonic and telegraphic communication, would have been the subject of considerable publicity in the newspapers of this country, but so modest are we in these matters that even the lesser achievement of relaying the Thanksgiving Service to Canada resulted in many letters of congratulation being sent to the National Broadcasting Company—of America!"

ERÖFFNUNG DER UNMITTELBAREN FUNKBINDUNG DEUTSCHLAND-SIAM (Opening of the Direct Wireless Service between Germany and Siam).—(*Telefunk. Zeit.*, May, 1929, V. 10, No. 51, pp. 90–91.)

DER WELTFERNSPRECHVERKEHR (The World's Telephone Service).—P. Craemer. (*E.T.Z.*, 4th July, 1929, V. 50, pp. 959–963.)

This general survey includes a world-map showing existing and projected services.

THE MARCONI-MATHIEU METHOD OF MULTIPLEX SIGNALLING.—G. A. Mathieu. (*Marconi Rev.*, April, 1929, No. 7, pp. 1–7.)

GENERAL PHYSICAL ARTICLES.

ÜBER DIE SYNTHESE VON ELEMENTEN (The Synthesis of Elements).—G. I. Pokrowski. (*Zeitschr. f. Phys.*, 21st March, 1929, V. 54, No. 1/2, pp. 123–132.)

The writer investigates the energy and frequency of the radiation which must be set free if single protons unite to form atomic nuclei of certain elements. He shows that the periods of these radiations must be whole multiples of "chronons." From considerations of energy he determines the most probable syntheses; the frequencies of the corresponding radiations agree completely with the observations of Millikan and Cameron on the cosmic rays. Finally he calculates the mass of the proton as 1667×10^{-24}, as compared with the experimental value 1662×10^{-24}. A second part appears in No. 9/10, 11th May, 1929, pp. 724–730. Here the writer shows that the loss of mass, on the union of proton and electron, fits in approximately with Aston's experimental law of atomic weight. He then calculates the thickness of the layer which emits the cosmic rays, and arrives at a figure of the same order of magnitude as the dimensions of the Galactic stellar system.

DIE NATUR DER HÖHENSTRAHLUNG (The Nature of the "Cosmic Rays.")—W. Bothe and W. Kolhörster. (*Naturwiss.*, 26th April, 1929, V. 17, pp. 271–273.)

A description of the tests, with two Geiger-Müller tube counters, referred to in June Abstracts, p. 344, leading to the conclusion that the "cosmic rays" are not a form of gamma radiation but are corpuscular rays.

PENETRATING RADIATION AND DE BROGLIE WAVES.—F. T. Holmes. (*Nature*, 22nd June, 1929, V. 123, p. 943.)

Referring to the Bothe and Kolhörster experiment from which these workers deduce a corpuscular rather than a wave nature for the "cosmic rays" (see June Abstracts, p. 344) the writer suggests, from consideration of the de Broglie wavelength formula and the experiments of Davisson and Germer and of Kikuchi, that the Bothe-Kolhörster experiment may be inconclusive.

Über eine neue Art sehr schneller Beta-Strahlen (A New Kind of Beta-Radiation).—D. Skobelzyn. (*Zeitschr. f. Phys.*, 11th May, 1929, V. 54, No. 9/10, pp. 686–702.)

The hypothesis that the fast beta-rays of uncontrolled origin, which occasionally appear in a Wilson expansion apparatus, represent secondary electrons produced outside the chamber and in its walls by the ultra-gamma cosmic radiation, is here investigated experimentally. Results leave little doubt that the hypothesis is correct.

Sur la Nature des Rayons ultrapénétrants—Rayons cosmiques (On the Nature of the Highly Penetrating Radiations—Cosmic Rays).—P. Auger and D. Skobelzyn. (*Comptes Rendus*, 1st July, 1929, V. 189, pp. 55–57.)

Referring to Bothe and Kolhörster's verdict that these rays are corpuscular and not of the gamma type (June Abstracts, p. 344), the writers point out that their own recent discovery (of very rapid beta rays apparently produced as secondary radiations by ultra-gamma rays) would lead to a different explanation of the above-named workers' results with their two Geiger ion-counters. They suggest that the cosmic rays are non-ionising ultra-gamma radiations producing by the Compton effect very rapid beta-rays which cause the ionisation associated with the cosmic radiations.

Thunderstorms and the Penetrating Rays.—B. F. J. Schonland. (*Nature*, 20th July, 1929, V. 124, p. 115.)

"Measurements of the intensity of the penetrating radiation underneath five active thunderstorms [in S. Africa] did not differ appreciably from measurements made during periods of fine weather."

Bemerkung zur Natur der Höhenstrahlung (A Note on the Nature of the Cosmic Rays).—A. K. Das. (*Naturwiss.*, 5th July, 1929, V. 17, pp. 543–544.)

By a combination of relativity principles and quantum mechanics, the writer applies the results of Ornstein and Burger (that the radius of a photon is equal to the wavelength of its associated wave) and of McLewis (that the radius of a photon is equal to that of an electron) to show that the effects of the highly-penetrating radiations would be produced by hydrogen nuclei travelling with a velocity $0.7 \times$ velocity of light. He quotes the Bothe-Kolhörster pronouncement as to the corpuscular nature of the rays as fitting in with his theory. A study of the behaviour of the rays in an electric and magnetic field would test its correctness.

Cosmic Radiations and Evolution.—J. Joly. H. H. Dixon. (*Nature*, 29th June, 1929, V. 123, p. 981.)

The first letter points out that there seem to be no sure grounds for believing that the penetrating radiations are uniformly distributed through space. If they are not, and if considerable variations in the strength of those reaching the earth have occurred in the past—possibly referable to translatory movements of the solar system—serious effects upon organic evolution may have taken place. Thus if the present small value of their energy is the result of a recent decrease, the conclusions of medical research on the effect of gamma and X-ray radiation on healthy and morbid tissue might suggest "an issue of rather sensational kind, and certainly at present purely speculative": —that the present world-wide increase of cancer may be due to the disappearance in recent times of a controlling factor which acted in the same manner as gamma or X-rays upon animal tissues.

The second letter refers to the above suggestion and to the recent discovery of the production of variation in the progeny of plants by the treatment of the parents with X-rays; the writer suggests that the cosmic radiations have been a factor in the production of variations by direct action on the germplasm.

MISCELLANEOUS.

Luminous Discharge in Gases at Low Pressures.—H. Pettersson. (*Nature*, 29th June, 1929, V. 123, pp. 978–979.)

Further development of the work on the electrodeless discharge referred to in July Abstracts, p. 404. The use of short coils in place of the Lecher circuit previously employed greatly increases the luminosity, and allows the discharge to be passed through quartz capillaries less than a millimetre in width. A source of light is thus obtained which is suitable in shape for spectrography and requires a very minute quantity of the gas to be examined. With a plate current of, say, 50 mA. at an anode potential of 1,000 v., the luminosity in the case of the inert gases is very intense, neon giving light of an intensity almost insupportable to the eye both in narrow capillaries and in wider tubes. Possibly experiments will show that krypton thus excited will be a suitable source of the line at 5,649 A.U., recently proposed as a new standard of wavelength. Various dissociation and spectroscopic effects are described.

Vital Rays.—(*Nature*, 13th July, 1929, V. 124, pp. 50–51.)

A review of Reiter and Gábor's book, "Zellteilung und Strahlung" (Cell Division and Radiation). The reviewer outlines the history of the theory (originated by Gurwitsch) of mitogenetic rays emitted by growing roots, bulbs, yeast cells and other living tissues or substances. Gurwitsch assumes that just as light-production in organisms is supposed to be due to a reaction between luciferin and luciferase, so these rays arise when "mitotin," which is killed by heat, unites with "mitotase" which survives a temperature of 60 deg. It has been claimed that in full-grown animals only the blood produces the rays, and more recently that the tissues of malignant tumours emit them. Their wavelength is supposed to be about 190–230 $\mu\mu$. The work under review gives experimental results in detail, confirms Gurwitsch's main statement and supports many of the hypotheses and conclusions arrived at by him and his co-workers.

Sur l'Utilisation de l'Énergie Thermique des Mers (The Utilisation of the Thermal Energy of the Seas).—G. Claude. (*Comptes Rendus*, 3rd June, 1929, V. 188, pp. 1460–1461.)

The writer has just discovered, in a *Revue Scientifique* of 1881, a communication from D'Arsonval anticipating the plan of Claude and Boucherot (Abstracts, 1928, V. 5, pp. 471–472), though suggesting the use of liquefied gas instead of the vapour of the water itself.

Utilisation des Sources d'Énergie naturelle (Utilisation of Sources of Natural Energy).—P. Drosne. (*Chaleur et Industrie*, February, 1929, V. 10, pp. 75–77.)

A somewhat pessimistic article on such plans as those of Claude and Boucherot (*see* above). The writer considers that such schemes suffer from restrictions analogous to those which limit the utilisation of the tides.

On the Writing of Scientific Papers.—W. H. Merriman. (*E.W. & W.E.*, July, 1929, V. 6, p. 384.)

Referring to Colebrook's article (August Abstracts, p. 466) the writer suggests an omitted point of importance—the choice of a title which shall be concise, readily keyed for a subject-matter index, and not a "verbal procession" as is so often the case.

Recent Developments in Educational Broadcasting.—H. L. Fletcher. (*Journ. R. Soc. Arts*, 19th July, 1929, V. 77, pp. 872–895.)

Application de la Théorie Électronique aux Mauvais Contacts (Application of the Electronic Theory to Imperfect Contacts).—H. Pélabon. (*L'Onde Élec.*, April, 1929, V. 8, pp. 160–170.)

Author's summary :—"The writer first recalls how the electrons are distributed in the interior and at the surface of a conductor. He lays stress on the difference of velocity of passage of these electrons in a perfect and in an imperfect contact. He then deduces from this expressions for the intensity of the direct and alternating currents in a circuit containing an imperfect contact. He also explains the rectifying action of contacts formed by identical metals in which one electrode is mobile. He considers the influence of electromagnetic shocks and shows that coherer effects are due to the displacement of the electrodes. He suggests an explanation of the negative coherer-effect found by Branly for lead dioxide." *Cf.* July Abstracts, p. 402 ; also April, p. 226, and Audubert and Quintin, same page.

Sur l'Existence d'un État conducteur des Liquids Dits Isolants (On the Existence of a Conducting State in So-called Insulating Liquids). — L. Brüninghaus. (*Comptes Rendus*, 27th May, 1929, V. 188, pp. 1386–1388.)

Experimental investigations have led to the following conclusions :—that below thicknesses of the order of one hundredth of a millimetre, and under the application of p.d.'s of the order of some 10–110 volts, insulating liquids can suddenly acquire metallic conductivity ; that this modification is reversible ; that it makes its first appearance in the form of an unstable state where the two régimes, conducting and insulating, are intermingled erratically. The writer has assured himself that there is no sparking or short circuiting. He points out that the phenomenon fits in with the known improvement of moving contacts by a film of vaseline, etc.

Beitrag zur Kenntnis der Vorgänge beim Stromdurchgang durch den menschlichen Körper (Contribution to our Knowledge of the Processes involved in the Passage of Current through the Human Body).—(*Bull. d. l'Assoc. Suisse des Élec.*, 7th July, 1929, V. 20, No. 13, pp. 428–441.)

These tests lead to the conclusion that under adverse conditions, and when circuit is made from hand to hand, 30 v. can be fatal for dry and 20 v. for wet hands. For a person in a bath, taking hold of a charged tap or lamp, the limit is reduced to 10 v. *Cf.* February Abstracts, p. 115.

Radio in Trains.—(*Journ. Am.I.E.E.*, June, 1929, p. 446.)

A paragraph on recent successful tests in Canada, where the signals from the train were transferred to the neighbouring telegraph wires and thence (at the terminal point) to the telephone system. At present, the terminal points must not be more than 150 miles apart or the voice is lost.

Fog Landing for Aeroplanes.—(*See* Dellinger & Diamond, under "Directional Wireless".)

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.

HIGH-EMISSION FILAMENTS.

Application date, 1st December, 1927. No. 307099.

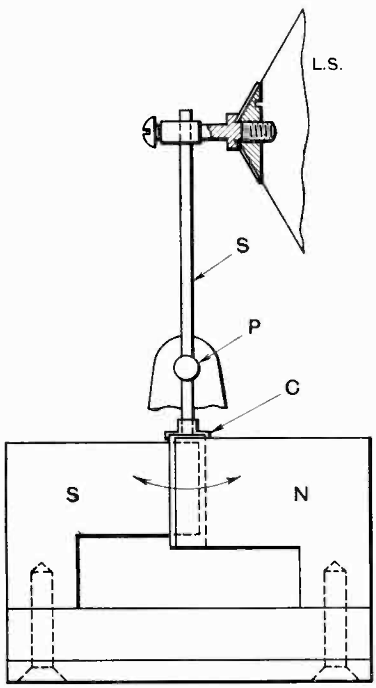
A nickel or platinum core is immersed in alkaline-earth metal powder and heated *in vacuo* for a considerable time, whereby the metal vapour so produced penetrates the core. No definite oxidising treatment is necessary. It is stated that the alkaline-earth metal diffuses through the core to form a molecular layer at its surface. In operation the oxygen or other gas necessary for high emission is furnished by the small quantity occluded in the electrodes of the finished valve.

Patent issued to E. Y. Robinson and Metropolitan-Vickers Electrical Co., Ltd.

MOVING-COIL SPEAKERS.

Application date, 30th November, 1927. No. 310759.

The moving coil *C* is located in the narrow gap formed between two pole pieces *N*, *S*, the former being of horseshoe shape with the point of the latter entering between its two horns. The coil is therefore vibrated in the direction of the arrows and communicates its movement to a spindle *S*, which is pivoted at a point *P* between the moving coil and the cone *L S* of the speaker. The point *P* is so chosen that the amplitude of movement of the diaphragm or cone is twice that of the coil *C*.



No. 310759.

Patent issued to The British Thomson Houston Co., Ltd., and A. P. Young.

INDIRECTLY HEATED VALVES.

Application date, 5th December, 1927. No. 307327.

The heating element is disposed inside a tubular emitter or cathode consisting of a number of different layers. The outer layer is a coating of alkaline-earth oxide having a high emissivity, laid on a layer of soft iron which serves as a magnetic screen for any field arising from the heating element. A second inner layer consists of a metal such as nickel and a refractory metallic oxide, the mixture having a high thermal and a low electrical conductivity. The last or inner layer consists of a metal such as platinum of high electrical conductivity. The heater element may be connected at its mid-point to the centre of the composite cathode.

No. 307326. The true cathode is heated by a positive ion bombardment from an auxiliary electrode to which the mains voltage is applied. The system is particularly suitable for gas-filled rectifiers, but may also be applied to "hard" valves by coating the surface of the heating-electrode with a mixture of magnetite, aluminium oxide, and cæsium nitrate, which gives a copious positive ion emission.

No. 307325. Here the emitter is energised by heat derived from dielectric losses set up across a condenser to which the mains voltage is directly applied. The dielectric material is zirconia, thoria, silica, or other refractory substance. The latter may be regarded either as an imperfect dielectric or as a very poor conductor. The heat resulting from the application of the A.C. mains voltage is radiated to the emitter or cathode of high emissivity.

Patent issued to Graham Amplion, Ltd., and P. Freedman.

DIRECTIVE AERIALS.

Convention date (Holland), 3rd October, 1927. No. 298131.

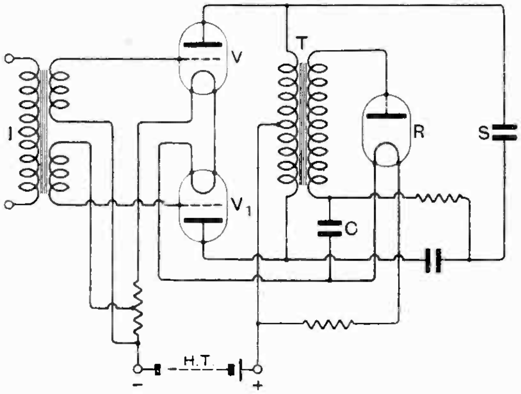
A directive aerial system consists of a symmetrical two-wire feed-line, to which are directly connected a series of radiating "doublets" arranged to extend on each side of the feeders. The radiators may be spaced half a wavelength apart, in which case the connections to the feeder are alternately crossed so as to maintain the currents in phase. Or they may be spaced a full wavelength apart and fed without crossing. It is stated that the phase relation is not affected by reflection at the tapping points, and that each doublet receives an equal quantity of current from the common feeder.

Patent issued to N. Koomans.

ELECTROSTATIC LOUD SPEAKER CIRCUITS.

Convention date (Germany), 10th November, 1927. No. 300252.

In order to increase the available voltage used for biasing a loud speaker of the electrostatic type, the speech frequency currents from a pair of L.F.



No. 300252.

amplifiers is rectified and used for this purpose. Acoustic currents from an input transformer *I* are applied to a pair of push-pull amplifiers *V*, V_1. The output is applied across the plates of an electrostatic loud speaker *S*, in addition to a D.C. biasing voltage from a battery *H.T.*, or from D.C. mains. As the speaker is voltage-operated, a transformer *T* is shunted across the valves *V*, V_1, the secondary voltage being applied to a rectifier *R* and charges up a condenser *C*. The effective biasing voltage across the loud speakers is thus made equal to that supplied by the source *H T.* and that built up across the condenser *C*.

Patent issued to E. Reisz.

ELECTROSTATIC PICK-UPS.

Application date, 26th September, 1927. No. 306855.

To connect an electrostatic gramophone pick-up to a wireless receiver, the detector valve is first removed, and an adaptor plugged into its place. The valve is then replaced in sockets on the upper face of the adaptor. The internal connections of the adaptor include a high-resistance and leak inserted between the grid and filament. An extra lead is connected to the positive of the high-tension supply to provide the necessary biasing voltage for the pick-up. A special screening lead is twisted around the feed connections.

Patent issued to H. Andrewes and Dubilier Condenser Co. (1925), Ltd.

PIEZO CRYSTAL MOUNTINGS.

Application date, 20th February, 1928. No. 309276.

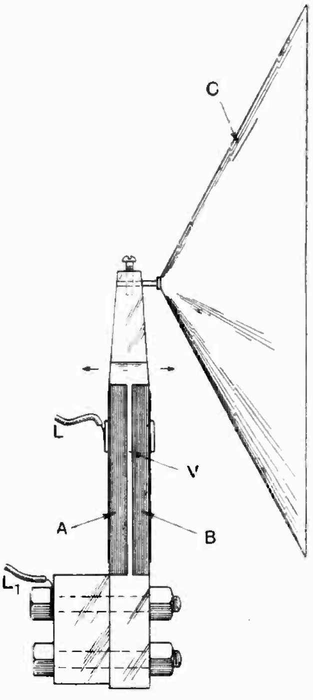
When a piezo crystal is subjected to the influence of modulated high-frequency oscillations, it tends to react as an electrical circuit of very low damping to the fundamental or carrier frequency. Accordingly it may fail to respond in the desired manner to the sideband components of modulation. To prevent this the crystal mounting is so arranged as to offer a definite mechanical or frictional damping to oscillations within the critical range. For instance, it may be mounted on a rubber block; or an air gap may be left of such size as to set up standing air-waves which produce the desired degree of friction.

Patent issued to The Gramophone Co., Ltd.; A. Whitaker, W. F. Tedham, and C. O. Browne.

A PIEZO-ELECTRIC SPEAKER.

Convention date (U.S.A.), 14th October, 1927. No. 298904.

The diaphragm of a loud speaker is driven by the reaction of a piezo-electric unit to the amplified speech-currents. The cone *C* is supported by a light metal member which is cut away to form a thin central vane *V* on each side of which is mounted a long section of piezo-electric material *A*, *B*. The crystal sections are so cut that one expands longitudinally whilst the other simultaneously contracts under the action of an applied voltage, thus tending to vibrate the member *V* in the direction of the arrows. Speech voltages are applied through conductors *L*, L_1, the former contacting with a metal foil covering the outer surface of both crystals and the matter with the central vane *V*.



No. 298904.

Patent issued to E. W. C. Russell.

DIRECTION-FINDING.

Convention date (Holland), 6th December 1927. No. 301831.

In order to prevent losses due to the use of sliding contacts between a rotating frame aerial and the input circuit of the receiver, the primary coil of the aerial transformer is wound rigidly around the supporting spindle of the aerial, whilst the secondary coil is wound around a stationary sleeve enclosing the spindle. The coupling remains constant for normal rotation, but can be adjusted to any desired value by moving the sleeve axially along the spindle.

Patent issued to Nederlandsche Telegraf Co.

PIEZO-CONTROLLED OSCILLATORS.

Convention date (U.S.A.), 21st March, 1927. No. 287484.

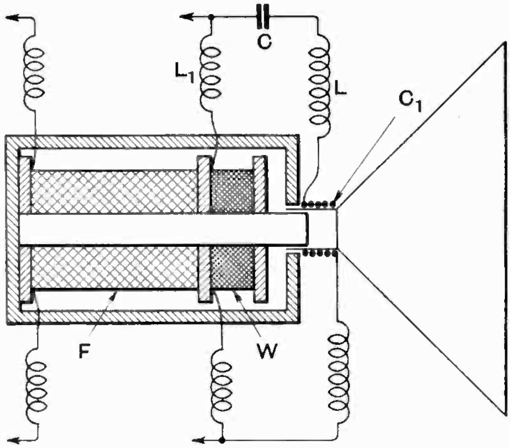
It is stated that the degree of control exercised by a crystal upon an oscillation circuit is an inverse function of the amount of regeneration necessary to make the crystal oscillate. Accordingly a more forceful arrangement than those hitherto known is obtained by combining the control crystal with means for stabilising or neutralising the inherent internal capacity of the valve oscillator, so as to reduce regenerative action to a minimum.

Patent issued to Marconi's Wireless Telegraph Co., Ltd.

LOUD-SPEAKER FILTER CIRCUITS.

Application date, 12th November, 1927. No. 311430.

The direct-current component passing through the choke coil of an output filter circuit is used to augment the normal exciting-current for the field-magnet of a moving-coil speaker. As shown in the Figure, speech-frequency currents pass to the moving coil C_1 through a condenser C and coil L. The steady plate current is diverted through a coil L_1 and passes through a special winding W



No. 311430.

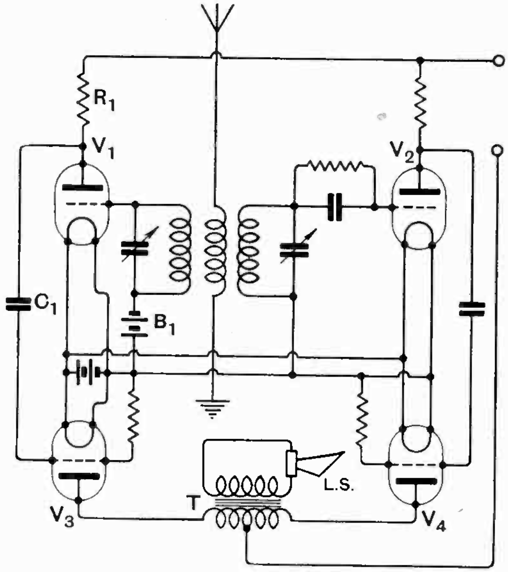
provided in addition to the ordinary field winding F. The whole filter unit is incorporated in the loud-speaker casing.

Patent issued to H. Green and Celebritone, Ltd.

RECEIVING CIRCUITS.

Application date, 24th January, 1928. No. 310764.

The aerial input is applied simultaneously to two detector valves V_1, V_2. The former V_1 is adjusted by means of a grid-bias battery so as to give bottom-bend anode rectification, whilst the latter V_2 operates on grid-leak rectification. The anode current in V_1 therefore increases whilst that in V_2 decreases, so that the two sets of detected oscillations are 180° out of phase. The output from V_1 is applied through the resistance R_1 and coupling



No. 310764.

condenser C_1 to a low-frequency amplifier V_3, whilst V_2 is similarly coupled to the amplifier V_4. The two currents are transferred cumulatively across a centre-tapped transformer T to the loud-speaker *LS*.

Patent issued to The Edison Swan Electric Co., Ltd., and L. H. Soundy.

MEASURING DISTANCES BY RADIO.

Convention date (France), 15th December, 1927. No. 302602.

The distance between two wireless stations may be ascertained by causing an outgoing train of waves from the first station to be automatically retransmitted from the second station back to the first, and so on, the periodic note set up at the first station being a function of the distance separating the two.

According to the present invention, an oscillating valve is interposed between the transmitting and receiving circuits at the first or active station, and serves to interrupt or modulate the outgoing wavelength at a definite frequency, the receiving circuit being rendered sensitive only during those intervals when the transmitter is quiescent. The distance between the local or active station and a distant or passive station is then determined by adjusting the frequency of the oscillating valve or modulator until maximum reception of the re-transmitted wave is obtained. This period corresponds to the time taken for a wave train to reach the distant station and return.

Patent issued to A. Koulikoff.

INDIRECTLY HEATED VALVES.

Application date, 13th December, 1927. No. 307857.

An indirectly heated valve comprises a carbon heating-filament wound on a porcelain rod mounted inside a central nickel tube which forms the cathode or electron-emitter. The surface of the latter is comparatively large and dissipates a considerable amount of heat. To prevent the heat from being trapped in the space between the cathode and anode, and so possibly raising the control grid to a temperature at which it may also emit electrons, the anode is so shaped or provided with openings or gaps as to allow the heat to escape freely. At the same time in order to prevent the electron stream from passing through the "open" anode, and so charging-up the glass wall of the bulb, a further perforated electrode is located concentric with but outside the anode, and is maintained at zero potential by a connection to the cathode.

Patent issued to E. Y. Robinson.

BEAM AERIALS.

Application date, 11th February, 1928. No. 311449.

Each radiating conductor in a multiple system of the Beam type is associated with a reflector unit consisting of a number of conductors so arranged as to have a ratio of inductance to radiation-resistance less than that of a single conductor. It is then found that over a band of frequencies extending on each side of the fundamental frequency of the reflector, the induced currents are larger and more nearly in phase than is the case with a single-wire reflector. The improved aerial system as a whole can therefore be operated over a wider band of frequencies than usual.

Patent issued to C. S. Franklin.

LOW-FREQUENCY AMPLIFIERS.

Application date, 16th February, 1928. No. 311466.

An amplifier, particularly adapted for undistorted telephony over long cables, comprises one or more thermionic valves or photo-electric cells provided with means for neutralising inter-electrode capacity effects, and an inter-valve coupling circuit so designed that the frequency characteristic of the amplifier as a whole is a rising curve which automatically compensates for the falling-off in the frequency values due to attenuation and similar losses along the carrier line or cable.

Patent issued to W. S. Smith and N. W. McLachlan.

SOUND REPRODUCERS.

Application date, 23rd November, 1927. No. 311826.

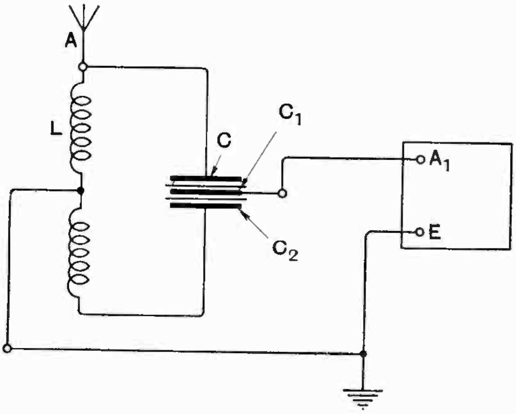
The main feature of the invention lies in the use, in an electro-dynamic microphone or loud-speaker, of a sound-responsive member in the form of a bag, substantially closed and forming or communicating with a gaseous reservoir. The bag functions as a collapsible diaphragm, free around the periphery yet substantially sound-tight. A conducting winding is bonded with the bag, and set between the poles of a magnet, an air space being left between the bag and the magnet, and between the bag and a resonant bronze backing. The gaseous reservoir contains cotton-wool to damp the air column. The bag may be folded into parallel layers and may be combined with ribs, stays, or honeycombs arranged in series or parallel formation.

Patent issued to A. F. Sykes.

INTERFERENCE ELIMINATORS.

Application date, 13th April, 1928. No. 311526.

A unit for improving selectivity in wireless reception consists of an inductance coil L shunted by a three-plate condenser C, C_1, C_2. The centre point of the coil L is connected to earth E, whilst the two outer ends are joined to the fixed plates C, C_2 of the condenser. The centre plate C_1, which may be protected by mica plates, is mounted on a screwed spindle for adjustment and is connected to the aerial terminal A_1 on the set. The arrangement permits the effective length of an outside aerial A to be varied at will within wide limits, thus increasing selectivity. At the same time undesired signals picked up on the earth lead from the set



No. 311526.

can be fed to the input in opposition to those picked up by the aerial proper, and so balanced out.

Patent issued to N. P. Hinton and Metropolitan Vickers Electrical Co., Ltd.

PIEZO-CONTROLLED VALVE OSCILLATORS.

Convention date (Germany), 2nd December, 1927. No. 301510.

The direct control by a piezo-electric crystal of a valve oscillator taking an input of more than a few watts presents difficulty owing to the tendency of the crystal to fracture under comparatively small loads. To overcome this defect two or more crystals of the same natural frequency are connected in series across the plate and filament so as to divide up the total control voltage in equal shares between them.

Patent issued to Lorenz A.G.

PICTURE TRANSMISSION SYSTEMS.

Convention date (*U.S.A.*), *25th November*, 1927. *No.* 301327.

In order to prevent "streakiness" and to secure a good half-tone effect in reception, the picture is scanned at the transmitting end, first in one direction, and then at a later period in a different direction, at an angle to the first. In this way each point of the picture is traversed by the light-ray and recorded twice, with an intervening period of time, the picture meantime being continuously advanced relatively to the scanning device. The resulting half-tone effect is thus made up of a series of separate lines woven in and out.

Patent issued to Marconi's Wireless Telegraph Co., Ltd.

DIRECTIVE AERIAL SYSTEMS.

Application date, *26th January*, 1928. *No.* 310451.

A concentrated beam of radiation, directed upwards at an angle to the horizontal, is obtained from a bank of antennæ spaced apart by a fraction of a wavelength. Each antenna consists of a single wire with an intermediate portion folded back on itself so as to suppress radiation from that part, leaving the upper and lower portions of the wire the only effective radiating elements. Both the effective and non-effective portions are made slightly longer than one wavelength, whereby the current in the upper part lags behind that in the lower, so as to give the emitted beam an upward trend.

Patent issued to C. S. Franklin.

THERMIONIC OSCILLATION GENERATORS.

Application date, *3rd February*, 1928. *No.* 310915.

An oscillation generator consists of a four-electrode valve to which suitable potentials are applied to cause it to operate over the falling or negative-resistance portion of its characteristic curve. The output circuit comprises two differently tuned oscillatory circuits, one of a radio and the other of audio frequency. The system generates two corresponding frequencies, one of which automatically modulates the other.

Patent issued to N. W. McLachlan.

LOUD SPEAKERS.

Application date, *16th April*, 1928. *No.* 311071.

A flat or conical diaphragm, propelled at its centre and flexibly supported around its periphery, is maintained in correct centring by means of a number of arms each secured at one end to the diaphragm and at the other to a suitable base. The arms are inclined to the axis of the diaphragm so as to apply a slight torsion or twist simultaneously with the normal plunger movement of the diaphragm. This is stated to allow greater freedom of vibration, whilst at the same time ensuring that the diaphragm always returns to its normal position.

Patent issued to Graham Amplion, Ltd., and P. K. Turner.

COOLING POWER GENERATORS.

Convention date (*U.S.A.*), *17th March*, 1927. *No.* 287463.

In valve generators of large power it is usual to apply cooling-water to the anode. As the water is at earth potential and has some conductivity, it will constitute a high-resistance shunt and may dissipate some of the radio-frequency energy. To avoid this source of loss, the inductance coils of the output circuit are made tubular and carry the cooling fluid. The fluid is fed into and leaves the inductance pipes at points which are at zero alternating potential, and is therefore only shunted across the D.C. supply. The arrangement has the additional advantage of maintaining the inductance coils at a constant temperature, so as to prevent any fluctuation in wavelength caused by impedance changes due to heating.

Patent issued to Marconi's Wireless Telegraph Co., Ltd.

ALL-MAINS AMPLIFIER.

Application date, *8th February*, 1928. *No.* 311305.

The first valve is resistance-capacity coupled to the second, which in turn is transformer-coupled to a bank of four power valves, the filaments of which may be arranged either in series or parallel. The eliminator unit consists of one two-plate rectifier in series with a baretter for the filament supply, and two half-wave rectifiers for the high tension. One of the smoothing chokes in the filament supply is also utilised to energise the field-windings of a moving-coil speaker. A tapped resistance for use with D.C. mains is also incorporated in the same unit. Grid bias is derived from a resistance inserted in the negative lead of rectified high-tension circuit. Provision is made for switching-in an electric pick-up for gramophone reproduction.

Patent issued to L. G. H. Cantle.

SCREENED-GRID VALVES.

Application date, *30th November*, 1927. *No.* 310760. (*Patent of addition to* 192464.)

A screened-grid valve comprises a spherical-coiled wire cathode totally enclosed by a similarly shaped anode. Between the two are a pair of spherical grids, spaced away from each other, and from the anode and cathode. Two such units may be arranged within the same glass bulb, in which case the electrodes are made hemispherical in shape.

Patent issued to W. R. Bullimore.

TELEVISION APPARATUS.

Application date, *30th November*, 1927. *No.* 312406.

The rotating disc used in reception to distribute the light and shade intensities from a neon lamp or similar light source on to a viewing screen is fitted with lenses of short focal length, or a single short-focus lens is mounted closely adjacent to the exploring disc. The object is to limit the angular dispersion of the emerging rays of light, and thereby to secure a brighter image on the viewing screen.

Patent issued to J. L. Baird and Television, Ltd.