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AND

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Editorial

The Production of Ultra-short Waves

A GREAT amount of attention is being paid to this subject. During the last few months the English, American and German technical journals have all contained articles describing experimental work directed to the elucidation and surmounting of the difficulties which are encountered in the production of a considerable amount of power at wavelengths in the neighbourhood of a metre.

A paper entitled " Vacuum Tubes as High Frequency Oscillators," by Kelly and Samuel of the Bell Telephone Laboratories, was published in the November number of *Electrical Engineering* (*Amer. Inst. of Elec. Eng.*), and Wagner and Hollmann have a paper on the same subject in the December number of *Elektrische Nachrichten Technik*. These papers deal with the three well-known methods, viz.: the ordinary negative-grid method, as employed for lower frequencies but with suitable modifications, the positive-grid or Barkhausen-Kurz method, and the magnetron method. If with the ordinary negative-grid method the frequency is progressively increased by reducing the capacitance and inductance, with the usual type of valve, the output and efficiency are not seriously affected until the wavelength is reduced to 20 or 30 metres, but beyond this they fall off rapidly, and at a wavelength of 2 or 3 metres the valve refuses to function as an oscillator.

There are several causes for this limitation. There are the increased losses in the valve at the higher frequencies, combined with the fact that as the external inductance and capacitance are reduced and finally eliminated, the valve elements form an increasingly important portion of the circuit. A further cause is the transit time of the electrons in the valve which begins to become comparable with the period of the oscillation. To reduce the inter-electrode capacitance the electrodes should be made small and far apart, whereas to increase their thermal dissipation they should be made large, and to reduce the transit time of the electrons they should be close together.

The design thus becomes a matter of compromise and beyond a certain point each design is only suitable for a relatively narrow band of frequencies if the best results are to be obtained from it. By reducing the length of the cylindrical anode but fitting it with external cooling fins, by carrying the electrodes on their connecting leads without any other support, and by bringing these leads in at three different points of the bulb, the inter-electrode capacitances were reduced to a quarter of their previous values and the valve was able to give an efficiency of 25 per cent. at a wavelength of 2 metres with an output of 40 watts. Its limiting wavelength was 1.5 metres.

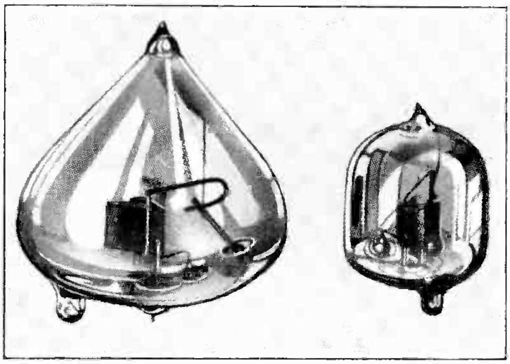


Fig. 1.—*Experimental valves for ultra-short waves.*

By reducing the size of the electrodes and bringing them closer together, thus keeping the capacitances much the same but reducing the transit time, the limiting wavelength was reduced to 0.75 metre, whilst the efficiency at one metre was about 16 per cent. with an output of about 20 watts. This valve was described by Fay and Samuel in a paper before the recent U.R.S.I. conference. The same workers have gone even further, and by doing away with the pinch and carefully designing the very small elements of the valve, especially the squirrel-cage grid, they have produced a valve with a limiting wavelength of 40 cm. and an output of 6 watts per valve at a wavelength of 60 cm. with 14 per cent. efficiency. These results were obtained with two valves in a push-pull circuit. The limiting factor was not anode heating but grid heating due to its proximity to the cathode, and special precautions had to be adopted to cool the grid.

Valves with still smaller clearances were made with which an output of one watt was obtained at a wavelength of 25 cm., corresponding to a frequency of 1.2×10^9, but they are not to be regarded as commercial articles at present. They are shown in Fig. 1.

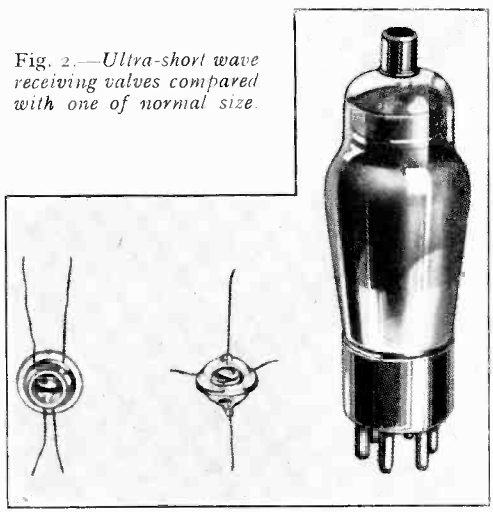
Where very little power is required, as for reception, very small valves have been evolved capable of oscillating at a frequency of 10^9 ($\lambda = 33$cm.).

They have plane electrodes, the cathode being oxide coated and indirectly heated. Their size can be judged from the photograph (Fig. 2), where two of them are shown beside an ordinary receiving valve.

The Positive-grid or Barkhausen-Kurz Method

Here the grid is at a high positive potential, whilst the anode potential is about the same as that of the cathode. The frequency is primarily determined, not by the constants of the external circuit, but by the time taken by the electrons to fly from the cathode through the grid to the neighbourhood of the anode, where they reverse and retrace their path and return through the grid. In the ordinary arrangement a Lecher wire circuit is arranged, one wire of which is connected to the anode and the other to the cathode, and to obtain optimum effects this circuit should be tuned to the frequency of the oscillating electrons by sliding the short-circuiting bridge to the correct position. If well designed the seal at which the Lecher wires leave the bulb forms the other nodal point

Fig. 2.—*Ultra-short wave receiving valves compared with one of normal size.*



of zero P.D., thus eliminating dielectric loss at this point. The engineers of the Bell Laboratories have developed a valve with a spiral grid which acts as an oscillating coil, the length of wire in the coil bearing a fixed relation to the wavelength. In this case the Lecher wires are not connected to the anode but to the two ends of this coiled grid. This type of valve was employed in the 17 cm. cross-Channel micro-ray link between Lympne and St. Inglevert. Such tubes have produced oscillations at a frequency of 3×10^9 ($\lambda = 10$ cm.). The efficiency obtained with the Barkhausen-Kurz positive-grid method of producing oscillations never exceeds about 6 per cent., and this method is comparable with the negative-grid method only for very short wavelengths of about 50 cm. or less. A series of valves with spiral grids ranging from outputs of several watts at 60 cm. down to fractions of a watt at 12 cm. all worked at efficiencies of about 1 per cent.

The "Magnetron" Oscillator

The simple cylindrical diode in an axial magnetic field has been largely replaced by the split-anode magnetron devised by Yagi and Okabe. A peculiar discovery was that the action of the valve was improved by giving the magnetic field a slight tilt away from the strictly axial position. Still better results are obtained by keeping the magnetic field axial, and skewing the radial electric field by means of end plates maintained at a positive potential. Although much higher frequencies have been obtained with the magnetron than with either of the other methods, the necessity of providing a powerful magnetic field is a serious disadvantage. The highest frequencies obtained are about 3×10^{10} ($\lambda = 1$ cm.) whilst an output of 2.5 watts has been obtained at 3×10^9 ($\lambda = 10$ cm.).

Both the papers referred to above give very extensive bibliographies of the subject, although one of the most complete bibliographies, referred to in both papers, was given by Megaw, whose papers in the 1933 *Journal of the Institution of Electrical Engineers* gave a very thorough critical review of the whole subject.

G. W. O. H.

Comparison of Radio-frequency Standards

B.B.C. Co-operation with Three Transmitters

FOR some time the International Union for Radio Research has organised special radio emissions for the international comparison of standards of frequency. Among the Institutions assisting in this work are the National Physical Laboratory, Teddington, and National Laboratories in the U.S.A. and in several countries of Europe.

In the comparisons of standards of frequency, agreement to one part in 10 million has been attained. During the work differences have been noted in the modes of arrival of the emitted wave, and on the occasion of the next international transmission during the night of 12–13th March, 1935, it is hoped to obtain the co-operation of persons and institutions possessing suitable apparatus to assist in the study of these differences.

The intercomparison of standards of frequency is made by sending out a very steady frequency from a radio transmitting station, the value of which can be measured at any place equipped with the necessary apparatus. The actual measurement is made by observing "beats" between two frequencies which are very nearly equal.

Observations of differences in mode of arrival can be made without requiring a local source of steady frequency. A comparison of the modulations arriving by the two carrier frequencies can be made by means of a low voltage cathode ray oscillograph supplied from the radio receiving apparatus, which must be free from distortion.

On the occasion of the next emission (12–13th March, 1935) the B.B.C. will modulate Droitwich and the Scottish Regional and Scottish National Stations simultaneously with the frequency of 1,000 cycles per second. A great part of England will be in the "fading" area of the Scottish Stations, and it is for physical observations, among which "fading" is an important phenomenon, rather than for quantitative measurements, that the two Scottish Stations are being provided. The main emission will last continuously for an hour and a half, preceded and followed by shorter ones for subsidiary purposes.

The National Bureau of Standards, Washington, U.S.A., is co-operating by a special emission of a frequency of reference of 5 million cycles per second. This is expected to be accurate to 1 cycle per second, and to be of sufficient intensity to be received satisfactorily in Europe.

In order to make best use of this opportunity it is requested that persons and institutions having suitable oscillograph apparatus will assist by making observations. More detailed information can be had on application to DR. E. H. RAYNER, National Physical Laboratory, Teddington, Middlesex.

The Interaction of Radio Waves*

By V. A. Bailey, M.A., D.Phil., F.Inst.P., and D. F. Martyn, Ph.D., A.R.C.Sc., F.Inst.P.

1. Introduction

THE first evidence that the waves from a wireless emitter might be influenced during their transmission by the radiations from a second emitter appears to have been obtained by Tellegen.[1] He observed when listening in Holland to the signals of the Beromunster broadcasting station in Switzerland, that the programme of the Luxembourg station could be heard faintly. The wide separation of the wavelengths of these stations (461 m. and 1,190 m. respectively) ruled out the obvious explanation of interference due to receiver imperfections, while the geographical situations of the stations and receiving site, which lie more or less on a straight line, with Luxembourg in the middle, suggest strongly that the interference was being produced above Luxembourg in that part of the Kennelly-Heaviside layer which must be mainly responsible for the reflection of the Beromunster signals received at Eindhoven. This hypothesis has since been supported by a number of further observations published in the correspondence columns of *World Radio*. In every case the distance between the receiver and the station whose signals are being observed is sufficiently great to ensure that a downcoming wave from the ionosphere is mainly responsible for the signal heard, while the interfering station is invariably situated somewhere between the receiver and the station observed. It seems certain therefore that the waves from the two transmitters interact in the ionosphere. It is proposed here to give an account of the mechanism by which this interaction can occur. At the recent London meeting of the U.R.S.I. Dr. Van der Pol gave an account[2] of some measurements which had been made upon the interference from Luxembourg. These measurements will be used in order to make quantitative tests of our theory.

* M.S. accepted by the Editor January 8th, 1934.

2. Non-linear Relationships in the Ionosphere

It is well known that two oscillations are incapable of exerting a mutual influence upon one another unless both act upon a non-linear device, that is, an element whose response is not proportional to the applied force. For example, the phenomena of cross modulation in receivers, the apparent demodulation of a weak signal by a strong one, the automatic synchronisation or "pulling-in" of two oscillators, and the production of heterodyne or beat tones, are all phenomena which depend for their existence upon the presence of a non-linear device, usually a thermionic valve having a curved grid volts-plate current characteristic. It is natural therefore to seek for some non-linear characteristic in the reflecting properties of the ionosphere. The latter influences radio waves in several ways. In the first place, by virtue of its refractive properties it is capable of so bending the waves which reach it that they return to earth. Secondly, by virtue of its conducting properties, it partially absorbs the incident radiation, so that only a fraction, though often an appreciable fraction, of the incident energy is so returned. Thirdly, owing to the presence of the earth's magnetic field, the ionosphere is capable of splitting up an incident ray into two or more rays of different velocities, and possessed of characteristic polarisations.

Now the observed phenomena suggest that it is the intensity of the Beromunster signal which is being affected by the Luxembourg station, so that we first examine the absorbing properties of the ionosphere, though bearing in mind that the other optical properties of the ionosphere may exert an appreciable but smaller influence on the apparent intensity of the Beromunster signal. It will, however, appear in the sequel that it is possible to explain quantitatively the phenomenon of the interaction of waves by consideration of the absorptive properties alone.

The ionised layers of the ionosphere may be considered to consist of air at a very low pressure in which free electrons move at random, with a mean velocity of, say, u cm. per second. From time to time each electron collides with a neighbouring molecule and an interchange of energy may occur. We shall denote by ν the average number of such collisions made per second by each electron. In the absence of an applied electric field we may suppose that thermal equilibrium exists, so that $\frac{1}{2}mu^2 = \frac{1}{2}MU^2$ according to the Principle of Equipartition of Energy, where m and M are the masses of an electron and molecule respectively, and U is the mean velocity of agitation of the molecules.

The reflecting power of the ionosphere depends upon its electrical conductivity, and would be 100 per cent. if the ionised layer were a perfect conductor. Now it is not difficult to show[3] that the reflecting power of an ionised layer of the type we are considering is nearly inversely proportional to ν. If then the layer is possessed of non-linear properties, that is, has a conductivity which varies with the applied electric force, then we should expect ν, and hence* u, to depend upon the applied electric force. A great many observations have long ago been made in the laboratory by Professor Townsend and his associates, which show that this is indeed so. The explanation may be put quite simply. Under the influence of an applied field of force the electrons rapidly acquire, on the average, additional kinetic energy. The balance of energy between the electrons and molecules is therefore upset. The velocity u increases to a limiting value at which the average energy transferred to a molecule at a collision is equal to the average energy gained from the field during the mean free time of an electron. The effect of an applied electric field is therefore to increase u, and hence ν, and so to decrease the reflecting power of the ionised layer. The greater the applied field the greater will be the reduction in the reflecting power of the layer. So if the applied field be modulated, this modulation will be impressed upon any radio wave reflected from the part of the ionosphere affected.

The more rapid the modulation the less time there is for a variation of ν from its average value, and so the less is the amplitude of such a variation. Consequently the modulation impressed on the reflected radio wave will be less for higher frequencies of modulation than for lower frequencies.

A simple quantitative discussion is given in the Appendix, which shows that for a given intensity of emission the impressed modulation is inversely proportional to $\sqrt{f^2 + R^2}$, where R is independent of f.

The theory further shows that the first harmonic of the modulation is also impressed on the radio wave and that this harmonic is weaker and inversely proportional to $\sqrt{4f^2 + R^2}$.

3. Quantitative Expression of the Impressed Modulation

So far we have outlined in qualitative form alone the explanation of the non-linear property of the ionosphere and its effects in giving rise to the phenomenon of the interaction of radio waves. It is now necessary to give quantitative expression to our theory. This requires consideration of such important factors as (a) the presence of the earth's magnetic field, (b) the extension of Townsend's ideas to high frequency electric fields combined with a constant magnetic field, and (c) the theoretical extension of Townsend's measurements to low field strengths. The complete theory, taking account of these factors, has been published elsewhere[4], and it will suffice here to quote only the following conclusion: If M' be the coefficient of the impressed interfering modulation, then*

$$M' = 4.6 \times 10^{16} \frac{(p^2 + \omega^2)C\nu^2Z^2M}{(p^2 - \omega^2)^2\sqrt{f^2 + G^2\nu^2 + cQZ^2}}$$

where p is the angular carrier-frequency of the interfering transmitter T_1,

f is the angular modulation-frequency of T_1,

$\omega = H_p e/m$,

H_p is the component of the earth's magnetic field perpendicular to the electric vector in the wave from T_1,

* For $u = l\nu$, where l is the mean free path.

* Within certain specified limits.

Z is the root mean square value of the electric intensity due to T_1,

M is the coefficient of modulation of the emissions from T_1,

ν is the collision frequency in the absence of electric forces,

G and c are constants equal to 26×10^{-4} and 1.2×10^{31} respectively,

$$Q = \frac{9.6 \times 10^{-18}(p^2 + \omega^2)\nu^2}{(p^2 - \omega^2)^2},$$

and C is a factor depending upon the frequency of the wanted signal from the second emitter T_2, the length of the path of this signal through the ionosphere, and the density and gradient of ionisation in the ionosphere.

It is clear that ω may not be regarded as a constant, since it will change continuously in value as the wave from T_1 is bent over in the ionosphere. It will have a maximum value of nearly 10^7 for European conditions, and a minimum value of zero. For values of ω nearly equal to p the formula does not apply, but this condition can hold only in such limited regions of the ionosphere that they do not contribute appreciably to the impressed modulation. The evaluation of ω over the path of the wave is further complicated by the fact that the electric vector in the wave takes an orientation defined by the magneto-ionic theory at each point of the path. We shall therefore make use of Van der Pol's measurement of the coefficient M' in order to derive the effective average value of ω.

Several deductions may be made from the above formula for M'. In the first place, it is to be noted that the impressed modulation varies as Z^2, the term cQZ^2 in the denominator being usually small compared with f^2. It follows that the interference experienced is nearly proportional to the power of T_1. Secondly, the interference is proportional to M, the coefficient of modulation of the interfering station. Again, the interference is proportional to ν^2, and so should be most marked at times when the ionosphere is low, as for example near sunrise and sunset, in the daytime if signals be audible, or during the night at times of abnormal ionisation in the E region of the ionosphere. Finally it is to be remarked that, as previously mentioned, the impressed modulation varies with the modulation frequency of T_1. In general $G^2\nu^2$ is considerably less than f^2, so M' is roughly inversely proportional to f. The impressed programme is therefore distorted, the higher modulation frequencies being relatively weak. This prediction from our theory[5] has been fully confirmed by Dr. Van der Pol's recent measurements.

He finds that the modulation impressed upon the Beromunster (T_2) carrier wave by the Luxembourg (T_1) emitter has a value 7.5 per cent. at a frequency of 100 cycles per second, and that it falls to 1.2 per cent. at 800 cycles per second.

These measurements allow us to calculate the value of ν at the E region of the ionosphere. Thus we have

$$\frac{(2\pi \times 100)^2 + 6.8 \times 10^{-6}\nu^2}{(2\pi \times 800)^2 + 6.8 \times 10^{-6}\nu^2} = \frac{1.2^2}{7.5^2}$$

so that $\nu = 2 \times 10^5$ collisions per second.

Having determined ν it is now possible to obtain an estimate of the average value of ω from the above expression for M'.

For the Luxembourg emitter it may readily be shown that Z has a value about 2×10^{-4} volts/cm at the ionosphere. We may further write $C\nu = 1$, corresponding to an average value of 30 per cent. for the reflection coefficient of the ionosphere. Substituting these numbers we find $\omega = 3.4 \times 10^6$. This appears to be a reasonable mean value for ω, which may have a maximum value of 10^7 as indicated above.

It is to be pointed out that these calculations have been made on the assumption that cQZ^2 is small compared with f^2. For Luxembourg this assumption is not quite justified, owing to the very high power of that station, and a small correction must be applied to the values deduced above. This may be done now that the approximate values of ω and ν are known. Utilising these approximate values we can solve again for ν. When this is done the corrected value of ν comes to 1.9×10^5 collisions per second. This value is in good agreement with that deduced by Chapman[6] from considerations based on the kinetic theory of gases, and is also in good agreement with the values deduced from consideration of the absorption[7] of radio waves in the ionosphere. Such agreement is very satisfactory, and suggests that measurements of this nature may eventually provide the most satisfactory means for the determination of ν in the regions of the ionosphere.

Another necessary consequence of our theory may be briefly mentioned. An emitter of the power and wavelength of Luxembourg, which produces an appreciable disturbance in the ionosphere, must necessarily have its own modulation distorted during transmission through the ionosphere. An observer listening to Luxembourg at such a distance that only the sky wave is receivable should therefore find a distortion* of the Luxembourg programme. This effect should be readily observable in England and will be shown by the relative weakness of the *low* notes in the received programme. It should also be evident in many parts of the British Isles on the transmissions of the new Droitwich long-wave emitter.

References

[1] *Nature.* 131 : 840 (1933).
[2] *Wireless World.* 35 : 263, Sept. 28th, 1934.
[3] Pedersen. "Propagation of Radio Waves." *Gad. Copenhagen.*
[4] Bailey and Martyn. *Phil. Mag,* 18 : 369, 1934.
[5] Bailey and Martyn. *Nature,* Feb. 10th, 1934, p. 218.
[6] *Proc. Roy. Soc.,* 137 : 169, 1932.
[7] F. W. G. White. *Proc. Phys. Soc.,* 46 : 91, 1934.

Appendix

We suppose for simplicity that the mean free path l is constant, $\nu << p$ and that there is no magnetic field present.

The work w_τ done by an alternating electric force $E = \sqrt{2}Z \sin pt$ on an electron traversing a free path τ is proportional to

$$\int Ee \,.\, dx$$

where x is the displacement of the electron in the direction of E and e is the electronic charge. Thus

$$m\ddot{x} = Ee = \sqrt{2}Ze \sin pt,$$

i.e.,

$$dx = (\sqrt{2}e/mp)Z \cos pt \,.\, dt.$$

Thus w_τ is proportional to Z^2. The average work $\bar{w}$ done on an electron over a mean free path is necessarily similarly related and so we may set

$$\bar{w} = aZ^2$$

where a is a constant.

Let g denote the proportion of its own energy $\frac{1}{2} mu^2$ lost by an electron on the average at a collision with a molecule. The number of collisions, or of free paths, occurring in an interval of time dt is νdt, so, in this interval,

the work done by the field $= \bar{w}\nu\, dt,$

the loss of energy in collisions $= g(\frac{1}{2} mu^2)\nu\, dt,$

the increase of kinetic energy $= d(\frac{1}{2} mu^2).$

* Beyond about 150 kilometres this distortion should diminish as the distance increases.

Applying the principle of the conservation of energy, and setting $u = l\nu$, we then obtain the equation

$$\frac{d\nu}{dt} + \tfrac{1}{2} g\nu^2 = aZ^2 \quad \ldots \quad (1)$$

where $a = a/ml^2$, and so is constant.

If g_0 and ν_0 are the steady values of g and ν respectively corresponding to a constant amplitude $\sqrt{2}Z_0$ then $d\nu_0/dt = 0$ and so

$$\tfrac{1}{2} g_0\nu_0^2 = aZ_0^2 \quad \ldots \quad (2)$$

If, in (1), Z is a modulated amplitude given by

$$Z = Z_0(1 + M \sin ft)$$

then, if M be sufficiently small, or if f be sufficiently large, ν will ultimately oscillate steadily about the value ν_0 by a small amount $\Delta\nu$, and $\frac{1}{2}g\nu^2$ will ultimately oscillate about the value $\frac{1}{2}g_0\nu_0^2$ by the small amount $R \,.\, \Delta\nu$ where

$$R = \frac{d}{d\nu_0}(\tfrac{1}{2} g_0\nu_0^2) \quad \ldots \quad (3)$$

Subtracting (2) from (1) we thus have

$$\frac{d}{dt}(\Delta\nu) + R \,.\, \Delta\nu = aZ_0^2(2M \sin ft + M^2 \sin^2 ft)$$

Ignoring the harmonic term on the right, we thus find that

$$\Delta\nu = \frac{2aMZ_0^2}{\sqrt{f^2 + R^2}} \sin(ft - \phi) \quad \ldots \quad (4)$$

where $\tan \phi = f/R$.

The final intensity E_2 of a second wave T_2 which has traversed the same region of space is a function of ν, and so we may set

$$E_2 = F(\nu) = F(\nu_0 + \Delta\nu)$$

Since $\Delta\nu$ is small we find by Taylor's theorem that

$$E_2 = F(\nu_0) + F'(\nu_0) \,.\, \Delta\nu = A + \frac{B}{\sqrt{f^2 + R^2}} \sin (ft - \phi)$$

where A, B and R are independent of f.

We thus conclude that T_2 is a modulated wave whose coefficient of modulation is inversely proportional to $\sqrt{f^2 + R^2}$.

Institute of Physics

"VACUUM Devices in Research and Industry" is the subject of a conference, to be held in Manchester from March 28th to 30th next, under the auspices of the Institute of Physics, and the President of the Conference is Prof. W. L. Bragg, Sc.D., F.Inst.P., F.R.S. Membership is open to all interested without fee. The subjects chosen for lectures include "Applications of Photoelectric Cells," "The Cathode-Ray Oscillograph in Research and Industry," and "High-Tension Vacuum Tube Devices in Research and Industry." Further particulars may be obtained from the Secretary of the Institute of Physics, 1, Lowther Gardens, London, S.W.7.

Oscillations in a Split Anode Magnetron*

Mechanism of Generation

By K. Posthumus

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Summary

THOUGH many publications have recently appeared in which the problem of the mechanism of magnetron oscillations has been studied to some extent, there is still no simple physical interpretation of the more or less complicated phenomena (see *e.g.* Fig. 3) available.

Megaw[1] distinguishes between "electronic" oscillations and "dynatron" oscillations.

In the first kind the frequency can be expressed in terms of the static angular velocity of the electrons, that is, the angular velocity at which the electrons move under the influence of the combined action of the static electric and magnetic fields. As is well known from former publications[2], this angular velocity is approximately constant throughout the electron path and equal to $H\frac{e}{2m}$ this according to Okabe[3] being equal to half the angular frequency $\omega = 2\pi f$ of the oscillations which are generated under the condition that H is near the critical value. This critical value of H is the magnetic field strength which is just high enough to cut off the anode current under static condition and is given by the equation

$$H^2\frac{e}{m} = \frac{8V_a}{r_a^2}$$

where V_a is the anode potential and r_a the anode radius. The efficiency of this kind of oscillations is rather low.

The second kind is explained by the presence of a static negative resistance, under certain conditions of the magnetic fieldstrength. When a potential difference is set up between the two anodes of a split anode magnetron, the current going to the anode of lower potential increases, the current to the other anode decreases, which condition makes oscillations possible when an oscillating circuit of suitable damping is connected between the anodes. From this explanation it follows that the frequency of these oscillations should be determined by the circuit only, and there should be no lower limit to this frequency.

During our own experiments we met with a third kind of oscillations, which, as we will see, could be called rotating field oscillations, where a preferred frequency is determined by the magnetic fieldstrength and the anode potential, as in the first case, but this frequency is found to be *inversely* proportional to the magnetic fieldstrength.

The magnetic fieldstrength in this case is generally very much above the critical cut-off value aforementioned, the efficiency is excellent and may reach 60 to 70 per cent.

Much advantage is obtained by raising the number of anodes to four; under the same conditions with regard to potential and magnetic field the frequency generated by the four-plate magnetron is twice as high as in the case of a two-plate magnetron. The two anodes opposite to one another are internally connected so that only two leads enter the tube. Special precautions have to be taken for the construction, however, in order to obtain full advantage of the remarkable properties of this four-plate magnetron. Though some results were arrived at with an eight-plate magnetron, the oscillations obtained were in this case very weak and critical.

A brief theory of this type of oscillation follows, which explains the diverse facts observed.

Theory of Rotating Field Oscillations

When once an oscillatory potential difference is present between the anodes, for this oscillating condition to be permanent, it is necessary that energy be taken from the source of anode potential and transferred to the oscillating circuit. This is possible when electrons can reach the plates with a velocity less than that corresponding to the

* MS. accepted by the Editor, November, 1934.

[1] E. C. S. Megaw, *Jrn. Inst. El. Eng.*, **72**, 313, 326, 1933.

[2] A. W. Hull, *Phys. Rev.*, **18**, No. 1, 1921.

[3] K. Okabe, *Proc. Inst. Rad. Eng.*, **17**, 652, 1929.

d.c. potential of the anodes. Now it is a well-known fact that when oscillations occur for which the time of one oscillation is comparable to the time of transit of an electron, the velocity of the electron can be widely different from the velocity corresponding to the potential at its momentary position in the space. It is, for instance, well-known[4], that electrons can bombard the filament with considerable energy, causing this filament to emit secondary electrons in such a large quantity that the mean anode current during oscillations may exceed the static saturation current.

We shall, therefore, study the electron paths in detail, in order to find the conditions under which electrons may reach the plate with considerably less energy than that corresponding to the plate potential.

We assume the magnetron to have k pairs of plates, and further we will base our calculations on the supposition of a *rotating electric field* with k pairs of poles. In reality we have a simple alternating field, with k pairs of poles, but we can always resolve this into two rotating fields rotating in opposite senses. We will neglect the rotating field, rotating oppositely to the static angular velocity, and only consider the other component. Later on it will be made plausible that this procedure is admissible.

In the absence of oscillations we have a radial electric fieldstrength F, independent of θ, and inversely proportional to r. When the oscillations are present we have an additional oscillating radial fieldstrength and an oscillating tangential fieldstrength.

We can put the first equal to $R_1\phi_1(k\theta)$. sin ωt, ϕ being some periodical function with a period 2π. In the same way the tangential component is equal to $T_1\psi_1(k\theta)$. sin ωt. R and T are functions of r only. The oscillating potentials are supposed proportional to sin ωt.

For the sake of simplicity we suppose ϕ_1 and ψ_1 to be simple harmonic functions, so that the radial as well as the tangential alternating fields can be split into two circular rotating fields. The two of the four rotating fields rotating in the sense of the static angular velocity are represented by

$$R\phi(k\theta + \omega t) \text{ and } T\psi(k\theta + \omega t).$$

R and T are again functions of r only, ϕ and ψ are simple harmonic functions.

[4] E. C. S. Megaw, *Nature*, **131**, 269, 1933.

The two simultaneous differential equations, determining the path of an electron, neglecting space charge, are[2]

$$\frac{d^2r}{dt^2} - r\left(\frac{d\theta}{dt}\right)^2 = F\frac{e}{m} - H\frac{e}{m}r\frac{d\theta}{dt} + \frac{e}{m}R\phi(k\theta+\omega t)$$

$$\frac{1}{r}\frac{d}{dt}\left(r^2\frac{d\theta}{dt}\right) = H\frac{e}{m}\frac{dr}{dt} + \frac{e}{m}T\psi(k\theta + \omega t)$$

We now examine whether a solution is possible, in which

$$k\theta = -\omega t + a, \text{ while } |\omega| \gg \left|\frac{da}{dt}\right|.$$

The physical meaning of an electron path defined by this equation is, that the electron moves around with approximately the same angular velocity as the rotating field, but its position relative to the line of maximum fieldstrength of the rotating field varies slowly and is given by the angle a.

In this case we may write:

$$\frac{d^2r}{dt^2} - r\frac{\omega^2}{k^2} = F\frac{e}{m} + H\frac{e}{m}\frac{r\omega}{k} + \frac{e}{m}R\phi(a) \quad \ldots \quad (1)$$

$$-2\frac{dr}{dt}\frac{\omega}{k} = H\frac{e}{m}\frac{dr}{dt} + \frac{e}{m}T\psi(a) \quad \ldots \quad \ldots \quad (2)$$

The second equation can be transformed to:

$$\frac{dr}{dt} = \frac{T\psi(a)}{-2\frac{m}{e}\frac{\omega}{k} - H} \quad \ldots \quad \ldots \quad (3)$$

The first equation can be integrated to:

$$\left(\frac{dr}{dt}\right)^2 - \left(\frac{dr}{dt}\right)_0^2 = (r^2 - r_0^2)\left(\frac{\omega^2}{k^2} + H\frac{e}{m}\frac{\omega}{k}\right) + 2(V_r - V_0)\frac{e}{m} + 2\frac{e}{m}\int R\phi(a)dr,$$

or on the supposition that r_0, V_0 and $\left(\frac{dr}{dt}\right)_0$ can be neglected:

$$\left(\frac{dr}{dt}\right)^2 = r^2\left(\frac{\omega^2}{k^2} + H\frac{e}{m}\frac{\omega}{k}\right) + 2V_r\frac{e}{m} + 2\frac{e}{m}\int R\phi(a)dr \quad \ldots \quad \ldots \quad (4)$$

V_r being the d.c. potential, and the integral $\int R\phi(a)dr$ being taken along the path of the electron considered.

The combination of equations (3) and (4) yields:

$$\left(\frac{T\psi(a)}{-2\frac{m}{e}\frac{\omega}{k} - H}\right)^2 = r^2\left(\frac{\omega^2}{k^2} + H\frac{e}{m}\frac{\omega}{k}\right) + 2V_r\frac{e}{m} + 2\frac{e}{m}\int R\phi(a)dr \quad \ldots \quad (5)$$

R not being absolutely necessary for the co ception of the picture of the synchronous motion of the electrons (Fig. 1), we consider at first only T and put $R \equiv 0$.

$\psi(\alpha)$ is a function of sinusoidal character and the group of electrons which we describe here moves in a spiral path, synchronously with the rotating electric field, but α (the angular distance from a line of reference moving synchronously with the rotating field) slowly increasing and decreasing, in order to keep the equation (5) satisfied, while T may be any prescribed function of r.

It is clear that for the electron motion to be stable it is necessary that α be such that the electrons are astern of the antinodal line of the rotating field, where $\psi(\alpha)$ is a maximum, the sign being such that the tangential force acting on the electrons is retarding. A momentary increase of angular velocity brings in this case the electron into

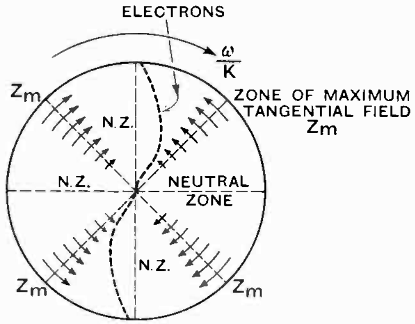

Fig. 1.

a region where $T\psi(\alpha)$ is stronger, so that the original angular velocity is restored.

The right-hand side of equation (5) vanishes for $r = 0$ and must have a positive value for $r \neq 0$, as $\left(\frac{dr}{dt}\right)^2$ must remain positive. The smaller this value is, the smaller T may be chosen, which increases the chance of oscillations building up. Now it is clear that, when the value of the right-hand side of equation (5) is > 0 for $r = r_a$, the value is positive for any other value of r, as V_r is a logarithmic function of r.

We define

$$P = r_a^2\left(\frac{\omega^2}{k^2} + H\frac{e}{m}\frac{\omega}{k}\right) + 2V_a\frac{e}{m} = \left(\frac{dr}{dt}\right)^2_{r_a}$$

The energy of an electron reaching the anodes s given by the equation:

$$\tfrac{1}{2}mv^2 = \tfrac{1}{2}m\left[\left(\frac{dr}{dt}\right)^2 + \left(r\frac{d\theta}{dt}\right)^2\right]_{r_a}$$

$$= m\left[r_a^2\frac{\omega^2}{k^2} + \tfrac{1}{2}r_a^2 H\frac{e}{m}\frac{\omega}{k} + V_a\frac{e}{m}\right]$$

$$= \tfrac{1}{2}mQ \text{ by definition.}$$

If all electrons should follow similar paths, then the energy taken from the d.c. potential source per electron is eV_a, the kinetic energy transformed into heat at the anode is $\frac{1}{2}mQ$, so the efficiency of the oscillations would be equal to

$$\eta_m = \frac{V_a e - \frac{1}{2}mQ}{V_a e}$$

η_m must therefore be considered as a maximum limit for the efficiency.

We now define

$r_a^2 H_{cr}^2 \frac{e}{m} = 8\,V_a$ (H_{cr} = the critical cut-off value of H)

$$\frac{H}{H_{cr}} = Z \qquad r_a\frac{\omega}{k} = xv_0$$

$$V_a\frac{e}{m} = \tfrac{1}{2}v_0^2$$

Then

$$P = v_0^2[x^2 + 2xz + 1]$$
$$Q = v_0^2[2x^2 + 2xz + 1]$$

$$\eta_m = \frac{V_a\frac{e}{m} - \frac{1}{2}Q}{V_a\frac{e}{m}} = \frac{-x^2 - xz}{\frac{1}{2}}$$

In Fig. 2 are plotted P and Q as functions of $r_a\frac{\omega}{k}$ for different values of z.

We see directly from the equation for the efficiency η_m, that only negative values of x are to be considered.

Magnetic Field above the Critical Value $z > 1$.

All frequencies below the values for which P vanishes are theoretically possible; for these latter frequencies the conditions are the most favourable, because P is as small as possible (low T) and η_m is as high as possible. On the other hand $\left(\frac{dr}{dt}\right)_{r_a}$ is zero and therefore a somewhat lower frequency may be obtained more easily. In any case the frequency for which P vanishes is the maximum frequency which is possible.

These values of ω are obtained by equating P to zero:

$$x^2 + 2xz + 1 = 0$$

$$x = -z \pm \sqrt{z^2 - 1}$$

$$= -z \pm z\sqrt{1 - \frac{1}{z^2}};$$

and, as $z^2 \gg 1$

$$x = -z + z\left(1 - \frac{1}{2z^2}\right) \approx -\frac{1}{2}\frac{1}{z}$$

(This approximated curve would appear in Fig. 2, as $Q = 2x^2v_0^2$ and $P = x^2v_0^2$, whilst the exact curve s is $Q = x^2v_0^2$ and $P = 0$. For $z \gg 1$ both curves determine practically the same frequencies). In that case

$$\eta_m = \frac{-\frac{1}{4z^2} + \frac{1}{2}}{\frac{1}{2}} = 1 - \frac{1}{2z^2},$$

so very near to 100 per cent.

When we go back to the original quantities, we get:

$$\frac{r_a\omega}{kv_0} = -\frac{H_{cr}}{2H}$$

$$r_a^2v_0^2H^2_{cr} = 16\ V_a^2$$

$$\frac{\omega}{k} = -\frac{v_0H_{cr}}{2r_aH}$$

$$v_0H_{cr} = \frac{4V_a}{r_a}$$

$$\frac{\omega}{k} = -\frac{2V_a}{r_a^2H}$$

The upper frequency limit is inversely proportional to H, for a 4-plate magnetron the frequency is twice that of a two-plate magnetron. In general a frequency near to this limit is obtained with max. energy and efficiency. We now proceed to the case:

Field Strength Roughly Equal to Critical Field Strength $z \approx 1$

As $|x|$ increases, P decreases, η_m first increases but reaches a maximum value of 50 per cent. for $x = -0{,}5$, then decreases again and vanishes for $x = -1$, where also $P = 0$.

The frequency for which $x = -0{,}5$ can be generated with large efficiency. In the original variables this frequency is equal to:

$$r_a\frac{\omega}{k} = -\tfrac{1}{2}v_0 = -\frac{2V_a}{r_aH_{cr}}$$

$$\frac{\omega}{k} = -\frac{2V_a}{r_a^2H_{cr}}$$

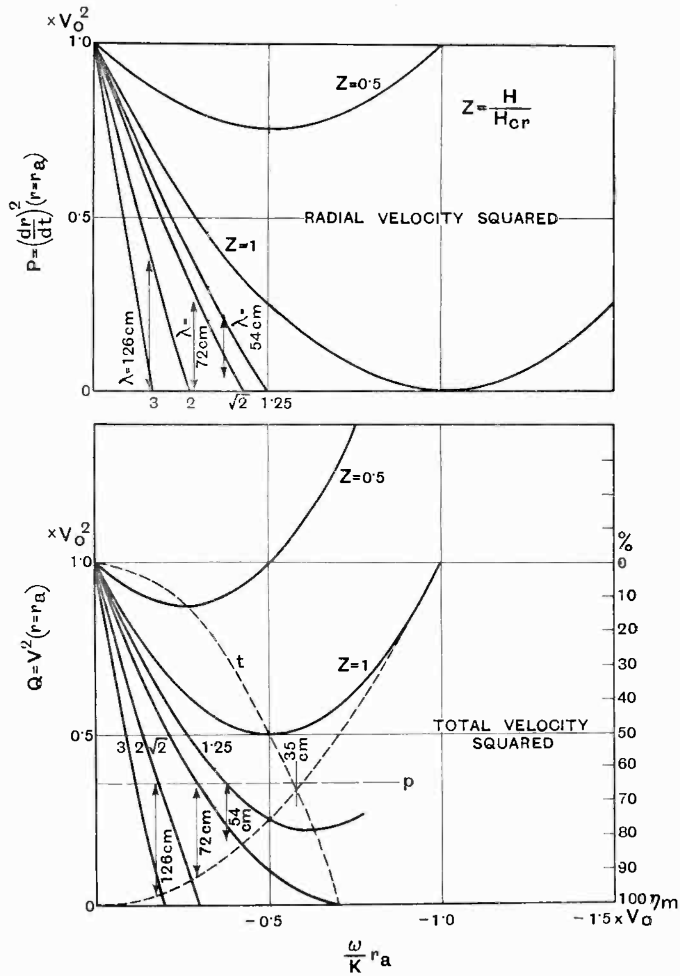

Fig. 2.

The equation

$$\frac{\omega}{k} = \frac{-2V_a}{r_a^2H}$$

therefore yields also for $H = H_{cr}$ the frequency which is most likely to occur.

For the special case of $z = 1$ we can also write

$$\frac{\omega}{k} = -\tfrac{1}{4} H_{cr} \frac{e}{m}$$

For a two-plate magnetron ($k = 1$) the frequency is $\frac{1}{4}$ of the frequency of the "electronic" oscillation, for a four-plate magnetron the frequency is half the frequency of the "electronic" oscillation.

There are, however, when $z = 1$, circumstances that favour the generating of higher frequencies. When $\frac{\omega}{k}$ approaches the static angular velocity $\frac{1}{2} H_{cr} \frac{e}{m}$, not only P diminishes, but also the denominator of the left-hand side of equation (5) decreases, which two circumstances co-operate to make the necessary T smaller. It is therefore to be expected that a frequency near to the static electronic frequency will be readily generated, but never with large efficiency.

When we construct the magnetron with a short-circuit near to the anodes, which prevents the lower frequency from being generated, it is easy to get higher frequencies when this short-circuit aforementioned tunes the magnetron to these frequencies.

In this way we obtained $\lambda = 20$ cm and $\lambda = 28$ cm under conditions where the expected wavelength would be about three times these values. We consider these results as harmonics of the regular wavelength, as we will see later on. In Fig. 2 the x must be taken equal to $\frac{1}{3}\frac{\omega}{k} r_a$ instead of equal to $\frac{\omega}{k} r_a$. For these two valves the representing points are then:

$\lambda = 20$ cm $x = 0{,}68$ $z = 1{,}05$ $Q = 0{,}50\, v_0^2$

$\lambda = 28$ cm $x = 0{,}49$ $z = 1{,}15$ $Q = 0{,}35\, v_0^2$

These values lie in the neighbourhood of curve s in Fig. 2, which supports the theory that these oscillations are to be regarded as harmonics of the normal frequency. For the valve which produced $\lambda = 28$ cm we obtained the fundamental wavelength of 84 cm in the same conditions as to anode tension, fieldstrength, etc. when the short-circuit near to the anodes was omitted. However, the wavelength of 60 cm could not be obtained.

When we plot the results by different writers for "electronic oscillations" in the same way, regarding them as third harmonics, we also get representing points near to those stated above. Therefore it is not to be excluded that our "third harmonic" oscillations are in reality "electronic oscillations" or the inverse may be true.

Magnetic Field below Critical Value $z < 1$

The curve for $z = \frac{1}{2}$ shows that oscillations are possible with approximately the same frequency as the upper frequency limit for $z = 2$, but much less efficiency, while also P is higher. So, if any, but feeble oscillations are to be expected.

We will now discuss some experimental results to see whether they can be made to fit into the above theory.

Experimental Results

Fig. 3 shows curves taken from a four-plate magnetron, the d.c. anode current is plotted as a function of the magnet current. The anode tension was 1,500 volts, $r_a = 0{,}5$ cm, $k = 2$. The critical fieldstrength H_{cr} is therefore 520 gauss, which corresponds to 0,73 amp magnetising current.

The circuit consists of two Lecher wires, connected to the two lead-in wires of the magnetron, each lead-in wire is connected internally to two opposite anodes. The bridge where also the anode feed is connected, remains in a fixed position throughout this test. A glowlamp is connected between the Lecher wires at a small distance from the bridge and also remains unchanged during this test.

When the field is slowly increased, at first oscillations on a wavelength of 54 cm start at a field current of 0,9 amp, which is indicated by a strong increase of d.c. current, to a value above the saturation current (see *Megaw*[4]). This wavelength is such that the distance Lecher bridge-anodes is effectively $\frac{7}{4}\lambda$.

The oscillations die down at a magnet current of 1.05 amp. and immediately thereafter the anode current leaps upward again, while oscillations are measured of a wavelength of 72 cm, the distance bridge-anodes now being $\frac{5}{4}\lambda$ effectively.

These oscillations continue until $i = 1.72$

amp. and are followed by a third oscillation on 126 cm wavelength, beginning at $i = 1.90$, the length of the circuit now being $\frac{3}{4}\lambda$ effectively.

The oscillations continue until $i = 2.35$ amp. When the field current is again slowly decreased, the three wavelengths appear again, but the magnet currents for starting and ceasing of the oscillations are different.

Further, there is a range of oscillations below $i = 0.9$ amp., where the d.c. value of the anode current is not stable, but oscillates in a low frequency.

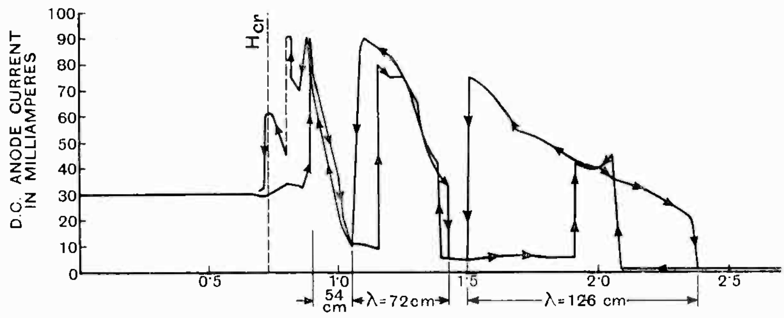

Fig. 3.

In order to see whether these phenomena fit into our theory, we first calculate the x for the three different frequencies.

As $$\frac{\omega}{k} = x\frac{4V_a}{r_a^2 H_{cr}}$$

we get the following table

$\lambda = 54$ cm $\omega = 35.10^8$ $x = 0.38$

Oscillations possible between $z = 1,44$ and $1,23$ and stable throughout this range

$\lambda = 72$ cm $\omega = 26,2.10^8$ $x = 0.285$

Oscillations possible between $z = 1,94$–$1,44$ Stable between 1,90–1,57

$\lambda = 126$ cm $\omega = 15.10^8$ $x = 0,165$

Oscillations possible between $z = 3,26$–$2,06$. Stable from 2,88–2,60

These experimental results are now also plotted in Fig. 2. We see that for all three frequencies the upper limit of H coincides with the theoretical upper limit, curve S, for which $\frac{dr}{dt} = 0$. The lower limit of H is found experimentally to be given by the line p, which corresponds to a maximum efficiency of 65 per cent.

When we determine the point of intersection of this line p with the curve S, we get a wavelength $\lambda = 35$ cm, which is also proved experimentally to be the shortest wavelength which could be generated by this magnetron, and also the necessary fieldstrength is found equal to approximately $1.15\ H_{cr}$, which was to be expected from Fig. 2.

Theoretical Assumptions Compared to Practical Conditions

In order to arrive at the above simple theory of the "rotating field oscillations," the most important simplifications were the following:

I. The radial component R of the rotating field is neglected. It is possible by making use of the relation between R and T: $\frac{\delta T}{\delta \theta} = r\frac{\delta R}{\delta r}$, following from Gauss' theorem, when an assumption for T or R as a function of r is made, to solve the integral equation (5) and so determine the path of the electron $\alpha = f(r)$ relative to the antinodal line of the rotating field. In view of the already excellent agreement between experiment and simplified theory, no big improvement is to be expected from this procedure, apart from the lack of generality by the arbitrary assumption of T as a function of r.

II. The inverse rotating field is neglected. The electrons remain during the whole time of transit near to the line of maximum tangential field of the rotating field moving in the same sense, the inverse rotating field gives alternative acceleration and retardation in such a quick succession that these actions are averaged out and only the influence of the first rotating field is efficient on an average. It is clear that therefore the angular velocity will not be constant, as would follow from the simple theory, but oscillates around the average value derived in the simplified theory, the angular velocity decreases during the periods that both rotating fields add, and increases during the periods that both fields are in opposition and the resulting tangential field vanishes.

III. The deviation from the simple sinusoidal form of the oscillating field and therefore the deviation from a circular rotating field by the components is neglected. When the electron is near to the anodes, the tangential force is only acting during the small time-intervals during which the electron is facing the gaps between the anodes.

The tangential field is therefore only important during these periods. Hence also odd harmonics of the fundamental oscillation corresponding to the angular velocity of the electron are possible. When e.g. the electron moves with an average angular velocity ω, it must pass the successive gaps between adjacent anodes during the retarding phase of the electric field. This is possible when the alternating potential of the anodes has the frequency $\frac{\omega}{2\pi}$ or an odd harmonic of this frequency.

In fact, it has been possible to obtain some watts of energy from two magnetrons of the same dimensions as the magnetron of Fig. 3, but having two anodes, on wavelengths of 28 cm and 20 cm respectively. In these magnetrons the leads to the anodes were bridged internally at very short distances from the anodes, in order to diminish the resistance of the oscillating circuit. The conditions of anode voltage and magnetic field corresponded to a normal wavelength of three times the measured values.

With the same angular velocity of the electrons ω, it is therefore possible to obtain an angular frequency of the oscillations :

ω by using two plates 2ω by using four plates	fundamental frequency large efficiency
3ω by using two plates	third harmonic small efficiency

Anode tension and magnetic field, as well as dimensions, can be equal in these cases, the last case, however, is very critical in operation and tilting of the magnetic field may be necessary. The frequencies of 28 cm and 20 cm in the above example were well in excess of the static electronic frequency of $\lambda = 40$ cm. Until now, no harmonic frequencies of a four-plate magnetron were detected ; this may be due to the fact that in a four plate magnetron the internal connection between opposite anodes is not sufficiently short for these high frequencies.

Another fundamental difference between the four-plate and the two-plate magnetron is caused by the fact that the tangential fieldstrength near to the filament is much less in the first case, assuming the same alternating potential. When the magnetic field is large compared to the critical fieldstrength, and therefore the electrons are confined to a small area round the filament when no oscillations are present, the starting of the oscillations is only possible in the four-plate case, when either the axis of the static magnetic field is made eccentric, or the filament system is more or less eccentric. For example, very good results are accomplished with one curved filament or with two filaments on both sides of the centre line. For the same reasons more than four anodes give no satisfaction until now. For operating conditions in the neighbourhood of the critical fieldstrength a central position of the filament, however, is better.

The standard four-plate magnetron-valves, constructed according to these principles, are able to yield either an output of 40–80 watts on wavelengths from 60–150 cm with rapidly diminishing output to about 5 watt at $\lambda = 45$ cm and central magnetic field, or an output of 30 watt at $\lambda = 40$ cm, slowly diminishing to about 10 to 20 watt at 150 cm, under the condition that the central axis of the magnetic field must be eccentric to the anodes for the longer wavelengths. The first type has eccentric, the second type centric filament system.

Often an efficiency of more than 50 per cent. is obtained.

The longer wavelengths are obtained at the stronger magnetic fields.

Still one concluding remark has to be made:

When from equation (5) the necessary tangential force is calculated for a certain $\frac{\omega}{k}$ much below $H_{cr}\frac{e}{2m}$, large values are found. So constant oscillations are only possible with large amplitude. This leads to curves of the kind of Fig. 3, where the oscillation on $\lambda = 126$ cm is possible when z lies between 3,26 and 2,06, but can only start from static conditions for z intermediate between 2,88 and 2,60. The exact nature of the transient phenomena from static to oscillatory conditions is still wanting explanation.

The Design of Class-B Amplifiers *

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Contents:

I. Introduction

As an introduction, a brief survey of the properties of class-B amplifiers will be given.

Class-B amplification is applied in two different forms: as L.F. amplification or as amplification of modulated H.F. energy.

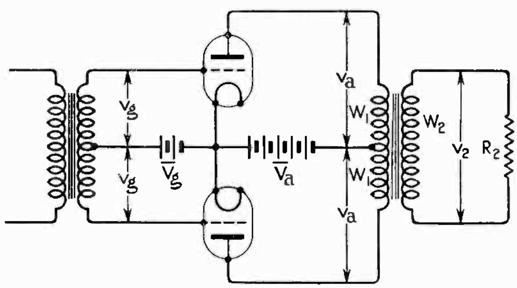
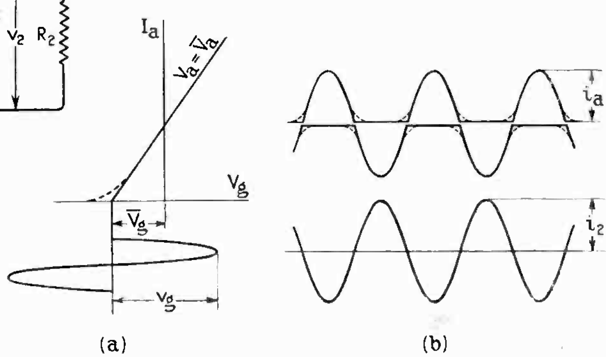


Fig. 1.

In both cases the advantage over the conventional method of linear undistorted amplification (class-A) is better efficiency and hence greater output. As a further advantage of the L.F. amplifier the fact should be mentioned that the input energy is very small, so long as no A.C. voltage is applied to the grids. As a consequence the average efficiency measured over the total period of operation is much higher.

Low-frequency Amplification.

The circuit employed is shown in Fig. 1. As is well known, class-B amplification is characterised by the fact that the grid bias $\bar{V}_g$ is adjusted to such a value that the anode current is just about cut off when there is no A.C. grid voltage (Fig. 2a). Contrarily to the assumption made by some, no limits will be imposed on the magnitude of this voltage. Eventually, the amplitude may be larger than the bias, in which case grid currents occur. These currents are rather strongly variable with varying A.C. grid voltage. To avoid distortion caused by this variable load on the preceding stage, it will often be advisable to connect an absorbing resistance between grid and filament, thus reducing the effect of the grid currents. If, by means of the input transformer, a sine-shaped A.C. voltage having an amplitude v_g is applied to the grid of each valve, the anode current curve of each valve will assume the form of a series of semi-sinusoids having an amplitude i_a (Fig. 2b). The effect of these anode currents, passing through the



(a) (b)

Fig. 2.

primary windings of the output transformer is such that a purely sinusoidal current having an amplitude i_2 is produced in the

* MS. accepted by the Editor August, 1934.

secondary winding. The curvature of the characteristic shown in Fig. 2a causes a slight deviation from the pure sinusoids (see Fig. 2b, upper curve). These deviations, however, will neutralise each other in their effect on the current produced in the secondary of the transformer, provided care is taken that the voltage $\bar{V}_g$ is equal to the value, indicated by the intersection of the produced straight part of the static characteristic with the V_g-axis. For the purpose of calculation the output transformer will be assumed to be an ideal one, viz., one in which the resistance, the leakage inductance, the natural capacity and the magnetisation current can be neglected. For frequencies ranging from 100 to 5,000 cycles this is practically true for all L.F. output transformers. It will further be assumed that the amplifier is loaded with the ohmic resistance R_2 as shown in Fig. 1.

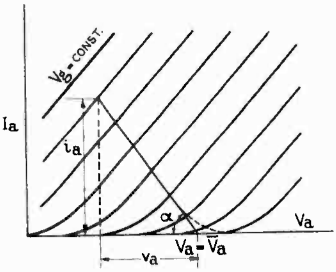


Fig. 3.

The current i_2 of the secondary circuit will produce at the terminals of this resistance an A.C. voltage of the amplitude $v_2 = i_2R_2$. If the number of turns of each of the primary windings of the transformer be w_1 and the number of turns of the total secondary w_2, then the amplitude of the A.C. voltage in each of the primary windings (which corresponds to the A.C. anode voltage per valve) will be :

$$v_a = \frac{w_1}{w_2} v_2 \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

and the equivalent load resistance in the anode circuit of each valve will be

$$R_a = \left(\frac{w_1}{w_2}\right)^2 R_2 \quad \ldots \quad \ldots \quad (2)$$

It should be kept in mind that in a push-pull class-A amplifier the external resistance per valve is

$$R_a = 2\left(\frac{w_1}{w_2}\right)^2 R_2$$

as in this case the curves of the primary currents are complete sinusoids.

The output of the amplifier, measured at the resistance R_2, amounts to $\frac{1}{2}\, i_2v_2$. The output per valve W will be one-half of this, or

$$W = \tfrac{1}{4}\, i_2v_2 = \tfrac{1}{4}\, i_av_a \quad \ldots \quad \ldots \quad (3)$$

As the resistance R_a is a purely ohmic one, it not only gives the ratio of the amplitudes v_a and i_a, but also of the momentary values of voltage and current so long as anode current is flowing. The working line of a valve plotted in a V_aI_a — diagram is therefore a straight line which intersects the V_a — axis at the point for which $V_a = \bar{V}_a$ ($\bar{V}_a$ is the D.C. anode voltage). This is shown in Fig. 3. For this line

$$\cot \alpha = R_a \quad \ldots \quad \ldots \quad (4)$$

As a result of the curvature of the static characteristics, both valves will operate simultaneously for a fraction of the cycle. The above is therefore not absolutely correct, and the working line is slightly curved as indicated by the dotted line in Fig. 3. For reasons already mentioned we can, however, ignore this and reckon with a purely straight line.

High-frequency Amplification.

Whereas in the case of L.F. amplification two valves were in principle required in order to avoid distortion in the output circuit, this is not necessary with H.F. amplification on account of the tuned anode circuit. It is only for the fundamental of the anode-current curve that this circuit presents a large resistance R_a (corresponding to an ohmic resistance) (Fig. 4). The amplitude i_0 of this fundamental is,

Fig. 4.

according to a Fourier analysis, equal to :

$$i_0 = \tfrac{1}{2} i_a \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

The amplitude of the A.C. anode voltage v_a will then be :

$$v_a = i_0R_a = \tfrac{1}{2}\, i_aR_a \quad \ldots \quad \ldots \quad (6)$$

and the output W :

$$W = \tfrac{1}{2} i_0v_a = \tfrac{1}{4}\, i_av_a \quad \ldots \quad \ldots \quad (7)$$

The ratio of the amplitudes v_a and i_a amounts to $\frac{1}{2}R_a$. Although this is not as obvious in the present case as it was in the case of L.F. amplification, this ratio holds good for all corresponding momentary values of voltage and current, at any rate so long

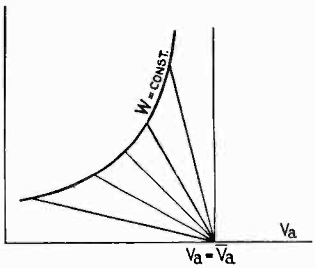


Fig. 5.

as anode current is flowing. The working line plotted in the V_aI_a-diagram, therefore, is a straight line as in Fig. 3, the only difference being that:

$$\cot \alpha = \tfrac{1}{2} R_a \quad \ldots \quad \ldots \quad (8)$$

II. Calculation of the Output of an L.F. Amplifier

(a) General Observations.

The output of an L.F. amplifier is given by equation (3). It is possible to determine the locus of the upper ends of the working lines for equal output in the V_aI_a-diagram. In order to do this, we put equation (3) in the following form:

$$i_av_a = 4W \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

This corresponds to an equilateral hyperbola whose asymptotes are the V_a-axis and a line perpendicular to it, passing through point $V_a = \overline{V}_a$ (Fig. 5). By successively assigning different values to the output and hence to the parameter W in equation (9), we obtain a set of hyperbolae. In Fig. 6 such a set of hyperbolae is shown in the V_aI_a-diagram of the Philips valve *MC* 1/50 for a value of $\overline{V}_a = 1{,}000$ *V*.

Various items which are of importance for designing the amplifier can easily be read from these curves; for instance, the maximum output that can be obtained at a given $\overline{V}_a$ and a given A.C. grid voltage, and the corresponding value of R_a. An interesting case is the one in which the grid current is just nil (Point *P*). The figure also shows directly how the output alters when another value of R_a is chosen. Furthermore, we see what limits are imposed on the output by permissible distortion with varying adjustment. If, for instance, the working line extends as far as the region in which the static characteristics come closer and closer together (*e.g.*, in Fig. 6 at about 100 *W* output), the peaks of the semi-sinusoids of the anode current become flattened, with the result that a current with flattened shape of curve is produced in the secondary circuit as well. It is true that in that case the output may no longer be calculated from the peak values of the current and voltage according to equation (3), so that the graphical calculation with the aid of the hyperbolae will not be absolutely correct neither, but in practice this hardly involves any limitation of the possibilities of application of this method, because the region in which distortion occurs will naturally be avoided as much as possible.

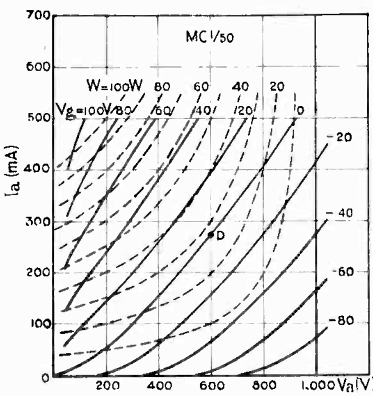


Fig. 6.

If the resistance R_2 is given, whilst R_a is determined in the above manner, the required ratio of the output transformer will, according to equation (2), be given by:

$$\frac{w_2}{w_1} = \sqrt{\frac{R_2}{R_a}} \quad \ldots \quad \ldots \quad (10)$$

(b) Relation between Output and D.C. Anode Voltage.

If some other value of $\overline{V}_a$ is taken as basis, the set of hyperbolae will have to be shifted. An obvious method is therefore to draw this set of hyperbolae on a separate sheet of transparent paper so that it can be made serviceable for all other D.C. voltages by simply shifting the paper.

The important question as to how the output depends on $\overline{V}_a$ in different cases can in this way be immediately answered.

(c) *Relation between Output and Type of Valve.*

In order to do the same with a larger valve, we would require a different set of hyperbolae. It is, however, possible to use the same set by simply multiplying the stated values of the output by a certain factor. We can now choose the scales of the valve characteristics in such a manner that this factor will always be a round figure. Its value can be stated on each characteristic sheet. In this way the sheet showing the set of hyperbolae will be serviceable for all valves.

(d) *Relation between Output and Anode Dissipation.*

A very important value for the limitation of the output is the anode dissipation W_a, which is equal to the difference of input and output per valve. Since the mean value of a series of semi-sinusoids as per Fig. 2b

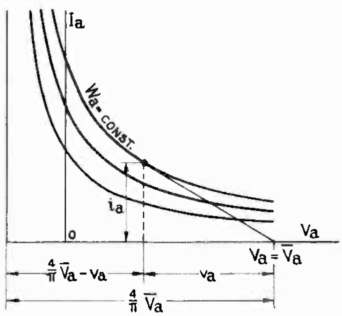


Fig. 7.

is equal to $\frac{1}{\pi} i_a$, the input per valve is $\frac{1}{\pi} i_a \overline{V}_a$. The dissipation will thus be :

$$W_a = \frac{1}{\pi} i_a \overline{V}_a - \frac{1}{4} i_a v_a \quad \ldots \quad \ldots \quad (11)$$

Exactly as has been done for the output, it is possible to determine the locus of the ends of the working lines for constant values of W_a. We therefore convert equation (11) into :

$$i_a\left(\frac{4}{\pi}\overline{V}_a - v_a\right) = 4W_a \quad \ldots \quad \ldots \quad (12)$$

A glance at Fig. 7 will show that this is a set of equilateral hyperbolae having as

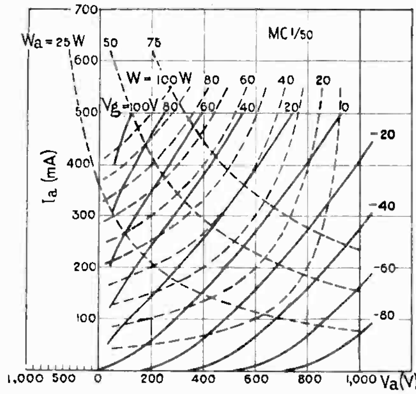


Fig. 8.

asymptotes the V_a-axis and a line perpendicular to it, passing through point

$$V_a = -\left(\frac{4}{\pi} - 1\right)\overline{V}_a$$

It should be noted that the coefficient of the entity on the right-hand side of equations (9) and (12) has the same value. This means that the set of hyperbolae for determining the output is exactly equal to the one for determining the anode dissipation. The numbers on the scales of the hyperbolae hold good for this case too, and what has been said above regarding the multiplication factor will also hold good for this case.

If we wish to change over to a different value of $\overline{V}_a$, the hyperbolae sheet will have to be shifted accordingly. A practical method is to make a graduation in the negative direction on the V_a-axis of the $V_a I_a$-diagram of a valve, which must be $\left(\frac{4}{\pi} - 1\right)$ times as great as the one in the positive direction.

This has been carried out in Fig. 8 which gives an example of the simultaneous use of the two sets of hyperbolae. In practice two separate transparent sheets will be used, giving far greater clearness and easier reading than the figure might lead one to suppose.

This figure at once shows in what manner the output is limited by the maximum permissible anode dissipation (in this case 75 watts) and what adjustments should be selected under specific conditions.

(e) Adjustment for Minimum Grid Current.

When using a class-B amplifier up to positive values of the grid voltage, there will be a load on the preceding stage during a brief part of the cycle as a result of grid current. It is known that, unless this stage is amply dimensioned, this may easily give rise to distortion. It is therefore desirable to minimise grid current and especially its peak value. The sets of hyperbolae also answer the question as to what adjustments will give the lowest grid current for a given output.

The maximum positive grid voltage during a cycle is indicated as $v_{g\,max.}$ (this is therefore equal to $v_g - \bar{V}_g$), whilst the minimum anode voltage, occurring at the same time (which is equal to $\bar{V}_a - v_a$), is indicated as $v_{a\,min.}$. We define :

$$\alpha = \frac{v_{g\,max.}}{v_{a\,min.}} \quad \ldots \quad \ldots \quad (13)$$

From a set of grid current characteristics it can be seen, if $v_{g\,max.}$ and $v_{a\,min.}$ are of the

Fig. 9.

same order of magnitude (α not much smaller than 1), that the corresponding grid current is not determined mainly by $v_{g\,max.}$, but by the relation α. As the current increases with increasing α, this entity must be as small as possible.

If, however, $v_{g\,max.}$ is small compared to $v_{a\,min.}$ (α small compared to 1) the grid current will be mainly determined by $v_{g\,max.}$.

We will investigate the first case more closely and therefore we will use an approximation of the set of characteristics of the triode, expressed by the following linear equation :

$$I_a = \frac{1}{R_i}(\mu V_g + V_a - \triangle) \quad \ldots \quad (14)$$

The meaning of the constant term $\triangle$ is shown by Fig. 9.

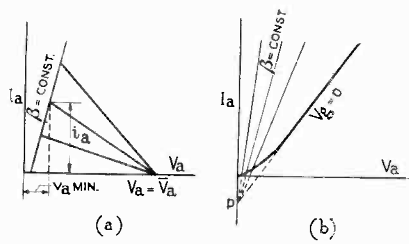


Fig. 10.

By substituting (13) in (14), we find the anode current corresponding to $v_{g\,max.}$ and $v_{a\,min.}$, that is to say, the amplitude i_a :

$$i_a = \frac{1}{R_i}(\mu \alpha v_{a\,min.} + v_{a\,min.} - \triangle) \quad \ldots \quad (15)$$

If : $\beta = 1 + \mu\alpha$

the equation becomes :

$$i_a = \frac{1}{R_i}(\beta v_{a\,min.} - \triangle) \quad \ldots \quad \ldots \quad (16)$$

This equation can likewise be shown in the $V_a I_a$-diagram of the valve. If β is kept constant, it will indicate the loci of the ends of all working lines, having the same β (Fig. 10a). For different values of β one will obtain a set of curves as shown in Fig. 10b. In this connection the following should be noticed : the smaller the value of the parameter β, the smaller will be the angle of inclination of the curve. All the curves pass through point P with coördinates $0, -\frac{\triangle}{R_i}$. As can easily be deduced from equation (14), the static characteristic for $V_g = 0$ will after prolongation also pass through this point.

From the condition already mentioned for minimum grid current (smallest possible value of α and hence also of β), we can draw the following conclusion in view of the above : For a given output, the adjustment giving the minimum grid current will be the one that is determined by the tangent point of the tangent from the point P to the hyperbola considered. Point P can easily be found by prolonging the straight part of the static characteristic for $V_g = 0$.

Of course the above method will not hold good with sufficient accuracy unless the valve characteristics in the region of the desired adjustment can actually be replaced by straight lines with a sufficient degree of approximation.

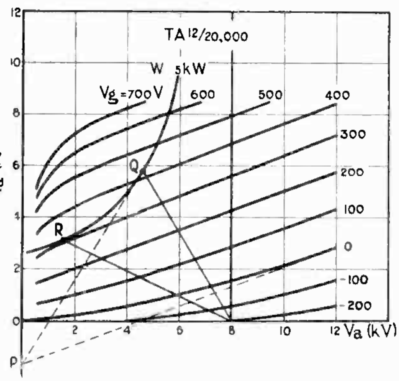


Fig. 11.

When dealing with the second case, however ($v_{g\,max.}$ small compared to $v_{a\,min.}$), the smallest grid current for a given output will occur at such a point of the hyperbola which relates to the smallest grid voltage.

Fig. 11 gives both cases for the Philips valve *TA* 12/20,000 with $\overline{V}_a = 8$ kV and $W = 5$ kW. Point Q possesses the minimum value of α, point R the minimum value of $v_{g\,max.}$. This minimum value of α amounts to about 0.1, the value of α for point R amounts to about 0.2. Both numbers are still small compared to 1, so that in this example the smallest grid current will occur in point R.

For the sake of a clear drawing, the output of 5kW was chosen quite low. Generally one will have to deal with much larger values, resulting in larger values of α. The adjustment for minimum grid current then moves gradually towards the tangent point of the tangent from point P. At all events, one can say that the wanted adjustment will never be found to the right of this point.

(f) Circuit containing Output Transformer Condenser and Choke.

This circuit, well known in the case of class-A amplifiers, is illustrated by Fig. 12. The capacity of the condenser and the self-induction of the transformer and choke are assigned such values that resonance will occur at a certain frequency located in the lowest part of the frequency spectrum. This renders it possible to give the frequency characteristic of the amplifier a more favourable trend in this region than would be the case with an output transformer alone. For this resonance frequency the external resistance R_a for a valve is not, as formerly, given by equation (2), but has another value which is likewise a purely ohmic one. For high frequencies, at which the reactance of the condenser is practically nil, whilst that of the choke is practically infinite, this equation, however, will still hold good.

The above also becomes apparent when all impedances are reduced to the primary side of the transformer. An ordinary high-pass filter of one πV-section is then obtained consisting of two inductances in shunt separated by a series capacity. This filter is between the valve and the loading resistance.

These two special values of R_a correspond to two different working lines. An example of this, chosen at random, is given in Fig. 13. The working line p belongs to the resonance frequency, the line q to a high frequency.

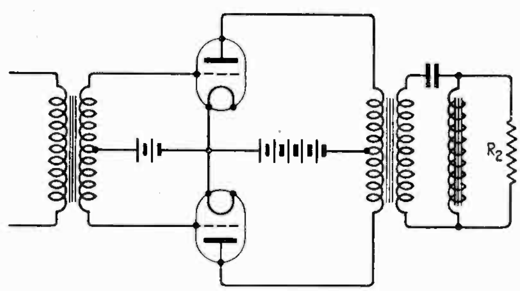


Fig. 12.

As in both cases the A.C. grid voltage is assumed to be the same, the ends of p and q will be located on the same static characteristic; for p the output per valve will now be W_p, whilst for q it will be W_q. For the A.C. voltages v_p and v_q respectively, which occur at the loading resistance R_2, equation

$$\frac{v_p}{v_q} = \sqrt{\frac{W_p}{W_q}} \qquad \qquad (17)$$

applies.

This quotient, which indicates the value of the frequency characteristic of the amplifier for the resonance frequency, may thus be greater than 1. Contrary to circuits like that of Fig. 1, by means of which in practical

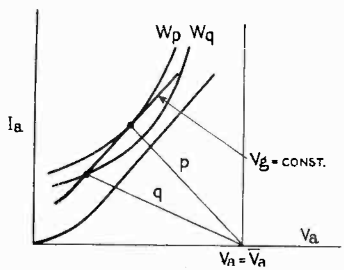


Fig. 13.

cases the low notes are always amplified less than the higher ones, it will thus be possible to obtain the opposite result by selecting the right values for the self-induction and capacity. In this way a loss in the low notes in other stages of the amplifier may be compensated for.

The method employed with the set of hyperbolae shows clearly whether a valve is more or less suited for this circuit and how great the ratio defined by equation (17) may approximately be. If the static characteristics chiefly run parallel to the part of the hyperbolae entering into consideration, then the valve is less suitable for this purpose (compare Figs. 6 and 11).

(g) *Circuit containing Normal Output Transformer, possessing Leakage Inductance and Stray Capacity.*

The circuit is given by Fig. 1, with this difference, that now the stray capacities of the primary and the secondary windings and the leakage inductance of the output transformer are taken into consideration. For high frequencies, and after reducing all impedances to the primary side of the transformer, an ordinary low-pass filter is obtained, consisting of one π-section (two capacities in shunt and one inductance in series). This filter also is between the valve and loading resistance.

For a certain resonance frequency in the higher part of the frequency spectrum, the external resistance R_a also possesses a purely ohmic value, not defined by equation (2). Thus everything which has been said before about the maximum obtainable peak in amplification also holds good for this case.

III. Calculation of the Output of an H.F. Amplifier

In the introduction it has been pointed out that these amplifiers also show a straight working line. Moreover, equation (7) which determines the output is entirely identical with equation (3), which does the same for L.F. amplifiers. From this it can be concluded that, for the purpose of calculation of the output, we may use exactly the same sets of hyperbolae, whilst all that has already been stated regarding the relation between output, D.C. anode voltage, type of valve and anode dissipation and regarding the adjustment for minimum grid current will be applicable here without alteration. A difference will occur only in the method of determining the resistance R_a; for this we apply equation (8) instead of equation (4).

The H.F. class-B system only being used in the case of modulated high-frequency amplification, it should be remembered that the word output naturally means the output in the modulation maximum. If we wish to know the output of the carrier wave, this amount must be multiplied by $\frac{1}{(1+m)^2}$ (m = modulation depth). This can, moreover, be effected just as well with the aid of the set of hyperbolae, viz., by shortening the working line down to the carrier-wave adjustment. The length of this line must for this purpose be multiplied by a factor $\frac{1}{1+m}$. This graphical solution offers the advantage of enabling us to read at the same time the anode dissipation for the carrier wave adjustment.

IV. Summary

The calculation of the output and anode dissipation, the determination of a given adjustment, in a word, the whole designing of a class-B amplifier as far as the electrical data are concerned, can be carried out graphically in a very simple manner by making use of the following.

The working lines in the V_aI_a-diagram, both for L.F. and for H.F. amplifiers, are straight lines which cut off from the V_a-axis a section equal to the D.C. anode voltage $\overline{V}_a$ (Fig. 3). The connection between the angle of inclination of such a line and the value of the external resistance R_a is in the first case given by equation (4) and in the second case by equation (8). If the loading resistance R_2 (Fig. 1) is known in the first case, then the required ratio of the output transformer will follow from equation (10).

The loci of the ends of these lines giving equal output are equilateral hyperbolae (Fig. 6). The origin of the axial system of this set of hyperbolae is situated on the V_a-axis, at the point $V_a = \overline{V}_a$.

The loci of the ends of the above-mentioned lines giving equal anode dissipation are perfectly identical equilateral hyperbolae (Fig. 8). The origin of the axial system of this set of hyperbolae is situated on the negative part of the V_a-axis, viz., at the point $V_a = -\left(\frac{4}{\pi} - 1\right)\overline{V}_a$. To facilitate location of this point, a separate graduation has been provided.

In order to render both sets of hyperbolae serviceable for all anode voltages, each of them has to be drawn separately on a sheet of transparent paper. Moreover, this gives easier reading than is the case if everything is combined on one sheet as in Fig. 8.

These sets of hyperbolae also hold good for larger valves when the figures marking the hyperbolae are multiplied by a certain factor. By correctly choosing the scale of the V_aI_a-diagram for these valves, we can make this factor a round figure, which has then to be indicated on the diagram in question.

These two sheets make it feasible to reply immediately to the following questions:

(1) How great may the maximum output be without causing distortion? [For this purpose the working lines must not extend as far as the region in which the static characteristics come closer and closer together.]

(2) What is the maximum output for a given D.C. anode voltage and a given A.C. grid voltage and how great must the external resistance be for these maximum values? A special case is the one in which the grid current is just nil. [Example point P in Fig. 6.]

(3) How great is the output at a different value of the external resistance? and how does the output generally depend on the A.C. grid voltage?

(4) How does the output depend on the D.C. anode voltage?

(5) How does the output and the required external resistance depend on the anode dissipation, and in particular: How are they limited by the maximum permissible anode dissipation?

(6) What adjustment gives the minimum grid current at a given output? [If the entity α defined by equation (13) does not deviate too much from 1, the setting is determined by the tangent point of the tangent from point P in Fig. 11 to the corresponding hyperbola (Point Q). Point P is found by prolonging the straight part of the static characteristic for $V_g = 0$. If α is small compared to 1, however, the setting is determined by the point on the hyperbola relating to the smallest grid voltage (Point R in Fig. 11)].

(7) The circuit shown in Fig. 12 in L.F. amplifiers is intended to amplify the lowest frequencies in the frequency spectrum just as well as or even better than the higher ones; in contrast to what is the case with the circuit shown in Fig. 1, in which the amplification of the lowest frequencies is always less than that of the higher ones. In this connection there are two different working lines (Fig. 13): p for the lowest frequencies and q for high frequencies. The ratio of the amplification of the former to that of the latter is then found from equation (17). The set of hyperbolae at once shows the best choice for these two working lines, and approximately which frequency characteristic can be obtained (compare Figs. 6 and 11).

(8) When in the circuit shown in Fig. 1, the stray capacities and the leakage inductance of the output transformer are taken into consideration, the same applies to the higher frequencies in the frequency spectrum, as has been said about the lower

in 7. Thus there are also two different working lines, from which the maximum obtainable peak in the amplification can be derived.

The first six points are applicable both to L.F. and to H.F. amplifiers. The output mentioned in these questions refers in the case of L.F. amplification to the output per valve at maximum signal strength, and in the case of H.F. amplification to the output in the modulation maximum. If, on the other hand, the carrier wave adjustment is wanted, the working line must be shortened $\left(\text{multiply by } \frac{1}{1+m}, \text{ where } m \text{ is the modulation depth}\right)$.

In order to carry out the above-mentioned method of designing, Philips Laboratory has compiled a set of detailed characteristic sheets for all Philips transmitting valves. To these sheets are added the two sets of hyperbolae drawn on celluloid.

Remark.—Much of what has been described in this article can also be applied with suitable modification to class-A amplification. The set of hyperbolae for the determination of the output, therefore, will often be useful in this case also. The origin of the system of coördinates should then coincide with the midpoint of the working line, and the values for the output given on the sheet be multiplied by two.

Correspondence

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

Receiver Performance Data

To The Editor, The Wireless Engineer

SIR,—The warning sounded (in your issue for January) by H. E. Stoakes against taking the accuracy of standard signal generator values too much for granted is timely. But the main ground of his criticism seems to be composed of a hazy understanding of the conventions employed in such measurements.

Between the attenuator output terminals of the generator and the input terminals of the receiver a dummy aerial is connected; and Mr. Stoakes rightly infers that the voltage delivered to the receiver depends on the nature of the input circuit. His error is in getting perturbed about this fact.

An aerial is not regarded as a part of the types of receiver under discussion, and it is therefore necessary to assume a standard aerial. It is possible that an aerial of different constants would suit some particular tuning circuit better; but as the designer has no control over the type of aerial which will actually be used it is perfectly legitimate to make all tests with an agreed standard type.

When the generator is set, say, to give 100μV, nobody supposes that 100μV exists across the input terminals of the receiver. If the designer likes to make a low impedance input, which brings down the voltage, and then steps it up to his tuned circuit—why, let him!

The suggestion by Mr. Stoakes that if the attenuator impedance were lowered it would damp the circuit under test is quite erroneous, for the dummy aerial resistance is chosen to be 25 ohms, *including the attenuator resistance*. The only trouble is that which occurs if the attenuator resistance is not constant, and particularly if it exceeds 25 ohms, for it is then not possible to fulfil the standard conditions. This is true of a certain popular model of generator at the larger outputs, and it is necessary to bear this in mind when interpreting results.

With Mr. Stoakes' advice to try an independent indication of modulation depth I entirely concur.

Bromley, Kent. M. G. SCROGGIE.

Book Review

Radio Round the World

By A. W. Haslett. Published by the Cambridge University Press, London and Cambridge, pp. 196 and 22 diagrams and 7 plates. Price 5s. net. 1934.

It is frequently difficult to conceive a title indicative of the scope of a wireless book, especially one on "popular" lines. The author of this new book has been fairly happy in his choice since more than half of the volume is devoted to the discussion of wave propagation.

The treatment is essentially popular and the presentation is always that of the journalist who has a story to tell. For example, in several places the presentation was obviously influenced by the "story" aspect rather than by the chronological or technical sequence that the scientist would most probably have adopted. Nevertheless, the story is interestingly told and the book gives a good popular account of the present state of our knowledge of propagation, including an account of the many factors now known to influence the "ionosphere." Incidentally the word "ionosphere" is carefully avoided throughout the volume, while no reviewer could refrain from comment on the somewhat naïve reference (p. 68) to "Dr. W. H. Eccles and Mr. H. Morris-Airey, both English amateurs."

The latter part of the book is definitely miscellaneous in character, dealing with television, the medical effect of high-frequency radiations, radio and safety at sea, radio in war (a somewhat speculative chapter) and radio and the weather forecaster.

The new volume is not a text-book for the technician, but is a very readable story for the lay reader who wishes a general picture of the world-wide travel of radio waves. J. F. H.

Continuously Evacuated Valves and their Associated Equipment

Paper by C. R. Burch, B.A., and C. Sykes, Ph.D., M.Sc., read before the Wireless Section, I.E.E., on February 6th, 1935

Abstract

IN their introduction the authors point out that the idea of a continuously evacuated valve is as old as the art of valve-making, for every valve is continuously evacuated unless and until it is sealed off from the pumps. Development of demountable valves, however, had to wait for developments in vacuum technique. The discovery of the possibility of operating a condensation pump without the necessity of expensive refrigerants led to the development of the valves and associated apparatus described in this paper.

While condensation pumps can reduce the pressure of permanent gas to a negligible value, they cannot reduce the pressure of the vapour of their own working fluid below that corresponding to the vapour-pressure of the fluid at the temperature of the water-jacket of the pump. A liquid capable of being boiled at reduced pressure without decomposition, but 1,000 times less volatile than mercury, offered a solution for the production, without refrigerants, of a vacuum adequate for valve exhaustion. In experiments on distilling lubricating oil in a molecular still it was found that the oil contained constituents which had to be heated to temperatures varying from room temperature to 350° C. to develop the same vapour pressure as that of mercury at room temperatures. Details of the process of distillation are given in the paper. It is also pointed out that the demountable valve involves a jointing material of very low vapour pressure, and that suitable substances were found to remain as undistillable residues when petroleum jelly or bitumen were distilled as completely as possible in the molecular still.

The authors' design of condensation pump for use with the oil is shown in Fig. 1.* The electric heater A boils the oil in B at a pressure of 0.1 to 0.2 mm. The vapour issuing from the up-take

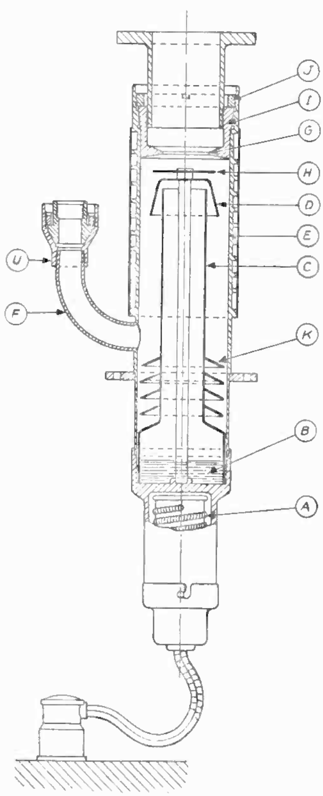


Fig. 1.—*Type O_3 condensation pump.*

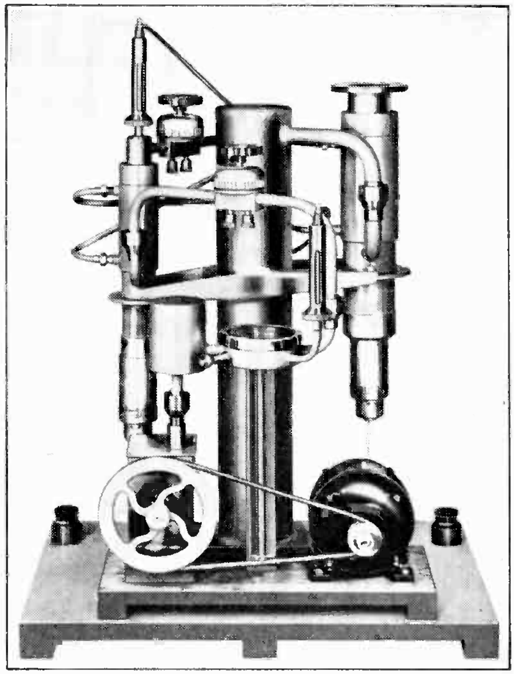


Fig. 5.—*Pumping plant.*

* The authors' original figure numbers are adhered to throughout this abstract.

pipe C is deflected by the cowl D, to form a blast downwards. This strikes the water-cooled condensing surface at E and carries with it those gas-molecules which happen to enter the vapour blast. The condensed oil runs back to the boiler, so that the process is continuous. Details of the design are fully discussed in the paper. In order to make the pumping gear as robust as possible the authors developed metal pumps and taps described in the paper, and these are connected together, using copper piping and conical unions; the appearance of the apparatus being shown in Fig. 5.

The construction of the electrode system and support of the triode Type 330 A is shown in Fig. 7 (*c*) and (*d*). This valve can be used to take an input of 50 kW at 10,000 V on a wavelength of 10 m with reasonable efficiency.

The filament is fitted into a base which can be screwed into the filament leads, consisting of a solid copper rod R_1 and a concentric tube T_1 which are connected to the two copper flanges R^1 and T^1. A short tube S_1 of either porcelain or silica is used to insulate the flanges one from the other. The active part of the grid G is mounted in a copper base which is connected by means of screws to the grid tube C. The grid flange C^1 is insulated from the lower filament flange T and the anode flange A by suitable lengths of insulating tubing S_2 and S_3. The various flanges contain water-cooling passages so that the joints can be kept cool. After grinding, the flanges carrying the filament and grid, together with the necessary silica or porcelain tubes are assembled together and tightly clamped. The anode D, machined from a solid block of copper, is supported by an insulating tube S_4, directly above the oil-diffusion pump. The two joints are also made using bitumen and are semi-permanent. The joint normally broken when a filament is renewed is that marked "J." A series of water-cooling channels is machined in the anode and very satisfactory cooling is maintained. Apart from the difference in external form (to simplify assembly) the fact that the grid and filament structures must be interchangeable calls for a much more robust structure than is normally used in valve design. For example, the structure of Fig. 7 (*c*) appears very massive when compared with the usual type of welded structure, but experience has shown that the requisite rigidity and interchangeability are only obtained by such construction.

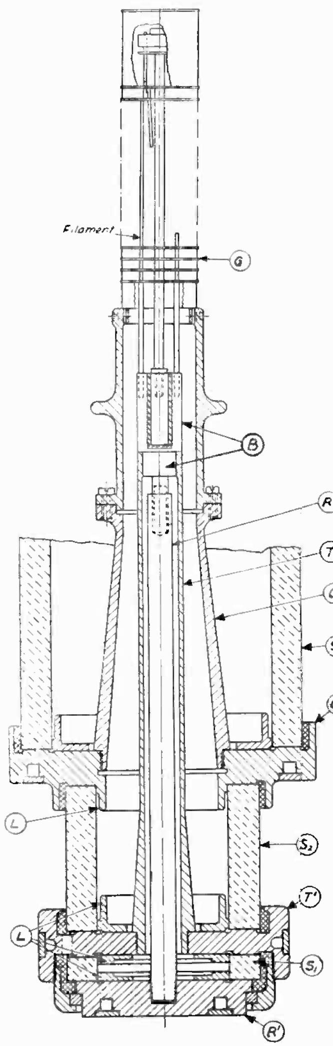


Fig. 7 (*c*).—*Filament-grid assembly.*

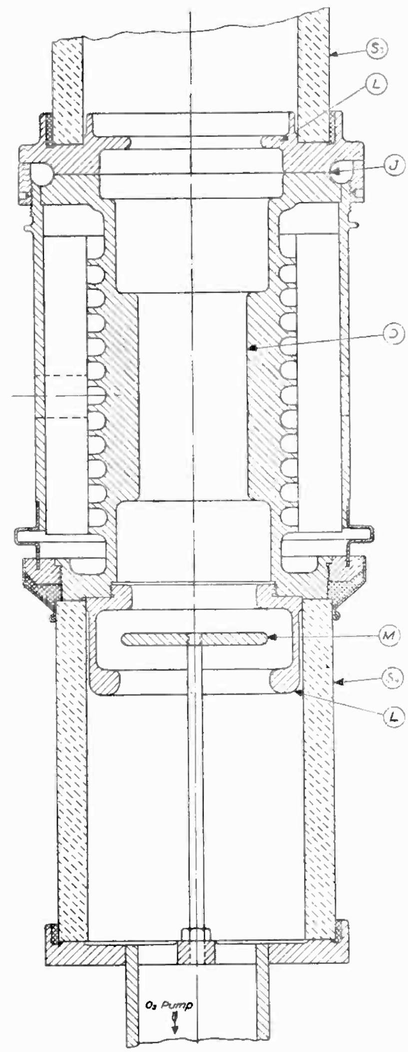


Fig. 7 (*d*).—*Anode.*

The paper gives details of the process of "conditioning" the valve before it goes into service, conditioning being effected both by treatment of the electrodes and by high-voltage A.C. treatment for "flash arc." Altogether the replacement of filaments in a pair of valves, the evacuation and conditioning can be finished comfortably in 6 hours.

No conditioning is required if the valves have been shut down under vacuum, and consequently under working conditions no further treatment after the initial one is required.

Once the valves have been put into service a certain amount of inspection and maintenance work on joints and pumping equipment is necessary. Occasionally it is desirable to add sealing compound to a joint or union. The phosphorus pentoxide should be changed as soon as it becomes badly discoloured or wet.

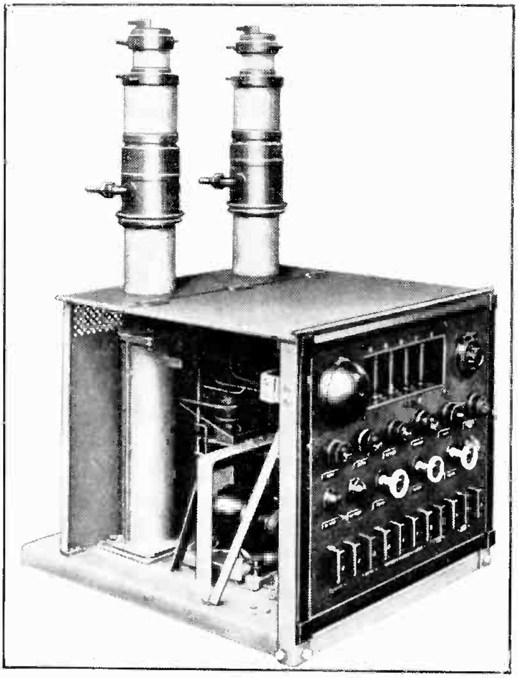


Fig. 8.—*Two Type 330 valves on pumping plant.*

The paper gives details of performance of several demountable valves that have been made,* viz.:

(*a*) Two valves operating as a 10,000-cycle generator to energise a 20-lb. h.f. furnace; 20–45 kW at 12,000 V d.c.

(*b*) One valve used in the GBR 50 kW stage as exciter for the 500 kW stage, 16,000 cycles; 0.8 A at 7,000 V d.c.

(*c*) Two valves used in the 60 kW stage of the GBS short-wave transmitter, 16 to 40 metres; 50 kW at 10,000 V d.c.

Discussion

MR. A. J. GILL, who opened the discussion, congratulated the authors on their technique. The pumping process had proved perfectly satisfactory in operation, after a few early troubles. The 50 kW valve and the two smaller valves referred to by the authors had now been in use for 1 to 2 years. The Post Office were also concerned with demountable screened-grid valves for power amplification and two of these were now in use at Leafield. An advantage of the demountable valve was the degree to which it could be overrun.

MR. B. S. GOSSLING considered that the authors' description of the pumping arrangements put the matter on a very sound basis. He then proceeded to a lengthy comparison between the demountable valves and existing sealed-off valves. The reconstruction of the sealed-off type was less expensive than at first sight appeared, since use was made of much of the machined materials and parts in the reconstruction. The sealed-off valve now had a good life. He concluded with the suggestion that, on account of time of repair, a set up of demountable valves should have a stand-by spare of sealed-off valves, which in these conditions of very occasional use would have an extremely long life.

MR. H. L. KIRKE raised a number of points of technical detail, *e.g.*, the effect of leads in the case of short and ultra-short waves, the existence of secondary emission, etc. He also referred to the high value of demountable valves in experimental work.

MR. A. S. GIBSON said that he had had recent experience of the authors' oil pumps, and found that they definitely gave a vapour pressure much lower than mercury condensation and liquid oxygen. He thought the demountable valve was interesting and useful in powers above 500 kW, but not below.

MR. WARREN referred to early experiences with the first demountable valve at Rugby, and to various details of construction in relation to maintenance.

MR. WALTON raised a few queries as to operating conditions at Rugby, *e.g.*, peak voltage, whether modulated or not, filament life, etc.

* In addition to the 500 kW valve originally made and described by Col. A. S. Angwin, *Journ. I.E.E.*, 1931, vol. 70, p. 33.

The Industry

ACHESON colloidal graphite, suspended in suitable liquids, is already widely used for the lubrication of moving parts in receivers, etc., and in the making of resistors. In connection with television, it has now been found highly suitable for forming an internal conductive coating on the bulbs of cathode ray tubes, and is so used in the new Ediswan hard tube. For this purpose, graphite in water (known as Aquadag) is employed; practical information on the subject appears in Technical Bulletin, No. 191.1, issued by E. G. Acheson, Ltd., Thames House, Millbank, London, S.W.1.

The new Ferranti factory at Moston, Lancs (about a mile from the present Works) has a floor area of 260,000 square feet and is to be devoted entirely to the manufacture of Ferranti radio apparatus, including valves.

Working demonstartions of the functioning of Belling-Lee anti-interference devices are given at the British Industries Fair on the firm's stands (at Olympia, No. G38, and at Birmingham, C736).

Abstracts and References

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PROPAGATION OF WAVES

649. ON THE STRUCTURE OF THE IONISED LAYER OF THE ATMOSPHERE (IONOSPHERE).—Th. Jonescu and C. Mihul. (*Comptes Rendus*, 3rd Dec. 1934, Vol. 199, No. 23, pp. 1301–1303.)

"Detailed analysis of the results of our researches on ionised gases has led us to the conclusion that the free electrons present in our tube possess a velocity smaller than that given by the accelerating potential. Its value is a function of the pressure of the gas; it indicates that there is no thermal equilibrium between the electrons and the molecules, and that the velocity is the same for all the electrons; in consequence, the velocities are not distributed according to Maxwell's law. This analysis has allowed us to verify quantitatively the formulae (1) giving the dielectric constant ϵ and the conductivity σ . . . . Starting from these results we have set ourselves to calculate the reflection of electromagnetic waves in the upper layers of the atmosphere, on the assumptions: (*a*) that the time interval between two collisions of an electron, in a given region of the atmosphere, is the same for all the electrons; (*b*) that the electrons are animated with a velocity greater than that demanded by the thermal equilibrium between the electrons and the gas molecules; and (*c*) that there is only one ionised layer in the atmosphere, whose electronic density N varies with the height in a continuous manner without presenting any minima or maxima in the region of the atmosphere where the reflection of waves is observed."

Referring to the diagram embodying their results, the writers say: "These curves reproduce perfectly the appearance of the phenomena observed. The consequent deduction is that the discontinuities found experimentally are only apparent, and that the levels of real reflection vary in a continuous fashion. Moreover, the reflections are not total but partial, and this explains why, as a general rule, the reflected energy is smaller than would be expected if there were always total reflection. The calculation indicates that the total reflection is merely a particular case realised at the moment when one passes from one level to another; this is in agreement with observation. The ranges of frequency reflected by a given layer are functions of the density and of its variation with height. For N increasing only slowly with height, multiple reflections may be observed for a certain wavelength.

"It is observed on the diagram that for frequencies superior to the frequencies of the discontinuities there are two pronounced levels of reflection (branches a' and r' of our curves)." See also 650.

650. THE PROPAGATION OF [SHORT] ELECTRIC WAVES: EXPLANATION OF ECHOES [including Long-Delay Echoes: "Canals" of Minimum Velocity].—Th. Jonescu and C. Mihul. (*Comptes Rendus*, 10th Dec. 1934, Vol. 199, No. 24, pp. 1389–1391.)

"We have shown [*see* 649] that the experimental results obtained in studying the normal reflection of electric waves can be explained if one assumes a continuous and increasing distribution of the ionisation N with the height h and if one takes into account the ratio τ/T in the calculation of the index of refraction n and in that of the coefficient of extinction k; in this ratio τ represents the time between two collisions of an electron with the molecules, and T the period of the wave in question. In this Note we propose to explain, for the same conditions of ionisation, the great range of short waves and the phenomenon of echoes.

"Having given that $dn/dh < 0$, the waves with oblique incidence will be totally reflected by the phenomenon of mirage. For rays at glancing incidence, the summits of the trajectories find themselves close to the lower limit of the ionosphere; as the incidence increases, the summits mount higher and higher until they arrive finally at the height of the level where partial reflection occurs for normal incidence. At the same time their range, about 2 000 km for glancing incidence, decreases to zero for normal incidence. Varying the wavelength, it is seen that for $\lambda > 100$ m reflection always takes place in the region where $\tau < T$. For wavelengths between 100 and 79.37 m the summits, for each wavelength, are confined between the lower ionosphere limits and an upper limit at the height where $T < \tau < 2T$. For wavelengths between 79.37 and 69.34 m, this limit is at the height where $2T < \tau < 3T$.

"The range of these waves is always comparatively small (< 2 000 km) except for those rays which have their summits quite close to the heights where τ is a whole multiple of T ($\tau = lT$). For these heights, special for each wavelength, the conditions are such [$dn/dh \to 0$ and $k = 0$] that a wave-train with its summit there follows such a layer ($\tau = lT$) to infinity, being able to make several journeys round the earth. In these layers the energy of the wave is only lost by despatches, in small quantities, down to earth. These layers are, in fact, veritable canals by which the energy of the waves is transported to great distances. These canals have another remarkable property: that at their heights the signal velocity has minima values. For the canals of a certain order μ this velocity diminishes as λ becomes greater, and tends towards zero when λ approaches the value for which reflection at normal incidence takes place exactly at the height where $\tau = \mu T$ . . . . If for a certain λ the ionosphere has several canals (small λ), this velocity decreases with their order. Thus for $\lambda = 69.33$ m there are 3 canals: $\tau = T$ with $v = c/1.29$; $\tau = 2T$ with $v = c/2.24$; and $\tau = 3T$ with $v = c/93$. Such a wave can circle the earth (40 000 km) by these three routes, in 0.173, 0.299, and 12.7 seconds respectively, so that two short-delay and one long-delay echo might be observed."

After elaborating this point and the possibility of concentrating the signals into one of the available canals, the writers mention that while N has been assumed proportional to τ, "in actual fact the variations of N are more complicated: it must pass through a maximum, so that there will be some waves (the shortest) which will pass right through for angles of incidence near the normal, and will only be reflected (by mirage action) for sufficiently large angles. For these waves there is a zone of silence around the transmitter, but since the absorption in their passage up to the canal height decreases with λ, they are specially valuable for long-distance transmission. The above theory demands very small values for τ. Thus for $\lambda = 75$ m normal reflection takes place at 220 km. The value of τ at this height requires the pressure here to be above 3×10^{-6} mm Hg, with the electron velocity not very different from that of light. . . . These electrons are evidently not due to ionisation by ultra-violet light: they must come directly from the sun. . . ."

651. SHORT WAVE ECHOES AND TENTATIVE EXPLANATION OF THESE PHENOMENA.—A. Turpain. (*Comptes Rendus*, 26th Nov. 1934, Vol 199, No. 22, pp. 1190–1192.)

A note on the geometrical ray paths and number of reflections required for transmission from Geltow to Rio, assuming pure reflection from an ionised layer at various heights. The lengths of path and time intervals are worked out and compared with observation, though no very accurate agreement is obtained. The writer is in favour of an explanation on the basis of pure reflection and thinks that the refraction theory of Baker and Rice (*Journ. Amer. Inst. Elect. Eng.*, June, 1926, Vol. 45, pp. 535 and 571) makes too many assumptions.

652. ON THE TRANSFERS OF MODULATION IN THE HEAVISIDE LAYER [Interaction of Wireless Waves].—Y. Rocard. (*Comptes Rendus*, 26th Dec. 1934, Vol. 199, No. 26, pp. 1601–1603.)

In 1929 it was reported that an increase in the effective current at the bottom of the Croix d'Hins aerial from 500 to 700 A produced a very marked increase in signal strength at Saigon: the writer investigated the possibility that this result might be due to an apparent change in dielectric constant in the Heaviside layer caused by an increased velocity of the electrons under the influence of the waves, increasing the number per second of the collisions with the molecules. What is now known as the "Luxembourg Effect" seems to be a related phenomenon, and the writer therefore gives his mathematical analysis. He finds that if V, the electron velocity in the layer due to thermal agitation, is around 10 000 m/s, the velocity V_1 which a free electron would take up, under the action of a field due to an aerial of effective height 200 m at a distance of 200 km with an aerial current of 200 A, would be 2 500 m/s, which is not negligible compared with V. "The dielectric constant of the upper atmosphere depends, for its average value for any given frequency, on all the waves of identical or different frequencies which are passing there. It is also modulated by the beats or direct modulations of these various waves, by the intermediation of the quantity V_1^2 which figures in it [equation 4] and which introduces the beats and modulations of the various currents i. The intensity of reception can be not proportional to the intensity of transmission when the variations of the effective dielectric constant under the influence of the wave itself have a critical character (transition from long-wave régime to short-wave). The intensity of reception depends in particular on the power of the other transmissions—whence the possibility of certain special 'fadings' due to this cause."

Thus the transfer of modulation from one carrier to another appears explained, and also the variation of this effect with the intensity of the waves involved. On the other hand the special effect noted by van der Pol and van der Mark, that the depth of modulation transferred is the weaker the higher the frequency of modulation, is not explained directly and needs a deeper study of the modification of the layer by an incident wave, and of the time constant intervening in the transformation into thermal energy of the energy communicated to the electrons by the wave. "The point of view of Jonescu and Mihul must also be taken into consideration, according to which the free electrons in an ionised gas are not in thermal equilibrium" [*see* 649, above].

653. THE "LUXEMBOURG EFFECT" [and Its Suggested Explanations].—Gehne. (*Funktech. Monatshefte*, November, 1934, No. 11, p. 436.)

654. EXPERIMENTS ON THE REFLECTION IN THE UPPER ATMOSPHERE OF TRAINS OF HIGHLY-DAMPED WAVES.—C. Gutton, Galle and Joigny. (*L'Onde Élec.*, December, 1934, Vol. 13, No. 156, pp. 485–492.)

A long *Comptes Rendus* Note on these tests was dealt with in 1934 Abstracts, p. 607. The present paper ends with a discussion of the differences in the action of sinusoidal and highly damped waves and the likelihood that such differences, and not electronic resonance, might account for the results obtained.

655. A FREQUENCY RECORDER [Semi-Continuous, for Simultaneous Recording of Several Frequencies: for Low or High Frequencies, with Application to Ionosphere Investigations, Monitoring of Radio Stations, etc.].—D. F. Martyn and H. B. Wood. (*Journ. Inst. Eng. Australia*, October, 1934, Vol. 6, No. 10, pp. 332–336.) Developed for the modified frequency-change echo method (1931 Abstracts, pp. 29–30). *See* also 894.

656. DENSITY OF THE UPPER ATMOSPHERE [from 30–150 km] CALCULATED FROM TWILIGHT PHENOMENA [and the Confirmation of the Lindemann-Dobson Results].—F. Link. (*Comptes Rendus*, 2nd Jan. 1935, Vol. 200, No. 1, pp. 78–80.)

657. "SHORT-WAVE COMMUNICATION OVER DISTANCES OF 100–1 000 KILOMETRES": ERRATUM.—Kolesnikov. (*L'Onde Élec.*, December, 1934, Vol. 13, No. 156, p. 544.) *See* 1934 Abstracts, p. 572.

658. EXPERIMENTAL INVESTIGATIONS ON NIGHT EFFECT PRODUCING D.F. ERRORS.—Borkowetz: Hagen. (*See* 761.)

659. TRANSMITTING AND RECEIVING TESTS WITH ULTRA-SHORT WAVES [3.1 m: Distances up to 4–5 km].—W. Möller: Hamburg Television Union. (*Funktech. Monatshefte*, November, 1934, No. 11, pp. 439–446.)

The transmitter, with its direct-coupled vertical aerial tuned to the third harmonic (with about 220 mA aerial current) was badly situated in a room in a large building of the big town. The receiver was in a motor car, with 1 and 2 metre aerials of Litz wire: no earth was made to the frame, nor was a counterbalance used. Some of the results were as follows:

No atmospheric disturbances were noticed, even during a thunderstorm. Passing beside a tramway caused no interference. Near the transmitter it was found that increasing the distance produced at first an increase in signals. Blocks of houses caused local fading. A cross street in the direction of the transmitter brought up the strength, as did also the moving of the receiver farther from the block of houses, out of their "shadow." Although a view of the transmitting point was never necessary, it was a great advantage to have an open field in front of the receiver in the direction of the transmitter. Under and behind groups of trees the signals decreased considerably. Daylight and darkness, sunny and cloudy weather, all had no effect. Signals could often be increased by altering the slope of the receiving aerial. In general, over the tested zone, signals were of completely sufficient strength.

The transmitter employed the well-known three-point connection, suitably adapted to ultra-short waves (Fig. 2). Of three modulation methods tested, the Heising (parallel-valve, "choke control") method gave the best results, but grid modulation was nearly equally good. Anode modulation was unsatisfactory. The receiver was developed from the three-point ultra-audion circuit (Fig. 11: *see* also 724) improved, for these very short waves, by the direct coupling of the aerial, and the series connection of the tuned-circuit condenser, shown in Fig. 12. Usually, however, super-regeneration was added (Fig. 13). Details of this last circuit are given.

A special series of tests was devoted to the comparison of transmitting aerials of three types: the direct-coupled third-harmonic aerial used in the main tests, a dipole with feeder, inductively coupled to the oscillator, and the Fuchs flywheel-circuit vertical aerial (0.46λ) of Fig. 16. The latter aerial gave the best results, closely approached by the dipole: the direct-coupled $\frac{3}{2}\lambda$ aerial was distinctly inferior. All the aerials were vertical: no decision has yet been reached as to the relative merits of vertical and horizontal aerials, though there seems to be evidence of some slight superiority of the latter.

660. NOTES ON THE ULTRA-HIGH-FREQUENCY DX WORK [New York/Hartford 56 Mc/s Contact with Directive Aerials: Apparent Well-Defined Correlation between Signal Strength and Relative Humidity: etc.].—R. A. Hull. (*QST*, December, 1934, Vol. 18, No. 12, pp. 8–9.)

661. AURORA HAS NO NOTICEABLE EFFECT ON RADIO RECEPTION IN ARCTIC CIRCLE.—R. Moe. (*QST*, December, 1934, Vol. 18, No. 12, p. 13.) In an article on the voyage of the schooner "Morrissey."

662. THE LOSS RESISTANCE OF HIGH-FREQUENCY CONDUCTORS.—Kaden. (*See* 883.)

663. STUDY OF EMERGENCE ANGLE AND PROPAGATION PATHS OF SEISMIC WAVES [Travel-Time Formulae].—M. Ewing and A. P. Crary. (*Physics*, October, 1934, Vol. 5, No. 10, pp. 317–320.)

664. AN INVERSE BOUNDARY VALUE PROBLEM IN SEISMOLOGY [Information Obtainable from Analysis of Wave-Form: Theoretical Paper].—C. L. Pekeris. (*Physics*, October, 1934, Vol. 5, No. 10, pp. 307–316.)

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY

665. THE LIGHTNING FLASH AS SOURCE OF AN ATMOSPHERIC.—E. V. Appleton and F. W. Chapman. (*Nature*, 22nd Dec. 1934, Vol. 134, p. 968.)

The writers use a string electrometer or cathode-ray oscillograph to follow the evolution of an atmospheric wave form, and find that, while the most frequent type of lightning discharge takes place in a single "step," the next most frequent type consists of two or three components, so that a thundercloud moment is frequently destroyed in a series of partial discharges. Atmospherics also have a tendency to occur in groups and two examples of this are shown in Fig. 1. The intermittent type of discharge appears to resemble the periodic sparking of a Wimshurst machine connected to a Leyden jar. The charge is regarded as pouring into the head of the discharge channel and reaching a certain critical value before discharge takes place. Replenishment takes place at a constant rate until the same critical value is again reached.

666. On the Nature of Lightning Discharges.—H. Norinder. (*Journ. Franklin Inst.*, December, 1934, Vol. 218, No. 6, pp. 717–738.)

A preliminary account of the experimental methods of this work was referred to in Abstracts, 1928, p. 517; for further developments *see* 1930, p. 581, and also p. 520 (Ackermann). Figs. 1 and 2 here show the cathode-ray oscillograph system used. This paper contains an analysis of 290 oscillograms of lightning discharges, of which visual observations were also made when possible. Fig. 3 shows the antenna circuit; a horizontal wire was used as the antenna. A sinusoidal time base with a time sweep of 20 or 10 μsec. was used to observe rapid field changes, while a general survey was made with a sweep of 10^4 μsec. Oscillograms with the latter are reproduced in Figs. 4–5 and show the phenomenon of successive partial discharges. Figs. 7–11 reproduce, in linear time scale, some of the most typical records. One of the most important results is that a lightning discharge, observed as one distinct flash, consists of several partial impulses with different time intervals varying from 200 μsec. to 3 000 μsec. Both vertical and horizontal flashes were observed; the former were mostly unipolar and of positive sign, the latter had a pronounced double polarity. All partial discharges with a pronounced long duration were positive. Typical partial discharge variations are reproduced in Figs. 15–17. Calculated field variations caused by typical lightning discharges are shown in Figs. 18–20. Time intervals are given in tables 1–3. Fig. 21 illustrates the maximum field changes in relation to the distance of the discharge channel.

667. A New Method of Recording Atmospherics for the Forecasting of Storms [as used by Tamanrasset Polar Year Expedition].—R. Faillettaz. (*Comptes Rendus*, 26th Dec. 1934, Vol. 199, No. 26, pp. 1647–1648.)

The l.f. output of the receiver is rectified and used to charge a condenser; the charge on this condenser determines the grid potential of a triode whose anode current actuates a "dotting" milliammeter-recorder. The condenser is discharged periodically, *e.g.* once a minute. Thus each dotted point gives a value based on the amount of energy stored in the condenser by the atmospherics over a period of time under the operator's control. The equipment is so sensitive that atmospherics can be recorded on short waves, which is specially advantageous for meteorological purposes. Thus the writer obtained atmospheric records on 60 and 300 m waves, differing greatly in their form from the more usual records on long waves.

668. On the Sources of Atmospherics and Their Localisation [Review of Goniometric and Non-Goniometric Methods].—R. Bureau. (*Comptes Rendus*, 2nd Jan. 1935, Vol. 200, No. 1, pp. 82–84.)

Regarding goniometric methods, the special advantages of the "differential opposition" and the "blocking opposition" principles are compared: in the latter method relays are so employed that one frame can only record an atmospheric if the other frame receives no atmospheric: in the former method not only the apparent direction but also the intensity of the field can be recorded. The two methods can be combined for special purposes. Regarding non-goniometric methods the writer has employed (*a*) nocturnal atmospherics, (*b*) the sunset "crevasse," (*c*) variations with wavelength, and (*d*) rapid rotation of near sources. Lugeon's methods are referred to. These and other non-goniometric methods are at present chiefly valuable in assisting in the interpretation of goniometric records.

669. Lightning Storms and Fires in the National Forests of Oregon and Washington [with Data of Usual Times, Rate of Movement, etc.].—W. G. Morris. (*Elec. Engineering*, December, 1934, Vol. 53, No. 12, p. 1676: summary only.)

670. Multiple Lightning Strokes [Successful Oscillographic Recording on Power Lines: up to 12 Successive Discharges: as Close Together as 1 Cycle (on 60-Cycle System) and as Far Apart as 9.5 Cycles].—K. B. McEachron. (*Elec. Engineering*, December, 1934, Vol. 53, No. 12, pp. 1633–1637.)

671. The Idea of Impurity in Globular Lightning.—E. Mathias. (*Comptes Rendus*, 19th Nov. 1934, Vol. 199, No. 21, pp. 1083–1086.)

672. Current/Voltage Characteristics of High-Potential, Direct-Current Brush and Glow Discharges [from Pointed and Spherical Electrodes] in Air at Atmospheric Pressure.—J. Zeleny. (*Journ. Franklin Inst.*, December, 1934, Vol. 218, No. 6, pp. 685–699.)

673. Experimental Investigations regarding the Applicability of Lichtenberg Figures to Voltage Measurement.—M. O. Jörgensen. (*Ingeniörvidenskabelige Skrifter*, A No. 37, 1934, 39 pp. and Plates: in English.)

674. Impulse and 60-Cycle Strength of Air.—Bellaschi and Teague. (*Elec. Engineering*, December, 1934, Vol. 53, No. 12, pp. 1638–1645.)

675. On a Class of Natural Movements of Viscous Fluids characterised by a Minimum of Dissipated Power [as in Atmospheric Circulation].—Dedebant, Schereschewsky and Wehrlé. (*Comptes Rendus*, 3rd Dec. 1934, Vol. 199, No. 23, pp. 1287–1289.)

676. On the Cause of the Variations of Conductivity of the Air in Grottoes.—Dauzère and Bouget. (*Comptes Rendus*, 26th Dec. 1934, Vol. 199, No. 26, pp. 1645–1646.) Following on the work referred to in 1934 Abstracts, p. 262.

677. Cosmic Radiation and Stellar Evolution [Cosmic Ray Ions emitted from Heavier Stars].—H. J. Walke. (*Nature*, 5th Jan. 1935, Vol. 135, p. 36.)

678. ELEMENTS IN EARTH'S CRUST FORMED BY COSMIC RAYS [from Iron and Nickel].—G. N. Lewis. (*Sci. News Letter*, 8th Dec. 1934, Vol. 26, No. 713, p. 356.)

679. A THEORY OF THE ORIGIN OF COSMIC RAYS [Magnetised Charged Spherical Earth attracts Cosmic Corpuscles].—L. G. H. Huxley. (*Phil. Mag.*, November, 1934, Supp. No., Series 7, Vol. 18, No. 122, pp. 971–983.) *See* also 64 of January, and 680 below.

680. A CRITICISM [of the Mathematical Assumptions] OF DR. L. G. H. HUXLEY'S THEORY OF THE ORIGIN OF COSMIC RAYS.—A. F. Stevenson. (*Phys. Review*, 15th Dec. 1934, Series 2, Vol. 46, No. 12, pp. 1111–1112.) *See* 64 of January, and 679, above.

681. ULTRA-PENETRATING CORPUSCLES OF THE COSMIC RADIATION.—Auger and Ehrenfest. (*Comptes Rendus*, 26th Dec. 1934, Vol. 199, No. 26, pp. 1609–1611.)

682. ANALYSIS OF THE COSMIC RADIATION AT HIGH ALTITUDE.—Auger and Leprince-Ringuet. (*Comptes Rendus*, 22nd Oct. 1934, Vol. 199, No. 17, pp. 785–787.)

683. ON THE STUDY OF COSMIC RAYS AT THE GREAT ALTITUDES [Portable Counters give Smaller Values than Ionisation Measurements].—S. N. Vernoff. (*Phys. Review*, 1st Nov. 1934, Series 2, Vol. 46, No. 9, p. 822.) Results agree with those of Johnson (1934 Abstracts, p. 434: "Coincidence Counter Studies").

684. THE RELATION OF THE PRIMARY COSMIC RADIATION TO THE PHENOMENA OBSERVED [Increase of Intensity with Altitude due to Increased Number of Secondaries].—W. F. G. Swann. (*Phys. Review*, 1st Nov. 1934, Series 2, Vol. 46, No. 9, pp. 828–829.) *See* also 65 of January.

685. MAGNITUDE OF COSMIC RAY BURSTS [Estimated Total Energy 6×10^{11} eV].—A. H. Compton. (*Nature*, 29th Dec. 1934, Vol. 134, p. 1006.)

686. A PRECISION RECORDING COSMIC-RAY METER.—Compton, Wollan and Bennett. (*Review Scient. Instr.*, December, 1934, Vol. 5, No. 12, pp. 415–422.)

687. COUNTER CALIBRATION AND COSMIC-RAY INTENSITY [Average Specific Ionisation 100 ± 3.7 Ion Pairs per cm Path of Ray].—J. C. Street and R. H. Woodward. (*Phys. Review*, 15th Dec. 1934, Series 2, Vol. 46, No. 12, pp. 1029–1034.)

688. TRANSITION EFFECTS IN THE COSMIC RADIATION [Air to Lead Transition indicates Lower Equilibrium Ionisation under Lead].—J. C. Street and R. T. Young, Jr. (*Phys. Review*, 1st Nov. 1934, Series 2, Vol. 46, No. 9, pp. 823–824.)

689. TRANSITION EFFECTS IN THE COSMIC RADIATION [Parallel with Variations in Shower Intensity].—J. C. Street and R. T. Young, Jr. (*Phys. Review*, 15th Nov. 1934, Series 2, Vol. 46, No. 10, p. 938.) Abstract only.

690. INVESTIGATIONS ON COSMIC-RAY CORPUSCLES [Absorption Experiments show Gradual Energy Loss: Production of Secondary Electrons, Existence of Gamma-Component].—H. Kulenkampff. (*Physik. Zeitschr.*, 1st Dec. 1934, pp. 996–997.) *See* also 691.

691. INVESTIGATIONS ON COSMIC RAY CORPUSCLES [using Two Vertical Counters and Iron Screens of Varying Thickness].—H. Kulenkampff. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 15, 1934, pp. 572–573.) *See* also 692; also *cf.* 1934 Abstracts, p. 263 (Hummel, Ackermann). Also 690, above.

692. COUNTER MEASUREMENTS ON COSMIC-RAY CORPUSCLES [Effect of Absorbing Layers: Probable Existence of Ultra-Gamma Radiation Component].—H. Maass. (*Physik. Zeitschr.*, 1st Nov. 1934, Vol. 35, No. 21, pp. 858–861.)

693. THE ABSORPTION OF COSMIC RADIATION IN VARIOUS MATERIALS [Pb, Fe, Al, C, H_2O, Hg: Improbability of Presence of Gamma-Radiation].—H. Tielsch. (*Zeitschr. f. Physik*, No. 9/10, Vol. 92, 1934, pp. 589–614.)

694. ANALYSIS OF THE ABSORPTION CURVE FOR COSMIC RADIATION [Elimination of Residual Ionisation by Differentiation of Curve].—B. Gross. (*Zeitschr. f. Physik*, No. 11/12, Vol. 92, 1934, pp. 755–758.)

695. THE RESOLVING POWER IN COINCIDENCE REGISTRATION [of Cosmic Rays] WITH SERIES-CONNECTED COUNTERS [Importance of Gas Filling, Electrode Material and Treatment].—J. N. Hummel. (*Physik. Zeitschr.*, 1st Dec. 1934, Vol. 35, No. 23, pp. 997–999: *Zeitschr. f. tech. Phys.*, No. 12, Vol. 15, 1934, pp. 573–575.)

696. DISCHARGE FORMS IN A CYLINDRICAL COUNTER [of Cosmic Rays]. II.—S. Werner. (*Zeitschr. f. Physik*, No. 11/12, Vol. 92, 1934, pp. 705–727.)

697. THE DARK PRE-DISCHARGE CURRENT AND THE ACTION OF THE CYLINDRICAL DISCHARGE AT ATMOSPHERIC PRESSURE AS A COUNTER.—A. Jodlbauer. (*Zeitschr. f. Physik*, No. 1/2, Vol. 92, 1934, pp. 116–142.)

PROPERTIES OF CIRCUITS

698. SKIN EFFECT IN LAYERED CYLINDRICAL CONDUCTORS.—H. Kruse and O. Zinke. (*Hochf:tech. u. Elek:akus.*, December, 1934, Vol. 44, No. 6, pp. 195–203.)

"Recently Fischer [Abstracts, 1933, p. 576] and Strutt [*ibid.*] have dealt with the formal calculation of the a.c. resistance for the special case of a solid cylinder with a coat of different conductivity. The important point however is not the pure mathematical solution with the help of Bessel and Neumann functions, but the derivation of formulae which are simple and make possible a rapid numerical evaluation. The work of Ekelöf [1933, pp. 323–324] comes nearer to this end, and his approximate formula for slight skin effect can be converted to the form here developed [though that for large skin effects differs from the results now obtained]. In the present work the formal solution of the differential equation is merely used to bring the concentric tube conductor into the calculation [section VI B]. For numerical calculation formulae are used which constitute a direct solution of the differential equation. By this method the round-about use of approximate solutions of the Bessel and Neumann functions is avoided."

The results are summarised as follows: "The determining factor for the skin effect is the value of the penetration depth t. The evaluation of the current densities and magnetic field strengths in cylindrical conductors, as functions of radius, is carried out for slight skin effect ($s < t$, where s is the thickness of the outer coat) and for large skin effect ($s > t$), and enables the total resistance to be calculated. It is found that with great skin effect in the outer conductor the resistance depends little on the core material and can be calculated as if the current flowed through an effective cross section given by circumference and penetration depth. Only when the penetration depth t in the coat is greater than the thickness s of the latter does the core material take part in the current conduction. In this case a close approximation of the total resistance is obtained by paralleling the a.c. resistances of coat and core. The collection of formulae given in section VI [not V as printed] allows the calculations to be carried out for any stratified cylindrical conductor; formulae are included for feeders with core and coaxial tube return."

699. On the Quasi-Periodic Solutions of the Equations of Non-Linear Mechanics, *and* On the Study of the Case of Resonance in Problems of Non-Linear Mechanics.—Kryloff and Bogoliuboff. (*Comptes Rendus*, 26th Dec. 1934, Vol. 199, No. 26, pp. 1592–1593: 7th Jan. 1935, Vol. 200, No. 2, pp. 113–115.)

700. Non-Linear Dependence.—F. W. Gundlach. (*Funktech. Monatshefte*, November, 1934, No. 11, pp. 431–435.) Rectification: generation of harmonics: formation of sum- and difference-tones: demodulation: cross-talk.

701. Influence of the Initial Charge of the Condenser on the Transient Phenomena obtained on the Excitation of a Ferro-Resonant Circuit.—E. Rouelle. (*Comptes Rendus*, 10th Dec. 1934, Vol. 199, No. 24, pp. 1386–1388.) Continuation of the work referred to in 388 of February.

702. Some Properties [Attenuation, Resonance] of Simple Electrical and Mechanical Oscillating Systems and Their Characterisation.—J. Fischer: Späth. (*Arch. f. Elektrot.*, 12th Dec. 1934, Vol. 28, No. 12, pp. 774–783.)

This paper consists of further elucidation of a paper by Späth (1934 Abstracts, p. 317) and gives in particular a more complete account of what is meant by attenuation and resonance both for forced and for free oscillations.

703. Undamped Electric Oscillation and Electrical Instability of a Transmission System.—Goto and others. (*Res. of the Electrotech. Lab.*, Tokyo, No. 366, 1934, 85 pp: in English.)

704. The Graphical Determination of Resultant and Input Resistances in Complex Circuits.—H. Reppisch. (*Funktech. Monatshefte*, December, 1934, No. 12, pp. 471–473.) Continuation of the article referred to in 1934 Abstracts, p. 557.

705. On the Functioning of a Distorting Element [Behaviour of a Circuit composed of Sinusoidal Generator, Distorting Element and Constant Resistances].—C. Budeanu. (*Comptes Rendus*, 26th Dec. 1934, Vol. 199, No. 26, pp. 1598–1600.)

706. Spheroidal Functions [Solutions of Differential Equations occurring in Filter Problems].—J. A. Stratton. (*Phys. Review*, 15th Nov. 1934, Series 2, Vol. 46, No. 10, p. 938.) Abstract only.

707. The Class B Amplifier: Useful Output Greater than Anode Dissipation: Grounds for the High Economy of the Class B Amplifier.—K. Schmoll. (*Funktech. Monatshefte*, October, 1934, No. 10, pp. 389–392.)

Comparison of the equations 4 and 14 shows that the useful output of the Class A amplifier is only 50% of the input, while this value rises to 78.5% for the Class B amplifier. But this is not the chief advantage of the latter system: equation 15 shows that the ratio of its useful output to the maximum anode dissipation is 246%, compared with 50% for Class A, so that with Class B a given useful output can be obtained with two valves whose maximum anode dissipation is only one-fifth of that of the corresponding Class A valves. Thus an amplifier for an undistorted output of 60 w would require, for Class A, a valve with 120 w anode dissipation, whereas for Class B two push-pull valves each of 12 w dissipation would suffice.

708. Circuit Theory on New Lines.—Hatschek. (*See* 751.)

TRANSMISSION

709. Investigations on Barkhausen-Kurz Oscillations [Experimental Work, particularly on the Energy Relations: Hollmann's Theory only Applicable to Small Amplitudes: etc.].—F. Herriger. (*Telefunken-Zeit.*, October, 1934, Vol. 15, No. 68, pp. 5–16.)

Author's summary:—Existing theories for the explanation of the B.-K. "electron dance" oscillations are examined critically. Möller's theory of anode- and phase-sorting [Abstracts, 1930, pp. 627–628: *see* also Helmholz, 1933, p. 390; also Edler, 1933, p. 211, whose assumptions, however, allow only for anode-sorting and not the phase-sorting which—with the usual cylindrical electrodes—is shown to play a decisive part] is found suitable for the elucidation of energy questions. The energy relations are thoroughly investigated experimentally and compared with Möller's theory.

By the development of a special valve with a "straight through" system [Lecher wire system traversing the bulb and connected to concentric grid and anode with axis parallel to the wires; cathode led out downwards at right angles; grid and anode voltages applied externally at one end of Lecher pair] it was possible to develop comparatively large outputs (4–5 w at 50 cm). The introduction of a "measuring cathode" into this special valve [fused into the bulb on the opposite side to the main cathode leads, and lying at 0.3 mm from the anode] enabled the alternating potential of the anode with respect to earth to be measured directly in a compensation connection. [Other points in the design are: main cathode of tungsten, so constructed as to be of comparatively open mesh and yet to stand a dissipation of 80 w: valve dimensions such that at normal 50 cm wavelength potential nodes are formed near the fused entrances of the Lecher wires, thus reducing dielectric loss: the design is such that no choking coils are needed in the cathode circuit].

The production of maximum output depends on the condition that the natural frequency of the external circuit should agree with the swinging frequency of the electrons. For a change of grid potential the wavelength corresponding to maximum output changes according to the Barkhausen relation $\lambda^2 . V_g =$ const. For an increase of emission current a slight increase in wavelength occurs owing to the increased space charge. The h.f. potential, under the best conditions of coupling, bears a fixed ratio to the grid potential and is independent of the amount of emission. At no load there is an automatic limitation of h.f. potential through the "sorting" mechanism [for which there is an optimum value of h.f. potential, so that when this is exceeded the "sorting" deteriorates and the oscillations diminish].

The efficiency is practically independent of the grid potential and thus of the wavelength. The maximum output is given when the negative anode potential has a quite definite ratio to the grid potential ($V_g/-V_a = 8$). The h.f. potential between anode and earth is then about equal to the negative anode potential. In this optimum condition a combined anode- and phase-sorting process takes place. For maximum outputs the saturation zone must be worked in [" Just as the space-charge cloud swings by the cathode, as many electrons as possible should enter this cloud: but if one is working in the space-charge zone there is a decrease in emission current when the cloud is close to the cathode"]. In the valve with "straight through" system [as already described] the Lecher system, when loaded with useful resistance, serves for transferring the output energy, whereas with the system unloaded it looks after the correct phase adjustment.

710. On the Use of Magnetic Fields for the Production of Ultra-Short Waves [and the Development of Split-Anode Magnetrons and Transmitters for 70–120 cm and 3.5–4.5 m Wavelengths].—M. Ponte. (*L'Onde Élec.*, December, 1934, Vol. 13, No. 156, pp. 493–523.)

In his discussion of methods of modulation the writer includes modulation by way of the magnetic field. Where this field is produced by air-cored coils the hysteresis difficulty is avoided, but even then, if the amplitude/frequency curves are to be correct, the variations of current in the coils must be independent of frequency, which involves complications. But it may be advantageous, especially in telegraphy, to use a "combined" modulation, which can be made to give a high efficiency; or it can be so arranged as to give a practically constant radiated power in spite of the anode potential varying for some reason or other (mains fluctuations, etc.). Finally the writer mentions a phenomenon of abnormal increase of anode current occurring, for a given anode potential, when the magnetic field approaches the value for instability. The anode current may rise to 20% above the saturation value measured in the absence of the field: the effect is probably due to a bombardment of the filament by electrons returning to it with a velocity not equal to zero. Methods of avoiding this effect are given.

711. Ultra-Short-Wave Transmitter, Huth-Kühn Circuit [Wavelengths down to about 4 m].—W. Möller: Hamburg Television Union. (*Funktech. Monatshefte*, October, 1934, No. 10, pp. 393–395.) *Cf.* 659.

712. Valves and Circuits for Ultra-Short Waves below 3 Metres.—Kelly and Samuel. (*See* 748.)

713. Brake-Field Circuit for the Generation of Micro-Waves.—R. Bechmann. (German Pat. 600 151, pub. 17/7/34: *Hochf:tech. u. Elek:akus.*, December, 1934, Vol. 44, No. 6, p. 213 and Fig. 2.)

A stronger generation is produced if an a.c. potential, approximately 180° out of phase with the a.c. potential of the brake electrode 4, is applied to the auxiliary control grid 2 between the positive grid 3 and the cathode.

714. A New System of Simultaneous Grid and Plate Modulation.—T. Hayasi. (*Rep. of Rad. Res. in Japan*, July, 1934, Vol. 4, No. 2, pp. 57–60.)

"In the conventional constant-voltage modulation the grid of the amplifier tube is maintained at a negative potential by means of a bias battery or by a high-resistance leak. The present method, however, makes use of the plate/cathode voltage drop of the modulator tube as the grid bias of the amplifier tube, resulting in grid modulation in addition to the normal plate modulation . . ." The input power required for a given depth of modulation is decreased: valve keying free from click is possible: the frequency characteristic is better than with the Heising system, no modulation choke or other circuit element being required with value dependent on frequency.

715. The Simultaneous Excitation of Two Frequencies in One Valve.—M. Lattmann and H. Salinger. (*E.N.T.*, November, 1934, Vol. 11, No. 11, pp. 384–388.)

Mögel has already investigated the simultaneous excitation of two stationary reaction-coupled oscillations (Abstracts, 1928, p. 401), but his circuit introduced unnecessary complications and the writers' circuit (Fig. 1), in which the two frequencies are equally strongly coupled, seems to be simpler. A phase-changing device is inserted in the anode circuit of the oscillating valve; it passes all frequencies, but each member (there are four) rotates the higher frequencies through 180° compared with the lower ones. There are thus two medium frequencies for which the total phase rotation amounts to 180° and 540° respectively and the phase condition for the reaction is fulfilled. The amplitude condition can also be satisfied. Adjustment of the grid bias prevents grid current flowing.

The oscillation onset is then calculated following Kautter (1934, p. 206), and Fig. 2 illustrates the practical production of two frequencies. Oscillograms are shown in Figs. 3, 4, 5, all taken with the middle point of the oscillation at the lower bend of the valve characteristic. Fig. 4 shows the effect of strong reaction, and Fig. 5 the onset of the oscillations. If the oscillation mid-point is on the linear part of the characteristic, the oscillations cannot be simultaneously excited. A theoretical explanation of this is given.

RECEPTION

716. The Amplification of Programme Transients in Radio Receivers.—G. Builder. (*Journ. Inst. Eng. Australia*, October, 1934, Vol. 6, No. 10, pp. 325–331.)

Here the word "programme" includes sound, television, telegraph signals and so on. "Design has, so far, been concentrated mainly on the attainment of a specified frequency characteristic of the equipment as defined by the amplitude of the response to sustained sinoids, without reference to the phase changes which occur. It is possible, however, that equipment designed in this way . . . may yet lack something in fidelity of programme reproduction, since programme e.m.fs must necessarily be largely transient in nature. The design of equipment with reference to its transient characteristics may perhaps be necessary in the further improvement of the technique of programme reproduction. It is the purpose of this paper to indicate the information already available on this subject, and to investigate further the response of typical valve circuits to programme transients. In some cases the circuit analysis is approximate, if the full equations are very complicated, but the approximations used give, for the usual cases met with in practice, a very close account of the behaviour of the circuits. . . . It is usually true [in accordance with the "theory of equivalence"] that if a network has a uniform frequency/amplitude response characteristic for all frequencies, the response to a transient is perfect. Design considerations, however, are generally such that a uniform frequency-response characteristic is only aimed at for a limited range of frequencies, so that it is necessary to investigate the effect of this limitation on transient response."

The results of Carson and Zobel, of Oatley (Abstracts, 1931, p. 504), and of Jackson (1932, p. 280) are discussed where relevant; they are in agreement with those of the writer: on the other hand, results given by Smith (1933, pp. 509–510) "are incompatible with the methods adopted in this paper, in that they are contradictory to the general theory of equivalence."

The writer deals in turn with programme-frequency amplifiers (resistance-capacity, choke-capacity and transformer couplings), low-pass filters, the highly selective tone-corrected receiver, and coupled circuits and band-pass filters for carrier frequencies. For his earlier discussion of transient distortion *see* the appendix of his paper on ionosphere investigations (1934, p. 86).

717. Note on the Power Consumed by Rectification in a Diode.—J. Marique. (*L'Onde Élec.*, November, 1934, Vol. 13, No. 155, pp. 458.)

The writer calculates the mean alternating power consumed by a rectifying circuit analogous to those used in receivers: namely a diode in series with a resistance shunted by an infinite capacity. He shows that the apparent resistance varies within wide limits with the amplitude of the voltage to be rectified, for diodes used in reception which follow the 3/2 power law at any rate over a wide range. For very small amplitudes the apparent resistance is equal to the internal resistance of the diode at its initial point of functioning. The external series resistance is not then directly involved, except in fixing this initial point. With a Marconi double-diode-triode and a series resistance of 47 000 ohms the internal resistance at the initial point was only 8 500 ohms. For larger amplitudes (*e.g.* above 1 volt) the apparent resistance takes on a high value which decreases, as the amplitude augments, towards a value half that of the external series resistance. Finally, for amplitudes such that the diode characteristic may be regarded as a straight line, the ratio of apparent resistance to external series resistance depends on the internal diode resistance and may be more than or less than 1/2, as shown in table 1.

718. Considerations on Detection [particularly the Faults of Diode Detection and the Superiority of Grid Detection with Additional Space-Charge Grid: Elimination of Condenser by Di-Phased Detection, with Benefit to Highest Frequencies].—M. Chauvierre. (*L'Onde Élec.*, December, 1934, Vol. 13, No. 156, pp. 524–532.)

The merits claimed for diode detection "are rendered illusory" by the fact that the actual characteristics have a pronounced curvature at the bottom end. Moreover, the diode is generally followed by a l.f. valve which is really better qualified to detect than to amplify (such as a h.f. pentode connected as a l.f. resistance stage), with the result not only of distortion (amplified in the final stage) but also of a second detection in phase-opposition to the first, due to the almost inevitable passage of a certain amount of r.f. to the l.f. stage. Thus the evil effect of double detection, found with grid rectifiers when anode-bend detection becomes superposed, is brought about. In receiving television with a diode detector followed by an E 446, the writer found that on removing the diode the image continued but in a reversed condition: "this proves the illusory qualities of the detection when used according to current practice."

Thus the diode detector is only advantageous if used with strong r.f. potentials and followed by a l.f. stage free from rectifying properties. For small r.f. potentials it has no advantage over a good grid detector; so it is often proposed to suppress the first l.f. stage and use more r.f. amplification. The objection to this is pointed out, and the writer goes on to maintain that the true solution, whether for grid detection or diode detection, is the use of an auxiliary grid next the filament to disperse the space charge and give an almost ideal detection characteristic. But there seems no need for a separate diode, for a properly designed grid detector starting from this basis should do all that is necessary: the d.c. component, for instance, can be used for AVC just as with a diode. The writer, for example, uses a hexode E 448 connected as in Fig. 6 which gives much better results (Fig. 5) than a diode detector followed by an E 446; although the l.f. stage amplification is only 60 instead of 100, this is made up for by the greater sensitivity of detection owing to the sharp bend of the characteristic. The first grid is the space-charge grid, the second the control, the third the screen and the fourth the suppressor. No doubt still better results would be obtained with a specially designed valve.

The detection and reproduction of the highest frequencies is of great importance in high-fidelity reception and still more in television, where frequencies of the order of 100 000 c/s have to be dealt with. The difficulty arises from the necessity of providing a condenser which will pass the high frequency, this condenser shunting the charging resistance of the diode. The system resistance-capacity in parallel constitutes a charging impedance whose value diminishes with the frequency, and also forms a system with a time constant which is opposed to good functioning on neighbouring frequencies superior to this time constant. Since the condenser cannot be diminished indefinitely, the resistance must be decreased; but this decreases the detection coefficient of the detector stage and may lead to the necessity for an additional amplifying stage. If, however, di-phased detection is employed the detecting condenser can be completely eliminated, for if the centre tap on the inductance is properly selected the potential there is zero. Then the reproduction of the highest frequencies presents no difficulty, since the leakage capacities are reduced to those between leads, which can be reduced to a minimum by a skilful disposition of components. This solution is applicable to commercial double diodes, but the extra space-charge grid should of course be introduced. Or a double-grid valve such as was made by Fotos, in which each grid has the same relations with regard to the cathode, would be satisfactory. A similar valve, indirectly heated, is the recent Wunderlich valve for di-phased detection: the writer considers that a valve of this type, with the addition of a space-charge grid, would give better results in sensitivity, linearity and high-frequency reproduction, than the majority of known systems. But, unluckily, "the study of receiving valves is no longer going on in France."

719. Diode Detectors [Conditions for Distortionless Operation on Deeply Modulated Signals: Load Circuit modified so that A.C. and D.C. Loads are Equal].—J. B. Lovell Foot. (*Wireless World*, 28th Dec. 1934, Vol. 35, pp. 547–548.)

720. The Anode-Bend Detector with Retroaction [Smooth Adjustment, when Grid Bias is obtained by Cathode-Lead Resistance].—E. Bottke: Ruhrmann. (*Funktech. Monatshefte*, October, 1934, No. 10, pp. 395–396.)

Ruhrmann (1934 Abstracts, p. 323) discusses retroaction as unsuitable for anode-bend detectors because of the harsh and unstable oscillation threshold due to the change in slope. The present writer, replacing the bias battery by a cathode-lead resistance to give the grid bias, found that the retroaction adjustment became particularly smooth, and was combined with a certain degree of automatic fading compensation. He discusses the causes of this, and in Fig. 3 gives a special circuit which should be free from a defect of the simple cathode-lead resistance: here, by the use of two resistances K_1 and K_2, the grid bias is built up of a constant component and a component which varies with the amplitude of the grid swing.

721. Increased Sensitivity with the Regenerative Detector [for C.W. Telegraphy: Advantages of Heterodyne over Autodyne Reception].—R. De Cola. (*QST*, December, 1934, Vol. 18, No. 12, pp. 24–26.)

722. Sirutor, a New Copper-Oxide Rectifier [for R.F. Circuits in Broadcast Receivers].—(*E.T.Z.*, 20th Dec. 1934, Vol. 55, No. 51, pp. 1255–1256.) *See* also 1934 Abstracts, p. 562.

723. Resistance-Coupled Amplifiers [Practical Design Details].—W. T. Cocking. (*Wireless World*, 11th and 18th Jan. 1935, Vol. 36, pp. 26–28 and 64–66.)

724. Receivers for Ultra-Short Waves [Audion and L.F. Pentode for 7 m Television Waves, and "Ultra-Audion" and L.F. Stage for Waves around 3 m].—W. Möller. (*Funktech. Monatshefte*, December, 1934, No. 12, pp. 473–476.) The "ultra-audion" connection has the *LC* circuit between grid and anode, as in the "three-point" transmitting circuit. *See* also 659.

725. The Brake-Audion in the Broadcast Band.—G. Schweitzer: Hollmann. (*Funktech. Monatshefte*, November, 1934, No. 11, pp. 421–423.) Simplification of Hollmann's papers (Abstracts, 1933, pp. 621–622; 1934, p. 205; *see* also 1934, p. 381—three).

726. Modern Reflex Circuits [using the H.F. Pentode with Diode, or Fading Hexode with or without Diode: as embodied in 1934/35 German Receivers].—E. Schwandt. (*Funktech. Monatshefte*, December, 1934, No. 12, pp. 477–479.) "Practically all the 2-valve and most of the 3-valve superheterodynes used the reflex circuit": *cf.*, for example, *Wireless World*, 31st Aug. 1934.

727. Correspondence on the Design of a Superheterodyne Receiver [Reduction of Background Noise by Immediate Change of Frequency by Separate Heterodyne as Strong or Stronger than Signals: etc.].—Couppez and others. (*L'Onde Élec.*, December, 1934, Vol. 13, No. 156, pp. 542–544.) Prompted by an article on the type "K-80" Receiver (422 of February).

728. THE SUPER-PRINCIPLE [the Present Position of the Superheterodyne Receiver: Methods of Generating the I.F. Oscillations and the Choice of the I.F.].—R. Rechnitzer. (*Funktech. Monatshefte*, September, 1934, No. 9, pp. 337–341.)

729. LIMITS TO AMPLIFICATION [Thermal Agitation, Shot Effect, etc.: Survey].—Johnson and Llewellyn. (*See* 756.)

730. A SIXTEEN-VALVE RECEIVER [9–565 and 850–2 000 Metres: "Midwest Radio Corporation"].—P. Besson. (*L'Onde Élec.*, December, 1934, Vol. 13, No. 156, pp. 533–541.)

731. THE SUPER-SYNCHROVOX 6–35 TYPE 3677 OF THE RADIO L.L. ESTABLISHMENT [19–50, 200–580 and 1 000–2 000 Metres].—P. Abadie. (*L'Onde Élec.*, November, 1934, Vol. 13, No. 155, pp. 477–484.)

732. HIGH-QUALITY PENTODE TWO-VALVE RECEIVER FOR A.C. MAINS.—H. Sutaner. (*Funktech. Monatshefte*, December, 1934, No. 12, pp. 487–492.)

733. RADIO BROADCAST RECEIVERS [Variable Selectivity, Easy Interchange of Valves, and "Rejectostat" Features: Tables of Principal 1934 Types].—J. S. Jammer and L. M. Clement. (*Elec. Communication*, October, 1934, Vol. 13, No. 2, pp. 115–124.)

734. THE DESIGN OF BROADCAST RECEIVERS FOR MOTOR BOATS, SAILING BOATS, ETC.—O. Nairz. (*Funktech. Monatshefte*, December, 1934, No. 12, pp. 479–480.)

735. THE GREAT GERMAN RADIO EXHIBITION, 1934.—E. Schwandt. (*Funktech. Monatshefte*, September, 1934, No. 9, pp. 341–359.)

736. THE 1934 PARIS RADIO EXHIBITION, *and* SOME NOTES ON RADIO EXHIBITIONS ABROAD.—(*L'Onde Élec.*, November, 1934, Vol. 13, No. 155, pp. 467–473 and 474–476.)

737. A RADIO BOGY [Unusual Causes of Fluctuating Signals and Interference: Intermittent Contacts in Re-Radiating Pipes: Contacts with Pipes in Same Conduit as Water Pipe serving as Earth: etc.].—F. G. G. Davey. (*Wireless World*, 11th Jan. 1935, Vol. 36, pp. 35–36.)

738. RADIO INTERFERENCE FROM HIGH VOLTAGE SYSTEMS.—E. A. Smith. (*Journ. Franklin Inst.*, December, 1934, Vol. 218, No. 6, pp. 653–663.)

The special sources of interference here discussed are pin and suspension type insulators. A standard pin type insulator is considered as the dielectric of a condenser of which one plate is the conductor and tie wire, the other plate being the pin. Consideration of the charging current flowing into the condenser shows that interference can be much reduced by overcoming resistance to its flow. Reduction of capacity can be attained by good insulation of the power lines and perfect contact between conductors, tie-wires and insulator surfaces. Other details of insulator design are described. Suspension type insulators are then discussed; they should be free from causing interference under ordinary conditions, but cotter keys on the clevis type insulator are sometimes at fault. Suitable design will prevent this. Wet or dirty insulators cause much disturbance. Fig. 1 gives a curve showing the attenuation of radio interference when propagated along a transmission line, in wet and dry weather. Fig. 2 shows the effect of attenuation at right angles to the transmission line. For various papers on the subject *see* 1934 Abstracts, p. 439, l-h column—three; also 739, below.

739. DISCUSSION OF PAPERS ON VARIOUS TYPES OF LINE INSULATORS [including the Subject of Radio Interference].—(*Elec. Engineering*, November, 1934, Vol. 53, No. 11, pp. 1531–1541.)

740. RADIO INTERFERENCE FROM ELECTRIC RAILWAYS AND TRAMWAYS.—E. Löfgren. (*Teknisk Tidskrift*, 1st Dec. 1934, Vol. 64, No. 48, Supp. pp. 177–184.)

AERIALS AND AERIAL SYSTEMS

741. RADIATION POWER AND CURRENT DISTRIBUTION OF A STRAIGHT AERIAL.—G. Hara. (*Hochf:tech. u. Elek:akus.*, December, 1934, Vol. 44, No. 6, pp. 185–193.)

"Previous theoretical treatments (*e.g.* those of Pistolkors, Abstracts, 1929, p. 329: the journal year should read '1929'; Bechmann, 1931, pp. 96–97; Tani, 1932, pp. 167 and 285; Carter, 1932, p. 585; and Hara, 1933, p. 624) have dealt with the special case where the aerial has a standing, sinusoidal current distribution with the same wavelength in the conductor as in space . . . The formulae used in practice, and well known in the literature, for the value of the radiation resistance are calculated on the above assumption of a current distribution which in actual fact never exists; they hold, therefore, only approximately. In the present work it is sought to determine the radiation power [of a straight vertical aerial excited by an incoming wave or a local e.m.f.] under the condition of the true current distribution."

Part I considers the distribution in a simple receiving aerial. This distribution cannot be determined on the basis of a single sinusoidal standing wave; all sinusoidal standing harmonic waves must be taken into account. The treatment of these harmonics and their mutual radiation resistance is based on a method whose theoretical foundations will be gone into more closely in a separate paper. The curves of Figs. 2a–d and equation 16 show that if $m \approx 1$ (where $m = 2l/\lambda$) the fundamental wave is predominant; for $m \approx 3$, on the other hand, the third harmonic; and so on. This shows that for the predominant harmonic in any particular case there is resonance: the predominant harmonic is therefore entitled the "resonance" harmonic. But besides the resonance harmonic there are a number of other harmonics present, only less marked. In the case of resonance, which is the important practical case, a first approximation can be obtained by taking the "resonance" harmonic alone, but the determination of the current distribution is the more accurate the more harmonics are taken into the calculation.

Taking the simplest and most important case of

$m \approx 1$ (resonance condition for the fundamental) the writer applies the theory to the first approximation of a straight-wire receiving aerial; then to the second approximation (fundamental and third harmonic) and finally to the third (fundamental with third and fifth harmonics), all for a given field strength, a given 20 m wavelength, and a wire diameter of 1.45 mm. He considers the three cases $m = 0.96$, 0.98 and 1.00 respectively. Fig. 3 shows how the effective value of the current at the centre of the aerial (*i.e.* at the antinode) varies with m, the curves 1, 2 and 3 corresponding to the first, second and third approximations. It is seen that the current values at the antinode in the two latter cases are only slightly below that calculated from the fundamental alone. Fig. 3 also shows that if, for a varying aerial length, resonance is defined as the condition of greatest current at the antinode, it does not occur exactly at the half-wavelength ($m = 1$) but at a rather smaller length—in this case about 3% smaller.

Part II considers the current distribution of a simple transmitting aerial, dealing with it in a similar way, and obtaining similar results, namely that for the representation of the current distribution in the resonance region it is sufficient in practice to take the sinusoidal, standing-wave distribution of the "resonance" harmonic. Here again l need not be equal to $n\lambda/2$. The numerical example shows that in the resonance condition the third harmonic is represented by rather less than 5% of the fundamental, and the fifth by rather less than 2.5%.

Part III deals with the radiation power and radiation resistance, on the basis of the current distribution results thus obtained. It is shown that these quantities are dependent on the ratio of aerial length to exciting wavelength, which for the exact resonance point is not a whole number. Thus, for the particular aerial and 20 m wavelength previously taken, the condition for resonance (defined as the condition in which the "resonance" harmonic has no imaginary component in the radiation resistance) corresponds to $m = 0.9695$; *i.e.*, the resonance length = 9.695 m. The writer creates a "shortening percentage" ν, where $\nu = (1 - m/n).100\%$; in the case quoted the "shortening percentage" of the resonance length is 3.05%. Thus the "shortening percentage" involves the order, n, of the "resonance" wave; the curves of Fig. 6 show that it also depends on the exciting wavelength and on the wire diameter.

Formula 34, for the radiation resistance of an aerial in resonance, is somewhat complicated; but the curves of Fig. 6 show that the equation $R_r = f(\nu)$ is nearly linear, so that the simple approximate formula 39 can be employed for practical purposes. This involves, besides ν, a "shortening coefficient" α whose values are given for $n = 1$ (0.018) to $n = 4$ (0.056). The value of ν is most conveniently obtained from experimental data. It is seen that for the selected aerial a shortening of length by 3.05% effects a reduction of radiation resistance by 5.5%—"a result which would hardly be expected at first sight." The paper finishes with experimental confirmation of the theoretical results; a 4.25 m wave was used. The calculated and measured resonance lengths of the experimental half-wave vertical receiving aerial are given in Fig. 9, for increasing heights above ground of the transmitting aerial: the wavy form of the curve is due to the effect of the ground, and the mean value (dotted straight line) can be taken as the resonance length without the ground effect. This gives $\nu = 3.87\%$, whereas the calculated value is 3.85.

742. THE EFFECT OF METAL MASTS, ETC., ON THE FIELD PATTERN OF HORIZONTAL DIPOLE AERIALS.—E. W. Sanders. (*QST*, December, 1934, Vol. 18, No. 12, pp. 33–34.)

743. COMPARATIVE TESTS ON THREE AERIALS FOR ULTRA-SHORT (3.1 m) WAVES.—Möller. (*See* 659.)

744. COAXIAL COMMUNICATION TRANSMISSION LINES.—Schelkunoff. (*See* 811.)

745. WIDE-BAND TRANSMISSION OVER COAXIAL LINES.—Espenschied and Strieby. (*See* 810.)

746. A RECESSED ROD CONDUCTOR FOR R.F. CURRENTS, ESPECIALLY AERIALS.—H. O. Roosenstein. (German Pat. 600 001, pub. 16.7.34: *Hochf:tech. u. Elek:akus.*, December, 1934, Vol. 44, No. 6, p. 214.)

A special current distribution along the conductor is obtained by hollowing out the cylindrical surface into a succession of long cup-like recesses (of length $\lambda/4$) surrounding the central core. Such a conductor may be used as an aerial with special radiating properties, or as a filter for r.f. currents.

747. PREVENTION OF RADIATION FROM FEEDERS BY INTRODUCTION OF CLOSELY COUPLED COILS WOUND IN SAME SENSE.—F. Gerth. (German Pat. 592 184, pub. 2.2.34: *Hochf:tech. u. Elek:akus.*, December, 1934, Vol. 44, No. 6, pp. 214–215.) Thus blocking currents of similar phase in the two lines and passing those of opposite phase.

VALVES AND THERMIONICS

748. VACUUM TUBES AS [Ultra-] HIGH-FREQUENCY OSCILLATORS [Special Valves, Oscillators and Amplifiers, for Wavelengths below 3 m: Circuits, Theory and Limiting Factors].—M. J. Kelly and A. L. Samuel. (*Elec. Engineering*, November, 1934, Vol. 53, No. 11, pp. 1504–1517.)

Among the special valves discussed and illustrated are those described by McArthur and Spitzer (Abstracts, 1932, p. 93), by Fay and Samuel (1934, p. 503, where a short summary only was available), and by Thompson and Rose (1934, p. 94); also the "spiral grid" types as used on the Lympne/St. Inglevert service.

749. LOW-POWER [10-Watts Anode Dissipation] SCREENED PENTODE TRANSMITTING TUBES. (*QST*, December, 1934, Vol. 18, No. 12, pp. 34 and 78.)

750. THE CLASS B AMPLIFIER: GROUNDS FOR ITS HIGH ECONOMY.—Schmoll. (*See* 707.)

751. [Valve] CIRCUIT THEORY ON NEW LINES [Valve "Constants" no Longer Constant but Variable according to Circuit Conditions].—P. Hatschek: Bartels. (*Funktech. Monatshefte*, December, 1934, No. 12, p. 469–471.) Based on Bartels' work on retroaction (395 of February).

752. THEORY OF MULTI-ELECTRODE TUBES.—H. A. Pidgeon. (*Elec. Engineering*, November, 1934, Vol. 53, No. 11, pp. 1485–1498.)

753. THE SIMULTANEOUS EXCITATION OF TWO FREQUENCIES IN ONE VALVE.—Lattmann and Salinger. (*See* 715.)

754. RATINGS OF INDUSTRIAL ELECTRONIC TUBES [High-Vacuum, Gas- and Vapour-Filled, and Photoelectric: and the Factors influencing Their Rating].—O. W. Pike and D. Ulrey. (*Elec. Engineering*, December, 1934, Vol. 53, No. 12, pp. 1577–1580.)

755. THE CLEAN-UP OF VARIOUS GASES BY MAGNESIUM, CALCIUM AND BARIUM [Study of "Contact-Gettering" in Vacuum Vessels].—A. L. Reimann. (*Phil. Mag.*, December, 1934, Series 7, Vol. 18, No. 123, pp. 1117–1132.)

756. LIMITS TO AMPLIFICATION [Survey with Bibliography].—J. B. Johnson and F. B. Llewellyn. (*Elec. Engineering*, November, 1934, Vol. 53, No. 11, pp. 1449–1454.)

Thermal agitation: shot effect and flicker effect without space charge: with space charge: ions in the space charge, causing anode-current fluctuations: noise in commercial tubes: other sources of noise (a.c. cathode-heating, vibration, poor insulation, faulty resistances): signal/noise ratio.

757. MEASUREMENT OF SHOT VOLTAGE USED TO DEDUCE THE MAGNITUDE OF SECONDARY THERMIONIC EMISSION.—E. B. Moullin. (*Proc. Roy. Soc.*, 1st Nov. 1934, Series A, Vol. 147, No. 860, pp. 100–118.)

This paper contains a review of the theory of the shot effect and a description of the experimental procedure adopted, with illustration by measurement of the electron charge. The difference between the number of primary and secondary electrons is measured by the anode current; the sum is deduced from the shot voltage so that each component can be evaluated separately. "Some deduced curves of primary and secondary current are shown for two types of valve working in the dynatron condition . . . a complicated system of emission occurs when the grid and anode are nearly at the same potential"; this is not discussed here.

758. TRANSITION OF ELECTRONS FROM METALS INTO DIELECTRICS [Decrease of Work Function compared with Vacuum/Dielectric Value].—N. Kalabuchow. (*Zeitschr. f. Physik*, No. 1/2, Vol. 92, 1934, pp. 143–147.)

759. THE INDEPENDENT IONISATION OF SODIUM AND CAESIUM VAPOUR AT INCANDESCENT TUNGSTEN AND RHENIUM SURFACES.—Alterthum, Krebs and Rompe. (*Zeitschr. f. Physik*, No. 1/2, Vol. 92, 1934, pp. 1–18.)

The production of ionised atoms of Na and Cs is found to be 20 and 50% at an Re surface and 8.5 and 45% at W. The temperature dependence of the Na/W production is correctly given by the well-known Langmuir formula, but the Cs/Re and Cs/W productions are much smaller than those predicted theoretically. Some possible reasons are discussed.

760. INVESTIGATIONS WITH THE KUNSMAN ANODE [Mixture of Iron Oxide, Aluminium Oxide and Alkali Salt: Ion Currents emitted with Changing Velocity].—G. Gille. (*Ann. der Physik*, Series 5, No. 4, Vol. 21, 1934, pp. 443–456.)

The anode is a thermionic source of positive alkali ions (*see* Kunsman, *Science*, Vol. 62, 1925, p. 269; *Journ. Franklin Inst.*, Vol. 203, 1927, p. 635). This paper investigates a velocity anomaly; the alkali ions, emitted thermionically and accelerated constantly, appear to change their most common velocity as the temperature of the ion source increases. Caesium ions were investigated with a velocity monochromator (mass spectrograph) and the work function was measured by Kunsman's method. The velocity was found to be constant from 650–900° C, to rise by 0.5 v between 900–1100° C and to be constant from 1100–1300° C. This is explained as due to a change in the work function, and is probably connected with changes in the iron present in the cathode.

DIRECTIONAL WIRELESS

761. EXPERIMENTAL INVESTIGATIONS ON NIGHT EFFECT PRODUCING DIRECTION-FINDING ERRORS: PARTS I AND II.—G. Borkowetz: A. Hagen. (*Hochf:tech. u. Elek:akus.*, November and December, 1934, Vol. 44, Nos. 5 and 6, pp. 174–178 and 181–185.)

The principle of the automatic minimum recorder is as follows (Fig. 2): the r.f. energy received on the regularly swinging frame (or goniometer search coil) 1 is taken *via* the screened coupling 2 to a high-quality receiver 3 and here heterodyned so that a note of about 1 000 c/s reaches the input transformer of the auxiliary unit 4, where the rectifying and amplifying first valve is so negatively biased that for zero signal no anode current flows. A signal produces an anode current which creates a voltage drop in the resistance W_2: this drop is so directed that it gives a strong negative bias to the "reversing" valve RE 134 and thus blocks it. As the frame passes through a minimum this blockage is removed and a current pulse (increased by the positive bias V_2) passes through the milliammeter to the electro-chemically acting recorder 5. An opposing battery V_3 stops the chemical action directly the pulse ceases: it is protected against short-circuit, in case of paper breakage, by the resistance W_3. The frame is swung through 180° or 360° and is mechanically coupled to the recording stylus so that this travels across the width of the paper, which is moved on through 1/3 mm at each dead point of swing. The *length* of the "minimum" mark depends on the quality of the minimum and on the total received energy; from the *position* of its mid-point the bearing of the minimum can be obtained, so that in the absence of night effect the successive marks form a broad straight line along the length of the paper, usually down the middle, while during night fluctuations this line deviates by amounts between ± 90° (parallel lines recorded simultaneously along the paper, also by electro-chemical means, represent angles of swing of 20° or 40° according to whether the "swing" is 180° or 360°). Time marks are provided by a clock. As a rule there are 6 swings (12 bearings) a minute, but sometimes a double speed is used. With a special apparatus using a goniometer 153 bearings a minute can be made successfully (*see* later).

With 1 to 4 portable equipments on these lines systematic investigations on the night errors of medium- and long-wave broadcasting stations were made. When two receivers were spaced only about 1/10th of the wavelength (120 m for the Königswusterhausen wave), identical curves were obtained (Fig. 6). This applied equally to frames and goniometers: when a unilateral arrangement (frames and vertical aerial) was used the only difference was that the variations were only about half as great as with the ordinary figure-of-eight characteristic—as would be expected on the Eckersley theory. Other methods of reducing night error will be dealt with in Part II. When the two receivers were used to record simultaneously two stations on neighbouring wavelengths and in practically the same spot (*e.g.* Paris Radio on 1 724 m and Paris Eiffel on 1 446 m) the two curves were quite different. Simultaneous records of various stations were compared, and it was found, for instance, that Huizen (1 875 m) regularly varied considerably less, and much later, than Königswusterhausen (1 634.9 m).

When three receivers were arranged at intervals of 1.5λ to 4λ (2–7 km for Königswusterhausen) more or less on a line pointing to the station, the three records were similar but showed certain differences in amplitude and also *displacements in time*, ranging from 2 minutes for a 2 km spacing to 6 minutes for a 7 km spacing. Such temporal displacements were entirely absent on some evenings, and on any particular evening might decrease gradually to zero. These results, showing a phenomenon which the writers believe not to have been reported before (except in Dieckmann's preliminary announcement—1932 Abstracts, p. 287), were checked by arranging momentary breaks in the transmission, producing lines right across the width of the paper on all three receivers simultaneously. At spacings of 15λ all resemblance between the curves had quite disappeared.

Tests on the 200–680 m broadcast band showed that owing to the much more rapid variations the equipments employed for the long waves were inadequate even at the double speed. The special high-speed equipment (153 bearings per minute) was therefore developed. The setting-in and disappearance of night error was similar to what was observed on the long waves. The succession of ± 90° errors, linked with strong fading, was about ten times as close as with the long waves, but between whiles the true daylight bearing could often be distinguished, which was not the case with the long waves. A comparison between Figs. 9 and 10 shows what remarkable frequency and extent of variations can occur on certain nights, on these waves as well as on the long waves: Fig. 9 gives the normal type of result, whereas Fig. 10 (North Regional, on a winter's night when simultaneous and independent height measurements by Dieminger showed unusual fluctuations of the Heaviside layer) shows the abnormal.

In the application of the above methods to the examination of systems for avoiding night errors, dealt with in Part II (Hagen, pp. 181–185), the Adcock system, apparently in its early form with raised receiver cabin, is first treated briefly (*cf.* Dieckmann, Abstracts, 1932, p. 287). Section III describes tests with a frame aerial with its plane at an angle to the vertical. "If one assumes that the downcoming angle of the space wave is dependent only on the distance between transmitter and receiver and the height of the reflecting layer, then with Gräfelfing as receiving point and Kö Wu [λ = 1 632 m] as transmitter a single reflection at a 100-km high layer should give a downcoming angle around 22°. If a frame, whose plane makes an angle of 68° with the vertical, is periodically swung through 360°, two minima occur, and on the above supposition it may be expected that in one case, where the frame is sloped away from the transmitter, only the normal day bearing would be obtained; while in the other, where it is sloping towards the transmitter, the usual wandering of bearings would occur." Fig. 3 shows the equipment, and in Fig. 4 each strip shows the two minima, the upper track representing the position sloping *towards* the transmitter. The frame-plane slopes (starting at the top record) range from 20° to 80° from the vertical. The greatest difference between the night variations of the two minima occurs with the 80° slope; this difference, however, does not remain constant but may alter with time. The writer states that "a reduction of night error occurs throughout these four record strips in the lower minimum track, *i.e.* when the frame-plane slopes *away from* the transmitter." But other records show — although only occasionally — a diminution when the frame is sloping *towards* the transmitter. The energy relations in the two minimum positions are very dissimilar: often only one minimum is recorded. Since the difference of the variation-amplitudes is the greater, the greater the slope of the frame, the space wave would appear to come down almost vertically; "the downcoming angle is, however, not constant since [as already mentioned] the difference in the variations is not constant in the same strip and a reduction of error can occur in either of the two minimum positions."

Section IV describes tests in which the energy values received on 3 dipoles at right angles to each other (vertical, longitudinal, and across—the two last being suspended about 10 m above the ground) were recorded on a multiple ink-writer and the resulting curves compared with the simultaneous minimum-variation records. The *C*-component, responsible for night error, affected only the cross dipole. The inclination of the *E* vector of the ground wave to the horizontal, due to the earth resistance, was balanced out by a suitable inclination of the longitudinal dipole. The vertical dipole could be replaced by a horizontal frame tuned to Kö Wu, or by a vertical frame in the position of day-time minimum for Kö Wu. In Fig. 7 the black line across the minimum record represents a short stoppage of Kö Wu transmission at 20^h 43 (in July). Immediately after this there is seen a marked decrease of energy in the vertical and longitudinal dipoles, to well below the day value, and an increase in the cross dipole: simultaneously violent bearing fluctuations, up to ± 90°, are seen. All the records show similar results: directly the energy in the vertical or longitudinal dipoles sinks below the day value, the night variations occur, which may far exceed ± 90° so that often the two minima of the 360°-swung frame appear interchanged. Errors of ± 50° and over are always accompanied by strong fading: "large errors never occur when the vertical dipole yields more energy than by day. An effect of the abnormally polarised *C*-component on the bearing error cannot be noticed so long as a vertical aerial yields more energy than by day." The energy measurements with the alternative frames mentioned earlier show that the night-time energy in a tuned horizontal frame is generally much lower than that in a similar vertical frame arranged at the day minimum for the transmitter.

The sloping-frame measurements of section III suggest an almost vertical arrival of the space wave. Energy and directional minimum tests (section V) were therefore made with a frame arranged in the day minimum position but swung through 180° about a horizontal axis at right angles to the direction of the transmitter, so that by day it was always at a minimum position and gave no record, while at night it received the abnormally polarised component of the space wave. At about sunset a clear minimum appeared at a nearly horizontal position, corresponding to an almost vertically descending space wave; on many nights this angle of descent seemed to remain constant, so that the minimum recorder gave a fairly constant bearing, in spite of the frequent appearance of fading. But on other nights numerous strong fadings occurred, accompanied by minimum variations up to ± 180°.

Section VI deals briefly with the "Knall-Peil" system ("Knall" may here be translated as a "clap") in which the more usual long dash is replaced by a 1–1.5 second signal (*see* Part I, Borkowetz). No improvement as to night error was found, errors up to ± 90° being recorded with the 1-second dots as with the 6-second dashes. "It must be noted, however, that in these tests both transmitter and receiver were on the ground." The signals were provided by the Fürth aerodrome station and by an aeroplane on this aerodrome.

The *E* vector of a wave incident on a surface of infinite conductivity must be perpendicular, so that at such a surface no abnormally polarised fields can be formed. Section VII deals with tests based on the above fact, a frame aerial being swung periodically over a highly conductive surface made up of soldered galvanised plates and netting, of an area of 190 sq. metres. The minimum records thus obtained were compared with those from a frame of the same dimensions 150 metres away in the D.F. tower. The conducting-surface records showed a decrease in night error of from 12–18%.

762. Direction Finders: Principles underlying the Design of Spaced Aerials.—R. H. Barfield. (*Electrician*, 7th Dec. 1934, Vol. 113, No. 2949, p. 742.) Summary of I.E.E. paper.

763. The Use of Frame Aerials for Direction Finding.—P. Hermanspann. (*Funktech. Monatshefte*, November, 1934, No. 11, pp. 424–430.)

Short survey. "Minimum" finders (and the effective heights of their aerials: correction curves: etc.); "maximum" and direct-reading finders; night errors (including the Adcock system).

764. Combination of Frame and Dipoles to eliminate Bearing Errors due to Space Wave.—R. Hell. (German Pat. 601 904, pub. 27.8.34: *Hochf:tech. u. Elek:akus.*, December, 1934, Vol. 44, No. 6, p. 215.)

765. A Radio Beacon at Southampton: Note from the "Times." (*Nature*, 5th Jan. 1935, Vol. 135, p. 17.)

ACOUSTICS AND AUDIO-FREQUENCIES

766. The Acoustics of Concert and Broadcasting Studios [Optimum Reverberation Time].—G. von Békésy. (*E.N.T.*, November, 1934, Vol. 11, No. 11, pp. 369–375.)

This paper describes experiments on the most favourable reverberation time of music studios, and its frequency dependence. The court and the chief studio of the broadcasting station at Budapest are first described; the frequency dependence of the latter's reverberation time was measured with an automatic arrangement due to E. Meyer (1930 Abstracts, pp. 512–513) and is shown in Fig. 2 for various degrees of covering of the walls; it decreases rapidly with increasing frequency, whereas that of the court, which gave a much better tone-colour, changed but little with frequency (Fig. 1). Various experiments with studios of different sizes are then described; a reverberation time, independent of frequency, of 0.7 sec. was found best for studios of 180 m³ and 400 m³: 0.8 sec. was the optimum value for 2 000 m³. Experiments with observers in a studio of 2 000 m³ are described; it was difficult to obtain reliable observations when the number of absorption units in the studio was gradually increased or decreased, owing to hysteresis effects in the observers' sensations. This is illustrated in Table 1, which gives the actual remarks made by the observers in a typical experiment, and by Fig. 3, which gives reverberation-time/frequency curves for best reproduction. Figs. 4 and 5 give similar curves for a small orchestra and for one of normal size. No real difference was found acoustically between Wagner's and Mozart's music. Fig. 7 shows the dependence on volume of the most suitable reverberation time, independent of frequency, and Fig. 8 the optimum increase of reverberation time corresponding to a given decrease in sound intensity, which may be made to compensate to some extent for a sound of insufficient intensity in a large studio. Fig. 9 shows changes in loudness of execution with the reverberation time: great artists are more sensitive to this than are ordinary musicians.

767. The Acoustical Insulation of Air-Conditioning Fans and Shafts [and the Use of Baffle Chambers, "Katelit" and "Korfund" Plates, etc.].—I. Katel. (*Génie Civil*, 24th Nov. 1934, Vol. 105, No. 21, pp. 482–483.)

768. The [Rapid] Measurement of the Coefficient of Absorption of Sound-Insulating Materials [Coated Cube with Internal Loudspeaker and Microphone: Constant Intensity Principle: Some Results].—H. Fontaine. (*Génie Civil*, 24th Nov. 1934, Vol. 105, No. 21, p. 490.)

769. Measurements on Dynamic [Moving-Coil] High-Power Loudspeakers.—O. Schäfer. (*Funktech. Monatshefte*, October, 1934, No. 10, pp. 385–388.)

Recent high-power types have brought loudspeakers into the field of electrical machinery by the possession of efficiencies in no way inferior to those of very small electric motors, and have thus opened up new paths in the design calculations of their associated amplifiers. The writer discusses the matching conditions and shows how all the important measurements can be carried out with simple equipment, with the accuracy required for practical purposes; he illustrates his test by measurements on the Dietz and Ritter loudspeaker "Maximus" and their improved "Imperial III." He stresses the result that it is impossible to choose a suitable output transformer simply from the impedance of the loudspeaker measured at one frequency. Attention must be paid to the curve of apparent efficiencies and to the changes caused by the primary winding of the transformer; and the transformation ratio must be so chosen as to give the greatest average efficiency. Moreover there is the possibility of influencing the tone, within certain limits, by under- or over-matching, and of limiting the lower cut-off point by the choice of the output valve.

770. A Transportable 10-Watt Public Address System.—C. B. De Soto. (*QST*, December, 1934, Vol. 18, No. 12, pp. 18–20 and 98, 100, 101.)

771. Transverse Current [Carbon] Microphone [Constructional Details].—D. W. Heightman. (*Wireless World*, 11th Jan. 1935, Vol. 36, pp. 29–30.)

772. Electrical Dynamometer for Very Small Forces [especially for Gramophone-Needle Friction Measurements].—E. C. Wadlow. (*Elec. Review*, 17th Aug. 1934.)

773. Magnetic Recording in [German] Broadcasting.—H. J. von Braunmühl. (*Funktech. Monatshefte*, December, 1934, No. 12, pp. 483–486.)

774. Sound-on-Film Reproduction without Background Noise [American Modification of Amplitude Process: Sound Track Transparent on Opaque Background: Half-Waves recorded Separately, in Two Staggered Tracks, giving Greater Available Width].—(*Funktech. Monatshefte*, September, 1934, No. 9, pp. 360–361.)

775. [Note on] Institution of Electrical Engineers' Library of Sound Films [and Address by Sir Oliver Lodge].—(*Nature*, 5th Jan. 1935, Vol. 135, pp. 11–12.)

776. Dispersion of Sound in Acoustic Filters.—E. Grossmann. (*Ann. der Physik*, Series 5, No. 4, Vol. 21, 1934, pp. 433–442.)

The theory of sound filters is given, on the lines due to Waetzmann and Noether (1932 Abstracts, p. 466, r-h col.), and the dispersion is measured experimentally by a comparison of the Kundt's dust figures in a smooth glass tube and in a glass filter tube (Figs. 1 and 2). Fig. 3 shows the theoretical and measured values of the ratio (velocity of sound in smooth tube)/(velocity in filter) and the corresponding attenuation characteristic of the (high-pass) filter. Figs. 4 and 5 show curves for other filters; Fig. 6 shows the microphone current as a measure of the sound pressure at the end of a smooth tube and a high-pass filter. Good agreement between theory and experiment was found throughout.

777. Absolute Measurement of Sound Intensity by the "Pull-In" (Mitnahme) Method.—K. Teodorchik and E. Sekerskaia. (*Journal of Tech. Phys.* [in Russian: *see* 913], No. 5, Vol. 4, 1934, pp. 1009–1013.)

The "pull-in" method was discussed in a previous article (*ibid.*, 1932, Vol. 2, p. 112). The present paper describes the apparatus used, which comprises a light movable rod controlled by a steel spring with adjustable tension and carrying a light membrane of the piston type and two small armatures each associated with an electromagnet. The windings of these magnets are connected to the input and output circuits respectively of a valve amplifier. The sound to be measured is produced by a loudspeaker connected in the output circuit of the amplifier, which is driven by a variable frequency a.f. oscillator.

A formula is derived enabling the sound pressure on the membrane to be calculated from the frequency band-width over which the pull-in effect takes place and the amplitude of the auto-oscillations of the system. The latter is measured by observing through a microscope the edge of a razor blade mounted on the rod. The band-width of the pull-in effect is measured by one of the following methods: (*a*) by direct listening through telephones; (*b*) by observing the needle of a milliammeter in the grid circuit of the last stage of the amplifier, or (*c*) by observing through the microscope the vibration of the rod.

A series of experiments was carried out to show that the band-width is inversely proportional to the amplitude of the auto-oscillations. The intensity of sound during these experiments was maintained constant and the amplitude of the auto-oscillations varied by means of a shunting resistance in the output circuit of the amplifier. It was next shown, by varying the intensity of the sound (by means of a potentiometer in the loudspeaker circuit), and keeping the amplitude of auto-oscillations constant, that the band-width is proportional to the pressure of sound on the membrane. Curves are given showing the results obtained.

It is stated that the instrument has proved suitable for measuring sound intensities down to 0.3 bar and that these measurements are not affected by acoustic interference from other sources (*e.g.* loud conversation, motor noise, etc.). The time taken in determining the band-width is 1 to 2 minutes. The drawback of this instrument is its narrow range (200 to 700 c/s).

778. Utility of the Noise Meter in Quantity Production.—W. E. Johnson. (*Gen. Elec. Review*, November, 1934, Vol. 37, No. 11, pp. 504–508.)

779. Decibel Meter [for Radio Interference, Gramophone Recording, Radio Relay Monitoring, etc.].—Salford Elec. Instr., Ltd. (*Journ. Scient. Instr.*, November, 1934, Vol. 11, No. 11, p. 368.)

780. Measurement of Noise from Power Transformers, *and* Measurement of Noise from Small Motors.—A. P. Fugill: C. G. Veinott. (*Elec. Engineering*, December, 1934, Vol. 53, No. 12, pp. 1603–1608 and 1624–1628.)

781. Portable Noise Measuring Apparatus.—Metropolitan - Vickers Company. (*Journ. Scient. Instr.*, October, 1934, Vol. 11, No. 10, pp. 332–333.) Based on the work dealt with in 185 of January.

782. Traffic Noise [Modern Intermittent Noise with Quick Rate of Change is Objectionable].—P. J. H. Unna. (*Nature*, 15th Dec. 1934, Vol. 134, p. 937.)

783. On the Mechanical-Acoustical Behaviour of Electrical Machines [Causes, Measurement, Identification and Reduction of Machine Noise].—E. Lübcke. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 15, 1934, pp. 652–660.)

784. A Study of an Electrically Maintained Vibrating Reed and Its Application to the Determination of Young's Modulus.—Part II. Experimental.—E. G. James and R. M. Davies. (*Phil. Mag.*, December, 1934, Series 7, Vol. 18, No. 123, pp. 1053–1086.)

For Part I *see* 458 of February. Details are given of an a.c. generating circuit, free from harmonics; of a Rayleigh bridge for measuring inductance and resistance; of the experimental method used, and of the accuracy of the observations. The frequency was measured by the bridge referred to in 1934 Abstracts, p. 48 (Davies). Many experimental curves are given for amplitude and motional impedance as functions of pulsatance; for apparent resonance pulsatance as a function of magnetising impedance and size of air gap; and for instability effects. The value found for Young's modulus agrees well with previous values and the method is found capable of an accuracy of about 1 in 1 000. It is found to be quite conceivable that "the indications of a frequency-meter of the reed type may be accurate for small amplitudes of vibration and yet be inaccurate for larger amplitudes."

785. The Magnetostrictive Oscillation of Chladni Plates.—R. C. Colwell and E. A. Bryant. (*Journ. Franklin Inst.*, December, 1934, Vol. 218, No. 6, pp. 739–748.) The full paper, a summary of which was referred to in 1934 Abstracts, p. 278.

786. The Velocity of Propagation of Sound in Quartz.—A. de Gramont and D. Béretzki. (*Comptes Rendus*, 3rd Dec. 1934, Vol. 199 No. 23, pp. 1273–1274.)

If a quartz plate cut with its faces perpendicular to an electrical axis is made to vibrate in a half-wave mode along this axis, discrepancies of about 20% are found between the observed frequency and that calculated from the Newtonian formula: thus Hund's empirical formula gives a velocity 5 740 m/s instead of the theoretical value 5 440. These discrepancies are sometimes wrongly attributed to impurities in the crystal: the form of the specimen may influence the velocity, but variations thus produced hardly exceed 2–3%. The fact is that Newton's formula only applies if the diameter of the plate is small compared with its thickness, *i.e.* compared with the half-wavelength of the supersonic wave; and this relation does not occur in piezoelectric plates. The present writers have investigated the conditions in which the velocity of sound in the quartz can be defined with precision, so that the resonance frequency can be calculated: they find that the velocity is variable and may take a series of values (in their tests, between 4 748 and 6 094 m/s) each value corresponding to well determined conditions. They took a plate of very pure quartz, perpendicular to a binary axis, and cut from this a series of long equal bars of differing orientation with regard to the optical axis. The table shows how the propagation velocity along the electrical axis (*i.e.* perpendicular to the primitive plane of the plate) starts at 6 094 m/s for a bar cut at an angle 0° to the optical axis, decreases to 4 745 for an angle of 30°, increases again to 5 992 at 100°, and rises to 5 725 at 160°. The bar dimensions were 4.5 mm × 4.5 mm × 21.5 mm.

On the other hand they were able, by keeping a constant thickness but varying the other dimensions, to obtain bars giving the same frequency whatever their orientation: "a plate of quartz reconstituted so as to respect these relative proportions presents among other properties the remarkable one of supporting a tension some ten times higher than that which would be tolerated by a circular disc. This special form applied to piezoelectric plates has allowed their range to be extended on the side of very high frequencies."

787. Experimental Investigations on the Oscillations of Single Cylindrical Crystals at High Elastic Frequencies [50 to 1 000 kc/s: Velocities of Various Modes of Oscillation of Cylinders of Zn, Cd, Sn].—H. Schoeneck. (*Zeitschr. f. Physik*, No. 5/6, Vol. 92, 1934, pp. 390–406.) *See* also Röhrich, Abstracts, 1932, p. 466; also Giebe and Blechschmidt, 1934, p. 99.

788. The Determination of the Specific Heat of Gases at High Temperatures by the Sound Velocity Method [using Vibrations from Piezo-Quartz Crystal]. I.—Carbon Monoxide.—G. G. Sherratt and E. Griffiths. (*Proc. Roy. Soc.*, Series A, 15th Nov. 1934, Vol. 147, No. 861, pp. 292–308.)

789. An Experimental Determination of Ultrasonic Absorption and Reflection Coefficients in Air and in Carbon Dioxide.—R. W. Curtis. (*Phys. Review*, 1st Nov. 1934, Series 2, Vol. 46, No. 9, pp. 811–815.)

In the frequency range between 88 and 1 000 kc/s, the absorption in air is found to increase with the square of the wavelength, as required by classical theory; in CO_2 a sharp maximum at about 98 kc/s is obtained. The reflection coefficient (brass reflector) decreases with increasing frequency for both gases.

790. Some [Demonstration] Experiments in Kundt's Tubes with High Frequency Sound Waves.—O. Brandt and H. Freund. (*Zeitschr. f. Physik*, No. 5/6, Vol. 92, 1934, pp. 385–389.)

791. New Optical Method for the Study of the Absorption of Supersonic Waves by Liquids.—E. Baumgardt. (*Comptes Rendus*, 10th Dec. 1934, Vol. 199, No. 24, pp. 1383–1385.)

792. Influence of the Electrolytes on the Formation and the Stability of Metallic Colloids produced by Supersonic Waves.—M. Reggiani. (*Comptes Rendus*, 7th Jan. 1935, Vol. 200, No. 2, pp. 123–125.)

793. "Voice Colour Profiles" in the Oscillograph Tube [Circular Patterns photographed on Cinema Film from Rotating Oscillograph Tube: Classified after the Bertillon System].—Panconcelli - Calzia. (*Funktech. Monatshefte*, December, 1934, No. 12, pp. 481–483.)

794. New Researches on the Timbre and Loudness of [German] Vowels.—E. Thienhaus. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 15, 1934, pp. 637–641.)

795. A Frequency Meter for Visual Tuning [Pitch Difference measured by Counting the Flashes of Neon Tube: Measurements on Various Musical Instruments].—A. Pitt. (*Journ. Scient. Instr.*, December, 1934, Vol. 11, No. 12, pp. 377–379.)

796. The Influence of Loudness on the Apparent Pitch.—O. Vierling. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 15, 1934, pp. 641–643.)

This phenomenon, dealt with by Zurmühl (Abstracts, 1931, p. 272) is not often met with, but with the introduction of electro-acoustic pianos, with their very large range of volume, it assumes importance. Thus if such a piano is tuned accurately with an ordinary piano, at equal volume levels, the new piano will sound very much out of tune with the old type when it is played much more loudly, although the effect is not found when the notes are struck simultaneously—only when struck in succession. The writer has therefore investigated the phenomenon for himself: he finds that the pitch difference, at various frequencies, increases with increased difference in volume: for a volume difference of 50 Phon there is, at 200 c/s, a lowering of pitch of the loud note by as much as 5%; this decreases steadily as the frequency rises, to about 1% at 1 500 c/s, and disappears at still higher frequencies. *See* also Stevens, 1934, p. 567, and Vrijdaghs, same column.

797. The Trautonium [Electrical Properties].—P. Kotowski and W. Germann. (*E.N.T.*, November, 1934, Vol. 11, No. 11, pp. 389–399.)

For a description of this instrument *see* 1933 Abstracts, p. 628 (Germann). The present paper discusses its electrical properties. Figs. 2 and 3 show its front panel and circuit respectively and Fig. 4 gives the calculated "trip" frequency as a function of the grid bias. Linear scales extending over 3½ or 4 octaves can be attained by making use of the curvature of the valve characteristic shown in Fig. 5. The "trip" oscillation diagram is given in Figs. 6 and 7. The decoupling circuit is shown in Fig. 9. The rest of the paper gives circuit decrements, frequency curves, and curves of changes in "trip" frequency, and discusses the constancy and touch of the instrument.

798. The Electro - Acoustical Organ.—O. Vierling. (*Zeitschr. V.D.I.*, 20th Oct. 1934, Vol. 78, No. 42, pp. 1217–1219.)

799. A New Electrical Organ.—H. Boucke: Vierling and Kock. (*Funktech. Monatshefte*, November, 1934, No. 11, pp. 437–438.)

800. The Determination of the Stimulus/Sensation Relation for Audition from Data on the Minimum Perceptible Changes of Intensity.—H. Davies. (*Phil. Mag.*, November, 1934, Supp. No., Series 7, Vol. 18, No. 122, pp. 940–949.)

801. The Localisation of Pure Tones.—Stevens and Newman. (*Proc. Nat. Acad. Sci.*, November, 1934, Vol. 20, No. 11, pp. 593–596.)

802. Discussion on "Stabilised Feed-Back Amplifiers."—H. S. Black. (*Elec. Engineering*, September, 1934, Vol. 53, No. 9, pp. 1311–1312.) For previous discussions *see* 1934 Abstracts, p. 328.

803. "Fortschritte der physikalischen und technischen Akustik" [Second Edition: Book Review].—F. Trendelenburg. (*Journ. Scient. Instr.*, October, 1934, Vol. 11, No. 10, p. 338.)

PHOTOTELEGRAPHY AND TELEVISION

804. Distortion in Television of Moving Objects.—O. B. Lurie. (*Journ. of Tech. Phys.* [in Russian: *see* 913], No. 4, Vol. 4, 1934, pp. 792–795.)

The two fundamental cases of a rectangle moving in a direction (*a*) parallel and (*b*) perpendicular to the direction of movement of the scanning beam are examined separately. In the first case the rectangle suffers angular distortion on reproduction and becomes a parallelogram, but has the same height as before. In the second case the rectangle is either shortened or elongated, depending on the relative signs of the velocities of the rectangle and of the scanning line, but remains rectangular. It is shown that in each case the distortion produced, *i.e.* the ratio of the displacement to the vertical dimension of the picture, is inversely proportional to the length of that side of the "frame" which is perpendicular to the direction of movement of the scanning beam. It is therefore recommended that the scanning of moving objects should always be made in a direction perpendicular to the longer dimension of the frame.

It is suggested that distortion (as defined above) up to 5% is quite permissible in practice. In the case of rotating objects the angular distortion between two consecutive frames should, with the present state of the technique, be not more than about 1°, since otherwise stroboscopic effects will appear.

805. The Position of Television, according to the Latest Tests of the German Post Office: the Reception Tests on the Brocken: Radio Exhibition Report.—Banneitz: Scholz: Kette. (*Funktech. Monatshefte*, October, 1934, No. 10, Supp. pp. 49–50: 50–51: 51–60.)

"The whole of Germany could be provided with [ultra-short-wave] television by 20–25 stations" by making use of the Brocken and other mountains and, for flat country and cities, high towers. A station on the Brocken should have a range of 100–150 km. The recent reception tests on the Brocken from the Witzleben transmitter (180 lines, vision on 6.7 m) showed the possibility of modulating a Brocken transmitter from the Berlin station over an u.s.w. link, although the transportable receiver employed did not give sufficiently perfect reception for that purpose. The field strength on the Brocken was 0.1 mv/m ± 50%. Tests in all type of weather, by day and by night, showed that with full modulation of the transmitter the signal/noise ratio was always sufficiently great for the interference (chiefly heterodyne background noise) to have no effect on the image quality. But for modulating a Brocken transmitter the ratio would need improving—by r.f. amplification, more efficient receiving aerials, decrease of background noise by the use of more suitable valves, etc.

806. Short-Range Tests on Ultra-Short (3.1 m) Waves.—Möller. (*See* 659.)

807. Television and the Cinema [and the Future Use of Films for Television for the sake of "Artistic Completeness"].—Dallas Bower. (*Wireless World*, 28th Dec. 1934, Vol. 35, pp. 550–552.)

808. Uniform Film Transport—a Necessity for Good Tele-Cinematography.—P. Hatschek. (*Funktech. Monatshefte*, December, 1934, No. 12, Supp. pp. 69–70.)

809. Mechanical Television Receivers for High Numbers of Lines [Possibilities of the Double Mirror Helix, "Spherical" Single Helix, and a Combination of the Two, giving 360 Lines].—F. von Okolicsanyi. (*Funktech. Monatshefte*, December, 1934, No. 12, Supp. pp. 67–69.)

810. Wide-Band Transmission over Coaxial Lines [for Multiplex Telephony or Television: Band Widths of 1 000 kc/s or more transmitted over Long Distances: Phoenixville Tests].—Ll. Espenschied and M. E. Strieby. (*Elec. Engineering*, October, 1934, Vol. 53, No. 10, pp. 1371–1380: *Elec. Communication*, October, 1934, Vol. 13, No. 2, pp. 159–172: *Bell S. Tech. Journ.*, October, 1934, Vol. 13, No. 4, pp. 654–679.) *See* also 811.

811. Coaxial Communication Transmission Lines [Non-Mathematical Discussion of Lines for Bands of 1 Mc/s and more].—S. A. Schelkunoff. (*Elec. Engineering*, December, 1934, Vol. 53, No. 12, pp. 1592–1593.)

The technical possibilities have been discussed by Espenschied and Strieby (*see* 810) and a comprehensive mathematical treatment was given by the present writer (435 of February).

812. The Amplification of Programme Transients in Radio Receivers.—Builder. (*See* 716.)

813. Contribution to the Construction of Cathode-Ray Tubes with High Vacuum for Television and Measuring Purposes.—M. von Ardenne. (*Hochf:tech. u. Elek:akus.*, November, 1934, Vol. 44, No. 5, pp. 166–173.)

The requirements of extremely high working constancy, life of several thousand hours, linear calibration and extensive independence of frequency, demanded by certain uses such as continuous recording (as in propagation research), modulation control of transmitters, and television, are best fulfilled by high-vacuum tubes (around 10^{-6} mm Hg). Medium-vacuum tubes of special design also comply with these requirements within certain limits, but this type has already been dealt with by the writer (Abstracts, 1934, p. 336). The type of tube which the writer has now arrived at is identical in its chief points with that described by George (1929, p. 584). Since the same type has been thoroughly discussed in two recent papers (Zworykin, 1934, p. 330, and Knoll, 1934, p. 219) the writer devotes himself in the present paper chiefly to questions of the best design dimensions, to describing some improvements, and to giving some practical results.

The relations in the deflecting chamber are first examined, particularly the important question of the best values for the converging angle (γ, Fig. 1). By departing from the optimum γ and optimum ray cross-section in the deflecting zone, and by lengthening the plates, tubes with two pairs of plates can be designed to work satisfactorily. Better conditions are obtained if, by the use of a push-pull stage in the "kipp" voltage amplification, it is arranged that the average potential of both plates with respect to the ray remains constant. A fuller treatment of the electron-optics of the deflecting system will be published later.

Much more distortionless image formation is given if only one deflecting condenser is used, with long plates widely spaced (3 or 4 ray diameters), particularly if the above-mentioned symmetry given by push-pull is obtained. The best results are given by magnetic deflection, but for frequencies above 500–1 000 c/s, if independence of frequency is required, the necessary energy expenditure for such deflection is too great for (*e.g.*) television purposes. It is therefore desirable to use a "mixed" system, employing magnetic deflection for the 25 c/s vertical direction and electrostatic for the 5 000 c/s line direction. With modern "kipp" circuits a deflecting current can be obtained as well as a deflecting voltage, so that the above plan is not unduly complicated. The converging angle suitable for such a system is discussed. The next section (IB) deals with the influence of the space charge on the spot size, as a function of anode current and anode voltage for various converging angles. "Fig. 4 shows that a required spot diameter can be obtained with greater ray current, the greater the initial diameter (and converging angle) and the greater the anode potential."

Conditions in the discharge chamber are next investigated (sections II A–C). Figs. 7–9 show the writer's system, developed from the double electrostatic concentration system given by George (*loc. cit.*) and shown in Fig. 6. A simple approximate formula (5) is given for the smallest possible spot diameter, showing clearly the conditions desirable. The factors controlling the value of the ray current are then examined, leading to the relation (for not too great emission cross-sections) between ray current and diverging angle β (Fig. 8) given by formula 6. For constant magnification in the main system, $\tan\beta$ is proportional to $\tan\gamma$. This shows that the existence of a large converging angle γ in the deflecting chamber has great importance for the design of the discharge system: for a given γ the only way to increase β is to reduce the focal length, that is, to increase the magnification. In the design, therefore, a compromise is necessary between spot sharpness and spot brightness.

Fig. 15 is a photograph of the electrode system of the writer's tube. The anode voltage used is 3000–4 000 v; the sensitivity 0.3 mm/v with a pre-concentrating electrode bias of 4 000 v; for the normal picture size of 13×18 cm the spot diameter is about $\frac{3}{4}$ mm.

814. THE DISTURBANCES PRODUCED BY THE DEFLECTING FIELDS IN A CATHODE-RAY OSCILLOGRAPH.—E. Hudec. (*E.N.T.*, November, 1934, Vol. 11, No. 11, pp. 376–383.)

Use of the cathode-ray oscillograph for television requires exact investigation of possible distortions, first of the radial spread of the electron beam in the deflecting field, *i.e.* of the diameter of the beam between cathode and fluorescent screen, and secondly of the deformation of the fluorescent spot itself and its deviation. § 1 gives a theoretical investigation of the effect of initial velocity on the motion of the electrons, with numerical data for a barium oxide cathode. The velocity component perpendicular to the axis of the tube is the source of disturbance and it makes the electrons move in a parabola, as shown in Fig. 2. After the electrons have passed the deflecting field their motion is linear (Fig. 3) and the diameter of the beam may be 11 mm at the end of a tube 40 cm long.

The motion of electrons in a concentrating field is discussed in § 2. Fig. 4 shows the lines of force in the control field of a television tube, and Fig. 5 various fields for electron concentration. Fig. 6 illustrates the focusing effect and Fig. 7 shows the arrangement of electrodes in an illumination-controlled tube. Fig. 8 illustrates the motion of electrons from a cathode of finite area. Increase of illumination involves increase of spot diameter. The latter may be decreased by increasing the distance of the concentrating field from the control field; it may thus even be possible to dispense with gas control.

§ 3 deals with deviations from linearity of the beam deflection. Fig. 10 shows the field between two deviating plates and Fig. 11 a field which has very little influence on the electron motion (asymmetric form and position of plates). § 4 discusses the deformation of the spot and Fig. 12a shows a photograph of a tube designed to minimise this, with deflecting plates at some distance from the anode. A cylindrical shield between anode and plates prevents disturbance by external fields. If gas concentration is to be avoided, the tube must be made very much larger. § 5 describes experimental results with a tube shown in Fig. 12b, with cathode as in Fig. 13. Fig. 14a shows a 90-line raster under various illuminations of the same duration, and Fig. 14b the same illuminations with proportionate durations. Fig. 14c is a magnification of strips of Fig. 14b, showing that they have practically the same degree of definition. For previous work *see* 1932 Abstracts, p. 531.

815. INVESTIGATION OF FLUORESCENT MATERIALS FOR USE IN TELEVISION AND CATHODE-RAY OSCILLOGRAPHS.—W. Schnabel. (*Arch. f. Elektrot.*, 12th Dec. 1934, Vol. 28, No. 12, pp. 789–797.)

The points investigated in this paper are: (1) the density of light on the fluorescent screen attainable with different materials, (2) the length of life of ordinary screens, and (3) the phosphorescent qualities of the most important screens and the importance of their light-decay curves for television. Voltages from 3 to 70 kv and currents from 0.1 to 1 mA were used. The light-density was measured as a function of one or other of these quantities, the other being kept constant. The duration of the life of a screen is determined by the light-density at any point, measured in watts/cm²; the values obtained lay between 1 and 60 watt/cm².

§ 3 gives a list of the fluorescent materials studied and the methods used to fix them to the glass screen; these were (1) mixing the material with water-glass and spreading the paste in a thin film, (2) sprinkling the material on a thin film of diluted water-glass, (3) suspension in ether, (4) suspension in alcohol. In § 4 the apparatus and methods used are described. Fig. 2 shows the arrangement of the photocell and the fluorescent material, Fig. 3 the circuit for measuring the light-density, and Fig. 4 the geometrical arrangement of the cell and photometer. The maximum sensitivity of the photocell used lay in the blue-green region (4 500 $\mu\mu$). Photocurrent differences of 10^{-4} lumen could easily be measured. Fig. 5 shows the Faraday cage used and Fig. 6 the circuit for measuring the light-decay curves.

The experimental results are given in § 7, where Figs. 7 and 8 show curves for the light-density as a function of the voltage used, with constant current density, for the various materials investigated. The values obtained are frequently from 1 to 2 times those found by other writers (von Ardenne, Zworykin) who however used metal screens or glass screens covered with a mixture of metallic dust and the fluorescent material, which are unsuitable for television purposes. No saturation with increasing voltage was found in the voltage range used (up to 70 kv). Fig. 9 shows the light-density as a function of the screen-current density, with constant voltage; here saturation phenomena occur for a current density of about 1 mA/mm². This may be due to charge on the screen, which an electrostatic voltmeter shows to be present. The apparent saturation must, however, always be taken into account. The power must be increased as much as possible, if great brightness is desired, and good conduction from the screen must be secured.

Figs. 10 and 11 show the length of life of different screen materials for a normal film thickness and for a very thin film respectively. Willemite gave a long life and very uniform screen surface. Figs. 12–15 show the surface structure by transmitted light of various materials. Long life depends largely on good heat conductivity (*i.e.*, uniform surface structure). Very thin films showed large initial brightness but very rapid fatigue. It was found that a screen of normal thickness (surface 100 cm²) could be exposed to the beam (60 watts) for 10–20 hours before the brightness fell by 10–20%. Figs. 16–24 show the decay curves of various materials, taken on the second oscillograph shown in Fig. 6. The calcium tungstate used had a decay time 1.6×10^{-5} sec. (Figs. 20, 21); another material of unknown composition had a decay time 0.6×10^{-5} sec. (Fig. 24). There was no noticeable increase of decay time with voltage. The summary (§6) gives data of an optical arrangement giving a point density of 1460.

816. EXPERIMENTS ON THE PHOTOELECTRIC EFFECT. PART I: SYSTEMATIC INVESTIGATION OF THE EXTERNAL PHOTOELECTRIC EFFECT IN THE ELEMENTS [Most Metals] OF THE PERIODIC SYSTEM.—R. Schulze. (*Zeitschr. f. Physik*, No. 3/4, Vol. 92, 1934, pp. 212–227.)

The long-wave limit of the photoelectric effect is defined as the wavelength which just does not produce an electron current of 10^{-15} amp. when the incident light energy is 10 erg/sec. Elements of the periodic system were investigated under exactly similar conditions and it was found that the long-wave limit was paralleled by the ionisation energy found from the series limits of the free atoms. The number of quanta obtained had the same value for all elements of any one group in the periodic table but differed by several orders of magnitude (10^{-1} to 10^{-8}) from group to group. The groups investigated were the alkali metals, the beryllium, aluminium, titanium, copper and zinc groups, also the elements of the horizontal series in the periodic table from potassium to selenium. Table 1 shows the periodic system; the groups chosen are marked with crosses and the values of the long-wave limit and the ionisation energy are given [misprint: H for K]. Fig. 7 shows curves of the output energy as a function of the wavelength, for various elements, and Fig. 8 shows the change in the long-wave limit of the elements from potassium to selenium, with other physical data for comparison.

817. MEASUREMENT OF THE SPECTRAL SENSITIVITY OF PHOTOCELLS.—M. Gurevich and E. Putseikol. (*Journ. of Tech. Phys.* [in Russian: *see* 913], No. 4, Vol. 4, 1934, pp. 748–767.)

The currents through photocells of different types (caesium, rubidium, selenium, etc.) were measured for excitation by monochromatic light, obtained by passing a beam of light from a tungsten filament lamp through an ordinary constant-deviation spectroscope. Methods are indicated for calculating the radiation energy for different wavelengths depending on the temperature of the filament, and correction factors are given for absorption and reflection losses, and for the fact that the beam obtained is not in practice strictly monochromatic. The calculations are summed up in a table for a given spectroscope and for different wavelengths between 400 and 700 mμ.

818. CONNECTION BETWEEN DIRECTION OF POLARISATION AND SELECTIVITY IN THE EXTERNAL PHOTOELECTRIC EFFECT OF SOME METALS.—F. Hlučka. (*Zeitschr. f. Physik*, No. 5/6, Vol. 92, 1934, pp. 359–366.)

Continuation of previous work (1933 Abstracts, p. 335). The writer now uses polarised light with the same apparatus and finds that selective maxima of the external photoelectric effect are produced not only by the light vector normal to the cathode surface but also by that parallel to the surface; the maxima corresponding to the two components respectively are slightly displaced from one another. Figs 3–8 show photoelectric current curves for Ag, Zn, Cu, Ni, Pt, Au; Fig. 16 gives curves for all metals on one diagram. Figs. 9–15 show the comparison between the calculated and measured curves. Alkali metals show no selectivity for the parallel component; this is probably due to the dependence of the optical data of these metals on the direction of polarisation.

819. THE EXTERNAL PHOTOELECTRIC EFFECT WITH COMPOSITE PHOTOCATHODES AT LOW TEMPERATURES.—R. Suhrmann and D. Dempster. (*Physik. Zeitschr.*, 1st Dec. 1934, Vol. 35, No. 23, pp. 973–975.) *See* 487 of February.

820. PHOTOVOLTAIC AND PHOTOELECTRIC CELLS WITH BARRIER LAYERS [Barrier-Layer Theory Not of General Application to Photovoltaic Cells.]—G. Athanasiu. (*Comptes Rendus*, 26th Dec. 1934, Vol. 199, No. 26, pp. 1604–1607.)

821. A CONTRIBUTION TO THE THEORY OF BARRIER-LAYER CELLS [Explanation of Direction of Current Flow].—R. H. Varian. (*Phys. Review*, 15th Dec. 1934, Series 2, Vol. 46, No. 12, pp. 1051–1054.)

The writer finds that the theory of the photovoltaic effect developed by Frenkel and Joffé (*Physik. Zeitschr. der Sowietunion*, 1932, Vol. 1, p. 1: *see* also Abstracts, 1932, p. 290) is incomplete, giving no adequate explanation of the direction of flow of the current. He here takes into account the great difference in the rate of loss of velocity of a photoelectron in the semi-conductor and the metal, and finds that rapidly moving electrons tend to migrate into the metal, where they lose their energy and become trapped. The theory accounts for the experimental results of Schottky (1932, p. 232) and the failure of Nasledow and Nemenow (1933, p. 336) to produce a barrier-layer cell in which electrons flow from the metal to the semi-conductor.

822. Methods of Constructing Barrier-Layer Selenium Photocells.—V. Lepeshinskaia. (*Journ. of Tech. Phys.* [in Russian : *see* 913], No. 5, Vol. 4, 1934, pp. 1077–1085.)

A description of the methods evolved in the Central Radio Laboratory of Leningrad. Although this type of cell can be used at atmospheric pressure, nearly all stages of the manufacture are carried out in a vacuum. A description is given with sketches and photographs of the vacuum system used which enables vacua up to 10^{-5} mm to be obtained and continuously measured by a specially developed thermocouple gauge. The process of manufacture resolves itself into the following three main stages :—(1) Deposition of selenium on a thin iron disc, (2) heat treatment, and (3) covering of the selenium layer by a semi-transparent gold electrode.

Selenium powder is first melted at about 220°C and slowly cooled. When cold it is cut into small pieces and put into a glass beaker round which a 3 ohm heater wire is wound. The beaker is placed inside a glass cylinder which is about 20 cms higher, and the top of the cylinder is covered by an iron disc previously cleaned with glass paper sprinkled with selenium powder. The whole system is put inside the vacuum chamber, which is evacuated down to 10^{-4} mm. A heating current gradually rising to 1.2 amps. is then passed through the resistance. After 20 minutes the current is switched off and the disc is taken out when cold. It is then subjected to heat treatment during which selenium is reduced from the metalloid to the metallic state. It is essential to arrest the change at a certain intermediate stage, which in practice is achieved by keeping the disc at a temperature of 200°C for about 3 hours and then rapidly cooling it to a room temperature by removal from the oven. A thin layer of gold is then deposited over the selenium by cathode sputtering. This operation takes place in an atmosphere of argon previously purified by high tension discharges in a special vessel. The pressure during cathode sputtering is maintained at 0.1 mm. The voltage applied to the electrodes is 1 000 volts, and the current flowing is of the order of 5 milliamps. After two minutes of this operation the photocell is taken out and is then ready for testing.

Curves are added showing the variations of the photoelectric current and e.m.f., and of the cell resistance, due to changes in intensity of light, temperature and external load. It appears that the sensitivity is the same at different points of the surface and does not alter with time. The total sensitivity is of the order of 300 μA per lumen. In conclusion various uses for this type of photocell are indicated.

823. Designation of Photoelectric Devices [including Suggestion of " Photo-emf " for Barrier-Layer Type].—C. H. Sharp. (*Elec. Engineering*, December, 1934, Vol. 53, No. 12, p. 1682.)

824. Response of the Photronic [Barrier-Layer] Cell to Modulated Light Flux at Audio-Frequencies [and a Method of Measurement applicable to Other Types].—J. H. Roe. (*Review Scient. Instr.*, December, 1934, Vol. 5, No. 12, pp. 441–445.)

825. Initial Velocity of Electrons in the Spray Discharge [No Cathode Voltage Drop Required for Discharge of Electrons from Semi-Conductor with Very Thin Oxide Film].—H. Fricke. (*Zeitschr. f. Physik*, No. 11/12, Vol. 92, 1934, pp. 728–740.)

826. The Use of Selenium Barrier-Layer Photoelements for Measuring and Recording Very Intense Illumination [Sensitivity Variations and Inertia Effects reduced by Removal of Red and Infra-Red Components : Desirability of Reduction of Selenium Layer Thickness and of Action of Posterior Limiting Layer].—G. Liandrat. (*Comptes Rendus*, 10th Dec. 1934, Vol. 199, No. 24, pp. 1394–1395.) For relevant literature *see* 219 of January ; also 1934, pp. 448 (Bergmann), 331 (Mittmann) and 391 (Liandrat).

827. The Sensitivity of Light Counters [Dependence on Intensity and Wavelength : Comparison with Photoelements].—M. W. Karev and S. F. Rodionov. (*Zeitschr. f. Physik*, No. 9/10, Vol. 92, 1934, pp. 615–621.)

828. Photophysical Changes in Silver—Silver Chloride Systems [" Photo-Adaptation "]. —A. E. Cameron and A. M. Taylor. (*Journ. Opt. Soc. Am.*, December, 1934, Vol. 24, No. 12, pp. 316–330.)

MEASUREMENTS AND STANDARDS

829. On the Measurement of High and Ultra-High Frequency Currents.—B. A. Ostroumov. (*Izvestia Elektroprom. Slab. Toka*, July, 1934, No. 6, pp. 39–46.)

A survey is given of the present state of the technique of h.f. current measurement and of the difficulties which are met with. It is suggested that the following current ranges are the ones most likely to occur in practice : up to 0.3 amp. at 2×10^6 to 2×10^5 kc/s ; to 3.5 amps. at 3×10^5 to 3×10^4 kc/s ; and to 40 amps. at 10^4 to 10^3 kc/s.

It is considered that for the first range the most suitable instruments are those which use a vacuum thermocouple with a heating wire not thicker than 0.02 to 0.03 mm, so that the error due to skin effect does not exceed 1 to 2% even on the highest frequencies. A description is given of an instrument designed by the author on these lines. With regard to the second range, skin effect and the effect of frequency on calibration cannot be ignored, and it appears that no satisfactory instrument is available. The difficulty of using thermogalvanometers for currents above 5 amps. in the third range has led the author to develop the following method. A short length of a tubular conductor carrying the current is replaced by a thin tube of resistance metal which serves as a heating element and is protected from outside temperature variations by being enclosed in a glass bulb. A thermocouple system is mounted inside the tube and leads are taken out to a galvanometer through the earthed end of the conductor. If the conductor is not earthed a mirror galvanometer can be mounted inside a metal cylinder which forms part of the conductor, and the deflection of the galvanometer observed through an aperture in the cylinder. The heating element for the thermocouple system must of course be at the current antinode.

The main drawback of thermo-instruments is their inertia, and in order to obviate this, research is being made into the possibility of using aperiodic circuits inductively coupled to the h.f. conductors and employing copper oxide or some other type of rectifier in series with a galvanometer. It is suggested that when using these circuits on frequencies of the order of 10^5 kc/s they should be mounted inside the tubular conductors and only the coupling coil and rectifier taken out, at the current antinode. The galvanometer is in this case connected to the circuit through the earthed end of the conductor.

830. Measurement of Small Dielectric Losses at Commercial Supply Frequencies.—N. Bogoroditsky and V. Malishev. (*Journal of Tech. Phys.* [in Russian: *see* 913], No. 5, Vol. 4, 1934, pp. 963–972.)

The dielectric losses in a 1.5 mm thick quartz test tube, and in a 1 mm thick glass plate, were measured by the Schering bridge method using mercury electrodes. A detailed account is given of the technique of these measurements and of the effect of such factors as humidity, surface of the sample, proximity of other objects and configuration of the field. The phase angle was determined with an accuracy of 0.01%.

831. The Technique of the Measurement of Dielectric Constants.—A. Büchner. (*Zeitschr. f. tech. Phys.*, No. 1, Vol. 16, 1935, pp. 10–12.)

(1) In dielectric constant measurements by the heterodyning method it is necessary to measure the oscillation amplitude in the signal generator so as to know the magnitude of the dielectric losses and to separate out their effect on the dielectric constant. Usually special high-frequency instruments have to be employed for this purpose, but the writer simplifies the equipment by making the signal-generator valve function as its own meter by arranging that it acts as a rectifier so that the anode d.c. is a measure of the oscillation amplitude. Thus only a d.c. instrument is required. The sensitivity of the arrangement may be increased by compensation of the anode d.c. repose current.

(2) After discussing Starke's method of measuring the dielectric constant of a solid of any shape, by varying the proportions of a mixture of two liquids of differing dielectric constant until the immersion of the solid body produces no change in capacity, the writer points out its limitations and the consequent necessity in certain cases of the straightforward method using plates cut out from the material under investigation. In the past, such plates have been provided with electrodes covering part only of their surface. This fact upsets the accuracy of the method since the conditions for the Kirchhoff capacity formula are not fulfilled: not only do the lines of the uniform field (1st term of the formula) pass through the dielectric but also the stray lines (2nd term), which should pass through air only. The writer shows that this error is avoided if the coatings are extended right up to the edges of the plate, so that the Kirchhoff formula applies with a good accuracy. He uses plates of various shapes, with faces accurately parallel: the electrode coatings are of silver deposited from vapour in a vacuum.

832. Measurement of the Dielectric Constants of Aqueous Solutions of Electrolytes at High Frequencies.—M. Röver. (*Ann. der Physik*, Series 5, No. 3, Vol. 21, 1934, pp. 320–344.)

A description of practical work by the method given theoretically by Hellmann (1934 Abstracts, p. 450). The intensity of the standing wave in a Lecher-wire system is measured with a double-crystal detector. The wavelength used was 110 cm, produced by Schott valves of type *n* in a B.-K. circuit, and the precautions taken to secure constancy of output to 0.5% are described, with the construction of the Lecher-wire system. This was tuned by varying the height of the liquid surface. Sources of error discussed in § 6 include (*a*) intensity fluctuations at the emitter, (*b*) change of wavelength (*c*) inconstancy of the detector, (*d*) change of intensity by variation of resonance wavelength, (*e*) temperature changes, (*f*) surface effect, (*g*) influence of the wave reflected from the terminal impedance, (*h*) influence of the observer's position. § 7 describes the calibration of the apparatus and § 8 the results with solutions of HCl, $MgSO_4$, $CuSO_4$ (Tables 2, 3, 4). The results agree with the Debye-Falkenhagen theory within the limits of its validity and, for more concentrated solutions, with measurements of Hellmann and Zahn (*Ann. der Physik*, Series 4, Vol. 81, 1926, p. 711).

833. Decrement Investigations of Quartz Resonators [Removal of Surface Imperfections reduces Decrement to 5.4×10^{-6}].—K. S. Van Dyke and J. P. Hagen. (*Phys. Review*, 15th Nov. 1934, Series 2, Vol. 46, No. 10, p. 939.) Abstract only.

834. [Local Variations in] the Piezoelectric Properties of Quartz and Tourmaline.—G. W. Fox and G. A. Fink. (*Physics*, October, 1934, Vol. 5, No. 10, pp. 302–306.)

The converse piezoelectric effect was measured, using the amplifying lever already described (Abstracts, 1933, p. 463). Considerable variation in the "constant" was found in different samples; the variations with surface conditions and repeated application of the electric field are discussed. The motion of plates under resonance and static conditions may however be widely different.

835. The Reversibility of Piezoelectric Phenomena.—P. Bernard. (*Comptes Rendus*, 10th Dec. 1934, Vol. 199, No. 24, pp. 1388–1389.) Tests showing the reversibility, at compression and decompression, of the charges developed in quartz, even for very rapid variations (around 1 millisecond) and for pressures as high as 289 kg/cm².

836. THE VELOCITY OF PROPAGATION OF SOUND IN QUARTZ [and the Design of Quartz Plates for Very High Frequencies].—de Gramont and Béretzki. (*See* 786.)

837. WAVEMETERS AND THEIR ACCURACY IN THE SHORT-WAVE BAND.—A. Habermann. (*Funktech. Monatshefte*, October, 1934, No. 10, pp. 399–402.)

838. A STUDY OF AN ELECTRICALLY-MAINTAINED VIBRATING REED AND ITS APPLICATION TO THE DETERMINATION OF YOUNG'S MODULUS.—James and Davies. (*See* 784.)

839. A THERMIONIC-TUBE MEASURING INSTRUMENT [Universal Meter using Symmetrical Wunderlich Valve: for Direct Measurement of Current, Voltage, Power and Power Factor over Wide Frequency Range].—T. B. Wagner: Wunderlich. (*Elec. Engineering*, December, 1934, Vol. 53, No 12, pp. 1621–1623.) For the Wunderlich detector valve *see* 1932 Abstracts, p. 409.

840. HIGH-VOLTAGE VOLTMETER ON AN ELECTRON-OPTICAL BASIS [Image of Cathode indicates Accelerating Potential].—E. Fünfer. (*Physik. Zeitschr.*, 1st Dec. 1934, Vol. 35, No. 23, pp. 1006–1008.) *See* also 520 of February.

841. A PEAK VOLTMETER FOR LOW VOLTAGES [Useful Range of Diode Voltmeter extended downwards to 1–10 Volts by Modified Circuit].—C. R. Stoner and G. L. Grisdale. (*Journ. Scient. Instr.*, October, 1934, Vol. 11, No. 10, pp. 313–315.)

842. THE THEORY OF MOVING-COIL GALVANOMETERS [including the Importance of Air Damping in Certain Cases].—A. V. Hill. (*Journ. Scient. Instr.*, October, 1934, Vol. 11, No. 10, pp. 309–313.)

843. A NEW CAPACITY METER.—Cambridge Instrument Co. (*Journ. Scient. Instr.*, December, 1934, Vol. 11, No. 12, p. 403.) On the principle described by Beck, 1934 Abstracts, p. 49.

844. AN A.C.–D.C. CIRCUIT TESTER.—Ferranti, Ltd. (*Journ. Scient. Instr.*, October, 1934, Vol. 11, No. 10, pp. 329–330.)

845. PORTABLE FIELD-STRENGTH MEASURING EQUIPMENT [Type 476, for Wavelengths 14–2 000 Metres].—Marconi Company. (*Journ. Scient. Instr.*, October, 1934, Vol. 11, No. 10, pp. 330–331.)

846. FIELD STRENGTH MEASUREMENT [Simple Portable Equipment].—T. C. Macnamara. (*Wireless World*, 4th Jan. 1935, Vol. 36, pp. 6–9.)

847. ON THE LOW-LOSS MUTUAL INDUCTANCE STANDARD.—R. Yoneda and T. Matsuyama. (*Res. of the Electrotech. Lab.*, Tokyo, No. 368, 1934, 21 pp: in English.)

SUBSIDIARY APPARATUS AND MATERIALS

848. THE RATIO OF THE BLACKENING PRODUCED [in Records with a Cathode-Ray Oscillograph] BY SCREEN RECORDING AND EXTERNAL ELECTRON RECORDING.—E. W. Friesewinkel. (*Arch. f. Elektrot.*, 12th Dec. 1934, Vol. 28, No. 12, pp. 826–832.)

The cathode-ray oscillograph used was referred to in 528 of February. The records were made (1) on roll-film behind a znscu screen and (2) through a "Zellon" foil of thickness 16μ. Fig. 1 shows the construction of the screen and Fig. 2 sections of oscillograms (screen recording above, electron recording below). Fig. 3 gives curves of the degree of blackening produced at different voltages. Figs. 4 and 5 show micro-photographs of the blackening. Figs. 6–9 give curves of various functions of the blackening; the final conclusion reached is that screen recording is superior to electron recording for voltages below 55 kv.

849. TWO RECENT PUBLICATIONS [by von Ardenne] ON GEOMETRICAL ELECTRON-OPTICS [Criticism and Reply].—E. Brüche: M. von Ardenne. (*Zeitschr. f. Physik*, No. 11/12, Vol. 92, 1934, pp. 815–821, 822–826, 826–827, 827.)

See 1934 Abstracts, pp. 159 and 336. Brüche here claims that, in the first paper, it is not made clear that the magnetic lens and achromatic lenses described are not suitable for practical use; and that, in the second, the magnification formula given is based on very doubtful approximations. Von Ardenne replies with reference to, and emphasis on, the exact text of his papers.

850. CONTRIBUTION TO THE CONSTRUCTION OF CATHODE-RAY TUBES WITH HIGH VACUUM FOR TELEVISION AND MEASURING PURPOSES.—von Ardenne. (*See* 813.)

851. THE DISTURBANCES PRODUCED BY THE DEFLECTING FIELDS IN A CATHODE-RAY OSCILLOGRAPH.—Hudec. (*See* 814.)

852. THE [Four-Electrode] IMMERSION OBJECTIVE OF GEOMETRICAL ELECTRON OPTICS.—H. Johannson. (*Ann. der Physik*, Series 5, No. 3, Vol. 21, 1934, pp. 274–284.)

For a previous paper *see* 1934 Abstracts, p. 51. The objective now discussed has four electrodes and consists of three plane circular stops of practically the same diameter (the cathode is the fourth electrode). The smallest attainable focal length was 1 mm as compared with 1.3 mm with the three-electrode objective. These numbers are of the same order of magnitude as the stop diameters. The magnification can be altered in the ratio 1 : 3 by varying the voltages on the grid stops (those nearest the cathode), when the cathode/grid distance is small. The performance of the four-electrode objective could be 50% above that of the three-electrode objective of similar construction. *See* also 853.

853. REMARK ON THE ATTAINMENT OF HIGH RESOLVING POWER [1.5μ: Effect of Grain Size] WITH THE ELECTRON-OPTICAL IMMERSION OBJECTIVE.—E. Brüche and W. Knecht. (*Zeitschr. f. Physik*, No. 7/8, Vol. 92, 1934, pp. 462–466.) *See* also 1934 Abstracts, pp. 51 (Johannson) and 107 (Brüche and Johannson). Also 852, above.

854. CONTRIBUTION TO KNOWLEDGE OF THE ELECTRON-OPTICAL IMMERSION LENS [Principal Planes displaced towards Smaller Potentials].—E. Hess. (*Zeitschr. f. Physik*, No. 3/4, Vol. 92, 1934, pp. 274–282.)

A discussion of the paths of electron beams through an immersion lens, *i.e.*, an electron lens placed between regions of different refractive index. An electric immersion lens, formed by two round apertures in plates raised to different potentials, is investigated; the positions of its principal and focal points are determined experimentally. It is found, in agreement with general theoretical considerations, that the principal planes are displaced towards the side with smaller refractive index (*i.e.* potential).

855. FORMATION OF ELECTRON-OPTICAL IMAGES WITH ELECTRONS EMITTED PHOTOELECTRICALLY.—J. Pohl. (*Physik. Zeitschr.*, 1st Dec. 1934, Vol. 35, No. 23, pp. 1003–1005.)

See 529 of February. The arrangement of this magnetic electron microscope for the investigation of photocathodes is shown in Fig. 1. Light from a mercury-arc quartz lamp is focused on the cathode and a specific emission of 10^{-7} to 10^{-6} amp/cm² is obtained corresponding to 10^{-11} to 10^{-10} amp/cm² on the fluorescent screen for linear magnification 100. The electrons were accelerated with 30 kv. Figs. 2–7 show examples of the images obtained, with the optical image for comparison. Cathodes inlaid with various metals were used, to show the variation in emissivity with material. The method was also used with platinum, to show the influence of adsorbed gas and crystal structure on the geometrical distribution of emission of light and thermelectrons.

856. COMBINATIONS OF FIELDS FOR VELOCITY AND MASS SPECTROGRAPHY. III [Homogeneous Magnetic Field, Magnetic Doublet Field and Cylindrical Electric Field, Compensated Rays, Electron-Optical Prism: Theoretical Investigation of Optical Data of Systems].—W. Henneberg. (*Ann. der Physik*, Series 5, No. 4, Vol. 21, 1934, pp. 390–404.) For previous parts *see* 1934 Abstracts, p. 451.

857. A DOUBLE WAVE DEVICE FOR USE WITH A CATHODE-RAY OSCILLOGRAPH [Thyratron/Triode Combination working with Linear Time Base to give Simultaneous Observation of Two Wave Forms].—Davidson. (*Journ. Scient. Instr.*, November, 1934, Vol. 11, No. 11, pp. 359–361.) Sewig's method (1933 Abstracts, p. 339) has the disadvantage of showing only half-waves, whereas it is usually desirable to show one or more complete waves, as is accomplished by the writer's arrangement.

858. CATHODE-RAY TUBES AND THEIR APPLICATION.—Stinchfield. (*Elec. Engineering*, December, 1934, Vol. 53, No. 12, pp. 1608–1615.)

859. THE BULB OF MANY USES [Cathode-Ray Tubes and Applications].—(*Wireless World*, 4th, 11th and 18th Jan. 1935, Vol. 36, pp. 4–5, 32–34 and 55–56.)

860. THE CRATER-LAMP OSCILLOGRAPH [Magnetic starting within a Few Microseconds].—McMorris and others. (*Gen. Elec. Review*, November, 1934, Vol. 37, No. 11, pp. 514–516.)

861. A NEW OSCILLOGRAPH [with Light Single-Turn Coil without Torsional Control or Attached Leads].—E. S. Shire. (*Journ. Scient. Instr.*, December, 1934, Vol. 11, No. 12, pp. 379–384.)

862. INVESTIGATION OF FLUORESCENT MATERIALS FOR USE IN TELEVISION AND CATHODE-RAY OSCILLOGRAPHS.—Schnabel. (*See* 815.)

863. THE EFFICIENCY OF THE X-RAY FLUORESCENT SCREEN, MEASURED ABSOLUTELY.—Gaertner. (*Zeitschr. f. tech. Phys.*, No. 1, Vol. 16, 1935, pp. 9–10.)

864. THE USE OF LITHIUM FOR AN X-RAY WINDOW.—Clay. (*Journ. Scient. Instr.*, November, 1934, Vol. 11, No. 11, pp. 371–372.)

865. PURIFICATION OF INERT GAS WITH MISCHMETAL.—Van Voorhis, Shenstone and Pike. (*Review Scient. Instr.*, October, 1934, Vol. 5, No. 10, pp. 367–368.)

866. SIRUTOR, A NEW COPPER-OXIDE RECTIFIER [for R.F. Circuits in Broadcast Receivers].—(*E.T.Z.*, 20th Dec. 1934, Vol. 55, No. 51, pp. 1255–1256.) *See* also 1934 Abstracts, p. 562.

867. [New Selenium] DRY-PLATE RECTIFIER FOR BROADCAST RECEIVERS.—Maier. (*E.T.Z.*, 29th Nov. 1934, Vol. 55, No. 48, pp. 1171–1174.)

868. ELECTROLYTIC CONDENSERS.—N. Bogoroditsky, A. Ivanov, S. Kotousov and L. Nikitin. (*Izvestia Elektroprom. Slab. Toka*, July, 1934, No. 6, pp. 65–70.)

The theory of electrolytic condensers and their operation is discussed and an account given of an experimental investigation to determine the most suitable electrolytes both for forming the anodes and for the working conditions. Ten solutions of boric acid and sodium borate having p_H values from 4.9 to 9.7 were experimented with and it was found that the sparking potential is determined by the p_H value of the *working* electrolyte and that it decreases with the increase of this value. The capacity and leakage currents are practically independent of p_H. The leakage current is reduced by the addition of camphor, which also prevents creeping of the electrolyte. Alcoholic solutions and also solutions of phosphoric and molybdic acids were found to be inferior to solutions of boric acid and sodium borate.

869. STABILITY OF PERMANENT MAGNETS.—Zaimovsky and Oparkin. (*Journ. of Tech. Phys.* [in Russian: *see* 913], No. 5, Vol. 4, 1934, pp. 946–948.)

Seven different kinds of steel were experimented with and it was found that in each case structural stability is obtained by reducing the coercive force to 85%. This can be achieved by keeping the steel sample at a temperature of 150°C for one hour, or 100°C for 6 to 15 hours. The effects of vibration, blows, cyclic temperature variations, etc., on the magnetic properties were then investigated, and it is shown that the magnetic stability is greatly increased by a partial demagnetisation (to 85 or 90%) by means of an alternating magnetic field.

870. A New Magnetic Alloy with Very Large Coercive Force [Neodymium with 7% Iron].—V. Drožžina and R. Janus. (*Nature*, 5th Jan. 1935, Vol. 135, pp. 36–37.)

871. New Ceramic Insulating Materials for Condensers, with Very High Dielectric Constants ["Kerafar" and "Condensa," and Some Types of Condenser].—W. Soyck. (*Funktech. Monatshefte*, October, 1934, No. 10, pp. 397–399.)

872. Discussion of Papers on Various Types of Line Insulators [including the Subject of Radio Interference].—(*Elec. Engineering*, November, 1934, Vol. 53, No. 11, pp. 1531–1541.)

873. A "New" Source of Filament Current [Air-Depolariser Cell].—R. W. Hallows. (*Wireless World*, 16th Nov. 1934, Vol. 35, pp. 387–388.)

874. A New "Kipp" Choke for Automatic Cut-In and -Out of Battery-Charging Rectified Current.—Maier. (*E.T.Z.*, 18th Oct. 1934, Vol. 55, No. 42, pp. 1026–1029.)

Unlike the similar device described by Baudisch (1934 Abstracts, p. 281) this choke uses the rectified current to provide the magnetic bias of the choke in the a.c. circuit. It is being incorporated in selenium rectifier equipments.

875. An Automatically Regulated Precision High-Voltage Source [D.C. Voltages from 100 to 2 200 Volts, within 1%, from A.C. Mains between 95 and 165 Volts].—Schmitt. (*Review Scient. Instr.*, December, 1934, Vol. 5, No. 12, pp. 435–437.)

876. A New Type of High Tension Direct Current Supply System.—Walter and Sinelnikov. (*Journ. of Tech. Phys.* [in Russian: see 913], No. 5, Vol. 4, 1934, pp. 1073–1076.)

A description of a 600kv installation for supplying power to gas-discharge tubes and similar devices. The system is based on the voltage-multiplying rectifying circuit proposed by Greinacher and comprises two pairs of these circuits connected in series and fed from two separate alternators which are at a high potential above earth. The installation has proved very satisfactory in service.

877. Automatic Start-Stop Apparatus for Morse Circuits [Recorders controlled by Received Signals].—A. M. Humby. (*Marconi Review*, Sept./Oct. 1934, No. 50, pp. 6–7.)

878. Contactless Watching Devices [for Smooth Remote Control of Motors, etc.].—N. N. Ostrjakov. (*Izvestia Elektroprom. Slab. Toka*, July, 1934, No. 6, pp. 58–65.)

879. "Thyratron" Tubes in Relay Practice [Normal and High-Speed].—R. Wideröe. (*Elec. Engineering*, October, 1934, Vol. 53, No. 10, pp. 1347–1353.)

880. Improvement of Contact in Switches and Plugs by use of Springy Stop so that Moving Contact Recoils to Recently Wiped Surface.—Bainbridge-Bell. (*Journ. Scient. Instr.*, December, 1934, Vol. 11, No. 12, pp. 405–406.)

881. A Simple Method of Winding Self-Supporting Low-Loss Coils of Wire or Tubing.—Muldoon. (*QST*, December, 1934, Vol. 18, No. 12, pp. 41–42.)

882. Skin Effect in Layered Cylindrical Conductors.—Kruse and Zinke. (*See* 698.)

883. The [Calculation of the] Loss Resistance of High-Frequency Conductors.—H. Kaden. (*Arch. f. Elektrot.*, 12th Dec. 1934, Vol. 28, No. 12, pp. 818–825.)

This paper gives an approximate theoretical method, based on conformal representation, for taking into account the influence of the asymmetrical current distribution on the surface of high-frequency conductors. The method is applied to calculate the resistance of a conductor of elliptical or very flat cross-section, of a double lead (effect of proximity of the leads) and of a conductor over a parallel conducting plane.

884. Thermal Agitation Voltages in Resistors [Substantiation of Nyquist's Theory].—C. Neitzert. (*Physics*, October, 1934, Vol. 5, No. 10, pp. 292–296.)

For Nyquist's theory *see* Abstracts, 1928, p. 581. The practical results obtained here substantiate it for resistances up to 1.7×10^7 ohms and frequencies between 1 and 10^4 c/s. A value of 1.366×10^{-16} ergs/degree is found for Boltzmann's constant (*cf.* Ellis and Moullin, 1932, p. 588).

885. The Silvering of Mirror Surfaces by Cathode Sputtering.—M. Romanowa and others. (*Physik. Zeitschr. der Sowietunion*, No. 5, Vol. 5, 1934, pp. 746–760.)

886. A New Instrument for the Determination of the Number of Shorted Turns in Coils.—Vitenberg. (*Izvestia Elektroprom. Slab. Toka*, July, 1934, No. 6, pp. 46–50.)

887. A New Method of Ground Fault Protection [New High-Resistance "Thyrite" and New 3-Element Cold-Cathode Glow-Discharge Tube].—Starr. (*Elec. Engineering*, November, 1934, Vol. 53, No. 11, pp. 1472–1477.)

888. A Tube Counter as Detector for Radio-active Ores.—Shrum and Smith. (*See* 925.)

889. The Sensitivity of Light Counters.—Karev and Rodionov. (*See* 827.)

STATIONS, DESIGN AND OPERATION

890. Proposal for a Reconstruction of the German Broadcasting Network.—W. Hahnemann: Arendt. (*Hochf:tech. u. Elek:akus.*, December, 1934, Vol. 44, No. 6, pp. 203–209.)

Arendt here gives an account of, and some comments on, Hahnemann's paper read before the

German Broadcasting Council and specially invited guests, in which the plan referred to in 569 of February was outlined.

891. THE NEW BROADCASTING STATION "RADIO ZURICH."—(*Génie Civil*, 22nd Dec. 1934, Vol. 105, No. 25, pp. 584–585.)

892. REDIFFUSION [over Independent Line Network] AND TELEPROGRAMME [over Telephone Network] SYSTEMS.—Rendall and Van Mierlo. (*Elec. Communication*, October, 1934, Vol. 13, No. 2, pp. 174–184.)

893. MAGNETIC RECORDING IN [German] BROADCASTING.—H. J. von Braunmühl. (*Funktech. Monatshefte*, December, 1934, No. 12, pp. 483–486.)

894. A FREQUENCY RECORDER [applicable to the Monitoring of Radio Transmitters, etc.].—Martyn and Wood. (*See* 655.)

At the end of the paper the writer outlines two methods of using the recorder for this purpose, the second one having the advantage that the monitoring station does not require a number of stable-frequency master oscillators; a continuous record of the frequencies of all broadcasting stations within range, together with a single reference frequency, being obtained on one chart in a few seconds by the use of a selective superheterodyne receiver. Cocking's "single span" receiver (1934 Abstracts, p. 500) is suggested as specially suitable.

895. RADIO-TELEPHONE LINK FROM SCOTLAND TO IRELAND: NOTE FROM THE "TIMES." (*Nature*, 5th Jan. 1935, Vol. 135, p. 17.)

896. ADVANCES IN COMMERCIAL WIRELESS [in 1934].—Chetwode Crawley. (*Wireless World*, 28th Dec. 1934, Vol. 35, pp. 544–546.)

897. "SHORT-WAVE COMMUNICATION OVER DISTANCES OF 100–1 000 KILOMETRES": ERRATUM.—Kolesnikov. (*See* 657.)

GENERAL PHYSICAL ARTICLES

898. THE DYNAMICS OF NON-STATIONARY GAS DISCHARGES. I. [Electrodynamics of the Intermittent Glow Discharge and of the Counter Effect].—H. Gawehn. (*Ann. der Physik*, No. 6, Vol. 20, Series 5, 1934, pp. 601–634.)

899. ON THE PRODUCTION OF ELECTRONS AND POSITRONS BY A COLLISION OF TWO PARTICLES.—L. Landau and E. Lifshitz. (*Physik. Zeitschr. der Sowietunion*, No. 3, Vol. 6, 1934, pp. 244–257: in English.) "The cross-section of this effect is obtained; it increases with the cube of the logarithm of the energy of the colliding nuclei."

900. THE ELECTRON IN A HOMOGENEOUS MAGNETIC FIELD ON DIRAC'S THEORY [Theoretical Demonstration of Precession round Field Direction—Pressure in Electron Beam].—M. von Laue. (*Sitzungsber. der Preuss. Akad. der Wiss., Phys.-math. Kl.*, 14th June, 1934, No. 18, pp. 305–319.)

901. THE VACUUM IN DIRAC'S THEORY OF THE POSITIVE ELECTRON [Charge and Current Induced in Vacuum by Field: New Assumptions Necessary].—R. Peierls. (*Proc. Roy. Soc.*, Series A, 1st Sept. 1934, Vol. 146, No. 857, pp. 420–441.)

902. THE DETERMINATION OF h/m BY MEASUREMENTS OF VELOCITY AND WAVELENGTH OF CATHODE RAYS [$h/m_0 = 7.25 \pm 0.03$].—J. Gnan. (*Ann. der Physik*, No. 4, Vol. 20, Series 5, 1934, pp. 361–376.)

903. AN EXPERIMENT ON THE ELECTRODYNAMICS OF MOVING BODIES [Condenser Capacity independent of Position relative to Earth's Motion].—W. Bünger. (*Ann. der Physik*, No. 7, Vol. 20, Series 5, 1934, pp. 773–779.)

904. THE PELTIER AND THOMSON EFFECTS AND ENTROPY.—Liénard. (*Comptes Rendus*, 29th Oct. 1934, Vol. 199, No. 18, pp. 838–840.)

905. BROWNIAN MOVEMENT OF AN ELLIPSOID: DIELECTRIC DISPERSION FOR ELLIPSOIDAL MOLECULES.—F. Perrin. (*Journ. de Phys. et le Rad.*, October, 1934, Series 7, Vol. 5, No. 10, pp. 497–511.)

906. [Negligible] EFFECT OF X-RAYS ON THE DIELECTRIC CONSTANT OF VARIOUS LIQUIDS [at Room Temperature].—J. F. Payne, Jr. (*Phys. Review*, 15th Aug. 1934, Series 2, Vol. 46, No. 4, p. 340: abstract only.)

907. SURFACE CONDUCTIVITY OF METALS [Boundary Conditions give Distinction between Surface and Space Electrons].—A. W. Maue. (*Naturwiss.*, 21st Sept. 1934, Vol. 22, No. 38, p. 648.)

908. THE DETERMINATION OF THE DEGREE OF MOTION OF THE CONDUCTION ELECTRONS [Experiment measuring Torsion on Suspended Horizontal Coil during Transient Currents: Use of Superconductivity].—E. Patai. (*Physik. Zeitschr.*, 15th Oct. 1934, Vol. 35, No. 20, p. 837.)

909. THE ANODIC BEHAVIOUR OF THALLIUM IN THE HALOGEN HYDRIDES [Formation of Barrier Layer in Electrolytes].—O. Pip. (*Zeitschr. f. Physik*, No. 5/6, Vol. 91, 1934, pp. 329–335.)

910. X-RAY INVESTIGATIONS OF THIN NICKEL FILMS [Thickness and Optical Constants].—R. Riedmiller. (*Ann. der Physik*, No. 4, Vol. 20, Series 5, 1934, pp. 377–403.)

911. CHANGE IN RESISTANCE OF THIN METALLIC FILMS WHEN CHARGED [Effect of Charge on Number of Electrons].—A. Deubner. (*Ann. der Physik*, No. 5, Vol. 20, Series 5, 1934, pp. 449–462.)

912. THE NATURE OF THE BINDING FORCES IN METALS [Theoretical Investigation, including Formula for Work Function of Positive Metal Ions].—H. Bomke. (*Zeitschr. f. Physik*, No. 5/6, Vol. 91, 1934, pp. 400–409.)

MISCELLANEOUS

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916. "Broadcasting Abroad" [General Organisation, etc.], *and* "Present and Impending Applications to Education of Radio and Allied Arts" [Book Reviews].—Nat. Advisory Council on Radio in Education, New York. (*Proc. Inst. Rad. Eng.*, October, 1934, Vol. 22, No. 10, pp. 1225–1226 and 1226.)

917. "Handbuch der Funktechnik" [Book Review].—von Ardenne, Günther and others. (*Hochf:tech. u. Elek:akus.*, November, 1934, Vol. 44, No. 5, p. 180.)

918. "Radio Communication" [Review of Handbook].—O'Dea. (*Wireless World*, 4th Jan. 1935, Vol. 36, pp. 13–14.) *See* 645 of February.

919. "L'Onde Électrique": Editorial on Modifications to the Journal.—Besson. (*L'Onde Élec.*, October, 1934, Vol. 13, No. 154, pp. 381–385.)

920. "L'Excitation électrique des Tissus" [Book Review].—A. M. Monnier. (*L'Onde Élec.*, October, 1934, Vol. 13, No. 154, pp. 47–48A.)

921. D'Arsonval Currents diminish the Neuro-Muscular Excitability [Effect opposed to that of Heat: probably at base of Analgesic Action of High-Frequency Fields].—Delherm and Fischgold. (*Comptes Rendus*, 26th Dec. 1934, Vol. 199, No. 26, pp. 1688–1690.)

922. Valve Diathermy Apparatus [Output 240 w: 2.3–3.3 Mc/s Frequency Range: for Medical and Surgical Purposes].—Marconi Company. (*Journ. Scient. Instr.*, November, 1934, Vol. 11, No. 11, pp. 367–368.)

923. Rapid Determination of Moisture in Grain [including the Burton-Pitt "Dielectric" Type of Meter].—Cook, Hopkins and Geddes. (*Canadian Journ. of Res.*, Oct. and Nov. 1934, Vol. 11, Nos. 4 and 5, pp. 409–447 and 547–563.)

924. Geophysical Prospecting of Beds of Raw Material.—Angenheister. (*Zeitschr. f. tech. Phys.*, No. 11, Vol. 15, 1934, pp. 413–417.)

925. A Portable Geiger-Müller Tube Counter as a Detector for Radioactive Ores.—Shrum and Smith. (*Canadian Journ. of Res.*, November, 1934, Vol. 11, No. 5, pp. 652–657.) *Cf.* Curtiss, 1934 Abstracts, p. 395. The present instrument is thought to be probably 20 times as sensitive.

926. Testing of High-Speed Turbine Rotors for Vibration.—Below and Konstantinow. (*Journ. of Tech. Phys.* [in Russian: *see* 913], No. 4, Vol. 4, 1934, pp. 844–858.)

927. The Quantitative Measurement of Vibration [and the "Inductive" and "Maximal" (Contact) Accelerometers].—Sell and Turetschek. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 15, 1934, pp. 644–652.)

928. Bolometer Instrument for Indication of Thermal Disturbances of the Atmosphere [for Gliders, etc.].—Claus and Kohlitz. (*Zeitschr. f. tech. Phys.*, No. 1, Vol. 16, 1935, pp. 16–18.)

929. An Automatic Compensating and Recording Equipment for Varying Forces.—Jurriaanse and van Lammeren. (*Zeitschr. f. tech. Phys.*, No. 1, Vol. 16, 1935, pp. 18–19.)

The varying force acts at one end of a balance beam, to whose other end is attached one of two coaxial coils in series, the other coil being fixed. The varying force is countered by a suitable "compensating" current through these coils: this is provided by the anode current of triode L_1. This compensating current i_c is controlled by the grid potential, and thus by the potential of the condenser C. This potential is regulated by the bringing-up and taking away of quantities of electricity by the triodes L_3 and L_4, which are connected as cathode-ray tubes in such a way that their anode currents depend only on their heating currents. In L_3 this remains constant, but in L_4 the filament current is provided by the anode current of triode L_2, controlled by a photoelectric cell.

The balance carries near its fulcrum a mirror which controls the light falling on this photocell. At the zero position of the balance the photocell current is such that the emission of L_4 balances that of L_3, so that C remains at a constant potential and the compensating current i_c through the coils just balances the force. An increase in this force reduces the amount of photocell illuminated, decreases the L_2 anode current and therefore the emission current of L_4, charges the grid side of C to a higher positive potential and thus increases the anode current of L_1 which is the compensating current i_c. Thus the continuous restoration of equilibrium goes on, and the current i_c, which can be recorded, gives the value of the varying force at different instants.

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.

SELECTIVE RECEPTION

Application date, 1st February, 1933. *No.* 414382

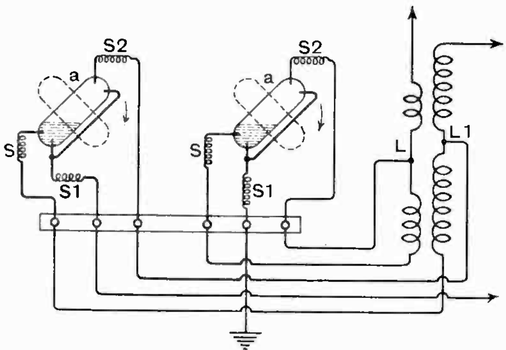
A highly-selective receiver for I.C.W. signals comprises a piezo-electric crystal tuned to the carrier wave so that its response at that frequency is considerably greater than its response to the side-band frequencies. The crystal is arranged in a bridge circuit, and the input is fed through a second circuit which is broadly tuned to a frequency differing from the carrier wave, and such that its response characteristic is opposite to that of the crystal for a side-band range. In this way the overall response of at least one of the side bands is kept uniform, so that reception is undistorted, whilst the selective response to the carrier remains unimpaired. Additional tone correction may be applied if necessary in the low-frequency stages.

Patent issued to J. Robinson and British Radiostat Corporation, Ltd.

WAVE-BAND SWITCHING

Application date, 16th February, 1933. *No.* 414441

To avoid mechanical drawbacks associated with the use of switches having rolling or sliding contacts, wave-band changes are effected by means of



No. 414441.

rotary or tilting mercury switches, which are suitably ganged together to bring the coils L, $L1$ into circuit. In the position shown in the drawing, the spring leads S, $S1$ are connected for long-wave reception. By rotating the switches *a* into the dotted-line position, the second terminal on each of the springs $S1$ is connected to the springs $S2$ to bring the lower sections only of the coils L, $L1$ into circuit, thus giving the short-wave setting.

Patent issued to A. T. Richter.

MAINS-DRIVEN SETS

Convention date (Germany), 9th May, 1933. *No.* 414627.

In the type of set which normally uses the mains as an aerial, but which is also fitted with terminals for an outside aerial, it is found that on the latter setting there is a tendency for "hum" to get through from the mains, and to cause interference. To avoid this a switch is provided which automatically earths the primary side of the mains-supply transformer as soon as the outside aerial is brought into circuit.

Patent issued to Telefunken Ges., Fur Drahtlose Telegraphie, m.b.h.

PIEZO-ELECTRIC OSCILLATORS

Application date, 13th February, 1933. *No.* 414764.

It is known that most crystal oscillators exhibit "privileged" modes of oscillation in addition to the fundamental frequency. In order to enhance the sharpness of the fundamental response the position of the nodal lines corresponding to that frequency is first determined by a lycopodium experiment, whilst the crystal is supported as freely as possible, and these nodal lines are then "loaded" either by bevelling the edges of the crystal, or by adding spongy rubber, paint, or other damping material. The crystal in operation is supported at selected sharp points chosen on these nodal lines, so that spurious modes of vibration are eliminated.

Patent issued to Standard Telephones and Cables, Ltd.

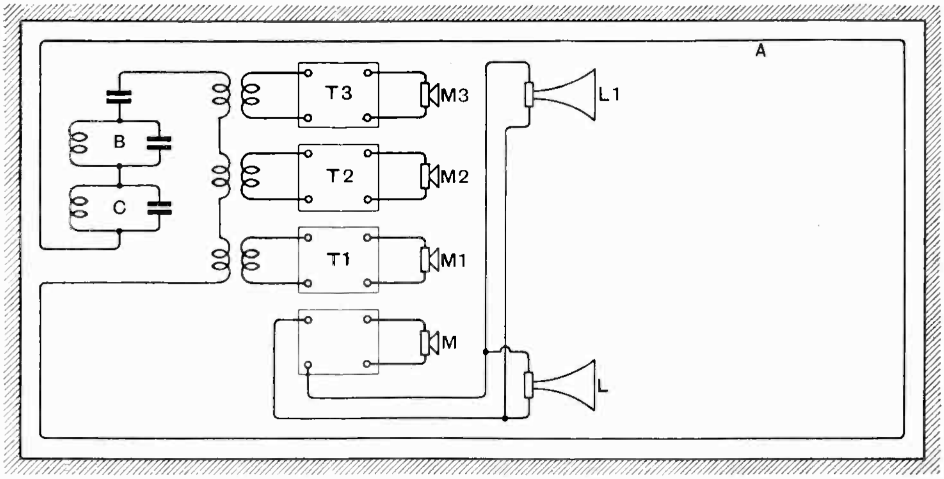
SHORT-RANGE SYSTEMS

Convention date (Switzerland), 7th July, 1933. *No.* 414560

Relates to a system for communicating to the various members of an International Conference the speech of a member either in the language he employs, or its translation in one or more other languages. The simplest case is that in which the address is written before being delivered so that whilst it is being read out directly, interpreters are simultaneously delivering the required translations. As shown, the Conference room is fitted with a loop aerial A tuned at B and C to radiate a number of different wavelengths. The speech is read directly to the microphone M and is reproduced through loud speakers L, $L1$.

At the same time different interpreters are speaking into microphones $M1$, $M2$, $M3$ associated with miniature transmitters $T1$, $T2$, $T3$ which feed the translations on different wavelengths into the radiating aerial *A*. Members desiring to hear the translations use portable receivers fitted with headphones—which also serve to block-out direct speech from the loud speakers *L*, *L*1. The radiated waves are picked up on a small loop aerial slung around the listener's shoulder.

Patent issued to Telefon Akt. L. M. Ericsson.

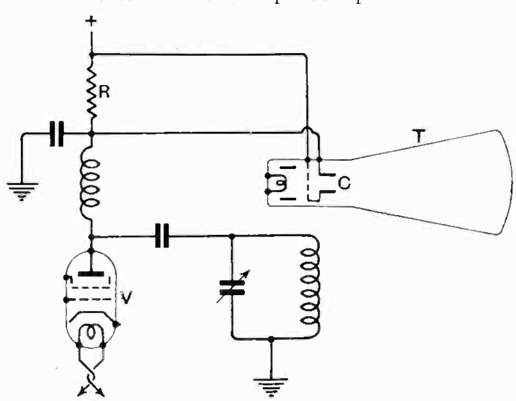


No. 414560.

VISUAL TUNING

Application date, 17th February, 1933.
No. 415101.

Covers the use of a cathode-ray tube to indicate the resonance point either in a "straight" receiver or in one fitted with A.V.C. As shown in the Figure, the visual indicator *T* is controlled by a resistance *R* inserted in the anode circuit of a valve *V* subject to A.V.C. The potential drop across the resistance *R* depends upon the A.V.C.



No. 415101.

bias applied to the grid of the valve *V*, and therefore upon the amplitude of the received carrier. This, in turn, determines the deflection imposed by the control electrodes *C* upon the path of the electron stream through the cathode-ray tube *T*. In the arrangement shown the spot of light on the fluorescent screen is at zero when no carrier wave is being received.

In a "straight" set using anode-bend detection the control resistance is inserted in the plate circuit of the detector valve, and the conditions are the same; but with power-grid detection the position of the spot of light is made zero when maximum plate current is flowing. The tuning indicator may be adapted to give a rising and falling "line of light" by replacing the usual control electrodes *C* by a grid of varying pitch, so that the number of electrons reaching the fluorescent screen varies with the applied voltage.

Patent issued to Standard Telephones and Cables, Ltd., and A. J. Young.

DIODE-TRIODE VALVES

Application date, 24th February, 1933.
No. 415441.

Relates to valves of the kind in which one or more auxiliary electrodes are mounted opposite the ends of a cathode (which is also common to a triode amplifier) and act as diode rectifiers. Since the ends of the cathode are usually cooler than the remainder, it is sometimes difficult to secure sufficient emission to operate the diode rectifier satisfactorily. According to the invention, the heating element, in the case of an indirectly heated valve, is wound with closer spirals at the end than in the middle. In the case of a directly heated valve the wire of the cathode is made thinner at the points opposite the auxiliary electrodes than elsewhere.

Patent issued to M.O. Valve Co., Ltd., and J. F. Jackson.

" HUM " ELIMINATORS

Application date, 20th June, 1933.
No. 415237.

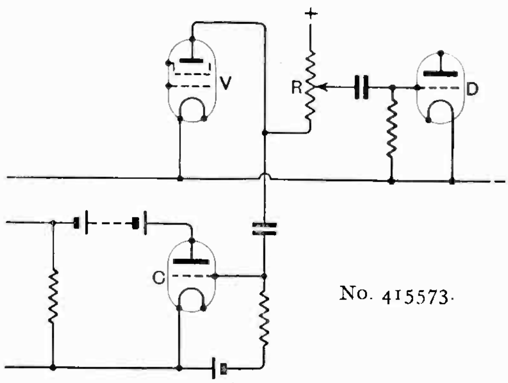
Low-frequency amplifiers of the kind in which the filaments are directly heated by A.C. from the mains are liable to give a high-pitched " hum " caused by the modulation of the electron stream by harmonic frequencies present in the supply. In order to eliminate this source of trouble the secondary of the transformer supplying the rectifier for the plate voltage is shunted by a series circuit, made resonant to the interfering frequency and serving to by-pass it away from the plate of the amplifier.

Patent issued to Siemens Bros. and Co., Ltd., and L. S. Crutch.

AUTOMATIC VOLUME CONTROL

Convention date (Germany), 28th September, 1932.
No. 415573.

For efficient A.V.C. it is desirable that the amplitude of the H.F. oscillations supplied to the control valve should be as large as possible, though this may result in overloading the detector valve. Accordingly, the last H.F. valve *V* is provided with a potentiometer coupling *R* so that only a part of the amplified H.F. carrier voltage is passed on to the receiver valve *D*, whilst the control valve *C* for producing amplified A.V.C. receives the full H.F. output.



No. 415573.

Patent issued to N. V. Philips' Gloeilampenfabrieken.

" THRESHOLD " A.V.C.

Convention date (U.S.A), 4th November, 1932.
No. 415598.

A single valve of the double-diode-triode type is used (a) as a direct-current amplifier for producing a control voltage sufficient to cut off the receiver output in the absence of signals below a predetermined threshold value, (b) as a detector, (c) as a low-frequency amplifier for the signal currents, and (d) as a source of rectified A.V.C. voltage.

Patent issued to Radio Frequency Laboratories, Inc.

ULTRA SHORT-WAVE VALVES

Convention date (Germany), 6th December, 1932. *No.* 415616.

Relates to valves suitable for generating or amplifying centimetre waves, the highly-positive grid electrode consisting of an open-ended spiral of wire set in an auxiliary magnetic field. According to the invention the spiral grid is so elongated that its " form factor," regarded as a radiating or receiving aerial, is smaller than unity. This form of spiral grid is stated to permit the generation of waves considerably shorter than the length of wire used in the spiral circuit. Also if the radius of the spiral is made small enough to verge upon the cathode space charge, the latter serves to lower the internal capacity of the winding and so brings about a further shortening of the effective wavelength.

Patent issued to J. Pintsch Akt.

RENEWING FILAMENTS

Application date, 28th February, 1933.
No. 415709

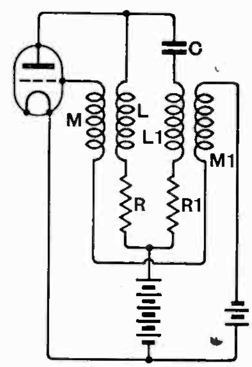
To allow the heating filament of an electron-discharge tube to be replaced, in the event of a burn-out, a number of spares are carried on a member which is capable of being rotated, relatively to the associated electrodes. The carrier member inside the bulb is geared to a spindle, which passes through a fluid-sealed joint in the wall of the tube and is operated by an external knob.

Patent issued to F. E. Bancroft and Associated Electrical Industries, Ltd.

CONSTANT-FREQUENCY GENERATORS

Application date, 28th February, 1933. *No.* 415716

The frequency of a back-coupled valve oscillator depends at least to some extent upon the relative phases of the grid and anode potentials. To prevent fluctuation in the generated frequency these potentials should be in phase-opposition. As shown in the Figure, this result is ensured by splitting the anode circuit into two parallel branches, one consisting of an inductance *L* and resistance *R*, and the other of a capacity *C* in series with an inductance L_1 and resistance R_1. The network as a whole is tuned to the working frequency and the resistances are adjusted so that each branch has the same power factor and induces the same voltage into each of the series grid-coils *M*, M_1. The feed-back voltage is then in exact antiphase with the alternating anode voltage.



No. 415716.

Patent issued to Marconi's Wireless Telegraph Co., Ltd., and E. B. Moullin.

H.F. CONDENSERS

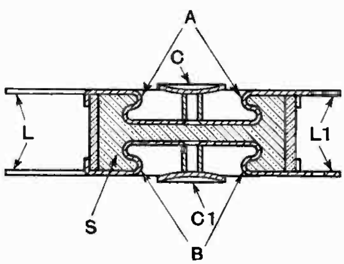
Application date, 28th February, 1933. No. 415745

A condenser for use in H.F. circuits is designed to have a constant reactance in spite of temperature changes under working conditions. The plates are made of "Invar" alloy, electrolytically coated with copper. Owing to the skin effect, the combination possesses the same effective resistance at radio frequencies as solid copper; whilst the thin copper coating, though subject to small mechanical stresses, produces no overall change in dimension under temperature variations.

Patent issued to Marconi's Wireless Telegraph Co., Ltd., and E. B. Moullin.

Convention date (U.S.A.), 3rd February, 1932. No. 415751

It has been observed that under working conditions the fixed condensers used in ultra short-wave transmitters are subjected to considerable vibration, which, in turn gives rise to undesirable fluctuation



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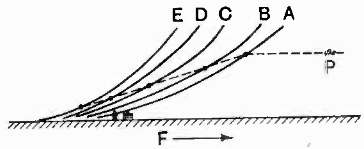
or modulation of the carrier wave. To avoid this the plates are so formed that they are in direct contact throughout with the dielectric, which is applied in liquid form, and, when set, binds the assembly firmly together. The plates *A*, *B* are curved at the ends as shown to provide a re-entrant recess for the dielectric *S*. Springy contact members *C*, *C*1 are connected at the centre of each plate and fixing-lugs *L*, *L*1 at each end.

Patent issued to Dubilier Condenser Co. (1925), Ltd.

AIRCRAFT NAVIGATION

Convention date (Germany), 29th November, 1932. No. 415784

To allow an aeroplane to land safely under conditions of low visibility a "bundle" of short-wave beams *A*——*E* are radiated so as to have curves of different intensity. The aeroplane *P* is fitted with a receiving set, the sensitivity of which is continually varied in a pre-determined manner by means of a resistance controlled by clockwork. As the aviator reaches the first beam *A* he switches the sensitivity-control into operation, and then flies down a curve of apparently constant field-strength, though in fact he intersects successive beams in the manner indicated in dotted lines. One advantage of the system over the use of the ordinary single landing-beam is that it allows the landing-curve to be varied according to the type of craft in action; another is that it provides a



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flatter "entry" for craft approaching the aerodrome at a considerable height.

Patent issued to C. Lorenz Akt.

Convention date (Germany), 17th January, 1933. No. 416246

To enable the pilot of an aeroplane to make a "blind" landing, say in foggy weather, two short-wave transmitters are located at the aerodrome, one radiating a concave field, relatively to the ground, whilst the other radiates a convex field, each transmitter being modulated with a characteristic note of different frequency. The aeroplane carries a receiver with a doubly-tuned input, and separate filter bands for the two modulation notes. The pilot flies along the track marked out in space by the locus of the points at which the ratio of the two field strengths have a predetermined value. This eliminates any error which may arise from fluctuations in the sensitivity of the receiver due to the battery, valves, or other components.

Patent issued to Telefunken Ges. für drahtlose Telegraphie m.b.h.

WAVE-BAND SWITCHING

Application date, 29th April, 1933. No. 415856

In order to reduce the mutual inductance between the medium wave-band coils in a pre-selector circuit, one of the long-wave coupling-coils is inserted between two of the medium coils. As it is short-circuited on the medium-wave setting, the long-wave coil serves as a screen between the shorter coils, and therefore allows the latter to be made of larger dimensions than is usually possible in the restricted space available. At the same time the long-wave coil serves its normal purpose on the long-wave setting.

Patent issued to E. K. Cole, Ltd., and G. Bradfield.

Convention date (Holland), 29th April, 1933. No. 415962

When changing-over say from medium to short-wave reception the overall sensitiveness of the set may tend to fall off. To offset this the wave-band switch is ganged to a network of biasing-resistances so that the effective potential on the grid is automatically reduced on the shorter waves. The resulting increase in the amplification factor of the valve raises the level of sensitivity. In some cases the ganged resistances are so arranged as to reduce sensitivity on the shorter wave-band.

Patent issued to N. V. Philips Gloeilampenfabrieken.

CATHODE-RAY TUBES

Application date, 4th March, 1933. No. 416043

The cathode consists of a disc of 5 mil nickel, coated with electron-emitting material, and spot-welded to the top of a looped heating filament of tungsten or molybdenum. The limbs of the filament pass through parallel holes in a steatite insulator, which is held by a tight-fitting metal collar to a rigid supporting member.

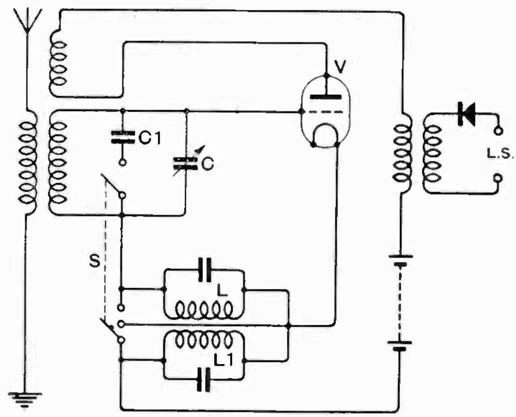
Patent issued to British Thomson-Houston Co., Ltd., and J. A. V. Fairbrother.

TUNING ARRANGEMENTS

Application date, 7th February, 1933. No. 416047

Relates to receivers provided with a " stand-by " switch for setting the circuits into a condition of high sensitivity but comparatively low selectivity. On the " tune " side of the switch the circuits are set to a condition of high selectivity. According to the invention, the change-over switch automatically brings into circuit an auxiliary tuning reactance, which compensates for the change in tuning conditions and so allows the operator to " keep touch " with the distant signal picked up on " stand-by."

As shown in the Figure, the valve *V*, when on stand-by, operates as a super-regenerator of high sensitivity, the coils *L*, *L*1 forming the quenching circuit. When a distant station is heard the switch *S* is thrown over, so as to short-circuit both of the quenching coils, thus converting the circuit into a " straight " high-frequency amplifier of high selectivity. Simultaneously a second condenser *C*1 is inserted in parallel with the ordinary tuning condenser *C*, and is of such value as to offset the change in tuning caused by altering the type of circuit. The compensating capacity *C*1 may be inserted in series with the main tuning condenser *C*; or, alternatively, a resistance is switched into circuit and effects the required compensation by altering the effective potential on the plate of the valve *V*.



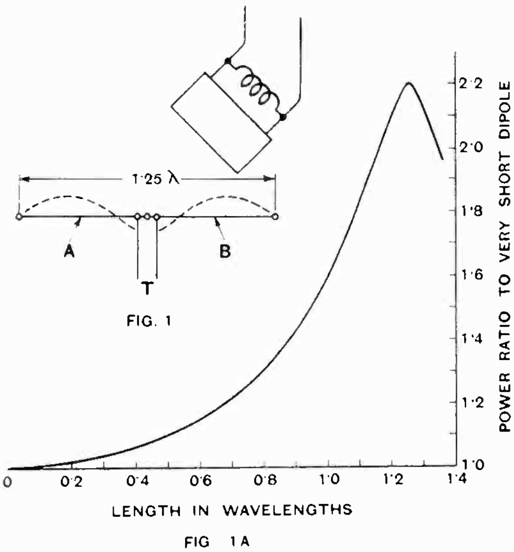
No. 416047.

Patent issued to Marconi's Wireless Telegraph Co., Ltd., and A. A. Linsell.

DIPOLE AERIALS

Convention date (U.S.A.), 10th May, 1933. No. 416296

A pair of dipole aerials *A*, *B* are given an overall length of 1.25 the working wavelength, instead of the usual half wavelength. H.F. energy is supplied to the system through a two-wire transmission line *T* across a central insulator, the current distribution over the two halves being shown in dotted lines.



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The arrangement is capable of radiating a given amount of energy from an input substantially less than that normally required. Fig. 1A is a curve showing the maximum radiation, in a direction at right-angles to the dipole, as the length of the latter is varied from zero upwards. The maximum output is reached when the aerial length is 1.25λ, though good results are indicated within a margin of ten per cent. of this optimum value.

Patent issued to Marconi's Wireless Telegraph Co., Ltd.

TELEVISION SCANNING

Convention date (Germany), 27th June, 1933. No. 416286

Scanning is effected by passing modulated rays of light from a neon lamp through a built-up prism of tourmaline crystals. Each crystal is cut so that the applied electric field from a saw-toothed oscillator is at right-angles to the optical axis. Owing to the effect of the control voltage on the refractive index of the crystal, the incident ray of light from the lamp is swung up and down the viewing screen. A mirror wheel is interposed to spread the lines laterally over the screen.

Patent issued to Suddeutsche Telefon-Apparate, Kabel, und Drahtwerke Akt. " Tekade."