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WIRELESS ENGINEER

The Journal of Radio Research & Progress

Vol. XX JANUARY 1943 No. 232

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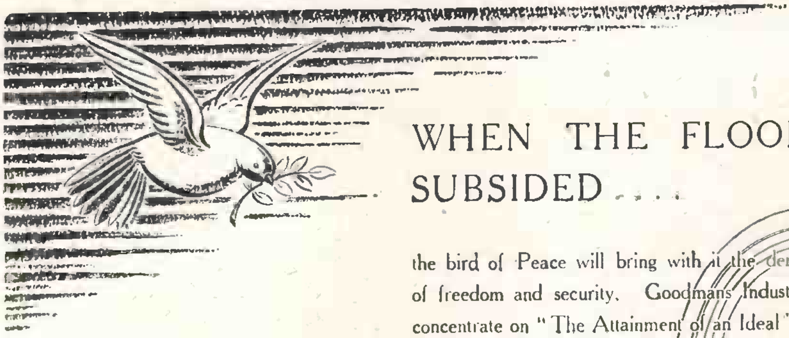

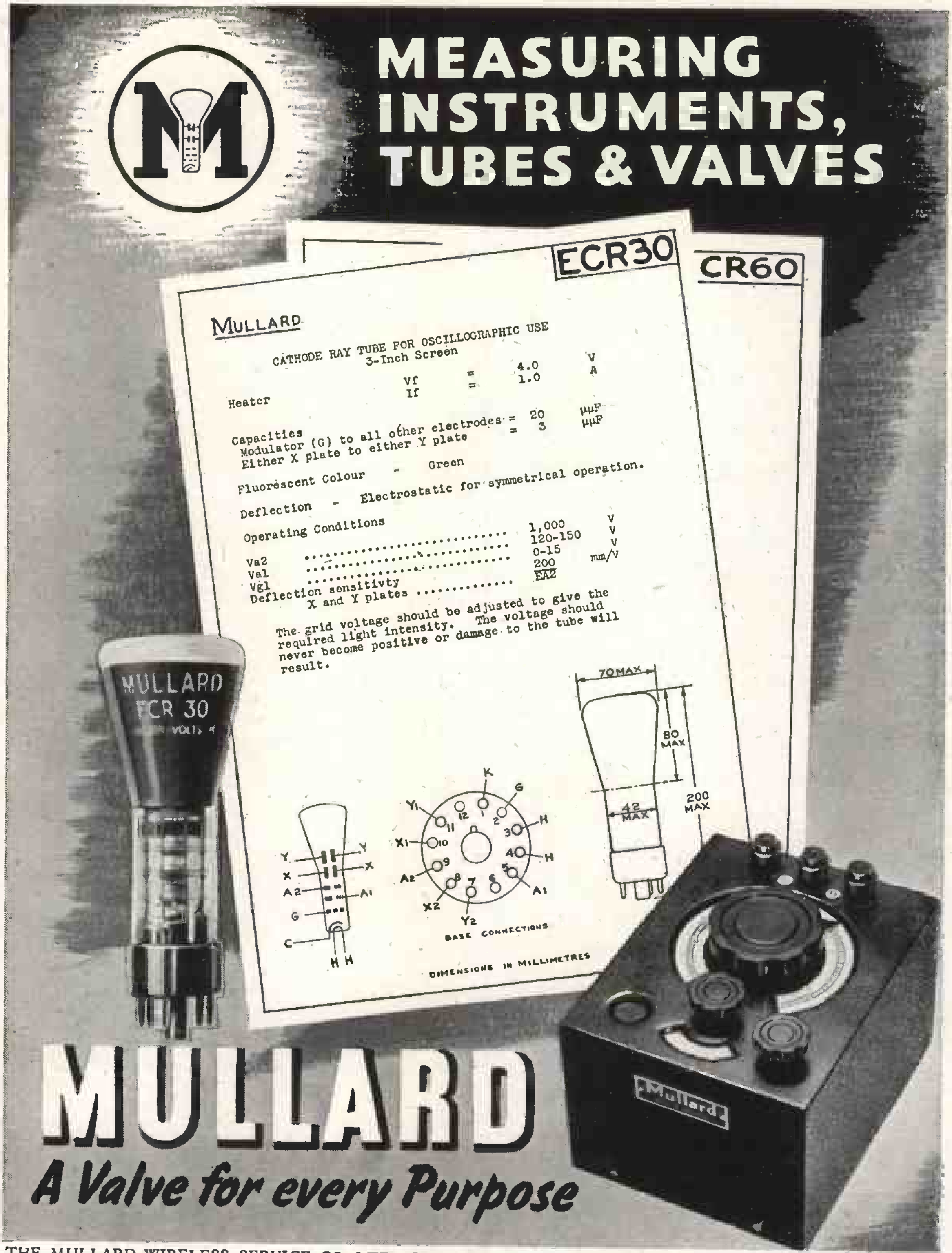

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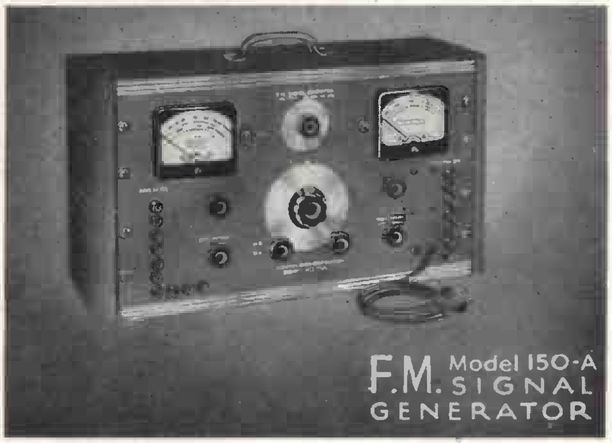

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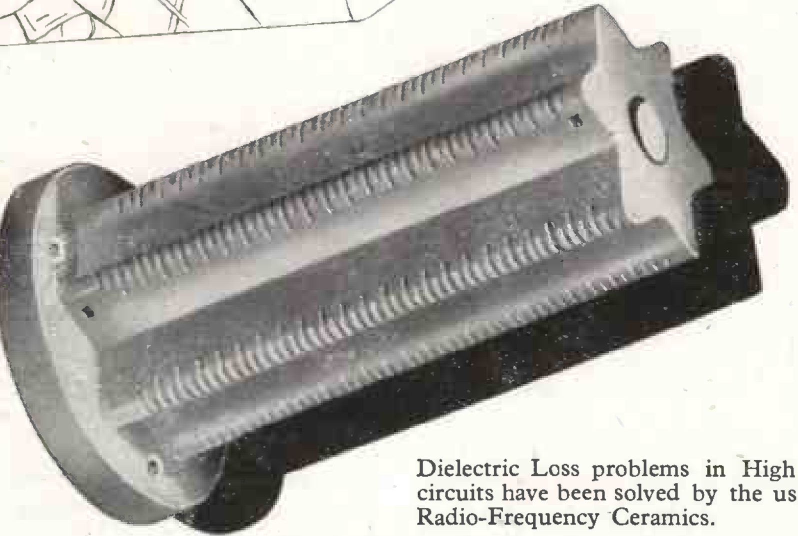

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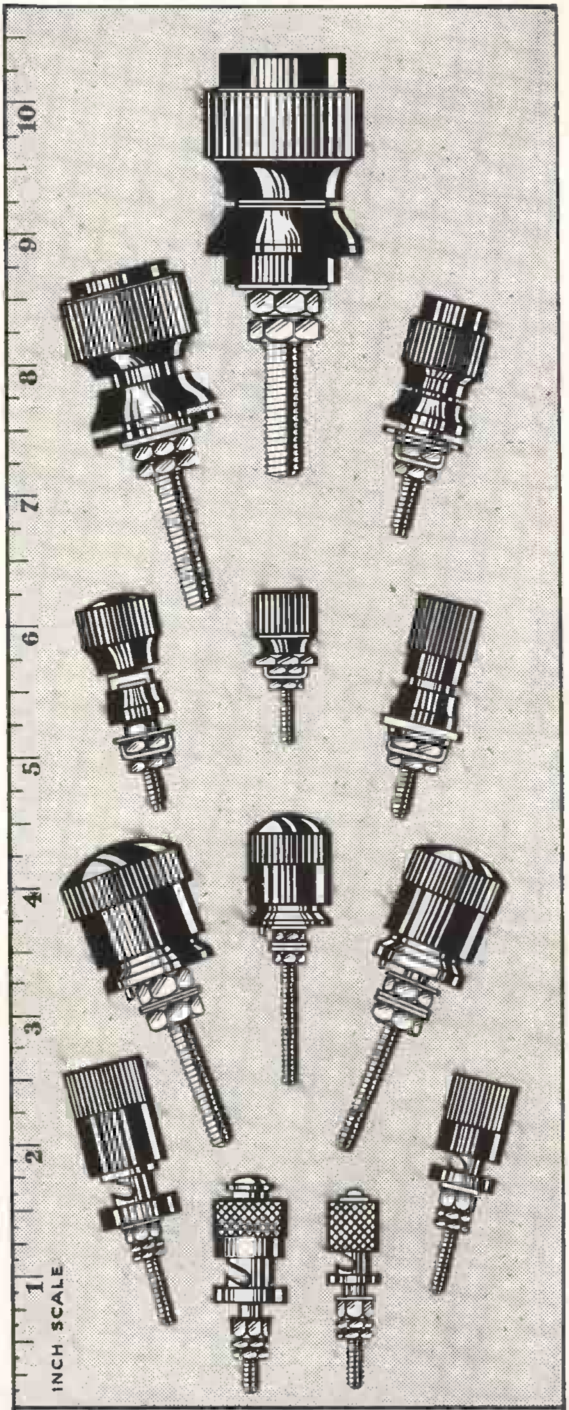
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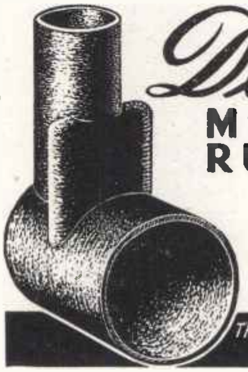

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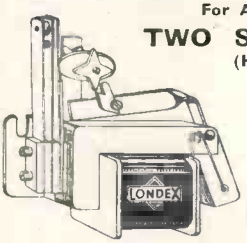
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WIRELESS
ENGINEER

Editor HUGH S. POCOCK, M.I.E.E. Technical Editor Prof. G. W. O. HOWE, D.Sc., M.I.E.E.

VOL. XX JANUARY, 1943 NO. 232

Editorial

On the Dimensions of Physical Quantities

IN the Editorial of September, 1941, we discussed two papers on this subject that had recently appeared in the *Proceedings of the Physical Society*, one by Burniston Brown and the other by Duncanson. There has since been a regular outpouring of papers on the subject, references to which are given at the end of this article. We shall confine our attention to the electromagnetic aspect of the subject, and shall therefore not discuss the paper by Benham[3] which deals exclusively with the vexed question of the dimensions of temperature. Yarnold[1] proves that the force on a unit pole in various media depends on H and not on B. Norman Campbell's contribution[10] is a brief note dealing with the importance of stating the end in view; he says " if all writers would state explicitly what end they have in view, and how that end is served by the considerations they present, their writings would become much more intelligible." He also says, " it is notorious that almost every proposition about dimensions asserted by one writer, has been denied by a writer of equal competence "; which reminds us of a typical remark of O'Rahilly that " the more bombshells the dimensionalists hurl at one another's pronouncements the sooner we may expect a return to sanity and reality ".

The short paper by Brown[5] is a reply to certain criticisms of his Physical Society paper by Prof. Wilson[2]; it contains a statement which with slight variations forms the text of several of the papers, notably those of Wilson and Dingle, viz., that " few physicists seem to realise that *the procedure that defines the unit defines the dimensions* ".

Permeability and Magnetic Constant

There is one point that is continually cropping up, but which can be disposed of at once. One can define μ as the ratio of the magnetic induction in a medium to that in a vacuum for the same magnetising force, in which case it is obviously dimensionless, or one can define it as the ratio of B to H, or by means of the equation $F = m_1m_2/\mu r^2$, in which cases its dimensions are a matter for discussion. The question is not really affected by writing $F = \frac{b}{\mu} \cdot \frac{m_1m_2}{r^2}$ as Yarnold advocates, and maintaining that μ is dimensionless but b is not. The same is true of the electrical formula which he prefers to write $F = \frac{a}{\kappa} \cdot \frac{q_1q_2}{r^2}$, maintaining that κ is a dimensionless ratio, but that the constant a may have dimensions. When one is discussing the dimensions of μ and κ, one is obviously not using them in the non-dimensional sense, but in the sense of μ/b or κ/a in the above forms of the equations. Guggenheim[6] makes the very reasonable suggestion that the ambiguity should be abolished by adopting different names for the purely numerical ratio and for the physical quantity. In the magnetic case he suggests retaining the name *permeability* for the physical quantity B/H, but referring to the numerical ratio of the permeability of any medium to that of empty space as the *magnetic constant of the medium*. The latter he would represent by the symbol μ, which would therefore be dimensionless. Similarly in the electric case, he recommends that the numerical ratio of the *permittivity of a medium* to that of empty space be designated the *dielectric constant* of the medium and represented by the symbol ϵ. This latter procedure is generally followed by electrical engineers, except for some difference of opinion about the symbol, but the magnetic suggestion runs counter to deeply ingrained usage. On p. 35 of his *Electromagnetics*, O'Rahilly calls b in the above formulae, the magnetic constant, μ the permeability, a the electric constant, and κ the dielectric constant. Guggenheim's proposals are much more suitable for general use.

Can one Multiply a Foot by a Pound?

This paper by Guggenheim is the most constructive of all the papers on the subject that have recently appeared, although we doubt the soundness of his argument that "it is perfectly legitimate to multiply together any two physical entities, such as a length and a force". He says, "If the reader naïvely asks: 'What, then, is the product of a foot and a pound?' I reply a 'foot-pound.' In case he suggests that this reply is unsatisfactory, I would point out that when a quarter is multiplied by three the product is 'three-quarters,' and when π is multiplied by $\sqrt{3}$ the product is $\sqrt{3}\pi$, and no simpler answer is possible". We suggest that a much more satisfactory answer is possible, viz., that although you can multiply a *number* (of feet) by a *number* (of pounds) you cannot multiply a foot by a pound unless you use the word "multiply" in a special and entirely different sense. The *product* of hydrogen and oxygen and a spark is water, and the *product* of a foot and a pound is a foot-pound; this analogy is not so far-fetched as it may appear, for the foot-pound is something entirely different from either the foot or the pound and not a multiplication of either.

The Franklin. A New Unit

Another suggestion made by Guggenheim is that a name should be given to the unit of charge in the c.g.s. electrostatic system, and he proposes to call it a *franklin*. For a vacuum he writes for the attractive force

$$f = -\frac{q_1 q_2}{ar^2}\text{ dynes}$$

where q_1 and q_2 are in franklins and r in cms. The value of the universal constant a is then $1\,\dfrac{\text{franklin}^2}{\text{erg cm.}}$. For any other medium $f = -\dfrac{q_1 q_2}{\epsilon a r^2}$ where ϵa is the permittivity of the medium and ϵ its dimensionless dielectric constant.

If now the two charges move parallel to each other with a velocity v at right angles to the line joining them, the distance between them being r, the force in a vacuum becomes

$$f = -\frac{q_1 q_2}{ar^2}\left(1 - \frac{v^2}{c^2}\right)\text{ dynes}$$

where c is another universal constant viz., the speed of propagation of electromagnetic effects in empty space. Although Guggenheim does not discuss the point, it is probably advisable to let the two charges move in circles, as this avoids any awkward question about the standard of reference from which the velocity v is measured, and, moreover, represents a practical experiment. If, instead of two charges moving with the velocity v, we have two current elements, the second term, which represents the magnetic attraction, becomes

$$f = \frac{i_1 ds_1\, i^2\, ds_2}{ac^2 r^2}$$

This is for empty space; in any other medium we have

$$f = \frac{\mu i_1 ds_1\, i_2 ds_2}{ac^2 r^2}$$

where $\dfrac{1}{ac^2}$ is the permeability of empty space, $\dfrac{\mu}{ac^2}$ that of the medium, and μ the dimensionless magnetic constant of the medium. The product of the permeability and permittivity of empty space is thus $1/c^2$ and that of any other medium $\epsilon\mu/c^2$ or n^2/c^2 where n is the refractive index and c/n

the velocity of light in the medium. Guggenheim says, " If is, therefore, important not to omit from any formula the symbol for any physical quantity merely on the grounds that in some particular unit its measure is one," or, as Rücker put it fifty years ago, putting $\kappa = 1$ in the equation $f = \frac{q_1 q_2}{\kappa r^2}$ does not do away with its dimensions, although it makes it easy to forget them. Guggenheim discusses the number of fundamental quantities having independent dimensions, and expresses the opinion that it is, to some extent, a matter of choice. He concludes with the strange and challenging statement that, if in the same problem " two authors make a different choice, the one choosing the greater number is likely to be the more competent physicist ".

Dimensions Depend upon Definitions

Wilson's paper[2] is a general discussion of the subject on classical lines, but he shows that all sorts of queer dimensions can be obtained for physical quantities by adopting suitably queer definitions and by suppressing the dimensions of one or more of the quantities involved.

Dingle[4] lays down a number of definitions and postulates which, in his opinion, should be observed in discussing the dimensions of any physical quantity. The principal point that he stresses is that dimensions are characteristic of magnitudes which are the results of measurements of physical quantities by strictly specified processes ; they are not characteristic of the physical quantities themselves. This point of view had, of course, been emphasised by several writers. Duncanson said " If there is any doubt concerning the dimensions of a quantity, this means, not that there is some hidden mystery as to the complete nature of that quantity, but merely that the quantity concerned had not been unambiguously defined ". One of Dingle's postulates is that the number of fundamental magnitudes is arbitrary. This is now generally agreed ; the days when L, M, and T were regarded as a sacrosanct trio are past. To illustrate that the dimensions depend on the definitions and processes rather than on the physical quantities Dingle follows a *reductio ad absurdum* procedure by adopting very unusual definitions and then, by suppressing the dimensions of some of the quantities involved, obtaining very strange dimensions. Unfortunataly, however, he assumes that the intensity of the magnetic field H at the centre of a coil carrying a given current is proportional to μ, and he uses this to determine the dimensions of μ. H is, of course, independent of μ, and it is therefore not surprising that he obtains some strange results. Lest any reader should doubt that the Professor of Physics at the Imperial College could possibly make such an assumption, we quote the actual words. " We find by experiment that a magnetic field exists at the centre of a circular coil carrying a current. We define the current as the charge passing any point of the circuit in unit time, and we measure it by indirect processes which are equivalent to measuring charge and time. We can also measure r, the radius of the coil, and H, the field created at the centre, and we find by experiment the relation $H = \frac{\mu q}{rt}$ where μ is constant . . . Now μ, defined in this way, is equivalent to permeability." To remove any doubt he also refers to H as " the intensity of the magnetic field ".

The second paper by Wilson[7] is mainly devoted to a criticism of Dingle ; he points out the error to which we have just referred, but which Dingle in his reply[9] does not appear to explain or rectify.

Perhaps the discussion contained in these papers can best be summed up by one of Dingle's concluding sentences viz., that " We do not observe electric charges or magnetic poles or electromagnetic fields ; we simply observe that bodies move in peculiar ways. Consequently all electrical and magnetic magnitudes must be expressible in terms of the magnitudes which serve to describe motion, *i.e.*, mechanical magnitudes. We need not, of course, so express them unless we wish. We can make new fundamental magnitudes for them, as we should do, for example, if we measured charge as a multiple of the electronic charge ".

G. W. O. H.

REFERENCES

[1] G. D. Yarnold. " Note on Electric and Magnetic Dimensions." *Proc. Phys. Soc.*, Vol. 54, p. 46, Jan., 1942.

[2] W. Wilson. " Dimensions of Physical Quantities." *Phil. Mag.*, Vol. 33, p. 26, Jan., 1942.

[3] W. E. Benham. "The Nature of Temperature." *Proc. Phys. Soc.*, Vol. 54, p. 121, Mar., 1942.

[4] H. Dingle. "On the Dimensions of Physical Magnitudes." *Phil. Mag.*, Vol. 33, p. 321, May, 1942.

[5] G. B. Brown. "A Note on Prof. Wilson's Paper." *ibid.* p. 367.

[6] E. A. Guggenheim. "Units and Dimensions," *ibid.* p. 479, July, 1942.

[7] W. Wilson. "Dimensions," *ibid.* p. 631, Aug., 1942.

[8] E. W. H. Selwyn. "The Dimensions of Physical Quantities." *Proc. Phys. Soc.*, Vol. 54, p. 428, Sept., 1942.

[9] H. Dingle. "On the Dimensions of Physical Magnitudes." *Phil. Mag.*, Vol. 33, p. 692, Sept., 1942.

[10] N. Campbell. "Dimensions and the Facts of Measurement." *ibid.* p. 761, Oct., 1942.

[11] W. Wilson. "Note on Dimensions," *ibid.* p. 842, Nov., 1942.

[12] W. E. Duncanson. "Note on some Recent Papers on Physical Quantities and their Dimensions." *Proc. Phys. Soc.*, Vol. 54, p. 504, Nov., 1942.

Erratum and Addendum

IN the Editorial entitled "Current Distribution Along a Straight Wire in a Uniform Field," in our November issue, a minus sign was omitted from the right-hand side of equation (3), which should be as follows :—

$$\frac{\partial^2 i}{\partial x^2} - CL\frac{\partial^2 i}{\partial t^2} = -C\frac{\partial e}{\partial t}$$

in which we have also put e instead of E for the instantaneous value of the induced e.m.f. A correspondent (Major E. W. B. Gill) has pointed out that in the simple case of the open-ended wire considered in the Editorial, equation (13) can be obtained in a much more straightforward manner than that adopted in the article, which was of wider application and was reproduced with some simplifications from the paper by Alford to which reference was made.

Putting $e = \hat{e}\cos\omega t$ and

$$i = \hat{e}\sin(\omega t - \phi)f(x)$$

in the above equation, we obtain $\phi = 0$ and $f''(x) + \frac{\omega^2}{c^2}f(x) = \omega C$ where $LC = \frac{1}{c^2}$

Putting $f(x) = A\sin(\frac{\omega}{c}x - \alpha) + B$ gives $B = C\frac{c^2}{\omega}$; hence

$$i = \hat{e}\sin\omega t\left[A\sin\left(\frac{\omega}{c}x - \alpha\right) + C\frac{c^2}{\omega}\right]$$

To determine A and α we have $i = 0$ when $x = 0$ and when $x = a$. In this way we find that

$$A = -\frac{c^2C}{\omega\cos\frac{a\omega}{2c}} \qquad \text{and } \alpha = \frac{a\omega}{2c} - \frac{\pi}{2}$$

Hence

$$\sin\left(\frac{\omega}{c}x - \alpha\right) = \sin\left(\frac{\omega}{c}x - \frac{a\omega}{2c} + \frac{\pi}{2}\right)$$

$$= \cos\frac{\omega}{c}\left(x - \frac{a}{2}\right)$$

Putting $\frac{\omega}{c} = K$ and $\sqrt{\frac{L}{C}} = z_0$

we obtain

$$i = \frac{\hat{e}\sin\omega t}{Kz_0}\left[1 - \frac{\cos K\left(x - \frac{a}{2}\right)}{\cos\frac{Ka}{2}}\right]$$

which is equation (13) from which the current distribution was calculated.

G. W. O. H.

Index to Abstracts

THE preparation of the Subject and Author Index to the Abstracts and and References published in *Wireless Engineer* during 1942 is well in hand, and it is hoped that it will be available by the middle of February.

As supplies of the 48-page Index, which will cost 2s. 8d., including postage, will be limited, our Publishers ask us to stress the need for those requiring copies to place their order in advance.

Diode as a Frequency-Changer*

An Analysis of Its Behaviour

By F. M. Colebrook, B.Sc. and G. H. Aston, M.A., Ph.D.

(Radio Department, National Physical Laboratory)

ABSTRACT.—The paper gives an analysis of the behaviour of the diode as a frequency changer, with particular reference to the diodes of the so-called "television" type. The main conclusions are as follows :—

1. The conversion-factor (i.e. ratio of beat-frequency output e.m.f. in the diode to applied signal-frequency voltage) is over 90 per cent. for oscillator voltages greater than two or three volts and is practically independent of the oscillator voltage.
2. The beat-frequency internal resistance of the diode is fairly low (order 10^3 ohms), and should be suitably matched to the beat-frequency output circuit, giving an overall conversion ratio of up to about 3 for a narrow-band receiver.
3. The signal-frequency input resistance of the diode is theoretically equal to the output or beat-frequency internal resistance, and in consequence the overall conversion-factor (i.e. aerial or signal-frequency e.m.f. to output beat-frequency p.d.) is independent of either resistance when both input and output circuits are properly matched to the diode.
4. With a suitable d.c. load resistance, the diode current is of sharply impulsive character, and the local oscillator may be set at half, third or even a fourth of the signal frequency plus or minus the beat frequency, with very little loss of conversion ratio. This is a valuable practical feature.
5. There is no practical advantage in using the diode with no d.c. load resistance or with a fixed negative bias. In general this is inadvisable.

Certain of the above theoretical conclusions have been confirmed by measurements at frequencies up to 600 Mc/s. In addition some rough comparative tests were made with a crystal detector (silicon-tungsten) as a frequency changer in order to bring out certain points of difference between this and the diode, arising from the different rectifying characteristics in the two cases. With the crystal there will in general be a best value of local oscillator voltage, this being relatively small (about half a volt), due to the reverse conductivity of the crystal detector. For the same reason, the harmonic mode of operation, which is a useful facility in the case of the diode, is not available in the case of the crystal except at the cost of a considerable loss in conversion efficiency.

1. Introduction

THE so-called television diode is now being extensively used as a frequency-changer for the supersonic heterodyne reception of very short wavelengths. It is often used with the frequency-change oscillator set to a sub-multiple of the signal frequency, plus or minus the intermediate frequency.

Various analyses of diode rectification have been published, (1) (2) (3), but there is a need for an analysis which gives the theoretical answers to the following questions with particular reference to the types of diode now in common use.

1. What amplitude conversion-ratio can be attained ?
2. How does the conversion ratio depend on circuit conditions ?
3. What decrease in conversion ratio is involved in the use of harmonics of the diode-current pulses ?
4. What are the effective input resistances of the diode at the signal and oscillator frequencies ?
5. What is the effective internal resistance of the diode at the beat (or intermediate) frequency ?

The present paper seeks to answer these questions.

2. Analytical method

Strutt[1] has given an analysis of the diode as a frequency-changer, based on a Fourier series expansion of the diode-current pulses. He assumed an exponential law for the characteristic, but simplified the pulse-form into a triangle for detailed analysis. It is found, however, that the curved foot of

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* MS. accepted by the Editor, October 1942.

the characteristic of the small television type of diode can be adequately represented by a discontinuous square-law function, and that this is amenable without simplification to Fourier analysis. This is therefore the method used in the present paper.

3. Assumptions

It is assumed that the foot of the characteristic can be represented by

$$i = f(v) = a(v + b)^2 \text{ for } v > -b$$
$$= 0 \qquad \text{for } v < -b$$

Fig. 1, for example, gives the measured characteristic of an EA50 diode, compared with a curve calculated from the relation

$$i = 1.798 \times 10^{-3}(v + 0.46)^2$$

It is assumed that a and b are independent of the frequency of v. This will probably not be true at the highest frequencies, but the available information suggests that transit-time effects are not very considerable at frequencies below about 500 Mc/s.

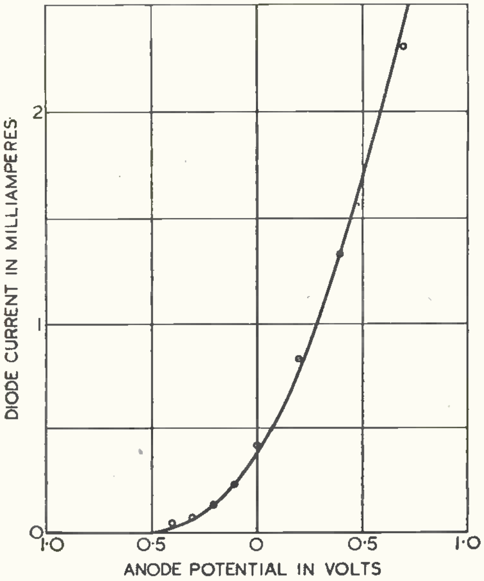


Fig. 1.—*Line* $i = 1.798 \times 10^{-3} (v + 0.46)^2$. *Points are measured values for an EA50 diode.*

It is further assumed that the load circuit of the diode is a resistance R for direct-current, a resistance R_b at the beat or intermediate frequency (usually a tuned-circuit impedance), and is of negligible impedance at the signal and oscillator frequencies and harmonics of these.

4. Analysis

The simplified circuit considered for analysis is shown in Fig. 2. It is true that so simple a circuit cannot be fully realised in practice, since the various voltages will have associated impedances, and the load conditions cannot be exactly fulfilled. The circuit can be approximated to in practice, but the chief justification for the simplification is that it enables sufficiently good answers to be given to the questions raised in the introduction. To include all the possible factors would complicate and obscure the analysis, without adding materially to the practical value of the answers.

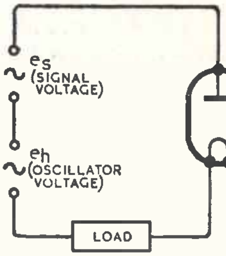


Fig. 2.—*Simplified diode frequency-changing circuit: the load is represented by R for direct current;* R_b *for beat-frequency currents and zero for all other frequencies.*

The detail of the analysis is given in the appendix. The main formulae deduced are as follows. They are expressed in terms of cos α where

$$\cos\alpha = \frac{v_c + v_o - b}{\hat{e}}$$

and where v_c is the change in the zero-frequency or direct back e.m.f. in the load resistance R. (It is shown in the appendix that 2α is the angular width of the pulses of diode current.)

For the discontinuous square-law characteristic,

Effective input resistance at oscillator frequency $= R_h$

$$= \frac{\pi}{a\hat{e}} \frac{1}{\frac{3}{2}\sin\alpha - 2\alpha\cos\alpha + \frac{1}{6}\sin 3\alpha} = \frac{\pi}{a\hat{e}} F_1(\alpha) \quad \ldots \quad \ldots \quad (3)$$

Effective input resistance at signal frequency $= R_s$

$$= \frac{\pi}{a\hat{e}} \frac{1}{2(\sin\alpha - \alpha\cos\alpha)} = \frac{\pi}{a\hat{e}} F_2(\alpha) \qquad (4)$$

Internal resistance at beat frequency $= R_i = R_s$ .. .. (5)

Overall conversion ratio

$$= \frac{\text{intermediate frequency output voltage}}{\text{input signal-frequency voltage}}$$

$$= \frac{\hat{v}_b}{\hat{e}_s}$$

$$= \frac{R_b}{R_b + R_i} \times \text{conversion factor} \quad .. \quad (6)$$

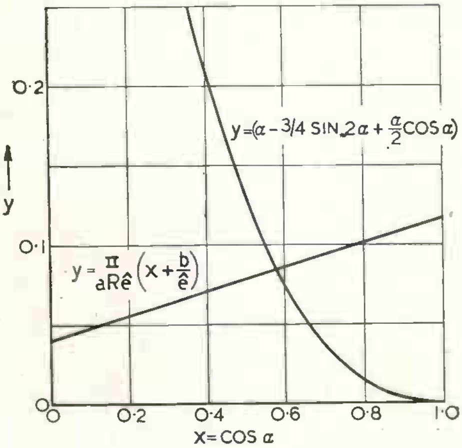


Fig. 3.

Conversion factor for fundamental

$$= \frac{\sin 2\alpha - 2\alpha}{4(\sin \alpha - \alpha \cos \alpha)} = F_3(\alpha) \quad .. \quad (7)$$

Finally the direct current component is given by

$$i_c + i_o = \frac{a\hat{e}^2}{\pi}\left(\alpha - \frac{3}{4}\sin 2\alpha + \frac{\alpha}{2}\cos 2\alpha\right)$$

$$= \frac{a\hat{e}^2}{\pi} F_o(\alpha) \quad .. \quad .. \quad (9)$$

Thus all the essential quantities are determined provided α can be determined.

5. Determination of α

We have, from (9),

$$i_c + i_o = \frac{a\hat{e}^2}{\pi} F_o(\alpha)$$

$$\therefore \quad \frac{v_c + v_o - b}{\hat{e}} = \cos \alpha = \frac{aR\hat{e}}{\pi} F_o(\alpha) - \frac{b}{\hat{e}} \quad .. \quad .. \quad (10)$$

Thus, putting $\left.\begin{array}{l} F_o(\alpha) = y \\ \cos \alpha = x \end{array}\right\}$ .. .. (11)

we have the two equations

$$y = \phi(x)$$

$$\text{and} \qquad y = \frac{\pi}{aR\hat{e}}\left(x + \frac{b}{\hat{e}}\right) \qquad (12)$$

and y and x for assigned values of R and $\hat{e}$ can be determined by the intersection of the two lines, as illustrated in Fig. 3 for $a = 2 \times 10^{-3}$, $R = 20{,}000$ ohms, $\hat{e} = 1$. Figs. 4 and 5 show the variation of v_c with $\hat{e}$ for this case, and for the same characteristic with $R = 100{,}000$ ohms.

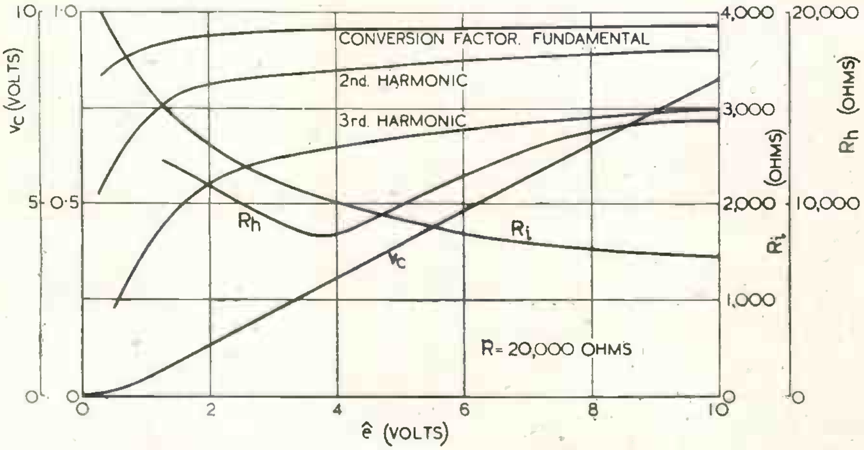


Fig. 4.

Conversion factor for 2nd harmonic

$$= \frac{\sin 3\alpha - 3 \sin \alpha}{12(\sin \alpha - \alpha \cos \alpha)} = F_4(\alpha) \quad .. \quad (8)$$

This graphical process is simple but rather laborious. It will be found, however, that for a given value of R, $\hat{e} \cos \alpha$ is a linear function of $\hat{e}$ when $\hat{e}$ is larger than two or three volts, i.e.

$$\hat{e}\cos\alpha = A\hat{e} - B \qquad \ldots \quad \ldots \quad (13)$$

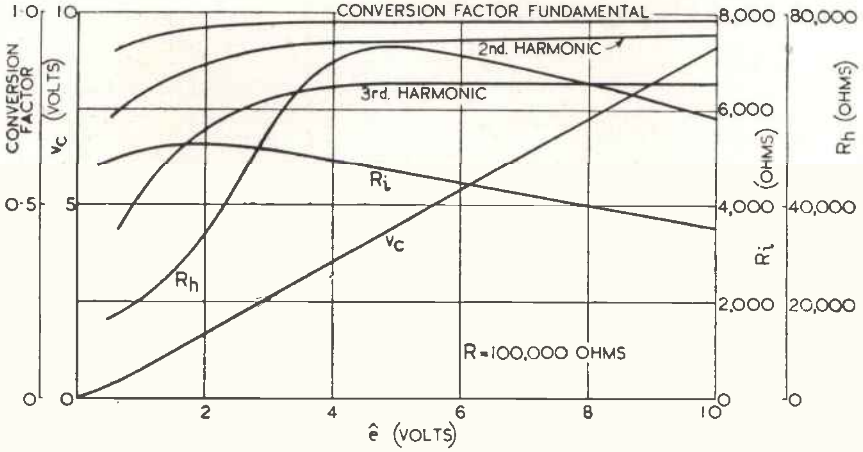


Fig. 5.

Comparing this with equation 10, it appears that

$$\left.\begin{aligned} B &= b \\ \text{and} \quad A &= \frac{aR\hat{e}}{\pi} F_o(\alpha) = \text{const.} \end{aligned}\right\} \qquad \ldots \quad (14)$$

Thus, if α is determined graphically for one or two values of $\hat{e}$, A can be determined and the line given by Eqn. (13) will determine all the significant quantities for a full range of values of $\hat{e}$. Figs. 4 and 5 were obtained in this way, using the curves in Figs. 6 and 7 for the other functions of α concerned. (The conversion-factor functions were plotted against cos α rather than α, as this brings out the fact that for the fundamental and second harmonic these functions are approximately linear in cos α.)

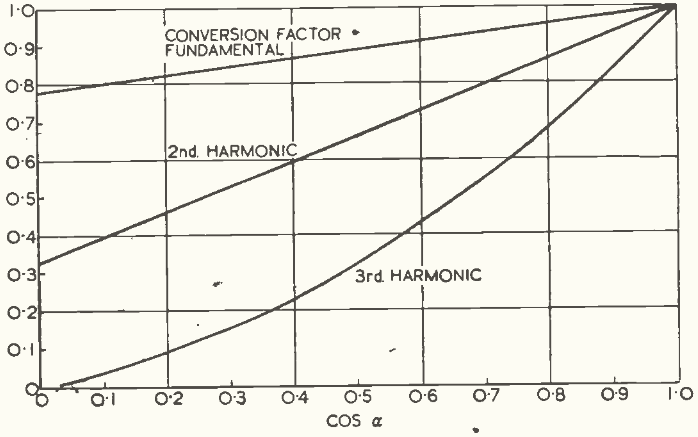


Fig. 6.

6. Discussion of Theoretical Results

a. *Variation of v_c with $\hat{e}$.*

It is interesting to note that in spite of the parabolic curvature of the characteristic assumed, v_c is very approximately a linear function of $\hat{e}$ for values of $\hat{e}$ greater than two or three volts. It was stated above that, from the graphical solution of the equation for $i_c + i_o$, it was found that

$$\hat{e}\cos\alpha = v_c + v_o - b = A\hat{e} - b$$

i.e.

$$\begin{aligned} v_c &= A\hat{e} - v_o \\ &\approx A\hat{e} - b \qquad \ldots \quad \ldots \quad (15) \end{aligned}$$

since, for the ordinary values of R, $v_o \approx b$. For

$R = 20{,}000$ and $a = 2 \times 10^{-3}$, $A = 0.90$

and for

$R = 100{,}000$ and $a = 2 \times 10^{-3}$, $A = 0.97$

This provides a useful means of estimating the local oscillator amplitude in a frequency-change stage.

It should be pointed out that an oscillation of amplitude $\hat{e}$ involves the characteristic up to a voltage of $\hat{e} - (v_c + v_o - b) \approx \hat{e} - v_c = \hat{e}\,(1 - A) + b$. For large values of $\hat{e}$ this will be outside the range of parabolic curvature. For such large values (i.e. $\hat{e}$ greater than six or seven volts) the behaviour will approximate to that given by the discontinuous linear function, which is briefly reviewed in section 9. The present theory, however, covers the range of values generally used in diode-frequency-change circuits in receivers.

b. *Input resistance at oscillator frequency.*

It is well known that for a discontinuous linear rectifying characteristic, the oscillator-frequency input resistance approximates fairly rapidly to $R/2$ as the amplitude increases. It can be shown that it approaches the same limit in the present case. As $R\hat{e}$ increases in Eqn. (14), A approaches unity as a limit.

i.e. $$\frac{aR\hat{e}}{\pi} \rightarrow \frac{1}{F_o(\alpha)} \qquad \ldots \quad \ldots \quad (16)$$

For small values of α

$$\frac{1}{F_o(\alpha)} \rightarrow \cdot \frac{15}{2\,\alpha^5} \qquad \ldots \quad \ldots \quad (17)$$

i.e. $$\frac{aR\hat{e}}{\pi} \rightarrow \cdot \frac{15}{2\,\alpha^5} \qquad \ldots \quad \ldots \quad (18)$$

From (3)

$$R_h = \frac{\pi}{ae} \cdot \frac{1}{\frac{3}{2}\sin\alpha - 2\,\alpha\cos\alpha + \frac{1}{6}\sin 3\alpha} \qquad \ldots \quad \ldots \quad (19)$$

$$\rightarrow \frac{\pi}{ae} \cdot \frac{15}{\alpha^5} \qquad \ldots \quad \ldots \quad (20)$$

Comparing (18) and (20)

$$R_h \rightarrow \frac{R}{2} \qquad \ldots \quad \ldots \quad \ldots \quad (21)$$

It is clear from Figs. 3 and 4, however, that this limit is approached rather slowly and in practice is probably never reached at all, since it corresponds to such large values of $\hat{e}$ that it lies outside the range over which the parabolic representation of the characteristic is valid. For smaller values of $\hat{e}$, R_h varies in a rather complicated way, and cannot be reduced to any simple general statement.

c. *Input resistance at signal frequency*

The input resistance at signal frequency (R_s) is an important quantity, since it determines the appropriate coupling of the signal frequency circuit to the diode. This matter is considered in section 7. As already pointed out, it is equal in the apparent internal resistance of the diode at the beat frequency. The nature of its variation with $\hat{e}$ and R is shown in Figs. 4 and 5, but the variation is not simple and does not admit of any simple general description.

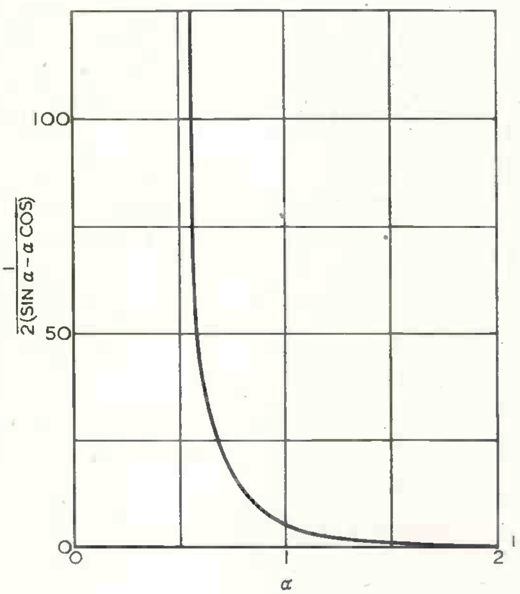


Fig. 7.

d. *Apparent internal resistance at the intermediate frequency*

The internal intermediate-frequency resistance is equal to the signal-frequency input resistance, and is in general low compared with easily obtainable values of the tuned-circuit impedance of a good intermediate-frequency circuit. Thus with direct connection of the intermediate-frequency circuit, the load-factor (see section 4) will be nearly unity, and the conversion ratio practically equal to the conversion factor. It will in general be desirable, however, that the intermediate-frequency circuit should be

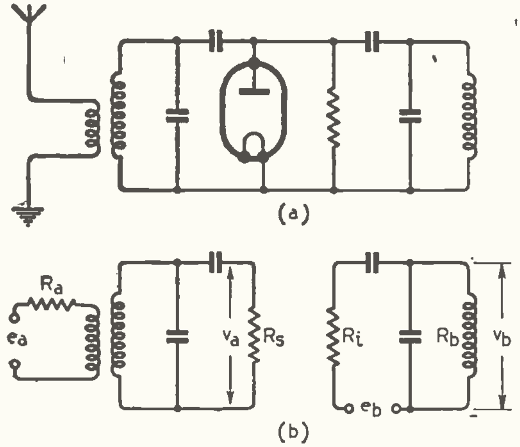
" matched " by a suitable coupling to the diode, giving a step-up of intermediate-frequency potential-difference. This is considered in more detail in section 7.

e. *Conversion factor*

For large values of the d.c. load resistance, R, the conversion factor is nearly unity for the fundamental mode of operation, and about 80 per cent. for the third harmonic. Theoretically, therefore, the use of the third harmonic of the diode-current pulses should not entail more than a 20 per cent. loss of sensitivity.

7. The Couplings of the Diode to its Associated Circuits

Consider the typical circuit shown schematically in Fig. 8 and the equivalent net work shown in Fig. 8. In Fig. 8 e_a is an effective aerial-circuit e.m.f ($\hat{e}_a \sin \omega_s t$) and v_a the corresponding potential difference across the diode, e_b is an effective beat-frequency e.m.f. ($\hat{e}_b \sin \omega_b t$) and v_b is the beat-frequency potential-difference across the tuned-circuit load, assumed to have a dynamic impedance R_b. The resistance R_i is as already defined. The inductive coupling of the aerial and the capacitive couplings of the tuned circuits to the diode are illustrated as typical means of " matching," and for the purposes of the present discussion may be regarded as replaced by any coupling systems capable of adjustment to the same end.



(a)

(b)

Fig. 8.

The transfer of power from the aerial to the diode is a typical case of transfer of power from a source to a sink through the agency of a tuned circuit, and has been fully discussed in a previous paper by one of the present authors[4], the main conclusion of which can be briefly stated as follows. There is no unique optimum condition of couplings, but an asymptotic approach to an optimum condition as the coupling of the source to the tuned circuit and of the tuned circuit to the load are increased continuously, in a certain ratio to each other, up the maximum closeness of couplings practically attainable. The optimum condition thus approached is one in which there is equal dissipation of power in the source and sink circuits, the effective resistances of which are doubled by their mutual association. The power dissipated in the tuned circuit is, as it were, an agent's commission on the transaction, and limits the closeness of the approach to the true optimum. Neglecting this parasitic loss, the optimum condition is given by

$$\frac{\hat{v}_a}{\hat{e}_a} = \frac{1}{2}\sqrt{\frac{R_s}{R_a}} = \frac{1}{2}\sqrt{\frac{R_i}{R_a}} \quad \ldots \quad \ldots \quad (22)$$

As already shown, the effective beat-frequency e.m.f. e_b is given by the conversion factor calculated as in section 5. Calling this F,

$$\hat{e}_b = F \,.\, \hat{v}_a \quad \ldots \quad \ldots \quad \ldots \quad (23)$$

The coupling of the intermediate-frequency tuned circuit to the diode is a simple two-circuit match giving the well known optimum condition

$$\frac{\hat{v}_b}{\hat{e}_b} = \frac{1}{2}\sqrt{\frac{R_b}{R_i}} \quad \ldots \quad \ldots \quad \ldots \quad (24)$$

Thus, for the theoretical optimum overall conversion of the signal e.m.f. e_a to the beat-frequency potential difference, we have, combining (22), (23), and (24)

$$\frac{\hat{v}_a}{\hat{e}_a} \cdot \frac{\hat{v}_b}{\hat{e}_b} = \frac{\hat{v}_a}{\hat{e}_a} \cdot \frac{\hat{v}_b}{F \,.\, \hat{v}_a} = \frac{1}{F} \cdot \frac{\hat{v}_b}{\hat{e}_a} = \frac{1}{4}\sqrt{\frac{R_b}{R_a}} \quad \ldots \quad \ldots \quad (25)$$

$$\text{i.e.} \quad \frac{\hat{v}_b}{\hat{e}_a} = \frac{F}{4} \cdot \sqrt{\frac{R_b}{R_a}} \quad \ldots \quad \ldots \quad (26)$$

It appears, therefore, that the only characteristic of the diode which enters into this theoretical optimum is the conversion factor, which, as already shown, can be made nearly unity.

It should be noted in passing that the

statement sometimes made that the voltage conversion ratio of the diode frequency-changer cannot exceed unity is not correct. In fact, for optimum coupling of the intermediate-frequency load circuit to the diode

$$\frac{\hat{v}_b}{\hat{v}_a} = \frac{F}{2} \cdot \sqrt{\frac{R_b}{R_i}}$$

The permissible value of R_b will, of course, depend on the band-width required in any particular application. Thus, for a narrow band-width, R_b may be as much as 100,000 ohms, in which case, taking R_i as, say, 4,000 ohms, the conversion ratio would be about 2.5.

8. Diode with fixed Bias Voltage and Zero D.C. Load Resistance

As an alternative means of producing the desired form of diode-current pulse, a fixed negative bias voltage may be used in series with the diode, and the d.c. load resistance reduced to zero. The anslysis for this case is immediately derivable from the foregoing by putting

$$v_c + v_o - b = v - b = \text{const.} \quad .. \quad (28)$$

$$\cos\alpha = \frac{v - b}{\hat{e}} \quad .. \quad .. \quad (29)$$

and $$\hat{e}\cos\alpha = v - b = \text{const.} \quad .. \quad (30)$$

The case will not be considered in any detail as it is not of any great practical interest. Fig. 9 shows the variation with $\hat{e}$ of R_h and R_i and the conversion factors for the fundamental and second and third harmonics, for $a = 2 \times 10^{-3}$, $b = 0.5$ and $v = 6$. It will be observed that, in contrast to the case when the bias voltage is due to a resistive load, the conversion factors decrease with the amplitude of the oscillator voltage. The high values, when $\hat{e}$ only slightly exceeds $v - b = 5.5$ volts are, however, associated with very high values of R_h and R_i. The latter decrease rapidly as $\hat{e}$ increases, but in practice will soon reach a lower limit as the voltage swing exceeds the range over which the parabolic representation of the characteristic is valid.

From a practical point of view, this arrangement is likely to compare unfavourably with the case in which a high resistance d.c. load is included in the diode circuit.

9. Brief Statement of Theory of Discontinuous Linear Detector

For a discontinuous linear characteristic

$$\left.\begin{aligned} i &= a(v + b) && \text{for } v > b \\ &= 0 && \text{for } v < b \end{aligned}\right\} \quad .. \quad (31)$$

it is easily shown by the methods described in the appendix and for the same circuit conditions and symbols, that

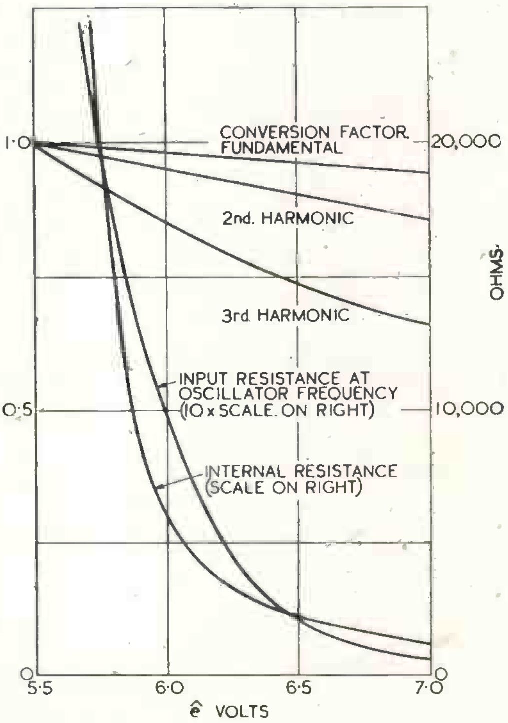


Fig. 9.

$$i_c + i_o = \frac{a\hat{e}}{\pi}(\sin\alpha - \alpha\cos\alpha) \quad .. \quad (32)$$

$$R_h = \frac{\pi}{a} \frac{2}{2\alpha - \sin 2\alpha} \quad .. \quad .. \quad (33)$$

$$R_s = R_i = \frac{\pi}{a} \cdot \frac{1}{\alpha} \quad .. \quad .. \quad .. \quad (34)$$

Conversion factor for fundamental

$$= \frac{\sin\alpha}{\alpha} \quad .. \quad .. \quad .. \quad .. \quad (35)$$

Conversion factor for nth harmonic

$$= \frac{\sin n\alpha}{n\alpha} \quad .. \quad .. \quad .. \quad .. \quad (36)$$

where i_0 = initial current with load resistance R and no applied alternating voltages.

$$= \frac{b}{R + 1/a} \quad \ldots \quad \ldots \quad (37)$$

and
$$\cos\alpha = \frac{v_c + v_0 - b}{\hat{e}} \quad \ldots \quad \ldots \quad (38)$$

The above relationships are exact. In practice, however, the theory is only of interest in relation to relatively large values of oscillator voltage—of the order of ten volts or more—since for smaller values the behaviour is determined by the curvature of the foot of the characteristic. For such large values it will be possible and convenient to neglect the term b and to take i_0 as zero. The above formulae hold, with the simplifications

$$i = av \text{ for } v > 0$$

$$= 0 \text{ for } v < 0 \quad \ldots \quad \ldots \quad (39)$$

$$i_c = \frac{a\hat{e}}{\pi}(\sin\alpha - \alpha\cos\alpha) \quad \ldots \quad (40)$$

$$\cos\alpha = \frac{v_c}{\hat{e}} \quad \ldots \quad \ldots \quad \ldots \quad (41)$$

From (34) and (35)

$$\frac{\cos\alpha}{\sin\alpha - \alpha\cos\alpha} = \frac{aR}{\pi} \quad \ldots \quad \ldots \quad (42)$$

whence it follows that for a given value of R, $\cos\alpha$ is determined and

$$v_c = k \,.\, \hat{e} \quad \ldots \quad \ldots \quad \ldots \quad (43)$$

The value of α for given values of a and R could, of course, be determined by plotting or tabulating the function in 42, but, for large values of $\hat{e}$ and R, where α is small

$$\alpha^3 = \frac{3\pi}{aR} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (44)$$

Under the same conditions

$$R_h = \frac{\pi}{a} \cdot \frac{3}{2\alpha^3} = \frac{R}{2}$$

$$R_i = \left(\frac{\pi}{a}\right)^{2/3}\left(\frac{R}{3}\right)^{1/3} \quad \ldots \quad \ldots \quad (45)$$

For example, taking

$$a = 2 \times 10^{-3},\ R = 10^5$$

$$\alpha^3 = \frac{3\pi}{2}\,10^{-2} = 0.0471$$

$$\alpha = 0.361$$

$$R_i = 4347$$

Conversion factor for fundamental

$$= \frac{\sin 0.361 \text{ rad.}}{0.361 \text{ rad.}}$$

$$= \frac{353}{361}$$

$$= 0.978$$

Conversion factor for 2nd harmonic

$$= 0.914$$

Conversion factor for 3rd harmonic

$$= 0.815$$

The main distinction between this case and that of the discontinuous square law is that the conversion factors and the various effective resistances are independent of the oscillator voltage and depend only on the quantity aR.

10. Experimental Confirmation

Certain features of the analysis have been confirmed by measurements at wavelengths ranging from 20 metres to ½ metre. For example, the conversion factor was measured for the fundamental at 20 metres and at 3 metres, for a large oscillator voltage (about 10) and a large d.c. resistance (about 100,000 ohms) and was found to be about 0.93, the theoretical value being about 0.98. It was confirmed that this was practically independent of the local oscillator voltage when the latter exceeded about 2 volts. A fairly detailed examination was made of the effect of utilising harmonics of the diode current pulses at 3 metres and at 20 metres, with large oscillator voltage (about 10 volts). Thus, at 20 metres, the conversion factor for the 2nd harmonic was about 0.6 db. down on that for the fundamental and for the 3rd harmonic about 1.1 db. down, i.e. conversion factors of 0.86 and 0.82, compared with theoretical figures of 0.94 and 0.82 respectively. For 3 metres the corresponding measured values were 0.86 and 0.79. At 3 metres, harmonics up to the ninth were used, and it was found that each successive harmonic gave an output about 1.2 db. down on that of the previous harmonic. It was confirmed, however, that the higher the order of the harmonic, the larger the oscillator voltage required to reach the maximum conversion factor. Thus, at 3 metres and using the 9th harmonic, i.e. with the oscillator at about 27 metres, the conversion factor began to fall rapidly when the oscillator voltage was reduced below about 5 volts. This is in accordance with the tendency of the theoretical curves.

It was not possible with the apparatus available at the time to get a reliable figure for the actual conversion factor at ½ metre, but it was found that the factor for the 3rd harmonic was about 2 db. down on that for the 2nd. This larger decrease was mainly due to the difficulty of getting a large oscillator voltage in the diode circuit at these frequencies.

There was no opportunity to make a more complete and systematic examination of the diode, but the above results were sufficient confirmation of the features of most importance in the application concerned, namely, as a frequency changer in field strength measuring equipment.

A Note on the Comparison of the Diode and Crystal as Frequency-Changers

In view of the use of various forms of crystal detector as a frequency-changer at frequencies higher than those for which the diode is effective, it may be of interest to call attention to the main points of difference between the two in the light of the foregoing analysis. These are chiefly due to the finite reverse conductivity of the crystal, as compared with the substantially zero reverse conductivity of the diode. The static characteristic of a crystal detector is generally of the form shown in Fig. 10. The crystal-current due to an applied local-oscillator voltage, with a d.c. resistance load, will not therefore have the form of the separate relatively narrow pulses associated with the diode and the harmonic content of the crystal current cannot be expected to have the uniformity of that of the diode current. Again, the more than proportional increase of reverse currents with voltage will result in a different variation of the conversion factor with oscillator voltage. In fact it might be anticipated that for any given signal and d.c. load there would be an optimum and fairly low value of oscillator voltage.

These anticipations were confirmed by a few measurements carried out at wavelengths of 20 metres and 2½ metres on a small cartridge type of crystal detector (silicon-tungsten). It was found, for example, that the maximum conversion factor was slightly less than that for the diode, and that increase of oscillator voltage beyond about half a volt gave an appreciable decrease of conversion factor, confirming the anticipated optimum magnitude of oscillator voltage. The harmonic operation was examined more fully at 2½ metres, and it was found that the factor for the second harmonic was about 3 db. down on that for the fundamental, for the 3rd harmonic about 13 db. down, and for the 4th about 18 db. down.

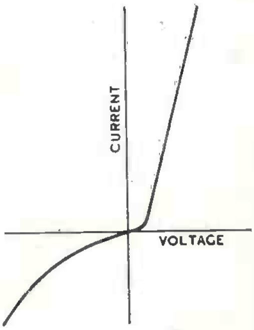


Fig. 10.—*General form of crystal-detector characteristic.*

The crystal unit available was not stable or reproducible enough for exact and systematic measurement, but it may be inferred from these observations and from the general character of the crystal detector characteristic that where a crystal detector is used in a frequency-change circuit there should be provision for the adjustment of the oscillator voltage to an optimum value, and that the harmonic mode of operation is not effective, at least for harmonics higher than the second.

Acknowledgment

This paper describes work carried out as part of the programme of the Radio Research Board. It was first circulated as a confidential report of the Board in May, 1941, and is now published by permission of the Department of Scientific and Industrial Research.

APPENDIX

The initial direct-current, with no applied alternating voltage, is given by

$$i_o = f(- v_o + b) = a(- v_o + b)^2 \qquad (46)$$

where

$$v_o = Ri_o$$

It is important to note that with the usual values of R, v_o will be very nearly equal to b.

When the oscillator and signal voltages are applied in series, as shown in Fig. 2, the total current is given by

$$i = f(\hat{e} \sin \omega t - v_c - v_o + b + \hat{e}_s \sin \omega_s t - v_b) \qquad (47)$$

$$= f(\hat{e}\sin\omega t - v_c - v_o + b) + (\hat{e}_s \sin\omega_s t - v_b) f'(\hat{e}\sin\omega t - v_c - v_o + b) \qquad \ldots \quad \ldots \quad (48)$$

where v_c is the change in the direct or zero-frequency back e.m.f. and

$$v_b = R_b\, i_b \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (49)$$

i_b being the beat-frequency component of i, and where

$$f'(v) = \frac{\partial}{\partial v} f(v) \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (50)$$

Expressing f and f' as Fourier series functions of time,

$$i = A_o + A_1(\sin\omega t + \theta_1) + A_2 \sin(2\omega t + \theta_2) + \ldots + (\hat{e}_s \sin\omega_s t - v_b)\,\{B_o + B_1 \sin(\omega t + \phi_1) + B_2 \sin(2\omega t + \phi_2) + \ldots\ldots\} \qquad \ldots \quad (51)$$

Equating separately the components of like frequency

$$i_c + i_o = A_o \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (52)$$

$$i_h = A_1 \sin(\omega t + \phi_1) \text{ (oscillator-frequency component)} \qquad (53)$$

$$i_s = B_o \hat{e}_s \sin\omega_s t \text{ (signal-frequency component)} \qquad \ldots \quad (54)$$

$$i_b = -B_o v_b + \hat{e}_s \frac{B_n}{2} \cos(\omega_b t + \phi_n) \text{ (beat-frequency component).} \qquad (55)$$

where

$$\omega_b = \omega_s \sim n\omega \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (56)$$

Putting

$$v_b = R_b i_b \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (57)$$

$$v_b = \frac{R_b}{R_b + \frac{1}{B_o}} \cdot \frac{B_n}{2B_o} \cdot \hat{e}_s \cos(\omega_b t + \phi_n) \qquad \ldots \quad (58)$$

Thus, all the significant quantities in the process appear as functions of the coefficients of the Fourier expansions of f and f', i.e.

$$i_c + i_o = A_o \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (59)$$

Effective input resistance at oscillator frequency

$$= R_h = \acute{e}/A_1 \qquad \ldots \quad \ldots \quad \ldots \quad (60)$$

Effective input resistance at signal frequency

$$= R_s = 1/B_o \qquad \ldots \quad \ldots \quad \ldots \quad (61)$$

Internal resistance at beat frequency

$$= R_s = 1/B_o \qquad \ldots \quad \ldots \quad \ldots \quad (62)$$

$$\text{Conversion ratio} = \frac{\hat{v}_b}{\hat{e}_s} = \frac{R_b}{R_b + \frac{1}{B_o}} \cdot \frac{B_n}{2B_o} \qquad (63)$$

It will be convenient to refer to the conversion ratio as consisting of two factors—the load factor and the conversion factor $B_n/2B_o$.

The values of these coefficients for the particular functional form here considered are easily determined in the usual way.

Putting

$$\cos\alpha = \frac{v_c + v_o - b}{\hat{e}} \qquad \ldots \quad \ldots \quad \ldots \quad (64)$$

$$A_o = \frac{a\hat{e}^2}{\pi}\left(\alpha - \tfrac{3}{4}\sin 2\alpha + \frac{\alpha}{2}\cos 2\alpha\right) = \frac{a\hat{e}^2}{\pi} F_o(\alpha) \qquad \ldots \quad \ldots \quad (65)$$

$$A_1 = \frac{a\hat{e}^2}{\pi}\left(\frac{3}{2}\sin\alpha - 2\alpha\cos\alpha + \frac{1}{6}\sin 3\alpha\right) \qquad \ldots \quad \ldots \quad (66)$$

$$B_o = \frac{a\hat{e}}{\pi} \cdot 2(\sin\alpha - \alpha\cos\alpha) \qquad \ldots \quad \ldots \quad (67)$$

$$B_1 = \frac{a\hat{e}}{\pi}(\sin 2\alpha - 2\alpha) \qquad \ldots \quad \ldots \quad \ldots \quad (68)$$

$$B_2 = \frac{a\hat{e}}{\pi} \frac{\sin 3\alpha - 3\sin\alpha}{3} \qquad \ldots \quad \ldots \quad (69)$$

$$B_n = \frac{a\hat{e}}{\pi} \cdot \frac{2}{n}\left\{\frac{\sin(n+1)\alpha}{n+1} - \frac{\sin(n-1)\alpha}{n-1}\right\} \qquad \ldots \quad \ldots \quad (70)$$

Thus

$$R_h = \frac{\pi}{a\hat{e}} \frac{1}{\frac{3}{2}\sin\alpha - 2\alpha\cos\alpha = \frac{1}{6}\sin 3\alpha} = \frac{\pi}{a\acute{e}} F_1(\alpha) \qquad \ldots \quad \ldots \quad (71)$$

$$R_s = R_i = \frac{\pi}{a\hat{e}} \frac{1}{2(\sin\alpha - \alpha\cos\alpha)} = \frac{\pi}{a\hat{e}} F_2(\alpha) \qquad \ldots \quad \ldots \quad (72)$$

Conversion factor for fundamental

$$= \frac{B_1}{2B_o} = \frac{\sin 2\alpha - 2\alpha}{4(\sin\alpha - \alpha\cos\alpha)} = F_3(\alpha) \qquad \ldots \quad \ldots \quad (73)$$

Conversion factor for 2nd harmonic

$$= \frac{B_2}{2B_o} = \frac{\sin 3\alpha - 3\sin\alpha}{12(\sin\alpha - \alpha\cos\alpha)} = F_4(\alpha) \qquad \ldots \quad \ldots \quad (74)$$

and all the significant quantities are determined, provided α can be determined.

It should be noted that 2α is the angular width of the diode current pulses when the signal voltage is zero, for then

$$i = f(\hat{e}\sin\omega t - v_c - v_o + b) \qquad \ldots \quad \ldots \quad (75)$$

$$= f\left\{\hat{e}^2\left(\sin\omega t - \frac{v_c + v_o - b)^2}{\hat{e}}\right\}; \quad +^{ve} \text{ values only} \qquad \ldots \quad \ldots \quad \ldots \quad (76)$$

$$= f\{\hat{e}^2(\sin\omega t - \cos\alpha)\}; \quad +^{ve} \text{ values only.} \qquad \ldots \quad \ldots \quad (77)$$

The function is $+^{ve}$ for all values of t between t_1 and t_2

where

$$\sin\omega t_1 = \sin\omega t_2 = \cos\alpha \qquad \ldots \quad \ldots \quad (78)$$

$$\left.\begin{aligned} &\text{i.e.} && \omega t_1 = \frac{\pi}{2} - \alpha \\ &\text{and} && \omega t_2 = \frac{\pi}{2} + \alpha \end{aligned}\right\} \qquad \ldots \quad \ldots \quad \ldots \quad (79)$$

i.e. for all arguments over a range 2α centred on $\pi/2$.

BIBLIOGRAPHY

[1] M. J. O. Strutt.—"Diode Frequency Changers." *Wireless Engineer*, 1936, Vol. 13, pp. 73–80.

[2] F. M. Colebrook.—"The Theory of the Straight Line Rectifier." *Wireless Engineer*, 1930, Vol. 7, pp. 595–603.

[3] S. E. A. Landale.—"An Analysis of Triode Valve Rectification." *Proc. Camb. Phil. Soc.*, 1929, Vol. 25, pp. 482–490.

[4] F. M. Colebrook.—"Effect of the Detector Load on Transformer Design." *Wireless Engineer*, 1935, Vol. 12, pp. 415–420.

Diode Frequency Changers*

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(Communication from the Research Staff of the M.O. Valve Co., Ltd., at the G.E.C. Research Laboratories, England)

SUMMARY.—A general analysis of a two-element frequency changer is given, and the results are applied to diodes having (a) a three-halves power characteristic, and (b) an exponential characteristic.

It is shown that:

(i) when circuit losses are negligible, if the ratio of the output power to the input power is adjusted to be optimum, the generator resistance, the input and output resistance of the diode and the I.F. load resistance are equal, and the optimum power ratio is given by

$$M = \frac{g_c^2}{[g_0 + \sqrt{(g_0^2 - g_c^2)}]^2}$$

where g_0 is the mean conductance of the diode and g_c is the conversion conductance.

(ii) when the input circuit loss is not negligible, the optimum effective power ratio is

$$M_e = \frac{g_c^2}{[\sqrt{g_0(g_0 + G_1)} + \sqrt{g_0(g_0 + G_1) - g_c^2}]^2}$$

where G_1 is the conductance of the input circuit. In this case, the diode output resistance is equal to the I.F. load resistance and the generator resistance is equal to the effective input resistance of the diode but the equality between input and output resistance does not hold.

When circuit losses are present, the power ratio calculated when the I.F. frequency is equal to the difference between the signal and oscillator frequencies is always greater than that obtained when the I.F. frequency is equal to the difference between the signal frequency and a multiple of the oscillator frequency; the difference increases as G_1 increases. When operating on a multiple of the oscillator frequency, it is possible that the power ratio may be greater than that calculated if harmonics are present in the oscillator.

Although the diode, when used as a frequency changer, is essentially a non-linear device, an equivalent circuit, consisting of a π-network of linear resistances, can be drawn, from which its performance can be deduced. Each leg of the π-network is equal to $g_0 - g_c$ and the bar is equal to g_c, g_0 and g_c being defined as above.

1. Introduction

THE study of the operation of a two-element frequency changer is complicated by the fact that there is large interaction between the input and output circuits. The problem of the diode frequency changer has been discussed by Strutt in two published papers[1],[2]. In these papers he is concerned with the voltage conversion gain of the diode and assumes a signal generator having no internal impedance—a condition which is not fulfilled in a practical receiver. He lays emphasis on the condition in which the I.F. circuit impedance and the D.C. bias resistance are large, in which case the conversion gains obtained when using the fundamental frequency or a multiple of the oscillator frequency are equal. When circuit losses are present or when the I.F. circuit impedance is low it will be shown that a loss of gain occurs when operating on a multiple of the oscillator frequency.

Since the power gain of any stage in the receiver plays a more fundamentally important rôle than the voltage gain, more emphasis is placed on power gain than on voltage gain in this paper. A signal generator internal impedance is assumed and the effect of circuit losses are considered.

The analysis given in Section 2 applies particularly to the diode frequency changer, but it is applicable to any two-element frequency changer such as a crystal or a metal rectifier.

2.1. General Analysis of the Diode Frequency Changer

Many circuit arrangements have been suggested for use with a diode frequency

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* MS. accepted by the Editor, November, 1941.

[1] M. J. O. Strutt, "On conversion detectors." *Proc. I.R.E.*, Vol. 22, pp. 981–1008, August, 1934.

[2] M. J. O. Strutt, "Diode Frequency Changers." *Wireless Engineer*, Vol. 13, pp. 73–80, February, 1936.

changer but most of the arrangements can be transformed into an equivalent circuit in which the signal source of internal impedance Z_2, the oscillator source of internal impedance Z_1, the intermediate frequency load impedance Z_3, and the zero frequency or D.C. load impedance Z_0, are all placed in series with the diode, as shown in Fig. 1.

It will be assumed in the analysis that:

(a) the impedance Z_0 is negligible at all frequencies other than zero frequency; this assumption is in general justified since Z_0 consists of a resistance R_0 in parallel with a large capacitance C_0, and

(b) the impedance of the I.F. load, Z_3, is negligible at all frequencies except the I.F. frequency f_3.

Normally the difference between oscillator and signal frequencies is small, so that the internal impedance of the oscillator will not be negligible at the signal frequency and vice versa. Let the impedance of the signal generator to oscillator frequency f_1 be Z_{21} and the impedance of the oscillator generator to signal frequency f_2 be Z_{12}.

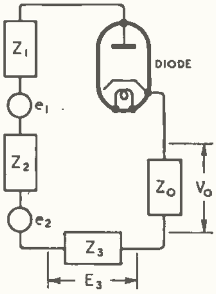


Fig. 1.

List of Symbols

α/π = fraction of the oscillator cycle over which diode conducts.
A = coefficient of the three-halves power characteristic.
D = coefficient of the exponential characteristic.
e = electronic charge.
ϵ = base of the Naperian logarithms.
e_1 = amplitude of oscillator e.m.f.
E_1 = amplitude of oscillator voltage across the diode input circuit.
e_2 = amplitude of signal e.m.f.
E_2 = amplitude of signal voltage across the diode input circuit.
E_3 = amplitude of I.F. voltage across the diode output circuit.
$f_1 = \frac{\omega_1}{2\pi}$ = oscillator frequency
$f_2 = \frac{\omega_2}{2\pi}$ = signal frequency
$f_3 = \frac{\omega_3}{2\pi}$ = I.F. frequency.
$G = \frac{1}{R}$ = series conductance of the aerial.
$G_1 = \frac{1}{R_1}$ = parallel conductance of the diode input circuit,
$G_3 = \frac{1}{R_3}$ = parallel conductance of the diode output circuit,
$G_i = \frac{1}{R_i}$ = input conductance of the diode caused by flow of current.
$G_a = \frac{1}{R_a}$ = output conductance of the diode caused by flow of current.
g = diode conductance $= \frac{di}{dV}$
g_0, g_1, g_2 = constants in Fourier expansion of g.
g_c = conversion conductance of diode.
$h = \sin \alpha/2$.
i = current.

i_0 = mean diode current.
$I_0(\ )$ = Modified Bessel Function of the first kind of zero order.
$I_1(\ )$ = Modified Bessel Function of the first kind of first order.
$I_2(\ )$ = Modified Bessel Function of the first kind of second order.
K = Boltzmann's constant.
$k = \frac{e}{KT_e}$
M = power ratio, expressed in db.
M_e = effective power ratio, expressed in db.
m^2 = impedance ratio of the diode input circuit.
P = power absorbed from the source
P_1 = power dissipated in G_1.
P_i = input power to the diode.
P_0 = output power from the diode.
R_0 = diode bias resistance.
T_e = diode cathode temperature.
V = voltage.
V_0 = diode bias voltage.
$Y_i = \frac{}{Z_i}$ = diode input admittance.
$Y_a = \frac{1}{Z_a}$ = diode output admittance.
Z_1 = internal impedance of the oscillator source.
Z_2 = internal impedance of the signal source.
Z_{21} = impedance of signal generator at oscillator frequency.
Z_{12} = impedance of oscillator generator at signal frequency.
$Y_2' = \frac{1}{Z_2 + Z_{12}}$
$\theta = \omega_1 t$

Let e_1 = amplitude of the oscillator e.m.f.
Let e_2 = amplitude of the signal e.m.f.
Let i_1 = amplitude of the current of frequency f_1 flowing round the circuit,
Let i_2 = amplitude of the current of frequency f_2 flowing round the circuit.
Let i_3 = amplitude of the current of frequency f_3 flowing round the circuit,
and i_0 = direct current flowing round the circuit.

The voltage across the diode will then be

$$\begin{aligned} E = {} & \{e_1 - i_1(Z_1 + Z_{21})\} \cos \omega_1 t \\ & + \{e_2 - i_2(Z_2 + Z_{12})\} \cos \omega_2 t \\ & - i_3 Z_3 \cos \omega_3 t - i_0 Z_0 \quad .. \quad (2.1) \end{aligned}$$

Let $E_1 = e_1 - i_1(Z_1 + Z_{21})$
= amplitude of the oscillator voltage appearing across the diode.
$E_2 = e_2 - i_2(Z_2 + Z_{12})$
= amplitude of the signal voltage appearing across the diode
and $V_0 = i_0 Z_0$ = D.C. bias voltage.

Then

$$\begin{aligned} E = {} & E_1 \cos \omega_1 t + E_2 \cos \omega_2 t \\ & - i_3 Z_3 \cos \omega_3 t - V_0 \quad .. \quad (2.2) \end{aligned}$$

Let the current-voltage characteristic of the diode be

$$i = F(E)$$

then the conductance of the diode at any voltage will be

$$g = \frac{di}{dE}$$

If a voltage $E = E_1 \cos \omega_1 t - V_0$ is applied to the diode there will be a pulse of current, or conductance once every cycle, as shown in Figs. 2a and 2b. g the value of the conductance at any instant will be a function of E, and can be represented by a Fourier Series, i.e.

$$g = g_0 + g_1 \cos \omega_1 t + g_2 \cos 2\omega_1 t + \ldots . . \quad .. \quad .. \quad (2.3)$$

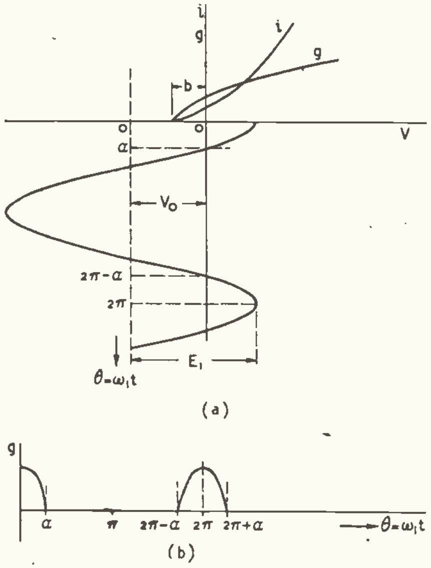
while the current, i, can be represented by

$$i = i_0 + i_1 \cos \omega_1 t + i_2 \cos 2\omega_1 t + \ldots . . \quad .. \quad .. \quad (2.4)$$

If an additional small voltage δE is applied to the diode, the resulting change in current δi will be

$$\delta i = \frac{di}{dE} . \delta E = g . \delta E.$$

If a small signal voltage $E_2 \cos \omega_2 t$ is superposed on the oscillator voltage E_1, an I.F. voltage E_3 will be developed across the output load Z_3. The total voltage superposed on the oscillator voltage will therefore be $E_2 \cos \omega_2 t - E_3 \cos \omega_3 t$.



(a)

(b)

Fig. 2.

Let the change in current through the diode due to $E_2 - E_3$ be

$$i_{(t)} = \delta i.$$

Then

$$\begin{aligned} i_{(t)} & = g(E_2 \cos \omega_2 t - E_3 \cos \omega_3 t) \\ & = (g_0 + g_1 \cos \omega_1 t + \ldots . .) \\ & \qquad (E_2 \cos \omega_2 t - E_3 \cos \omega_3 t) \\ & = (g_0 E_2 - \frac{g_1}{2} E_3) \cos \omega_2 t \\ & \quad + (\frac{g_1}{2} E_2 - g_0 E_3) \cos \omega_3 t \\ & \quad + \text{terms in } (\omega_1 + \omega_2), (2\omega_1 - \omega_2) \ldots \\ & \quad \text{etc.} \quad .. \quad .. \quad (2.5) \end{aligned}$$

where $\omega_3 = \omega_1 - \omega_2$ or $\omega_2 = \omega_1 - \omega_3$

The amplitudes of the currents of frequency f_2 and f_3 respectively are therefore

$$i_2 = g_0 E_2 - \frac{g_1}{2} E_3$$

$$i_3 = \frac{g_1}{2} E_2 - g_0 E_3.$$

and since

$$E_3 = i_3 Z_3$$

$$i_2 = \left\{ g_0 - \frac{\left(\frac{g_1}{2}\right)^2 Z_3}{1+g_0 Z_3} \right\} . E_2 \quad \ldots \quad (2.6)$$

$$i_3 = \frac{g_1}{2} \frac{E_2}{1 + g_0 Z_3} \quad \ldots \quad \ldots \quad (2.7$$

If $\omega_3 = n\omega_1 - \omega_2$, i.e. if the nth harmonic of the oscillator is utilised instead of the fundamental, then the currents of signal and intermediate frequency are given by

$$i_2 = g_0 E_2 - \frac{g_n}{2} E_3$$

$$i_3 = \frac{g_n}{2} E_2 - g_0 E_3$$

or since

$$E_3 = i_3 Z_3$$

$$i_2 = \left\{ g_0 - \frac{\left(\frac{g_n}{2}\right)^2 Z_3}{1+g_0 Z_3} \right\} E_2 \quad \ldots \quad (2.8)$$

$$i_3 = \frac{g_n}{2} \cdot \frac{E_2}{1 + g_0 Z_3} \quad \ldots \quad \ldots \quad (2.9)$$

The only way in which (2.6) and (2.7) differ from (2.8) and (2.9) is that g_1 is replaced by g_n, otherwise the formulae are identical.

If the signal voltage, E_2, and the I.F. voltage, E_3, are small in comparison with the oscillator voltage E_1, then the mean rectified current and the current of frequency f_1 will be approximately the same as with E_1 operating alone, i.e. the mean current is equal to i_0 of equation (2.4) while the amplitude of the oscillator frequency current will be i_1 where

$$i_0 = \frac{1}{2\pi}\int_0^{2\pi} i d(\omega_1 t) = \frac{1}{2\pi}\int_0^{2\pi} F(E) \,.\, d(\omega_1 t)$$

and $$\ldots \quad \ldots \quad (2.10)$$

$$i_1 = \frac{1}{\pi}\int_0^{2\pi} i \cos \omega_1 t d(\omega_1 t) = \frac{1}{\pi}\int_0^{2\pi} F(E) \cos \omega_1 t d(\omega_1 t)$$

$$\ldots \quad \ldots \quad (2.11)$$

2.2. Conversion Conductance

The conversion conductance of a frequency changer is defined as the ratio

$$\frac{\text{(I.F. current in the output circuit)}}{\text{(Signal frequency voltage at the valve input)}}$$

when the external output impedance at intermediate frequency is zero.

Therefore, putting $Z_3 = 0$ in equation (2.7), we have

$$i_3 = \frac{g_1}{2} \,.\, E_2 \quad \text{or} \quad \frac{i_3}{E_2} = \frac{g_1}{2}$$

i.e. the conversion conductance g_c of the diode when operating on the fundamental frequency of the oscillator is

$$g_c = \frac{g_1}{2} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2.12)$$

2.3. Input Admittance

The input admittance of the diode to signal frequency is

$$Y_i = \frac{i_2}{E_2},$$

which from equation (2.6) is

$$Y_i = g_0 - \frac{g_c^2}{g_0 + Y_3} \quad \ldots \quad \ldots \quad (2.13)$$

where $Y_3 = \frac{1}{Z_3}$

2.4. Output Admittance

Since equation (2.5) is symmetrical in E_2 and E_3 it follows that the output admittance to I.F. is given by

$$Y_a = g_0 - \frac{g_c^2}{g_0 + Y'_2} \quad \ldots \quad \ldots \quad (2.14)$$

Where $Y'_2 = \frac{1}{Z_2 + Z_{12}}$

The input admittance of the diode is therefore a function of the I.F. load, while the output admittance is a function of the signal generator admittance.

2.5. Equivalent Circuit

It follows from equation (2.6) and (2.7) that although a diode, when used as a frequency changer is necessarily non-linear an equivalent circuit of linear resistances can be drawn from which its performance can be deduced. This equivalent circuit is shown in Fig. 3. It consists of a π-network, in which the bar is equal to g_c and each leg

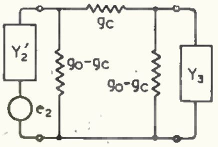


Fig. 3.

to $g_0 - g_c$. It must be remembered, however, that this circuit is only valid when the signal voltage is small in comparison with the oscillator voltage.

2.6. Voltage Gain

The conversion voltage gain of the diode is given by A

where $$A = \frac{E_3}{E_2} = \frac{i_3 Z_3}{E_2}$$

which from (2.7) is

$$A = g_c \frac{Z_3}{1 + g_0 Z_3} = \frac{g_c}{g_0 + Y_3} \quad .. \quad (2.15)$$

If Y_3 is made very small in comparison with g_0, then $A \simeq g_c/g_0$. It will be shown later that in certain circumstances g_c can be made very nearly equal to g_0, so that A becomes nearly unity.

2.7. Power Ratio

The power ratio of a frequency changer is defined as the ratio of the I.F. power output to the input signal power.

In most cases, the input and output circuits will consist of tuned elements so that the effective reactances at the respective resonant frequencies are zero, and the impedances will resolve themselves into pure resistances.

i.e., $$Z_3 = R_3 = \frac{1}{G_3}$$

and $$Z'_2 = R'_2 = \frac{1}{G'_2}$$

The input and output admittances then become real and are given by

$$Y_i = G_i = g_0 - \frac{g_c^2}{g_0 + G_3} \quad .. \quad (2.16)$$

$$Y_a = G_a = g_0 - \frac{g_c^2}{g_0 + G'_2} \quad .. \quad (2.17)$$

The I.F. power output from the frequency changer is

$$P_0 = \frac{i_3^2 R_3}{2} = \frac{i_3^2}{2G_3}$$

but $$i_3 = \frac{g_c E_2}{(1 + g_0/G_3)}$$

so that $$P_0 = \frac{g_c^2 E_2^2}{2G_3\left(1 + \frac{g_0}{G_3}\right)^2}$$

The input power to the diode is

$$P_i = \frac{E_2^2 G_i}{2}$$

so that the power ratio, M, will be given by

$$M = \frac{P_o}{P_i} = \frac{g_c^2 G_3}{(G_3 + g_0)^2 G_i} \quad .. \quad (2.18)$$

Substituting the value of G_i from equation (2.16) in (2.18) we have

$$M = \frac{g_c^2 G_3}{(G_3 + g_0)^2 g_0 - g_c^2 (G_3 + g_0)} \quad (2.19)$$

If G_3 is varied, M has an optimum value when $G_3^2 = g_0^2 - g_c^2$. Substituting this value in (2.19), then

$$M = \frac{g_c^2}{(g_0 + \sqrt{g_0^2 - g_c^2})^2}$$

$$= \frac{1}{\left(\frac{g_0}{g_c} + \sqrt{\left(\frac{g_0}{g_c}\right)^2 - 1}\right)^2} \quad .. \quad (2.20)$$

If this value of $G_3 (= \sqrt{g_0^2 - g_c^2})$ is substituted in the expression for the input conductance G_i, then

$$G_i = \sqrt{g_0^2 - g_c^2} \quad .. \quad .. \quad (2.21)$$

The power transfer from the signal generator to the mixer will be a maximum when the internal impedance of the generator is adjusted to be equal to the input impedance of the frequency changer, i.e. when

$$Z'_2 = Z_i \quad \text{or} \quad G'_2 = G_i$$

If $G_i = \sqrt{g_0^2 - g_c^2}$ is substituted for G'_2 in equation (2.17), the output conductance becomes

$$G_a = \sqrt{g_0^2 - g_c^2} \quad .. \quad .. \quad (2.22)$$

Therefore when the power output from the diode is adjusted to be optimum, the input circuit resistance, the input and output resistance of the diode, and I.F. load resistance are equal, i.e.

$$G'_2 = G_i = G_a = G_3$$

When $\omega_3 = \omega_1 - \omega_2$, $g_c = \frac{g_1}{2}$, while when

$$\omega_3 = 2\omega_1 - \omega_2,\ g_c = \frac{g_2}{2}.$$

Therefore, the conditions for obtaining optimum power gain depend on whether the fundamental or a multiple of the oscillator frequency is used.

When the conditions for obtaining these

optimum conditions are satisfied, the maximum power output is obtained when $g_0 = g_c$. When this is the case the power ratio M is 0 db and all the impedances must be infinite. These conditions are never realised in practice, however, since circuit impedances are always finite.

2.8. Effect of Circuit Losses

The signal source is in general coupled to the diode by some matching circuit which will necessarily have some loss. Therefore, of the signal power absorbed from the source, some fraction will be dissipated in the input circuit, so that the effective power ratio of the frequency changer stage is smaller than M.

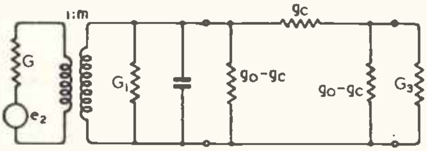


Fig. 4.

Consider the circuit shown in Fig. 4. G is the series conductance of the source, G_1 the conductance of the diode input circuit in the absence of the source and G_3 the conductance of the I.F. circuit. The input and output conductances of the diode are G_i and G_a respectively.

The actual power ratio of the diode is given by equation (2.18), i.e.

$$M = \frac{P_0}{P_i} = \frac{g_c^2 \, . \, G_3}{(G_3 + g_0)^2 G_i}$$

Let the power dissipated in the conductance G_1 be P_1

$$P_1 = E_2^2 G_1$$

while

$$P_i = E_2^2 G_i$$

If the power absorbed from the source is P, then

$$P = P_1 + P_i$$

Let the effective power ratio of the frequency changer stage be M_e, defined by

$$M_e = \frac{P_0}{P}$$

Then

$$M_e = \frac{P_0}{P_1 + P_i} = \frac{P_0}{P_i} \cdot \frac{P_i}{P_1 + P_i}$$

$$= \frac{P_0}{P_i} \cdot \frac{G_i}{G_1 + G_i}$$

$$= M \cdot \frac{G_i}{G_1 + G_i}$$

$$= \frac{g_c^2 \, . \, G_3}{(g_0 + G_3)^2 (G_1 + G_i)} \quad .. \quad (2.23)$$

Substituting the value of G_i from (2.16), equation (2.23) becomes

$$M_e = \frac{g_c^2 G_3}{G_3^2(g_0 + G_1) + G_3(2g_0G_1 + 2g_0^2 - g_c^2) + g_0^2 G_1 + g_0^3 - g_0 g_c^2} \quad .. \quad .. \quad (2.24)$$

If G_3 is varied, the effective power ratio has an optimum value when

$$G_3^2 = \frac{g_0(g_0G_1 + g_0^2 - g_c^2)}{g_0 + G_1} \quad .. \quad (2.25)$$

Substituting this value of G_3 in equation (2.24), then

$$M_e = \frac{g_c^2}{\{\sqrt{g_0(g_0 + G_1)} + \sqrt{g_0(g_0 + G_1) - g_c^2}\}^2}$$

$$= \frac{g_c^2}{g_0^2} \cdot \frac{1}{\left\{\sqrt{\left(1 + \frac{G_1}{g_0}\right)} + \sqrt{\left(1 + \frac{G_1}{g_0} - \frac{g_c^2}{g_0^2}\right)}\right\}^2} \quad .. \quad .. \quad (2.26)$$

Comparing (2.26) with (2.20), it will be seen that g_0^2 in equation (2.20) is replaced by $g_0(g_0 + G_1)$ otherwise the expressions are identical.

If m^2 is the impedance ratio of the input coupling circuit, then when the source is matched to the diode, i.e. when

$$m^2 = \frac{G}{G_1 + G_i}$$

the effective conductance, looking back from the diode, is equal to

$$G_1 + \frac{G}{m^2} = 2G_1 + G_i$$

Therefore from Fig. 4, the diode output conductance is

$$G_a = g_0 - g_c + \frac{1}{\frac{1}{g_c} + \frac{1}{g_0 - g_c + 2G_1 + G_i}}$$

$$= g_0 - \frac{g_c^2}{g_0 + 2G_1 + G_i} \quad .. \quad (2.27)$$

Substituting the value of G_1 from equation (2.16) the output conductance G_a becomes

$$G_a = \frac{2g_0(g_0^2 + g_0G_1 - g_c^2) + G_3(2g_0^2 + 2g_0G_1 - g_c^2)}{(2g_0^2 + 2g_0G_1 - g_c^2) + 2G_3(g_0 + G_1)} \quad \ldots \quad \ldots \quad (2.28)$$

If the value of G_3 for optimum power ratio given by equation (2.25) is substituted in (2.28), it will be found that

$$G_a = G_3$$

i.e. when the input circuit is matched to the source, and the conductance of the output circuit is adjusted for optimum power ratio, the output conductance of the diode is equal to the load conductance. However, the input conductance is not equal to the output conductance as is the case when G_1 is zero.

3.1. Form of Diode Characteristic

The full line of Fig. 5 shows an experimentally determined anode current/anode voltage characteristic of a typical diode.*

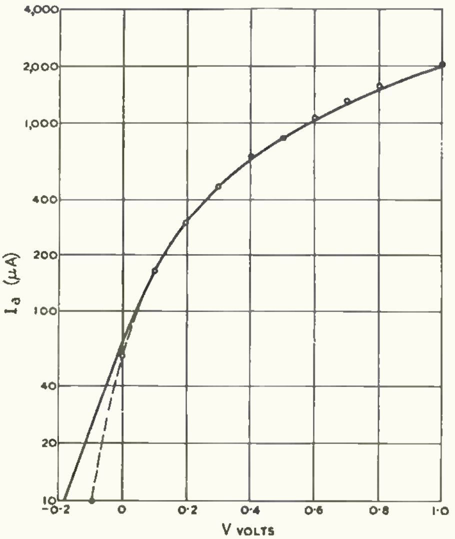


Fig. 5.—*Static characteristics of a diode. Full line, measured experimentally; points calculated from* $i = 183\ (v + 0.1)^{3/2}$.

The points surrounded by circles are calculated from the equation

$$i = 1.83 \times 10^{-3}(V + 0.1)^{3/2} \quad \ldots \quad (3.1)$$

and it will be seen that the calculated curve is a good approximation to the experimental curve for currents higher than about 100 microamperes. For currents smaller than this, however, the experimental curve is exponential and is given approximately by

$$i = 68 \times 10^{-6}\, \epsilon^{10V} \quad \ldots \quad \ldots \quad (3.2)$$

Most of the diode characteristic can, therefore, be represented by the combination of a three-halves power characteristic and an exponential characteristic. The performance of a diode having these characteristics will therefore be considered.

3.2. Three-halves Power Characteristic

Let the relation between the instantaneous current i, and the instantaneous voltage between cathode and anode of a diode be represented by

$$i = A(V + b)^{3/2} \text{ when } V + b \geqslant 0 \quad (3.3)$$

$$\text{and} \quad i = 0 \quad \text{when} \quad V + b < 0$$

where A is a constant for the diode, which depends on cathode area and the anode-cathode clearance, and b is a constant which depends on the contact potential and the cathode temperature.

The instantaneous diode conductance, g, is given by

$$g = \frac{3}{2}A\,.\,(V + b)^{1/2} \quad \ldots \quad \ldots \quad (3.4)$$

If an oscillator swing, of amplitude E_1, is applied to the diode in series with a D.C. bias V_0, the diode will conduct over a fraction α/π of the cycle, if E_1 is greater than $V_0 - b$ as shown in Fig. 2a, while if E_1 is less than $V_0 - b$ the diode will conduct over the whole of the oscillator cycle. In practice, the available oscillator voltage is, in general, large, so that it is necessary to consider only the case where E_1 is greater than $V_0 - b$.

It is shown in Appendix I, that for a three-halves power characteristic, the conductances g_0, g_1 and g_2 and the mean rectified current i_0 are given by :—

$$g_0 \simeq \frac{3A}{4}\sqrt{2E_1}\,.\,h^2\left(1 + \frac{h^2}{8}\right) \quad \ldots \quad (3.5)$$

$$g_1 \simeq \frac{3A}{2}\sqrt{2E_1}\,h^2\left(1 - \frac{3h^2}{8}\right) \quad \ldots \quad (3.6)$$

---

* The point of intersection of the characteristic with the voltage axis will vary from valve to valve, due to changes in contact potential.

$$g_2 \simeq \frac{3A}{2}\sqrt{2E_1}\,.\,h^2\left(1-\frac{15}{8}h^2\right) \quad .. \quad (3.7)$$

$$i_0 \simeq \frac{3A}{8}(2E_1)^{3/2}\,h^4\left(1+\frac{h^2}{12}\right) \quad .. \quad (3.8)$$

where

$h = \sin \alpha/2.$

3.3. Exponential Characteristic

At small anode current, the characteristic of the diode is given by

$$i = D\epsilon^{kV} \quad .. \quad .. \quad .. \quad (3.9)$$

where $k = \frac{e}{KT_c}$

e = electronic charge.

K = Boltzmann's Constant.

T_c = cathode temperature in degrees Kelvin.

D = constant.

The instantaneous diode conductance is given by

$$g = kD\,\epsilon^{kV}$$

It is shown in Appendix II that for the exponential characteristic g_0, g_1, g_2 and i_0 are given by

$$g_0 = D\epsilon^{-kV_0}kI_0(kE_1) \quad .. \quad .. \quad (3.10)$$

$$g_1 = 2D\epsilon^{-kV_0}kI_1(kE_1) \quad .. \quad .. \quad (3.11)$$

$$g_2 = 2D\epsilon^{-kV_0}kI_2(kE_1) \quad .. \quad .. \quad (3.12)$$

$$i_0 = D\epsilon^{-kV_0}kI_2(kE_1) \quad .. \quad .. \quad (3.13)$$

where $I_0(kE_1)$ is the zero order modified Bessel coefficient

$I_1(kE_1)$ is the first order modified Bessel coefficient

$I_2(kE_1)$ is the second order modified Bessel coefficient.

3.4. Variation of Power Ratio with Conducting Angle for a 3/2 Power Law Diode

Fig. 6 shows the variation with the conducting angle α, of effective power ratio M_e, calculated from equation (2.26), for a diode having the static characteristic given by equation (3.1), and having an oscillator voltage of 1 volt peak. The power ratio is calculated for values of input circuit conductances, G_1 of 10^{-3} mhos, 10^{-4} mhos, 10^{-5} mhos and 0 mhos respectively.

Curves A_1, B_1, C_1 and D_1 correspond to case I, where the signal beats with the oscillator fundamental, i.e $\omega_3 = \omega_1 - \omega_2$. In this case the conversion conductance $g_c = \frac{g_1}{2}$. Curves A_2, B_2, C_2 and D_2 correspond to case II where $\omega_3 = 2\omega_1 - \omega_2$ and therefore $g_c = \frac{g_2}{2}$. The values of g_0, g_1 and g_2 were calculated from equations (3.5), (3.6) and (3.7) respectively.

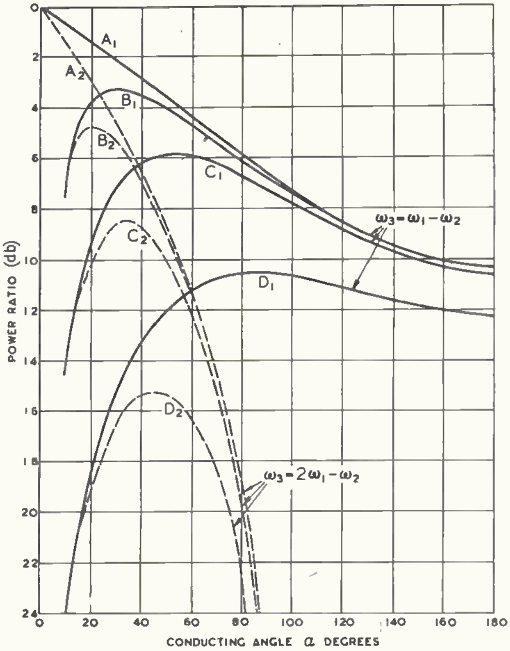


Fig. 6.—*Variation of power ratio with conducting angle for a diode with anode-current/anode-voltage characteristics given by* $i = 1.83\,(v + 0.1)^{3/2}$. *For curves* A_1 *and* A_2, $G_1 = 0$; B_1 *and* B_2, $G_1 = 10^{-5}$ *mhos*; C_1 *and* C_2, $G_1 = 10^{-4}$ *mhos*; D_1 *and* D_2, $G_1 = 10^{-3}$ *mhos.*

It will be seen that when $G_1 = 0$, i.e. when the loss in the input circuit is zero, the power ratio approaches 0 db as the conducting angle approaches zero, in both cases I and II. When G_1 is finite, however, there is an optimum angle for which the effective power ratio is a maximum, and this angle increases as the circuit conductance increases, the optimum power ratio becoming progressively lower.

In all cases, the power ratio, when operating on the oscillator second harmonic is less than when operating on the fundamental, the difference increasing as the circuit losses increase. The optimum angle is also smaller for the same circuit loss, and is more critical.

When $\omega_3 = 2\omega_1 - \omega_2$, the power ratio approaches zero when $\alpha = 90$ deg., i.e. when the diode is operated with zero bias. This is not the case when $\omega_3 = \omega_1 - \omega_2$.

3.5. Variation of i_0, g_0, g_1, and g_2 with Oscillator Peak Voltage E_1 and with Bias Resistance R_0

In a practical diode frequency changing circuit, the bias voltage V_0 is obtained by means of a resistor R_0 connected in series with the diode, and the parameters which can be readily varied are the oscillator peak voltage E_1 and the bias resistor R_0. When either of these parameters is varied, the mean current, i_0, will vary, and as this current can be conveniently measured, the diode performance is best expressed as a function of i_0.

For the 3/2 power characteristic the mean current, i_0, can be expressed in terms of E_1, R_0 and α as follows:—

$$i_0 = \frac{V_0}{R_0}$$

and

$$V_0 - b = E_1 \cos\alpha$$

Therefore

$$\begin{aligned} i_0 &= \frac{E_1 \cos\alpha + b}{R_0} \\ &= \frac{E_1(1 - 2\sin^2\frac{\alpha}{2}) + b}{R_0} \\ &= \frac{E_1(1 - 2h^2) + b}{R_0} \qquad \ldots \quad \ldots \quad (3.14) \end{aligned}$$

where $h = \sin\dfrac{\alpha}{2}$

But i_0 must also satisfy (3.8). Therefore combining (3.8) and (3.14),

$$\frac{3}{8}A(2E_1)^{3/2}h^4\left(1 + \frac{h^2}{12}\right) = \frac{E_1(1 - 2h^2) + b}{R_0} \qquad \ldots \quad \ldots \quad (3.15)$$

The maximum value of h is 1, so that no appreciable error is involved if $h^2/12$ is neglected in comparison with 1. On making this approximation equation (3.15) reduces to

$$\frac{3}{8}A2^{3/2}R_0E^{1/2}h^4 + 2h^2 - \left(1 + \frac{b}{E_1}\right) = 0 \qquad \ldots \quad \ldots \quad (3.16)$$

which is a quadratic in h^2, and on solving gives

$$h^2 = \sin^2\frac{\alpha}{2} = \frac{\sqrt{1 + x\left(1 + \frac{b}{E_1}\right)} - 1}{x} \qquad \ldots \quad \ldots \quad (3.17)$$

where

$$x = \frac{3}{8}A2^{3/2}R_0E_1{}^{1/2}$$

From equation (3.17), angle α can be calculated for any value of R_0 and E_1, and when α is known i_0, g_0, g_1 and g_2 can be determined.

For the exponential characteristic $i = D\epsilon^{kV}$ which more accurately represents the condition obtaining when the mean current is small, the mean current i_0 is given by (3.13), i.e.,

$$i_0 = D\epsilon^{-kR_0i_0}I_0(kE_1) \qquad \ldots \quad \ldots \quad (3.18)$$

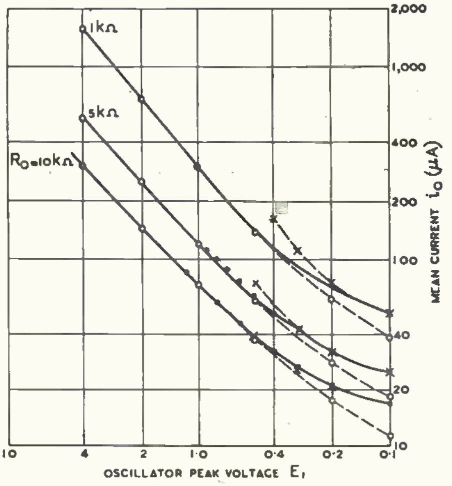


Fig. 7.—*Variation of mean current i_0 with oscillator voltage for a Diode. Points marked with a circle, calculated from 3/2 power characteristic; those marked with a cross, calculated from exponential characteristic; those with a dot are measured values.*

This equation can be solved for i_0 for various values of E_1 and R_0, while g_0, g_1 and g_2 are then given by

$$g_0 = ki_0$$

$$g_1 = 2g_0 \cdot \frac{I_1(kE_1)}{I_0(kE_1)}$$

$$g_2 = 2g_0\frac{I_2(kE_1)}{I_0(kE_1)}$$

Fig. 7 shows the mean current i_0, plotted against E_1 for various values of the bias resistor R_0. The points surrounded by circles are calculated from the 3/2 power law, while those shown by crosses are calculated from the exponential characteristic. The rectified current was determined experimentally at a low frequency for $R_0 = 10{,}000$ ohms and 5,000 ohms respectively and the points are shown by dots on the curves. It will be seen that the values calculated from the exponential characteristic agree very well with the experimental results at low currents (below 50 micro-amperes) while at higher currents the values derived from the 3/2 power characteristic give a good approximation.

Fig. 8 shows the values of g_0 and $\frac{g_1}{2}$ plotted against E_1 for $R_0 = 5{,}000$ ohms. As in Fig. 7, the circles are the points calculated from the 3/2 power law and the crosses for the exponential case, while the values determined experimentally are shown by dots. The values calculated from the exponential characteristic agree with the experimental results at low oscillator voltage and those obtained from the 3/2 power characteristic at high oscillator voltages. The transition region between the two characteristics is small, so that for any other value of bias resistor any error involved in interpolating between the two curves is small.

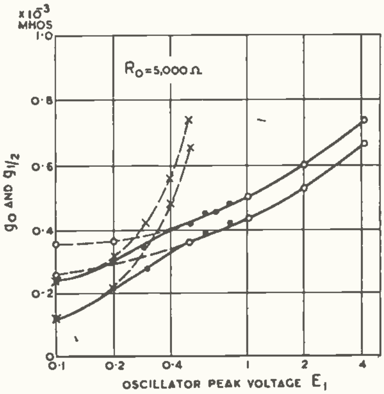


Fig. 8.—*Variation of mean conductance g_0 and conversion conductance $g_1/2$ with oscillator voltage for a diode. Points marked with a circle, calculated from 3/2 power characteristic; those with a cross, calculated from exponential characteristic; those with a dot, measured values.*

3.6. Variation of Power Ratio with Oscillator Peak Voltage

Knowing the variation of g_0, $\frac{g_1}{2}$, and i_0 with the oscillator peak voltage E_1, the power ratio can be plotted as a function of i_0. Curves are shown in Fig. 9 of the power ratio plotted against i_0 for various values of G_1, the input circuit conductance, the D.C. bias resistance R_0 being constant at 5,000 ohms and the current being varied by varying the oscillator voltage. A scale showing the oscillator voltage is also drawn, and it will be seen that for voltages above about 1.0 volt, the increase in power ratio is small, except when the conductance G_1 becomes appreciable.

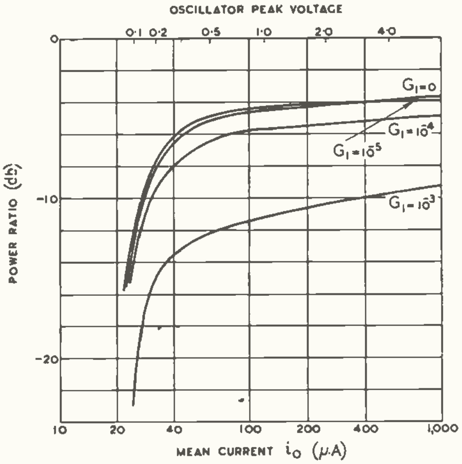


Fig. 9.—*Variation of effective power ratio with oscillator voltage and mean diode current.*

With this particular diode and the particular bias resistor the maximum power ratio obtainable is about -4 db, which occurs when the input circuit conductance is zero. A value of G_1 of 10^{-5} mhos hardly affects the ratio, but a drop of about 1 db occurs with $G_1 = 10^{-4}$ mhos and of about 5 to 6 db when G_1 is increased to 10^{-3} mhos. It is important therefore to keep the losses in the input circuit as low as possible.

3.7. Variation of Output Conductance G_a, and Input Conductance G_i with Oscillator Voltage

When both input and output circuits are matched for optimum gain, the output conductance of the diode is equal to the I.F. load conductance.

i.e. $$G_a = G_3 = \sqrt{\frac{g_0(g_0G_1 + g_0^2 - g_c^2)}{g_0 + G_1}}$$

Fig. 10 shows the output conductance, G_a, plotted against mean current, i_0, for the diode having the static characteristic shown by Fig. 5.

G_a is calculated for values of G_1 of 0, 10^{-5}, 10^{-4} and 10^{-3} mhos respectively, the D.C. bias resistance being 5,000 ohms in each case. At low values of current, i.e., at low values of oscillator drive voltage, the output conductance is affected very little by the input circuit conductance, but at a current of about 500 μA, the presence of an input circuit loss of 10^{-3} mhos increases G_a from about 0.3×10^{-3} mhos to 0.6×10^{-3} mhos.

The value of the diode input conductance depends on the value of the I.F. load, which, for optimum power ratio, depends on the input circuit loss. Therefore, the input conductance G_i also depends on G_1.

If the values of G_a from Fig. 10 are substituted for G_3 in equation (2.16), the variation of input conductance G_i with mean current for various values of G_1 may be calculated. Curves of G_i versus i_0 for values of $G_1 = 0, 10^{-5}, 10^{-4}$ and 10^{-3} mhos, R_0 being constant at 5,000 ohms, are shown in Fig. 11. It will be seen that the curve for $G_1 = 0$ is the same as the curve of G_a for $G_1 = 0$ which follows from equation (2.21).

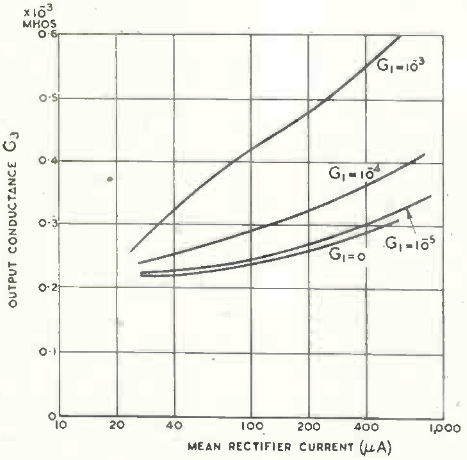


Fig. 10.—*Variation of output conductance with mean current.*

The above values of G_a and G_i are only shown for one value of bias resistance R_0, and the magnitude of both G_a and G_i will change with change of R_0; as R_0 is increased G_a and G_i will decrease and vice versa. However, if the mean current is greater than about 200 to 500 μA the effect on the power ratio is small.

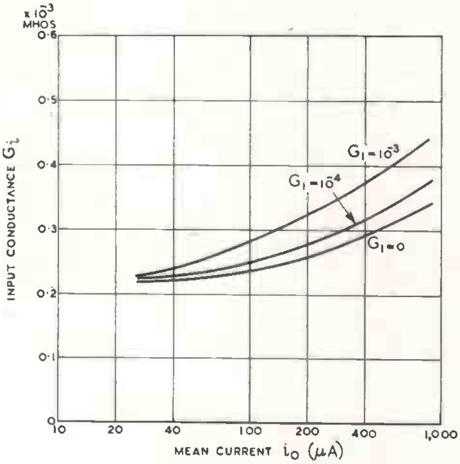


Fig. 11.—*Variation of input conductance with mean current.*

The authors desire to tender their acknowledgment to the General Electric Company and the Marconiphone Company, on whose behalf the work was done, which has led to this publication.

APPENDIX I

4.1. Analysis of the Three-Halves Power Characteristic

Let the anode current–anode voltage characteristic of a diode be given by

$$i = A(V + b)^{3/2} \text{ when } V + b \geqslant 0$$

and $i = 0$ when $V + b < 0$

The instantaneous conductance g is given by

$$g = \frac{3}{2}A(V + b)^{1/2}$$

When an oscillator voltage $E_1 \cos \omega_1 t$ is applied to the diode, the resulting diode current and conductance can be expressed by two Fourier Series

$$i = i_0 + i_1 \cos \theta + i_2 \cos 2\theta + \ldots\ldots$$

and $$g = g_0 + g_1 \cos \theta + g_2 \cos 2\theta + \ldots\ldots$$

where $\theta = \omega_1 t$

The constants of these series which are of importance in this paper are :—

$$i_0 = \frac{A}{2\pi}\int_0^{2\pi}(V + b)^{3/2} d\theta$$

$$g_0 = \frac{3A}{4\pi}\int_0^{2\pi}(V + b)^{1/2}d\theta$$

$$g_1 = \frac{3A}{2\pi}\int_0^{2\pi}(V + b)^{1/2}\cos\theta d\theta$$

$$g_2 = \frac{3A}{2\pi}\int_0^{2\pi}(V + b)^{1/2}\cos 2\theta d\theta.$$

If the bias voltage on the diode is $-V_o$, the instantaneous voltage across the diode is $E_1 \cos\theta - (V_o - b)$, so that

$$i = A[E_1 \cos\theta - (V_0 - b)]^{3/2}$$

and $$g = \tfrac{3}{2}A[E_1 \cos\theta - (V_0 - b)]^{1/2}$$

Two cases arise :—One in which E_1 is less than $V_0 - b$ and one in which E_1 is greater than $V_0 - b$. Only the latter is considered here.

4.2. Mean Diode Current i_0

If α/π is the fraction of the oscillator cycle during which the diode conducts, it will be seen from Fig. 2a that

$$V_0 - b = E_1 \cos\alpha$$

Then, the mean diode current, i_0 is given by

$$i_0 = \frac{A}{2\pi}\left[\int_0^{\alpha}\{E_1\cos\theta - (V_0 - b)\}^{3/2} + \int_{2\pi-\alpha}^{2\pi}\{E_1\cos\theta - (V_0 - b)\}^{3/2}\right]d\theta$$

Substituting $x = \dfrac{\theta}{2}$,

$$E_1 \cos\alpha = V_0 - b$$

$$\alpha/2 = \beta$$

$$i_0 = \frac{2A}{\pi}(2E_1)^{3/2}\int_0^{\beta}(\sin^2\beta - \sin^2 x)^{3/2}dx$$

Further putting $\sin x = \sin\beta\sin\xi$

and $$h = \sin\beta = \sqrt{\frac{E_1 - V_0 + b}{2E_1}}$$

Then $$i_0 = \frac{2A}{\pi}(2E_1)^{3/2}\int_0^{\pi/2}\frac{h^4\cos^4\xi}{(1 - h^2\sin^2\xi)^{1/2}}d\xi$$

Putting $\sin^2\xi = \eta$

$$i_0 = \frac{4A}{\pi}(2E_1)^{3/2}\int_0^{1}h^4(1 - \eta)^{3/2}\eta^{-1/2}(1 - h^2\eta)^{-1/2}d\eta$$

The integral is of the form which defines the hypergeometric function

$$\int_0^1 \eta^{\beta-1}(1 - \eta)^{(\gamma-\beta-1)}(1 - u^2\eta)^{-\alpha}d\eta = B(\beta, \gamma - \beta) . F(\alpha, \beta ; \gamma ; u^2)$$

where $$B(\beta, \gamma - \beta) = \frac{\Gamma(\beta)\Gamma(\gamma - \beta)}{\Gamma(\gamma)}$$

and $$F(\alpha, \beta ; \gamma ; u^2) = 1 + \frac{\alpha\beta}{\gamma}u^2 + \frac{\alpha(\alpha + 1)\beta(\beta + 1)}{\underline{|2}\,\gamma(\gamma + 1)}u^4 + \ldots\ldots$$

so that

$$i_0 = \tfrac{3}{8}Ah^4 B(\tfrac{1}{2}, \tfrac{5}{2})F(\tfrac{1}{2}, \tfrac{1}{2} ; 3 ; h^2)$$

which for small values of h reduces to

$$i_0 \simeq \tfrac{3}{8}Ah^4(2E_1)^{3/2}(1 + \frac{h^2}{12}) \quad \ldots \quad \ldots \quad (4.1)$$

4.3. Mean Diode Conductance g_0

The mean diode conductance g_0 is given by

$$g_0 = \frac{3A}{\pi}\int_0^{\alpha}\{E_1\cos\theta - (V_0 - b)\}^{1/2}d\theta$$

Substituting as for i_0

$$g_0 = \frac{3A}{\pi}(2E_1)^{1/2}\int_0^{\beta}(\sin^2\beta - \sin^2 x)\,dx$$

$$= \frac{3A}{\pi}(2E_1)^{1/2}\left[\int_0^{\pi/2}\frac{h^2 - 1}{(1 - h^2\sin^2\xi)^{1/2}}d\xi + \int_0^{\pi/2}(1 - h^2\sin^2\xi)^{1/2}d\xi\right]$$

But $$\int_0^{\pi/2}\frac{d\xi}{(1 - h^2\sin^2\xi)^{1/2}} = K(h)$$

Where K is the complete elliptic integral of the first kind

and $$\int_0^{\pi/2}(1 - h^2\sin^2\xi)^{1/2} = E(h)$$

Where E is the complete elliptic integral of the second kind.

So that $g_0 = \dfrac{3A}{\pi}(2E_1)^{1/2}[E(h) - (1 - h^2)K(h)]$

which for small values of h reduces to

$$g_0 \simeq \frac{3A}{4}(2E_1)^{1/2}h^2(1 + \frac{h^2}{8}) \quad \ldots \quad \ldots \quad (4.2)$$

4.4. Fundamental Component of Diode Conductance g_1

g_1 is given by

$$g_1 = \frac{3A}{\pi}\int_0^{\alpha}\{E_1\cos\theta - (V_0 - b)\}^{1/2}\cos\theta d\theta$$

Substituting as before

$$g_1 = \frac{6A}{\pi}(2E_1)^{1/2}\int_0^{\beta}(\sin^2\beta - \sin^2 x)^{1/2}(1 - 2\sin^2 x)\,dx$$

$$= 2g_0 - \frac{12A}{\pi}(2E_1)^{1/2}\int_0^{\pi/2}\frac{h^4\sin^2\xi\cos^2\xi}{(1 - h^2\sin^2\xi)^{1/2}}\,.\,d\xi$$

But

$$\int_0^{\pi/2} \frac{\sin^2 \xi \cos^2 \xi}{(1 - h^2 \sin^2 \xi)^{1/2}}\, d\xi = \tfrac{1}{2}B(\tfrac{3}{2}, \tfrac{3}{2})\, F(\tfrac{1}{2}, \tfrac{3}{2}\,;\; 3\,;\; h^2)$$

so that

$$g_1 = 2g_0 - \frac{6A}{\pi}\,(2E_1)^{1/2}\, h^4\, B(\tfrac{3}{2}, \tfrac{1}{2})\, F(\tfrac{1}{2}, \tfrac{3}{2}\,;\; 3\,;\; h^2)$$

which for small values of h reduces to

$$g_1 \simeq \frac{3A}{2}\,(2E_1)^{1/2}\, h^2(1 - \tfrac{3}{8} h^2) \quad \ldots \quad \ldots \quad (4.3)$$

4.5. Second Harmonic Component of Diode Conductance g_2

g_2 is given by

$$g_2 = \frac{3A}{\pi}\int_0^{\alpha}\{E_1 \cos\theta - (V_0 - b)\}^{1/2} \cos 2\theta\, d\theta$$

$$= 2g_0 - \frac{24}{\pi}\, A(2E_1)^{1/2}\, h^4\, B(\tfrac{7}{2}, \tfrac{3}{2})F(-\tfrac{1}{2}, \tfrac{3}{2}\,;\, 3\,;\, h^2)$$

which, for small values of h reduces to

$$g_2 = \frac{3A}{2}\,(2E_1)^{1/2}\, h^2(1 - \frac{15}{8}\, h^2) \quad \ldots \quad \ldots \quad (4.4)$$

APPENDIX II

5.1. Analysis of the Exponential Characteristic

Let the anode current/anode voltage characteristic of a diode be given by

$$i = D\epsilon^{kV}$$

then, the instantaneous conductance g is given by

$$g = kD\epsilon^{kV}$$

In order to obtain the Fourier Constants i_0, g_0, g_1, and g_2, use is made of the following relationship

$$\frac{1}{2\pi}\int_0^{2\pi} \epsilon^{z\cos\theta} \cos n\theta\, d\theta = I_n(z) \quad \ldots \quad \ldots \quad (5.1)$$

Where $I_n\,(z)$ is the modified Bessel Coefficient.

$$I_n\,(z) = \sum_{m=0}^{\infty} \frac{1}{\underline{/m}\,.\,\underline{/n+m}}\,(z/2)^{n+2m}$$

If a voltage $E_1 \cos\theta - V_0$ is applied to the diode, the mean current i_0 is given by

$$i_0 = \frac{1}{2\pi}\int_0^{2\pi} i\,.\,d\theta = \frac{1}{2\pi}\int_0^{2\pi} D\epsilon^{-kV_0}\,\epsilon^{kE_1\cos\theta}\, d\theta$$

which from (5.1) becomes

$$i_0 = D\epsilon^{-kV_0}\, I_0(kE_1) \quad \ldots \quad \ldots \quad \ldots \quad (5.2)$$

The constants g_0, g_1 and g_2 are

$$g_0 = \frac{1}{2\pi}\int_0^{2\pi} g\, d\theta = \frac{1}{2\pi}\int_0^{2\pi} kD\epsilon^{-kV_0}\,\epsilon^{kE_1\cos\theta}\, d\theta$$

$$= kD\epsilon^{-kV_0}\, I_0(kE_1) \quad \ldots \quad \ldots \quad \ldots \quad (5.3)$$

$$g_1 = \frac{1}{\pi}\int_0^{2\pi} g \cos\theta\, d\theta = 2kD\epsilon^{-kV_0}\, I_1(kE_1) \qquad (5.4)$$

$$g_2 = \frac{1}{\pi}\int_0^{2\pi} g \cos 2\theta\, d\theta = 2kD\epsilon^{-kV_0}\, I_2\,(kE_1) \qquad (5.5)$$

Correspondence

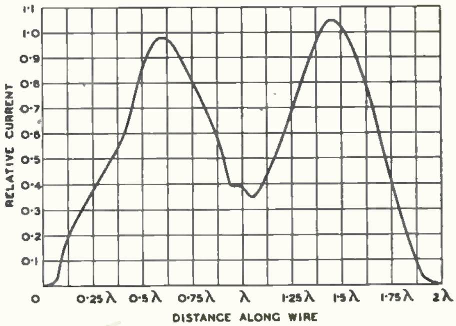
"Current Distribution along a Straight Wire in a Uniform Field."

To the Editor, "Wireless Engineer"

SIR,—With reference to your Editorial in the issue for November, 1942, dealing with current distribution along a straight wire in a uniform electro-magnetic field, it may be of interest to describe some experiments which I carried out during 1940 to confirm the theoretical results and also to determine the magnitude of the resonance effect.

A horizontal wire was erected parallel to an array of horizontal dipoles carrying equal co-phasal currents. The array was two wavelengths wide and it was assumed that three wavelengths from the array the field was substantially uniform over a distance of two wavelengths, the maximum wire length used. The current in the wire was measured by a meter coupled by a small pick-up coil placed close to the wire; no attempt was made to measure the phase of the current.

The measurements showed reasonably good agreement with the theoretical results and one particular case, for a wire two wavelengths long, is shown.



Current distribution along a straight wire two wavelengths long in a uniform magnetic field.

It was also found that resonance effects, though present, were not marked. This is to be expected if the radiation from the wire is taken into account. Inasmuch as the current distribution is sinusoidal for wires an odd number of half wavelengths long, the induced current in these cases can be calculated by classical methods. It is found that the ratio of the maximum current when the wire is an odd number of half wavelengths long (the resonant condition), to that when the wire is an integral number of wavelengths long (the anti-resonant condition) is Z_0/Z, where Z_0 is the characteristic impedance of the wire and Z is the self-impedance measured at the mid-point of the resonant wire. In general this ratio will not be large and hence the resonance effect will not be marked.

It is of interest to note that the result quoted in your Editorial for the current in a wire placed in a uniform electro-magnetic field has previously been given by Palmer and Gillard (*Nature*, June 5th, 1937) and a more general result for a wire in a non-uniform electro-magnetic field has been given by Brown (*Proc. I.R.E.*, September, 1939).

London, S.W.12 H. PAGE.

Wireless Patents

A Summary of Recently Accepted Specifications

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

RECEIVING CIRCUITS AND APPARATUS

(*See also under Television*)

547 896.—Rotary tuning-control device which is self-locking against accidental movement, and free from back-lash.

Standard Telephones and Cables and H. Bullas. Application date, 14th March, 1941.

548 148.—Pentode oscillator giving an output of constant amplitude over a frequency range which can be varied by altering the potential applied to the second control-grid.

A. C. Cossor and O. H. Davie. Application date, 25th March, 1941.

548 191.—Frequency-modulating system which includes means for preventing frequency fluctuations other than those representing the desired signal.

G. Guanella. Convention date (Switzerland), 14th September, 1939.

TELEVISION CIRCUITS AND APPARATUS

FOR TRANSMISSION AND RECEPTION

547 949.—Resistance-condenser time-base generating circuit with a linearising device comprising a two-stage valve unit with a common cathode load.

Marconi's W. T. Co. and N. L. Yates-Fish. Application date, 13th March, 1941.

548 147.—Cathode-ray television transmitter with means for converting a normally-curved electrostatic field into a substantially plane surface.

H. Miller and Electric and Musical Industries. Application dates, 25th March, 1941, and 19th March, 1942.

CONSTRUCTION OF ELECTRONIC-DISCHARGE DEVICES

547 945.—Construction and mounting of secondary-emission cathodes in an electron multiplier.

F. J. G. van den Bosch; E. T. J. Tapp; and Vacuum Science Products. Application date, 10th February, 1941.

547 971.—Construction and arrangement of the electrodes of a valve of the electron-multiplier type.

F. J. G. van den Bosch; E. T. J. Tapp; and Vacuum-Science Products. Application date, 10th February, 1941.

547 998.—Magnetic focussing system for a cathode-ray tube, particularly of the image-dissector type.

Standard Telephones and Cables (assignees of W. A. Knoop). Convention date (U.S.A.), 28th September, 1940.

548 119.—Valve of the resonant-cavity type in which the electrodes are contained in an envelope having the form of a hollow toroid.

Standard Telephones and Cables (assignees of C. V. Litton). Convention date (U.S.A.), 11th May, 1940.

SUBSIDIARY APPARATUS AND MATERIALS

547 968.—Construction of valve-base or holder with apertures and projecting ribs spaced to form a castellated rim.

Carr Fastener Co. and G. Wagstaff. Application date, 10th July, 1941.

547 991.—Magnetic circuit and apparatus for detecting cracks in ferrous metals.

L. Johnson. Application dates, 12th August and 21st November, 1941.

548 057.—Screening means for preventing radiation from the ignition system of internal-combustion motors, particularly for aircraft.

Bendix Aviation Corporation. Convention date (U.S.A.), 22nd March, 1940.

548 095.—Variable-impedance drive for applying frequency or amplitude modulation to a "bunched" or velocity-modulated stream of electrons.

Standard Telephones and Cables (assignees of C. V. Litton). Convention date (U.S.A.), 19th September, 1940.

548 097.—Spring and bayonet-slot coupling or fastening for connecting a valve to a socket with radial contact pins.

A. F. Bulgin and H. T. Stott. Application date, 11th June, 1941.

I.E.E. Meeting

A DISCUSSION on "Quartz Crystal Applications" will be opened by Capt. C. F. Booth at the Informal Meeting of the Wireless Section of the Institution of Electrical Engineers on Tuesday, January 19th, at 5.30.

Brit. I.R.E.

THE British Institution of Radio Engineers notifies us that its headquarters are now at 9, Bedford Square, London. W.C.1. The next meeting of the Institution will be held at the Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1, on Saturday, January 23rd, at 6.30, when J. H. Cozens, B.Sc., A.M.I.E.E., will deliver a paper on "Modern Condenser Technique, with Special Reference to Electrolytic Condensers."

GOODS FOR EXPORT

The fact that goods made of raw materials in short supply owing to war conditions are advertised in this journal should not be taken as an indication that they are necessarily available for export.

Abstracts and References

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For the information of new readers it is pointed out that the length of an abstract is generally no indication of the importance of the work concerned. An important paper in English, in a journal likely to be readily accessible, may be dealt with by a square-bracketed addition to the title, while a paper of similar importance in German or Russian may be given a long abstract. In addition to these factors of difficulty of language and accessibility, the nature of the work has, of course, a great influence on the useful length of its abstract.

PROPAGATION OF WAVES

1. The Propagation of Electromagnetic Waves in Parabolic Pipes.—R. D. Spence & C. P. Wells. (*Phys. Review*, 1st/15th July 1942, Vol. 62, No. 1/2, pp. 58–62.)

The writer concludes: " Thus it is of interest to know that the behaviour of electromagnetic waves, in so far as the above theory applies, is the same for all cylindrical pipes whose cross sections are defined by coordinates which separate the scalar wave equation " [rectangular, circular, elliptical, and parabolic].

2. Corrections to " The Calculation of the Skin Effect by the Perturbation Method."—S. M. Rytov. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 1, Vol. 11, 1941, p. 196.) *See* the same journal, Vol. 10, 1940, p. 176, and for a French version, 4191 of 1940.

3. Waves in Guide Tubes [Survey, with Field Patterns for Circular & Rectangular Sectioned Guides, for Various " H " and " E " Types: Limiting Wavelengths, Propagation Velocity, Methods of Excitation: Attenuation, Matching: Possible Applications: Radiation from Various Horns: Bibliography].—A. Riedinger. (*T.F.T.*, Feb. 1942, Vol. 31, No. 2, pp. 40–50.)

4. On the Most General Solution of the Maxwell Equations for Closed Cylindrical Cavities.—E. Ledinegg. (*Ann. der Physik*, 13th Aug. 1942, Vol. 41, No. 7/8, pp. 537–566.)

In his 1919 *Phil. Mag.* paper, Bromwich showed how the system of Maxwell's equations for periodic processes could be solved by integration only of a scalar differential equation of the form $\Delta U + k^2 U = 0$. The present writer shows that the multiplicity of solutions thus arising for metallically closed, singly linked cylindrical spaces represents the most general solution for the given boundary conditions. Bromwich's method allows also a large number of complicated electromagnetic phenomena to be solved in a particularly clear and illuminating fashion: particularly the propagation of electromagnetic waves in hollow " guides," the natural frequencies of metallic cavity resonators, and the propagation of the energy of electromagnetic waves, all of which have been thus treated by Borgnis (3874 of 1939; 50 of 1941; 357 of 1942). Apart from Borgnis's work, " little use has at present been made of the Bromwich method, though its many-sided applicability should have attracted a far wider interest ".

The present treatment deals in turn with the derivation of the field components; the construction of the general solution through the superposition of the fields of electric and magnetic types; the structure of the E_1 field component; the construction of a field distribution of the electric type which coincides, in one field component, with an arbitrary solution satisfying the Maxwell equations; an integral law for the Lecher-type $[\mathfrak{E}^o, \mathfrak{H}^o]$ field; and the Lecher type in singly and doubly related spaces (*i.e.* cylinder without inner conductor and cylinder with concentric inner conductor). " The proposed superposition principle, namely the representation of an arbitrary field satisfying the Maxwell equations, for cylindrical cavities, by the vectorial addition of two fields of electric and magnetic types, is completely established. This superposition principle can be extended, by suitable modification of the boundary conditions, to cover plane electromagnetic waves in infinitely long hollow cylindrical guides."

5. Propagation over the Ultra-Short-Wave Link [5 & 8 m] between Guernsey and England.—R. L. Smith-Rose & A. C. Stickland. (*Electrician*, 6th Nov. 1942, Vol. 129, p. 496 : summary of I.E.E. paper.)

6. Chalmers Ionospheric Observatory, Göteborg, Sweden.—O. E. H. Rydbeck. (*Terr. Mag. & Atmos. Elec.*, Sept. 1942, Vol. 47, No. 3, pp. 215–218.)

7. Further Notes on the Electron-Density Distribution of the Upper Atmosphere [Some New Curves of True Distribution for F Region, computed from Quiet-Day Virtual-Height Data (Huancayo) : Proof of Incompleteness of Description of F Layer when only Virtual Heights & Max. Electron-Density are given (Total Number of Electrons required) : f_k/f_c generally lies between Values for Parabolic & Epstein Layers : etc.].—O. E. H. Rydbeck. (*Terr. Mag. & Atmos. Elec.*, Sept. 1942, Vol. 47, No. 3, pp. 219–226.)

8. What do Spectrum-Analytical Investigations say as to the Constitution of the Upper Atmosphere ?—R. Penndorf. (*Gerlands Beiträge z. Geophysik*, No. 2, Vol. 59, 1942, pp. 175–190.)

A critical survey of recent investigations by the writer, Bhar, Cario & Stille, Götz, Harang, Vegard, and others. Among the conclusions reached are the following :—the composition of the air remains constant up to about 80 km (leaving out of account the traces of sodium, calcium, aluminium, etc.),but above that height atomic and molecular oxygen occur together, while above about 120 km the molecular form can no longer be traced, only the atomic : molecular nitrogen occurs right up to 1000 km, atomic nitrogen only from 100 or 120 km upwards. " Nothing is said in the present paper about the percentage distribution, since the necessary calculations will be published elsewhere " : but as regards the moot point of the predominance or otherwise of N over N_2 at heights above 100–120 km, the writer's opinion is that the proportion varies with latitude, so that in polar regions there is more N_2 above 120 km than in more southerly regions : this would explain the presence of the line 5198 AU in the auroral spectrum at Arosa and not at Tromsö. "The question of the percentage distribution of N and N_2 has an important bearing on the temperature of the F layer. In an earlier paper (1582 of 1941) I have calculated the ionospheric temperatures under the assumption of various distributions of the gas : the greater the proportion of atoms to molecules, the lower the temperature . . . the assumption of 41% N_2, 40% N, and 19% O leads to a temperature of 437° K, while if more N is present than N_2 a still lower temperature would be arrived at, which is just what we meteorologists want."

Among conclusions derived from spectroscopy of the light of the night sky, it is considered that while the atoms of Ca and Al are almost certainly meteoric in origin, the Na atoms may have a terrestrial origin, from NaCl : Cario & Stille give a height of 80 km for the sodium layer, and the writer points out that this particular height is one of special importance (beginning of temperature rise, luminous night clouds, etc.) : he remarks that the collection of the sodium atoms under a boundary layer would argue in favour of a terrestrial origin. He pays special attention to the Jouaust-Vassy suggestion (362 of 1942) that the sodium is responsible for Dellinger effects : he sums up : " Since a concentration of only 10^{-12} Na atoms is enough for the reflection of the electric waves, the normal ionisation of the D layer (produced by radiation from the solar photosphere) can thus be explained by the Na layer, while the sodium can also be made responsible for the abnormal D layer (resulting from the emission of the chromospheric Ca lines). This new theory of the ionospheric D layer still requires confirmation : simultaneous records are necessary of the intensity of the Na lines and the fade-out phenomena. . . . The investigations on the height and the degree of max. ionisation of the D layer have not yet led to definite conclusions. Apparently both vary from day to day, and the height seems to range between 60 and 80 km." Some of Jouaust & Vassy's conclusions seem perhaps a little premature : " the D layer is the coming problem of ionospheric research. . . ."

9. Distribution of Energy in the Phosphorescence Spectrum of Oxygen [New Experimental Results].—R. Herman & L. Herman. (*Génie Civil*, 28th Feb./7th March 1942, Vol. 119, No. 9/10, p. 105 : summary of a *Comptes Rendus* Note.)

10. " Veröffentlichungen des Geophysikalischen Instituts der Universität Leipzig : II Serie, Band 12 " [Book Review].—(*Physik. Zeitschr.*, 20th Sept. 1942, Vol. 43, No. 18, pp. 371–372.) Including Stranz's paper on measurements of the brightness of the sky near the sun, and Effenberger's on the variation of the nucleus and dust content of the atmosphere with meteorological factors.

11. On the Secular and Periodic Variations of Longitude [Curves of Periodic Variation (1920/1939) show Connection with Solar-Activity Curves : Pulsations of Earth, considered as Elastic Body, suggested as Cause], *and* Remarks on the Preceding Note [Variation of Speed of Propagation of Wireless Signal as an Alternative Explanation : Need for Systematic Study of Apparent or Absolute Speed Variations].—N. Stoyko : E. Esclangon. (*Comptes Rendus* [Paris], 16th March 1942, Vol. 214, No. 11, pp. 558–559 : pp. 559–561.) For earlier work *see* 1933 Abstracts, p. 437 (two) ; 1934 Abstracts, p. 375 ; and 8 & 2924/5 of 1935 and 2856 & 3595 of 1937.

12. On the Predominance of Positively Charged Particles in the Spectrum of the Cosmic Radiation [at 1000 m above Sea Level : Definite Evidence of 1.35 : 1 Predominance, at any rate in Hard Rays : Discussion of Cause].—L. Leprince-Ringuet & others. (*Comptes Rendus* [Paris], 16th March 1942, Vol. 214, No. 11, pp. 545–547.)

13. ON ALFVÉN'S THEORY OF MAGNETIC STORMS AND OF THE AURORA [Differences between This Theory & Chapman–Ferraro Theory: Dependence of Quantitative Results on Two Parameters: with Suitable Choice of These, Remarkably Good Agreement with Observation: Serious Criticisms].—T. G. Cowling: Alfvén. (*Terr. Mag. & Atmos. Elec.*, Sept. 1942, Vol. 47, No. 3, pp. 209–214.)

14. WORLD-WIDE HIGH-FREQUENCY COMMUNICATIONS PATTERNS: INFLUENCE OF MAGNETIC CONDITIONS IN 1942 [with Azimuthal Charts centred at San Francisco & Washington].—E. Dillon Smith. (*QST*, Aug. 1942, Vol. 26, No. 8, pp. 38–39.)

15. GEOMAGNETIC BAYS, THEIR FREQUENCY AND CURRENT-SYSTEMS [Annual Variation in Frequency: Daily Variation: Qualitative Comparison of Current-System of Bays with Observation: etc.].—H. C. Silsbee & E. H. Vestine. (*Terr. Mag. & Atmos. Elec.*, Sept. 1942, Vol. 47, No. 3, pp. 195–208.)

16. GEOMAGNETIC GIANT PULSATIONS OF MARCH 1ST 1942: *also* OSCILLATIONS AND PULSATIONS RECORDED DURING THE YEAR 1941, AT THE MAGNETIC OBSERVATORY, HERMANUS, SOUTH AFRICA, *and* CHARACTERISTICS OF MAGNETIC STORMINESS AT GJÖAHAVN, 1904.—D. la Cour: A. Ogg: K. F. Wasserfall. (*Terr. Mag. & Atmos. Elec.*, Sept. 1942, Vol. 47, No. 3, pp. 265–266: pp. 227–233: pp. 235–241.)

17. A SIMPLE APPARATUS FOR THE DEMONSTRATION OF THE RELATION BETWEEN PHASE AND GROUP VELOCITIES.—E. Mollwo. (*Physik. Zeitschr.*, 20th July 1942, Vol. 43, No. 13/14, pp. 257–258.)

18. REFLECTION AND REFRACTION OF SPHERICAL WAVES: SECOND-ORDER EFFECTS.—H. Ott. (*Ann. der Physik*, 8th July 1942, Vol. 41, No. 6, pp. 443–466.)

In a series of "schlieren" photographs (optical striae method) von Schmidt showed that the reflection of spherical waves at optically less dense media was accompanied by a noticeable subsidiary wave which had hitherto escaped observation (441 of 1937 and 1368 of 1939). This wave he recognised (on the Huyghens principle) as lateral radiation of the glancingly refracted ray progressing with higher velocity in the lighter medium; he named it the "head" wave (Kopfwelle) of this ray. To avoid confusion with the "head" wave of projectiles the present writer suggests the name "flank" wave. "The suggestion (*loc. cit.* and Burkard, 690 of 1941) that such 'flank' waves at the ionosphere may play a part in wireless telegraphy has attracted much attention to the problem of the supplementary waves. According to a remark by Joos & Teltow (2642 of 1939), the Schmidt waves are already contained implicitly in Sommerfeld's 1909 paper on radio-wave propagation, and it is his splitting of the field into the two components Q_1 and Q_2 that is brought to our eyes in the Schmidt experiment. But since the Sommerfeld treatment was limited to the immediate neighbourhood of the boundary surface, and above all assumed a source of radiation in a special position, namely in the boundary layer itself, it offers no comprehensive comparison with Schmidt's case: while the numerous later papers of other workers neglect the 'flank' wave completely, no doubt chiefly because it is an effect of the second order in $1/R$ and moreover, for reflection at conducting ground surfaces, exclusively considered, would be an undetectable inhomogeneous wave. The necessary generalisation, extended to include also the acoustical case, is therefore the object of the present paper, an object which cannot be attained by a simple extension of Sommerfeld's calculations," but by a fresh formulation of the problem and a new treatment.

Author's summary:—"The reflection and refraction of spherical waves (explosive sound waves or electromagnetic signals), taking into account sharp wave-pulses with and without dispersion, are investigated; the source of radiation is taken either in the boundary surface or else at a distance from it. In addition to the usual reflected and refracted spherical waves, further waves ('flank' waves) are found, in agreement with the observations of O. von Schmidt."

19. ON THE SOLUTIONS OF THE WAVE EQUATION WITH DISCONTINUOUS DERIVATIVES [with Extension of Results to include Reflection & Refraction].—F. G. Friedlander. (*Proc. Cambridge Phil. Soc.*, Nov. 1942, Vol. 38, Part 4, pp. 378–382.)

20. THE "TOTAL TRANSMISSION" OF DIFFRACTION GRATINGS [Inverse Phenomenon to Total Reflection: Theory, & Experimental Indications].—G. T. di Francia. (*La Ricerca Scient.*, Aug./Sept. 1942, Vol. 13, No. 8/9, p. 490.)

21. ELASTIC WAVES AND VIBRATIONS OF THIN RODS.—Prescott. (*See* 100.)

22. ELECTRIC DETERMINATION OF FILM-VOLUME AND FILM-DENSITY [including the Temporal Variations of the Dielectric Constant of the Soil in the Western Desert after a Rainy Day].—H. Löwy. (*Phil. Mag.*, Oct. 1942, Vol. 33, No. 225, pp. 772–774.) For previous work *see* references "1" and "2," and Abstracts, 1933, p. 640; 3430 of 1935; 382 of 1938; and 3705 of 1940.

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY

23. RECENT DEVELOPMENT, AND EXPERIENCE IN SERVICE, OF LIGHTNING ARRESTERS IN SWITZERLAND: SYMPOSIUM.—(*E.T.Z.*, 10th Sept. 1942, Vol. 63, No. 35/36, pp. 417–418: summary only.) Including Gantenbein's paper on new knowledge of the conduction mechanism in voltage-dependent resistances (unimportance of gaseous discharges, and consequent possibilities of improvement by impregnation: etc.).

24. ELECTRICAL RESISTANCE OF A VERTICAL COLUMN OF AIR OVER WATHEROO (WESTERN AUSTRALIA) AND OVER HUANCAYO (PERU).—

G. R. Wait. (*Terr. Mag. & Atmos. Elec.*, Sept. 1942, Vol. 47, No. 3, pp. 243–249.) With certain deductions from the "extra resistance" at Huancayo.

PROPERTIES OF CIRCUITS

25. On the Most General Solution of the Maxwell Equations for Closed Cylindrical Cavities.—Ledinegg. (*See* 4.)

26. Corrections to "The Calculation of the Skin Effect by the Perturbation Method."—Rytov. (*See* 2.)

27. Radio Data Charts: No. 2 (3rd Series)—Effect of a Screening Can on the Inductance and Resistance of a Coil.—J. McG. Sowerby. (*Wireless World*, Nov. 1942, Vol. 48, No. 11, pp. 254–257.) Based on Bogle's equations (821 of 1941).

28. The Piezoelectric "Bending Strip" as Electro-Mechanical Converter, *and* The Electrical Equivalent Circuit of Piezoelectric Sound Receivers.—Keller: Schäfer. (*See* 75 & 76.)

29. On the Interference Voltages due to Transients in Band-Pass Filters.—Kamphausen. (*See* 51.)

30. Graphical Means for the Calculation of Telephone Apparatus [in Particular Connection with the Many "Unfavourably Designed" Equipments in Invaded Territories, having (*e.g.*) Too High Input Impedances for linking to the "Great Germany" System].—K. Oettl. (*T.F.T.*, March 1942, Vol. 31, No. 3, pp. 61–66.)

31. On the Question of the Ideal Compensation of the Impedance or Admittance of Two-Terminal Networks, and an Application to a Separating-Filter Problem.—W. Lippert. (*Hochf:tech. u. Elek:akus.*, July 1942, Vol. 60, No. 1, pp. 11–19.)

Author's summary:—"A simple and clear method is given for the ideal compensation of the impedance or admittance of two-terminal networks with frequency characteristics of the resonance type. For ten simple but practically important resonance networks (table 1: nos. 5 and 6 are "Boucherot circuits"—*cf.* 2999 of 1942) the quantities necessary for compensation are calculated and collected into a table. It is shown that the compensation even of complicated two-terminal networks can be reduced to the application of the elementary case.

"A further important but little known compensation circuit for such networks is discussed [Figs. 4 & 5]: it consists of an ohmic resistance and, in parallel or in series with it, a two-terminal network which is arbitrary but representable by an iterative parallel and series connection.

"As an example of the application of the compensation methods here discussed to problems in the filter-circuit field, two simple low/medium/high separating filters with constant input operative resistance are described. With the help of an example, the more general, well-known compensation methods for two-terminal networks, based on the theory of rational positive functions, are discussed and compared with the compensation capabilities dealt with in the paper. The possible application of these methods to the design of more general separating filters with constant effective input resistance is pointed out."

32. Graphical Method of determining the Partial Resistances of a Quadripole in "T" Connection from Its Open-Circuit and Short-Circuit Characteristics.—W. Artus. (*Zeitschr. f. Fernmeldetech.*, 15th July 1942, Vol. 23, No. 7, pp. 103–105.)

33. The Real Power Output of a Generator, with Constant Internal Resistance and Constant Electromotive Force, to Arbitrary Complex External Impedances [Simple Geometrical Construction giving Complete Picture].—A. Weissfloch. (*Hochf: tech. u. Elek:akus.*, July 1942, Vol. 60, No. 1, pp. 10–11.)

34. The Calculation of the Voltage Distribution in a Multiple Chain Network [and the Conditions for a Faithful Oscillographic Reproduction of Steep Surge Voltages].—R. Elsner. (*Wiss. Veröff. a. d. Siemens-Werken*, No. 2, Vol. 20, 1942, pp. 83–90.)

35. A Diagram for the Calculation of Inductively Coupled Current Branches, especially 90° Artificial Circuits.—H. Poleck. (*Wiss. Veröff. a. d. Siemens-Werken*, No. 2, Vol. 20, 1942, pp. 13–19.) Following 2779 of 1941.

36. On the Mode of Action of the "Cathode" Amplifier.—R. Wunderlich. (*E.N.T.*, May 1942, Vol. 19, No. 5, pp. 63–66.)

"For the purpose of a d.c. transmission of voltage, or for matching at the input of a cable, for pre-stages of amplifiers, etc., the cathode amplifier stage is often used in valve arrangements with earthed negative pole [the only reference given is to a paper by J. Költer, on the valve as impedance converter, in *Hausmitt. d. Fernseh-G.m.b.H*, No. 1, 1940]. The circuit has the advantage that the voltage delivered is obtained at points which are free from the anode voltage; the input voltage is, of course, applied between the input grid and earth. With a single- or multi-grid valve, which behaves normally as a class A amplifier, a voltage amplification of less than unity must be tolerated: and also, in certain cases, a d.c. voltage which is produced by the repose current in the load resistance [in cathode/earth lead] and which must be taken into account in the subsequent stages. Thus the cathode amplifier stage only enables a power amplification to be obtained."

For the present theoretical analysis the behaviour of the circuit to alternating voltages is studied, but the results can be applied also to d.c. voltages. The simple equivalent circuit of Fig. 4 is obtained. The formula for the power amplification ratio of the stage shows that there is no phase reversal between the input and output voltage, as is the case in most amplifier circuits: and that this amplification ratio must always be below unity:

it is zero when the complex load resistance z is zero, and when z increases it increases also, and approaches the limiting value $1/(1 + D)$ as z becomes very large compared with R_i. At the same time the magnitude of the voltage which can be applied without causing over-modulation also increases. In practice it is therefore generally advisable to make z as large as possible, and on occasion to lead-in separately a d.c. bias for adjustment to the correct working point (Fig. 5). Experiments on an AD1 triode (circuit Fig. 9) show excellent agreement with the theoretical results.

37. OVER-ALL VOLTAGE GAIN OF LOW-FREQUENCY AMPLIFIERS WITH NEGATIVE RESISTANCE.—A. S. Rao. (*Indian Journ. of Phys.*, April 1942, Vol. 16, Part 2, pp. 111–118.) A preliminary note on this work was dealt with in 2313 of 1942.

38. NON-LINEAR CIRCUITS AND SOME EXAMPLES OF THEIR APPLICATION [as Relays for Control & Supervision Purposes].—K. Steuernagel. (*AEG-Mitteilungen*, Jan./April 1942, No. 1/4, pp. 11–17.)

Analysis of the functioning of a voltage-resonance (series) circuit containing an iron-cored choke, of a current-resonance (parallel) circuit containing an iron-cored choke, and of the first circuit again with the addition of a series resistance, leads to the description (pp. 15–17) of an investigation, theoretical and experimental, of a voltage-resonance circuit having an iron-cored choke and also a resistance in parallel with the condenser. This paralleled resistance takes the form of a selenium rectifier supplying a d.c. meter or relay: this combination is merely to indicate the conditions in the resonant circuit.

The investigation shows that the critical voltage, at which the " kipp " or relaying action due to the shape of the circuit characteristic begins, depends on the number of turns in the choke winding, and thus on the inductance: a way of adjusting the operating voltage is therefore provided by drilling a hole into the shell of the core and fitting it with a set screw of magnetic material. The adjustment of the screw gives a control range of about ± 5%. The " release " voltage can be adjusted by a variable resistance in the load circuit. Apart from such use, the circuit can be used for monitoring frequency or r.p.m., thanks to the frequency characteristic of the critical voltage (Fig. 10). Among the several advantages of such devices over the various electromagnet types of relay, perhaps the most important are their insensitiveness to vibration and their quick response.

39. THE LAWS GOVERNING AUTOMATIC CONTROL PROCESSES [Completely General, Purely Mathematical Treatment starting from the Küpfmüller Integral Equation].—E. Görk. (*Wiss. Veröff. a. d. Siemens-Werken*, No. 2, Vol. 20, 1942, pp. 109–144.)

TRANSMISSION

40. THEORY OF THE MAGNETRON: II—OSCILLATIONS IN A SPLIT-ANODE MAGNETRON [Large Oscillations in Certain Frequency Ranges depending on Number of Segments ($2n$: Frequencies given by $y_5 < y < n - \sqrt{2}$, $n < y < n + \sqrt{2}$, eqn. 64, where $y = 21310/\lambda H$): Calculation of Internal Resistance: etc.].—L. Brillouin. (*Phys. Review*, 1st/15th Aug. 1942, Vol. 62, No. 3/4, pp. 166–177.) A summary was dealt with in 1354 of 1942: for I *see* 107 & 1681 of 1942.

41. SPECTRA AND NON-LINEAR-DISTORTION FACTORS OF FREQUENCY- AND AMPLITUDE-MODULATED OSCILLATIONS: PART I—SPECTRUM ANALYSIS: PART II—" KLIRR " FACTORS DUE TO ALTERATIONS IN THE SPECTRUM.—M. Kulp. (*E.N.T.*, May & June 1942, Vol. 19, Nos. 5 & 6, pp. 72–84 & 96–109.)

From the Telefunken laboratories. Author's summary:—" A series of problems is dealt with which are of importance in the design of transmitters and receivers for frequency-modulated oscillations. These problems relate to the distribution of the frequencies in the spectrum when the carrier is modulated, and the distortions of this modulation by overtones or combination tones. The whole work is divided into three parts. In Part IA the distribution of the frequencies in the spectrum is calculated for the case of pure frequency modulation with one, two, and finally an arbitrary number of modulating frequencies. The number, position, and intensity of the frequencies in the spectrum are given in eqn. 2 for a single modulating frequency, in eqn. 7 for two, and in eqn. 11 for an arbitrary number of modulating frequencies. The over-all width of the spectrum which has actually to be taken into account is also given, phase influences are considered, and illustrative examples added (Figs. 1–3).

" Part IB calculates the changes in the spectrum when amplitude modulation is added to the frequency modulation. The resulting new intensity distribution is given by eqn. 17. Conditions for symmetry of the distribution are given. The width of the spectrum is increased by this additional amplitude modulation; in certain special cases, however, it may be decreased [end of section a]. Application of the results allows the action of an amplitude limiter on a frequency- and amplitude-modulated spectrum to be calculated. The appearance of a spectrum given by additional amplitude modulation and subsequent elimination of this by an amplitude limiter is seen in Figs. 4–6, and in a second example in Fig. 7. Arbitrary phasing of the amplitude modulation is taken into account in eqn. 31 . . .

" In Part II the treatment is reversed, and it is shown how, from an arbitrary given intensity distribution in the spectrum, it can be calculated with what tones and to what depth the carrier is frequency- and amplitude-modulated. For the amplitude-modulated component eqn. 13 gives the strengths of the fundamental and overtones, while eqn. 22 gives these coefficients for the frequency-modulated component. The possibility is thus offered of determining, for a spectrum of known modulating frequencies, what new modulation tones will appear (or what ' klirr ' factors and disturbances of modulation will result) if any intensity changes are brought about in this spectrum, as for example by the passage of the modulated oscillation through filters, oscillatory circuits, or other arrangements. The particularly important special case of a carrier with pure frequency modulation by a single frequency is dealt with in section AC. Non-linear distortion factors can occur not only as a result of intensity changes of the individual spectral frequencies, but also through phase displacements: this is shown in section AD. Only circuit components with linear frequency-dependence of phase produce no non-linear distortion.

"Chapter IIB specialises the calculation of 'klirr' factor to particular cases. In section BA it is shown that for intensity changes symmetrical to the carrier frequency, only odd harmonics of the frequency modulation, and an amplitude modulation with only even harmonics, occur. . . ." Asymmetric intensity changes are dealt with in section Bb, while section Bd gives a simplification of the calculation for single-sideband telephony and carrier-suppression. Part III, when it appears, will apply the results already obtained to the treatment of special problems such as the demodulation of frequency-modulated oscillations, questions of multi-channel working, and the calculation of "klirr" factors for single-sideband systems, both for amplitude and frequency modulation.

42. THE EXPERIMENTAL RECORDING OF THE FREQUENCY SPECTRUM OF A RADIOTELEGRAPHIC TRANSMISSION [including Description of the Analysing Voltmeter, with Quartz Filter having about 80–110 c/s Pass-Band, Logarithmic-Scale Circuit resembling Ballantine's (1931 Abstracts, p. 161), & Wide Voltage Range: Some Results (including Confirmation of Good Effect of *RC* Retarding Network between Key & Control Electrode): etc.].—P. Bernardi & C. Poledrelli. (*Alta Frequenza*, July 1942, Vol. 11, No. 7, pp. 306–332.)

An appendix deals particularly with the design of the quartz filter and of the frequency-conversion stage, and the difficulty in the latter due to electron coupling between the control and oscillator grids.

43. ON AMPLITUDE MODULATION IN THE PRESENCE OF SEVERAL FREQUENCIES.—R. Rasch. (*Wiss. Veröff. a. d. Siemens-Werken*, No. 2, Vol. 20, 1942, pp. 54–73.)

Previous treatments of modulation, by Carson in 1921 onwards, Bennett (Abstracts, 1933, p. 389, and 1934, pp. 611–612) and Schmid (1741 of 1937), all suffer from the limitation that they deal only with two frequencies. Modulators used in practice always develop a large number of frequencies of various amplitudes: hence the desirability of the present theoretical investigation, using the methods developed by the last two workers.

Author's summary:—"The strength of the modulation products produced by a modulator depends on the form of the modulator characteristic employed, on the amplitudes of the frequencies constituting the modulation product, and on the amplitudes of extraneous frequencies not forming part of the modulation product. The paper calculates the strengths of various modulation products for the cases of parabolic, exponential, and sharply bent characteristics, and investigates particularly the way in which they are influenced by the presence of a third frequency which does not form part of the modulation product. The results show that this influence is always slight so long as the third frequency has only a small amplitude. If, however, it has an amplitude greater than that of the other two, its influence in the case of the linear characteristic with a sharp bend, both with and without biasing voltage, is considerable: the amplitude of the modulation product is damped, the degree of damping depending on the order of the particular modulation product [for the modulation product $\Omega \pm \omega$, for instance, there is a linear relation, so that an extraneous frequency 10 times larger in amplitude would damp the amplitude of the modulation product by a factor of 10]. The calculation of the modulation products for characteristics with a sharp bend shows also that the introduction of a biasing voltage causes the production of new modulation products."

44. THE TELEFUNKEN SINGLE-SIDEBAND TRANSOCEANIC TRANSMITTER.—W. Buschbeck & P. G. Rothe. (*See* 224.)

45. ON A NEW PIEZOELECTRIC OSCILLATOR [Negative-Resistance Circuit].—Pinciroli. (*See* 118.)

46. SIMPLIFIED BAND-SWITCHING: "LINK" NEUTRALISATION FOR EASY BAND-CHANGING.—H. E. Jones. (*QST*, Sept. 1942, Vol. 26, No. 9, pp. 31–35.)

RECEPTION

47. CIRCUIT FOR THE DETECTON OF ULTRA-SHORT WAVES.—M. J. O. Strutt & A. van der Ziel. (*Hochf:tech. u. Elek:akus.*, July 1942, Vol. 60, No. 1, p. 27.) Philips Patent, D.R.P. 715 817: "since the input circuit has only to supply the energy necessary to accelerate the electrons, it is less damped than in the usual grid detector."

48. THE SENSITIVITY OF VELOCITY-MODULATED VALVES USED FOR RECEPTION.—J. Müller. (*Hochf:tech. u. Elek:akus.*, July 1942, Vol. 60, No. 1, pp. 19–21.)

The h.f. amplifier stage here considered is outlined as follows: "The electrons move with current strength J from left to right (Fig. 1) and pass first through the electrode system a, b, to which the input circuit (with aerial) is connected: they then traverse the drift-tube space b, c, and arrive at the electrode system c, d, for the output circuit. The advantage is the possibility of good decoupling between input and output, provided by the necessary drift space which separates the two pairs of electrodes. In calculating the valve noise it must be taken into account that the electron flow carries with it a noise convection current $\mathfrak{J}$. If all the electrons carry out the same motion in the stationary state (neglect of Maxwellian velocity distribution, of deflection and current-sharing at the electrons, and of space charge), then the noise convection currents are arranged along the electron flow completely according to phase. The discharge gap between a and b is to be regarded as a diode, invaded by a stream of electrons with constant initial velocity v_0 and mean current value J, on which is superposed a small alternating noise current $\mathfrak{J}_a$. Such a diode, where the entering electron current is saturated, behaves as a loss-endowed capacitance (Müller, 1933 Abstracts, pp. 443–444)," in which the loss factor tends towards zero as the path-time angle becomes small, as is assumed here. The drift-space between *b* and *c* is also to be regarded as a diode, in which an electron current modulated both in intensity and velocity enters at *b*. The important point for this investigation is the intensity modulation (and thus the convection alternating current) at electrode *c*. This convection current can be calculated by the general formula in the earlier paper (*loc. cit.*), which for the present case leads to eqn. 1 (p. 20).

Such is the arrangement for which the selectivity is sought on the lines given by Fränz (3240 [and 3564] of 1942). The noise power per cycle/second of band width is the smaller (that is, the sensitivity is the better) the lower the volt-velocity of the electrons in the drift space and the greater the path-time angle in the drift space, the current strength, and the circuit resistance. If we make $U_0 = 500$ v, the path-time angle $\omega\tau = 4\pi$, the circuit resistance $R_K = 20$ kilohms, and the electron current $J = 10$ mA, then the noise power per cycle/second of band width comes out at $2500.KT_0$, a very large value when it is remembered that with a pentode on long wavelengths, values under $1.KT_0$ can be obtained.

49. The Highest Attainable Sensitivity of Receivers with Band-Filter Input.—H. Behling: Fränz. (*E.N.T.*, May 1942, Vol. 19, No. 5, pp. 66–72.)

Fränz, in his paper dealt with in 3126 of 1939, made a thorough investigation of the theoretical limit of sensitivity of a receiver having a single oscillatory circuit as its input. The present writer extends this work to a receiver having as its input a band-filter consisting of two coupled circuits.

Author's summary :—" For receivers which, for pre-selectivity purposes, are provided with a band-filter as input circuit, the sensitivity (signal/noise ratio) is calculated. The sensitivity is a function of the coupling x of the aerial to the band-filter, and involves two parameters, $\alpha = R_{\ddot{a}}/R_p$ and $\beta = k/d$. From this function, which is represented in curves, it becomes clear that an input band-filter, as compared with a single input circuit, always brings with it a certain loss in sensitivity, which only vanishes if the coupling between the band-filter circuits is infinitely tight (and the aerial coupling correspondingly tight).

" But this tight coupling would imperil the selectivity of the band-filter, since the closer aerial coupling involves an increased damping of the first circuit of the band-filter, and a consequent decreased selectivity for the filter. The selectivity of the filter, thus damped by the aerial, is calculated with x and k/d as parameters, and for $k/d = 1$ is plotted in curves for various values of x [$x = 0$, 0.6, 2, and ∞ : Fig. 9].

" In actual practice a tolerable compromise would be reached between selectivity and sensitivity : it would be logical to take the selectivity as the starting point, since it was with this attribute in view that the band-filter was chosen as input circuit. Thus the coupling of the band-filter circuits, k/d, and the aerial coupling x would be so chosen that the selectivity requirements are fulfilled : the corresponding loss of sensitivity, which can be derived by the formulae and curves given, must be accepted as necessary."

A numerical example is worked out : a receiver, with band-filter as input circuit, is worked on a frequency of 20 Mc/s : the tuning capacitance is 150 pF, the damping 1%, the equivalent valve-noise resistance 5 kilohms. It is required to find the optimum coupling conditions to satisfy both selectivity and sensitivity requirements. Assuming that the two circuits of the band-filter are similar, R_{p2} comes out at 5 kilohms, so that α $(= R_{\ddot{a}}/R_{p2})$ is equal to unity. Now Fig. 4 (curves showing sensitivity as a function of the coupling k/d_2 between the two filter circuits) shows that k/d_2 must be chosen at least equal to unity if more than 60% of the max. possible sensitivity is not to be lost. Then if $\alpha = 1$ and also $k/d_2 = 1$, Fig. 5 (curves for opt. aerial coupling x as a function of α, for various values of k/d) shows that x_{opt} is about 0.6 : this is also seen in Fig. 3, giving for various α, β values the variation of the sensitivity as a function of x.

For $x_{opt} = 0.6$ approx., the loss in selectivity (given by eqn. 35 and the curves of Fig. 9, mentioned above) would be 1 : 1.83, a comparatively small loss. If, to increase the sensitivity, the value of k/d_2 were increased from 1 to 3, then Fig. 5 would give $x_{opt} = 0.14$: this would yield a sensitivity gain of 1 : 1.5, but at the cost of a 4.7 times increase in loss in selectivity, which is unreasonable. The useful compromise obtained by choosing $k/d_2 = 1$ and $\alpha = 1$ is therefore considered in greater detail on p. 71, r–h column. Eqn. 20 and Figs. 4 & 5 are applied to solve the case of an aerial dissipative resistance of 100 ohms and a total receiver band width of 10 kc/s : thus to obtain a signal/noise ratio 1 : 1 the aerial voltage (signal-generator voltage) must be 0.486 μv. The danger is mentioned of obtaining false values of sensitivity when, in working with low-ohmic signal generators, the aerial resistance is not simulated : such values would be over-optimistic, as would be found when the receiver came to be operated on an aerial.

50. Reduction of Noise Level in Superheterodyne Reception by maintaining the Optimum Ratio between Signal and Local-Oscillator Amplitudes.—K. Koschmieder. (*Hochf:tech. u. Elek:akus.*, July 1942, Vol. 60, No. 1, p. 26.) Lorenz Patent, D.R.P. 714 733 : part of the received carrier is rectified and used to control the oscillator.

51. On Interference Voltages due to Transients in Band-Pass Filters [with Particular Reference to Interference produced by Keying, in One Channel of Multiplex System, in the Neighbouring Channels].—G. Kamphausen. (*T.F.T.*, Jan. & Feb. 1942, Vol. 31, Nos. 1 & 2, pp. 11–20 & 50–56.)

Based on Küpfmüller's work on transients, but obtaining new and simple formulae, suitable for practical purposes, by limiting the treatment to cases where the principal frequencies of the suddenly applied electromotive force lie outside the pass band of the filter. The results of the various calculations, for six types of transient wave-form and various time conditions, are collected in Table VI: they find useful application in investigations on all types of communications systems in which relatively narrow frequency bands are used. The paper ends with a long oscillographic confirmation of the theoretical conclusions.

52. Fluorescent-Lamp Radio Interference.—(*QST*, Sept. 1942, Vol. 26, No. 9, pp. 58–59: summary, from *Sylvania News*.)

53. A New Apparatus for Testing the Insulation of High-Tension Lines and Switching Plant in Actual Service [Method of H.F. Field].—B. Koske. (*AEG-Mitteilungen*, May/Aug. 1942, No. 5/8, pp. 54–55.)

54. The Design-Calculations of Smoothing Arrangements for the L.F. Interference Suppression of Rectifier Plant [particularly 6- and 12-Phase: for Prevention of Hum in Receivers worked off the System].—R. Moebes. (*T.F.T.*, March 1942, Vol. 31, No. 3, pp. 73–77.)

55. A Moisture-Proof High-Frequency Copper-Oxide Rectifier, and Other Papers on Dry-Plate Rectifiers.—Renne & others. (*See* 168 & adjacent items.)

56. The Telefunken Single-Sideband Receiver for Two Speech Channels.—Kotowski & others. (*See* 224.)

57. The "Professional Label" for Broadcast Receivers [Compulsory Labels issued by U.S.E., and the Necessary Steps to obtain Them: the Required Data, & Methods of Measurement].—(*Génie Civil*, 1st Oct. 1942, Vol. 119, No. 22, pp. 271–272.)

58. European Listeners: Comparative Figures of Radio Density.—(*Wireless World*, Nov. 1942, Vol. 48, No. 11, p. 267.)

59. Rediffusion: a Development of Broadcasting.—P. Adorjan. (*Endeavour*, Oct. 1942, Vol. 1, No. 4, pp. 161–165.)

AERIALS AND AERIAL SYSTEMS

60. Waves in Guide Tubes [Survey, including Radiation from Various Horns].—Riedinger. (*See* 3.)

61. Contribution to the Measurement of the Transmission Constants of Concentric Cables in the Decimetric-Wave Region [with Some Results for Oppanol & Styroflex Types].—Ditl. (*See* 110.)

62. "Rhombic Antenna Design" [Book Review].—A. E. Harper. (*QST*, Sept. 1942, Vol. 26, No. 9, p. 36.)

63. On the Burying-Depth of Stay Blocks.—K. Machens. (*T.F.T.*, May 1942, Vol. 31, No. 5, pp. 133–139.) For previous work *see* 3003 of 1942.

VALVES AND THERMIONICS

64. Theory of the Magnetron: II—Oscillations in a Split-Anode Magnetron.—Brillouin. (*See* 40.)

65. The Sensitivity of Velocity-Modulated Valves used for Reception.—Müller. (*See* 48.)

66. Probe Investigations on "Stabilised" Mercury-Vapour Arcs [including an Examination of the 10–30 cm Plasma Oscillations].—G. Wehner. (*Ann. der Physik*, 13th Aug. 1942, Vol. 41, No. 7/8, pp. 501–519.) Further development of Fetz's work (1976 of 1942: for later work *see* 158, below).

67. The Elementary Process in the Secondary-Electron Emission of Polar Crystals [Experimental Investigation on Thin Films of Alkali Halides (deposited on Platinum or Copper) with Various Primary Electron Energies: the Relation to Energy Levels of the Crystals, as indicated by Absorption Bands: etc.].—O. Krenzien. (*Wiss. Veröff. a. d. Siemens-Werken*, No. 2, Vol. 20, 1942, pp. 91–108.)

68. The Secondary-Electron Emission from Semiconductors and Insulators.—G. Maurer. (*Zeitschr. f. Phys.*, 22nd Sept. 1941, Vol. 118, No. 1/2, pp. 122–144.)

Beginning with a short review of the contradictory results of past Russian, Dutch, and American researches, the writer proceeds to formulate a general picture of the process, from which he derives a formula (eqn. 14) for J, the emission-current density in amperes/cm², and another (eqn. 15) for the secondary-emission coefficient s. According to this picture the predominant source of the secondary electrons is the highest fully occupied energy band (in the case of alkali halides, the halogen ions): the emission of the secondary electrons is impeded by the potential threshold, at which the backwards reflection is the greater, the higher the threshold: the collision frequency of the primary electrons with the crystal electrons is so large that on the average, for the materials in question, an electron leaves the fully occupied band after at most three passages through a lattice plane.

Comparing the theory with observed results, it is seen that eqn. 14 makes the secondary-emission current J proportional to the primary current P, while according to eqn. 15 the s.e. coefficient s is independent of P: these results agree with observation. Eqn. 15 agrees qualitatively with the observed behaviour of s at oblique incidence of the primary electrons, with measurements (with the apparatus of Fig. 3) of the dependence of s on the energy of the primary electrons, in the range of 50–900 v, and with various other measurements described.

69. The Electric Field in Semiconductors due to the Flow of Current, and the Ejection of Electrons by this Field.—M. Kosman & N. Ivanyuk. (*Journ. of Exp.*

& Theoret. Phys. [in Russian], No. 1, Vol. 11, 1941, pp. 85–88.)

It was assumed that if a current flows through a semiconductor a strong electric field is built up near its positive surface which must lead to the ejection of electrons. Experiments were conducted with a glass plate 1.5 cm thick, which have confirmed that if a potential difference of 800 v is applied to the plate and the plate heated up, electrons with velocities up to 700 v are ejected from it.

70. The Secondary Electron Emission from Potassium.—M. S. Joffe & I. V. Nechaev. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 1, Vol. 11, 1941, pp. 93–95.)

Experiments were made investigating (a) the relationship between the coefficient of secondary electron emission σ for potassium and the energy V_p of the primary electrons, and (b) the energy distribution of the secondary electrons. It was found that σ is dependent on the time elapsing after the layer of potassium has been deposited, and final measurements were therefore made while continuous slight evaporation of potassium was maintained. A curve $\sigma = f(V_p)$ is plotted (curve 1 in Fig. 1) from which it can be seen that σ reaches a maximum of 0.69 at $V_p = 200$ v. Curves showing the energy distribution of secondary electrons for $V_p = 100$ v (Fig. 3) and $V_p = 1400$ v (Fig. 4) are also plotted. It appears that these curves are similar to those of other metals.

DIRECTIONAL WIRELESS

71. Wireless Position-Finding [by Pulse Transmission to Two Receiving/Transmitting Stations & Measurement of the Two Path-Times].—W. Runge. (*Hochf:tech. u. Elek: akus.*, July 1942, Vol. 60, No. 1, p. 28.) Telefunken Patent, D.R.P. 713 335.

72. Rotating Beacon giving Distance of Receiver from Beacon by the Number of Signals counted during One Passage of the Beam.—J. Pintsch Company. (*Hochf: tech. u. Elek:akus.*, July 1942, Vol. 60, No. 1, pp. 27–28.) D.R.P. 714 896.

73. Direction-Finder with Figure-of-Eight Diagram and Automatic Extinction of the False Minimum.—F. Johnske & H. Rebmann. (*Hochf:tech. u. Elek:akus.*, July 1942, Vol. 60, No. 1, p. 27.) Telefunken Patent, D.R.P. 714 734.

74. "Die physikalischen und technischen Grundlagen des akustischen Landehöhenmessers" [Acoustic Altimeter: Book Review].—E. Kutzscher & P. Orlich. (*Zeitschr. f. tech. Phys.*, No. 7, Vol. 23, 1942, p. 190.)

ACOUSTICS AND AUDIO-FREQUENCIES

75. The Piezoelectric "Flexural Strip" [Compound (Twin) Rochelle Salt or Quartz "Bender"] as Electro-Mechanical Converter.—H. Keller. (*Hochf:tech. u. Elek: akus.*, July 1942, Vol. 60, No. 1, pp. 5–10.)

I.—The twin strip and the direct effect: (i) development of potential in the idealised strip: (ii) the effect of electrode dimensions: (iii) the effect of asymmetry (of the internal electrode). II.—The twin strip and the reciprocal effect: similar treatment. III.—The twin strip held at both ends: (i) direct effect: (ii) reciprocal effect: (iii) practical formulae.

"The relation between the electrical potential and the deflecting force is linear in all the above equations. This generally desirable property makes the flexural strip a valuable and versatile electro-mechanical converter. The formulae derived in this paper provide a grasp of its transformation properties and the means of adapting these data to the different conditions of the various practical applications. The formulae for the direct effect give the open-circuit potential (electromotive force)." The internal resistance and the electrical equivalent diagram of the crystal element, needed for the determination of the voltage at the terminals, are known from O. Schafer's paper [76, below].

76. The Electrical Equivalent Circuit of Piezoelectric Sound-Receivers.—O. Schäfer. (*Akust. Zeitschr.*, No. 6, Vol. 6, 1941, p. 326 onwards.) Referred to in 75, above.

77. Preamplifier-Filter for Crystal Pick-Up [for broadcasting Ordinary, Orthacoustic, & Constant-Velocity Records].—C. Affelder. (*Electronics*, April 1942, Vol. 15, No. 4, p. 78.)

78. Home-Made Pick-Ups.—G. A. Hay: Brierley. (*Wireless World*, Sept. 1942, Vol. 48, No. 9, p. 222.) Prompted by 3020 of 1942 (where the author's name was mis-spelled). For further notes, and replies to queries, *see* November issue, p. 258.

79. How Recordings are Made: No. 1—Principles of Disc Recording: No. 2—The Recorder: No. 3—The Amplifier.—C. B. De Soto. (*QST*, July, Aug. & Sept. 1942, Vol. 26, Nos. 7, 8, & 9, pp. 30–34, and 94, 96: pp. 56–59 and 104 . . 110: pp. 65–72 and 118, 120.)

80. Player-Piano *versus* Gramophone [Correspondence on the Reproduction of the Former being Better than That of the Latter: and the Question of "Touch"].—(*Wireless World*, Nov. & Dec. 1942, Vol. 48, Nos. 11 & 12, pp. 271 & 290.)

81. "Automatic Record Changers and Recorders" [Book Review].—J. F. Rider. (*Electronics*, April 1942, Vol. 15, No. 4, p. 70.)

82. An Apparatus for the Measurement of Fluctuations of Synchrony in Sound Carriers.—G. Guttwein. (*E.N.T.*, June 1942, Vol. 19, No. 6, pp. 85–89.)

Previous methods involve loop oscillographs or photographic recording: the German broadcasting service has adapted the Neumann high-speed transmission-level recorder to a circuit in which a frequency derived from the sound record (*e.g.* gramophone disc or magnetophone record) is superposed on a constant frequency from a tuning-fork generator, and the difference tone applied to the steep flank of a filter: the resulting amplitude fluctuations are registered by the high-speed recorder.

83. NEGATIVE FEEDBACK FOR STABILISING LIGHT-VALVES [in Sound-Film Recording].—W. J. Albersheim & L. F. Brown. (*Electronics*, May 1942, Vol. 15, No. 5, pp. 84..88.)

84. OPTIMUM RESPONSE SCANNING SLIT-IMAGE [in Sound Reproduction from Film: Calculations leading to Formula for Optimum Slit-Image Height].—G. Logan. (*Electronics*, June 1942, Vol. 15, No. 6, pp. 140..142.)

85. A NEW PRE- AND MAIN-AMPLIFIER OF THE STATE BROADCASTING CORPORATION.—W. Schlechtweg. (*E.N.T.*, June 1942, Vol. 19, No. 6, pp. 90–95.)

The introduction of the moving-coil microphone demanded special properties in the amplifiers as regards noise voltages: they were obtained by the use of a calibrated negative-feedback adjustment including the first two valves, followed by an output stage with fixed negative feedback. All three valves are standard broadcasting types, EF12. The whole design combines considerable economy in material and power consumption with improved electrical properties.

86. IMPROVEMENT IN CONVERTERS WITH CAPACITIVE INTERNAL RESISTANCE, PARTICULARLY CONDENSER MICROPHONES. — A. Martin. (*Hochf:tech. u. Elek:akus.*, July 1942, Vol. 60, No. 1, p. 28.)

Siemens & Halske Patent, D.R.P. 715 143. To prevent a grid potential displacement due to fluctuations in insulation, some of the insulating surface around the terminals of the microphone, where surface leakage is liable to occur, is coated with a metallic layer by which the leakage current is led away to the negative pole of the grid-bias source.

87. RADIATION PATTERN OF THE HUMAN VOICE.—D. W. Farnsworth [& H. K. Dunn]. (*Bell Lab. Record*, Aug. 1942, Vol. 20, No. 12, pp. 298–303.) *See* 3283 of 1942.

88. HEARING-ACUITY MEASURING APPARATUS—AUDIOMETERS.—H. Teuchert. (*Hochf:tech. u. Elek:akus.*, July 1942, Vol. 60, No. 1, pp. 21–24.)

A survey of the subject leading to a description of the equipment developed by the writer. One special point in this design is the provision of two separate and independent attenuators and the necessary switching, to allow both ears to be tested either simultaneously or in quick succession, as is necessary in certain investigations such as the so-called Stenger test. The note frequency, adjustable from 30 to 20 000 c/s, is produced by a Siemens heterodyne-generator, whose 0.5 w output is amplified in a 20 w output stage. The attenuators, adjustable in decibel steps up to 120 db, lie between the note generator and the output stage, while between the latter and the loudspeaker an additional 30 db of attenuation can be switched in to suppress the mains hum, particularly during measurements on the lower frequencies. When, in cases of severe deafness, the cutting out of the 120 db is not enough, this extra 30 db can be switched out also, since the mains hum would not interfere. Further, even for normal ears this 30 db attenuation must be cut out during testing in the higher range of frequencies: the mains hum is then cut out by switching in (by switch S_5) a high-pass filter. By the two-way switch S_1 the note-generator can be connected, instead of to the loudspeaker, to the two headphones: the output stage is no longer necessary. The two headphones can have their signals adjusted independently in 5 db steps up to 95 db. The absolute calibration of the equipment is described, and the various sources of error are discussed. The note-generator is provided with a "howl unit" (giving ± 50 c/s variations) to avoid standing-wave complicatons when the measurements are carried out in ordinary rooms.

89. HEARING AIDS [Doubt thrown on the Reality of the Dangers of Non-Cooperation with Medical Profession]. — J. A. Hamilton. (*Wireless World*, Nov. 1942, Vol. 48, No. 11, pp. 271–272.) Continuation of the correspondence referred to in 3625 of 1942.

90. "ACOUSTIC DESIGN CHARTS" [Book Review]. —F. Massa. (*QST*, Sept. 1942, Vol. 26, No. 9, p. 36.)

91. GRAPHICAL MEANS FOR THE CALCULATION OF TELEPHONE APPARATUS [in Particular Connection with Equipments in Invaded Territories].—Oettl. (*See* 30.)

92. THE NEED FOR SOME JOINT-TRAFFIC ARRANGEMENT FOR TELEPHONY AND TELEVISION BY COAXIAL CABLES.—H. Th. Holm. (*Electrician*, 30th Oct. 1942, Vol. 129, p. 464: paragraph only.)

93. BEAT-FREQUENCY OSCILLATOR TYPE 913-A [dispensing with Temperature Control & Other Complicated Stability-Maintenance Systems, by Special Design of Circuit Elements to have Minimum Temperature Coefficients]. — General Radio. (*Review Scient. Instr.*, Sept. 1942, Vol. 13, No. 9, pp. 406–407.)

94. A NEW AUDIO-FREQUENCY BRIDGE [with One Arm consisting of Primary of Mutual Inductor: Opposite Arm, Fixed Condenser: Remaining Arms, Ohmic Resistances].—L. M. Chatterjee. (*Indian Journ. of Phys.*, June 1942, Vol. 16, Part 3, pp. 139–145.) Dealt with in 752 of 1942.

95. AN EXPERIMENTAL STUDY OF TRUMPET EMBOUCHURE. — H. W. Henderson. (*Journ. Acous. Soc. Am.*, July 1942, Vol. 14, No. 1, pp. 58–64.)

96. THE EFFECT OF THE MEAN COEFFICIENT OF SOUND ABSORPTION ON THE LEVEL OF SOUND: PART I.—L. D. Rosenberg. (*Journ. of Tech. Phys:* [in Russian], No. 19, Vol. 10, 1940, pp. 1634–1638.)

The paper considers the case of a room having a sound-absorbing lining and containing a source of noise, and indicates methods for calculating the effect of the lining on the sound level both within and without the room. The effect of a sound-proof box covering the source of noise is also discussed.

97. On the Solutions of the Wave Equation with Discontinuous Derivatives [with Extension of Results to include Reflection & Refraction].—F. G. Friedlander. (*Proc. Cambridge Phil. Soc.*, Nov. 1942, Vol. 38, Part 4, pp. 378–382.)

98. On the Reflection of a Spherical Sound Pulse by a Parabolic Mirror.—F. G. Friedlander. (*Proc. Cambridge Phil. Soc.*, Nov. 1942, Vol. 38, Part 4, pp. 383–393.)

Including the derivation of a Stieltjes integral (eqn. 13), representing the reflection of an arbitrary pulse in terms of the solution for a rectangular pulse, which is valid for all reflection problems.

99. Reflection and Refraction of Spherical Waves: Second-Order Effects.—Ott. (*See* 18.)

100. Elastic Waves and Vibrations of Thin Rods [and the Complete Failure of the Usual Equation for the Transverse Vibrations for Small Wavelengths].—J. Prescott. (*Phil. Mag.*, Oct. 1942, Vol. 33, No. 225, pp. 703–754.)

101. The Application of the Laplace Transformation to a Problem on Elastic Vibrations [using Carslaw-Jaeger Method].—C. J. Tranter. (*Phil. Mag.*, Aug. 1942, Vol. 33, No. 223, pp. 614–622.)

102. Propagation of Sound in Liquids, and Viscosity.—G. Suryan. (*Indian Journ. of Phys.*, April 1942, Vol. 16, Part 2, pp. 77–81.)

Author's summary:—"An empirical relation $v = G\eta^{11/9}$ is given between sound velocity v and viscosity η of liquids. The propagation of sound in liquids is discussed on the basis of energy transference between molecules. The relation $v \propto 1/\sigma^9$ between sound velocity and molecular diameter σ is also deduced theoretically therefrom . . . . Dispersion of acoustic velocity with frequency is shown to be true from the theory. The frequency range for dispersion is also discussed." From the empirical relation for v given above, an equation can be derived for the temperature change of velocity [*see* also 1431 of 1942]. Later, the writer hopes to extend the theory to solids.

103. The Measurement, by the Optical ["Schlieren"] Method, of Supersonic Absorption in Cases.—F. A. Korolev. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 1, Vol. 11, 1941, pp. 184–193.)

A method has been developed for investigating supersonic absorption, which is a combination of the Töpler method of striae and photographic photometry. Measurements were made in liquids and gases, and a number of photographs of supersonic fields are shown. It was found that the absorption constant $\alpha\Lambda^2$ (α = absorption coefficient and Λ = wavelength in cm) for air at atmospheric pressure and a temperature of 20°C is equal to $(2.6 \pm 0.3) \times 10^{-4}$ cm. It was also found that within the frequency range of 930 to 3530 kc/s used in these experiments α is proportional to the square of the frequency. The results obtained are in good agreement with the more reliable investigations by other authors, but differ by 60% from the simplified formula (17) based on hydrodynamic theory.

104. "Die physikalischen und technischen Grundlagen des akustischen Landehöhenmessers" [Acoustic Altimeter: Book Review]. — E. Kutzscher & P. Orlich. (*Zeitschr. f. tech. Phys.*, No. 7, Vol. 23, 1942, p. 190.)

PHOTOTELEGRAPHY AND TELEVISION

105. The Need for Some Joint-Traffic Arrangement for Telephony and Television by Coaxial Cables.—H. Th. Holm. (*Electrician*, 30th Oct. 1942, Vol. 129, p. 464: paragraph only.)

106. On the Discoloration of Alkali-Halide Crystallites: II—Discoloration Investigations on Microcrystalline Films coloured by Cathode Rays.—H. Kurzke & J. Rottgardt. (*Ann. der Physik*, 13th Aug. 1942, Vol. 41, No. 7/8, pp. 584–596.)

"The further extension of the previous investigations [1748 of 1941], to cover down to the smallest grain sizes, has brought the possibility of certain technical applications, which will be discussed briefly . . . The short discolouring times attainable make possible the use of such films as cathode-ray screens for special purposes": Rosenthal's papers on large-screen television projection are also mentioned (2328 & 3501 of 1940).

107. The Volt/Ampere and Light Characteristics of Antimony-Caesium Photocells, *and* The Fatigue of Antimony-Caesium Photocathodes.—N. S. Khlebnikov: Khlebnikov & P. A. Sinitsyn. (*Journ. of Tech. Phys.* [in Russian], No. 22, Vol. 10, 1940, pp. 1908–1912: pp. 1913–1918.)

In the first paper experimental volt/ampere and light characteristics are given for Sb–Cs photocells. It appears that contrary to the conceptions previously held by the authors the volt/ampere characteristics of photocells with metallic base approach saturation, which is delayed if the light flux is increased. The light characteristics of these cells are linear for light fluxes reaching values of the order of several hundreds of lumens, provided that the cell is not fatigued and the anode voltage is sufficiently high. In the second paper experiments are described showing that the vacuum Sb–Cs photocells not only possess a high spectral sensitivity but are also liable to only very slight fatigue, even after prolonged operation, as for example in a sound cinema. Changes taking place in the spectral characteristic and caused by fatigue are shown, and a new parameter is suggested for comparing photocells with respect to their fatigue.

108. New Oxygen – Silver – Caesium Photocathodes.—N. S. Khlebnikov & P. A. Sinitsyn. (*Journ. of Tech. Phys.* [in Russian], No. 22, Vol. 10, 1940, pp. 1919–1923.)

Further to a previous paper (3250 of 1939) experiments are described with (Ag–O–Cs)–Ag photocathodes derived from the ordinary (Ag–O–Cs) type by the introduction of additional silver and subsequent heat treatment, as first suggested by Asao & Suzuki. It appears that in the spectral characteristic of the new photocathodes the low-frequency maximum is displaced towards higher frequencies. Moreover the new photocathodes show higher sensitivity in the region of 6000–4000 AU, and while also possessing higher integral sensitivity are hardly liable to any fatigue. The latter combination is particularly valuable since it makes the new photocathodes suitable for replacing the gas-filled oxygen–silver–caesium type when the Sb–Cs photocathodes can not be used for this purpose owing to the peculiarities of their spectral sensitivity.

109. The Long-Wave Selective Photoeffect in "Excess" (Reduction) Semiconductors [interpreted as a Result of Combined Action of Internal & External Photoeffects: This "Double Photoeffect" Theory explains Various Observed Phenomena, including Kuschnir's Effect of Magnetic Field on Photoemission of Caesium/Caesium-Oxide Cathodes].—G. Maurer. (*Zeitschr. f. Phys.*, 22nd Sept. 1941, Vol. 118, No. 1/2, pp. 104–121.)

MEASUREMENTS AND STANDARDS

110. Contribution to the Measurement of the Transmission Constants of Concentric Cables in the Decimetric-Wave Region.—A. Ditl. (*Hochf:tech. u. Elek:akus.*, July 1942, Vol. 60, No. 1, pp. 2–4.)

This problem, so important in the further development of decimetric-wave technique, was quite satisfactorily solved by Kaufmann (3328 of 1941 and back reference) for any particular frequency for which his measuring apparatus was designed: measurements over a wide frequency band were impossible by his method. Such measurements are, however, very valuable: for instance, constructional irregularities in the concentric cables can be estimated by the characteristics of the constants plotted over a band of frequencies. The writer, therefore, describes how his Wollaston-wire voltmeters (493 of 1942) can be used in the circuit of Fig. 1 to make simple and accurate measurements over the wide frequency range from 50 to 1000 Mc/s.

If the input end of an open-ended cable is supplied with a h.f. voltage, the ratio voltage-at-input/voltage-at-output is dependent on frequency, reaching a minimum when the electrical length of the cable is an odd multiple of a quarter wavelength. This minimum is equal to the attenuation equivalent. The measurement of the voltage at the free end requires a voltmeter with an infinitely large input impedance: this requirement cannot be fulfilled in the decimetric-wave region by any valve voltmeter, but a Wollaston-wire voltmeter can be so designed as to be independent of frequency up to 1000 Mc/s and to present a practically pure ohmic input impedance of more than 4000 ohms. With such a voltmeter only a simple correction factor is necessary in the case of the cables generally met with, having characteristic impedance below 200 ohms.

In Fig. 1 the Wollaston-wire voltmeter *A* at the cable input is a low-resistance one, with a range of 0.1 to 1.0 volt, its d.c. resistance being measured by the bridge shown below it. The voltmeter *C* is a high-resistance one (over 4000 ohms) with a range of 1 to 12 volts: its own bridge circuit is seen below it. In each voltmeter the external tube is connected, for high frequencies, to the outer sheath of the cable by a condenser wound directly onto the cable. As the frequency of the signal generator is varied, the voltage indicated by voltmeter *C* changes very little, while that shown by *A* gives strongly marked minima: it is easy to determine a minimum of the ratio of voltages. All such minima, one after the other, are thus determined throughout the whole frequency range.

The examples given are measurements on a 8.835 m length of Oppanol cable (Fig. 2) and a 29.72 m length of Styroflex cable (Fig. 3). In each diagram the straight line shows the calculated attenuation due to resistance. For the Styroflex cable, in which air forms so much of the dielectric, the measured attenuation equivalent agrees quite well with the calculated, above 250 Mc/s and up to the limit of 1000 Mc/s: for the Oppanol cable the measured values are higher than the calculated owing to the additional attenuation due to the Oppanol dielectric (loss factor 1×10^{-3}). For both cables the measured values display an irregular behaviour at the lower frequencies, indicating constructional irregularities.

111. A New Apparatus for Testing the Insulation of High-Tension Lines and Switching Plant in Actual Service [Method of H.F. Field].—B. Koske. (*AEG-Mitteilungen*, May/Aug. 1942, No. 5/8, pp. 54–55.)

112. On the Theory of the "Q" Meter and Its Corrections [Investigation of Marconi-Ekco Type TF 329 D].—V. V. L. Rao. (*Indian Journ. of Phys.*, June 1942, Vol. 16, No. 3, pp. 197–203.)

113. Analysing-Voltmeter Equipment for Investigation of the Sidebands of Keyed Transmissions.—Bernardi & Poledrelli. (In paper dealt with in 42, above.)

114. Calculation of Variable-Condenser Capacities: a Simplified Time-Saving Method.—L. F. Leuck. (*QST*, Sept. 1942, Vol. 26, No. 9, pp. 37 and 92.)

115. Precision Variable Air Condenser [Type D-14-A: primarily for Investigation of Dielectric Properties of Insulating Materials: 50–1250 μμF or Other Ranges].—Muirhead, Ltd. (*Journ. of Scient. Instr.*, Nov. 1942, Vol. 19, No. 11, p. 172.)

116. The Measurement of the Temperature Coefficient of Capacitance of Small Condensers [Simple Apparatus for Use with N.P.L. Dielectric Test Set (351 of 1937), giving Rapid & Accurate Measurements].—T. Iorwerth Jones. (*Journ. of Scient. Instr.*, Nov. 1942, Vol. 19, No. 11, pp. 166–167.)

117. Multivibrator Action: Principles of Operation.—E. Hughes. (*Wireless World*, Nov. 1942, Vol. 48, No. 11, pp. 266–267.)

118. On a New Piezoelectric Oscillator.—A. Pinciroli. (*Alta Frequenza*, July 1942, Vol. 11, No. 7, pp. 341–343.)

With the advent of modern quartz elements (with practically zero temperature coefficients, sputtered electrodes, etc.) the cause of any possible instability of frequency lies more and more in the means adopted to maintain the quartz in oscillation; a fact which makes it necessary to examine this problem afresh to see whether a fundamental departure from the classic Pierce circuit and its slight modifications may not be desirable.

One such departure is represented by the piezoelectric oscillator in a negative-resistance connection described in the present letter: a simple circuit involving one pentode only. Both the short theoretical treatment and the writer's experimental tests indicate that this simplicity is combined with a high stability of frequency.

119. The Vibration of Piezoelectric Plates [Rigorous Treatment of Free Vibrations of Infinite Plate vibrating between Two Grounded Infinite Electrodes: Cady's Particular Solution an Excellent First Approximation but Not Self-Consistent: Dependence of Free-Vibration Frequencies on Electrode-Separation should *Not* be Linear: Higher Frequencies *Not* Exact Harmonics of Fundamental: etc.].—A. W. Lawson. (*Phys. Review*, 1st/15th July 1942, Vol. 62, No. 1/2, pp. 71–76.) *See* also 2493 of 1941.

120. Small Quartz Clocks [Development of the Three-Pole "Filter Quartz" (used as Oscillator) for 1000 c/s enables Simple Clock Design to be carried out without Any Frequency Division: Tests at Hamburg Naval Observatory: Pros & Cons of Use in Ships, as Chronometers].—H. Dobberstein. (*Zeitschr. f. Instrum:kunde*, Sept. 1942, Vol. 62, No. 9, pp. 296–301.) *See* also Rohde & Leonhardt, 1956 of 1941.

121. On the Distribution of Warmth and the Air Circulation in a "Constant Temperature" Room: the Temperature Conditions in the Clock Room of the Collm Geophysical Observatory, *and* The Temperature Conditions in the Geomagnetic Variation Building.—D. Stranz: R. Penndorf & D. Stranz. (*Gerlands Beiträge z. Geophysik*, No. 2, Vol. 59, 1942, pp. 214–223: pp. 224–236.)

122. Supersensitive Frequency Meter [with Full-Scale Range reduced to 59.75–60.25 c/s: Single Tuning Fork (of Maginvar) in Circuit utilising the Large Phase Shift in the Narrow Frequency-Band of the Resonant Peak].—W. H. Janssen & H. L. Clark. (*Gen. Elec. Review*, Aug. 1942, Vol. 45, No. 8, pp. 443–445.) *See* also *Electrician*, 30th Oct. 1942, pp. 471–472.

123. Experimental Investigations on Magnetic Amplifiers for Measuring and Control Technique [and Recent Progress in Increasing the Magnification Factor and Reducing the Voltage & Temperature Dependence].—W. Geyger. (*Wiss. Veröff. a. d. Siemens-Werken*, No. 2, Vol. 20, 1942, pp. 33–47.) Continuing 2857 of 1941.

124. A Current Detector of High Sensitivity [for Photoelectric Currents 10^{-14} to 10^{-15} A] and the Measurement of Colour Temperatures.—C. M. Garelli. (*La Ricerca Scient.*, Aug./Sept. 1942, Vol. 13, No. 8/9, pp. 407–409.) Using the Townsend compensation method applied to a Perucca-type electrometer (2929 of 1938).

125. The Behaviour of Moving-Coil Galvanometers to Periodic Currents, especially in the Case of Half-Wave Rectification [for Measuring Purposes, in Telemetering, etc: Theoretical Investigation with Experimental Confirmation].—K. Fistl. (*Wiss. Veröff. a. d. Siemens-Werken*, No. 2, Vol. 20, 1942, pp. 20–32.)

126. A Range Switch for Ballistic Galvanometers [where Conventional Ayrton Shunt is Inconvenient for Sensitivity Control].—E. F. Coleman. (*Review Scient. Instr.*, Sept. 1942, Vol. 13, No. 9, pp. 405–406.)

127. Note on "Direct Pen Recording of Galvanometer Deflections" [Acknowledgment of Suitability of General Electric Photoelectric Recorder for Direct Recording of Galvanometer Deflections].—D. J. Pompeo & C. J. Penther. (*Review Scient. Instr.*, Sept. 1942, Vol. 13, No. 9, p. 405.) *See* 3179 of 1942.

128. Overhauling Moving-Coil Meters: Procedure for carrying out a Delicate Operation.—(*Wireless World*, Nov. 1942, Vol. 48, No. 11, pp. 250–252.)

129. Multi-Purpose Indicating Instrument [Model 7 (Universal AvoMeter)].—(*Journ. of Scient. Instr.*, Nov. 1942, Vol. 19, No. 11, pp. 170–172.)

130. The "P & B" Maximum and Minimum Voltmeter [for A.C. only: Thermal (Bimetallic) Principle].—(*Journ. of Scient. Instr.*, Nov. 1942, Vol. 19, No. 11, p. 170.)

131. "American Standard Definitions of Electrical Terms" [Book Review].—A.I.E.E. (*QST*, Sept. 1942, Vol. 26, No. 9, p. 36.)

132. DIMENSIONS AND THE FACTS OF MEASUREMENT.—N. Campbell. (*Phil. Mag.*, Oct. 1942, Vol. 33, No. 225, pp. 761–771.) An invited contribution to the discussion referred to in 3070 of 1942: *see* also Wilson, August issue, No. 223, pp. 631–637.

133. THE MEASUREMENT OF SHORT TIMES WITH THE CATHODE-RAY TUBE, USING AN UNBROKEN, TIME-LINEAR RASTER [Zig-Zag Time Base, the "V-Curve" Raster, covering the Whole Screen Surface].—J. Kömmnick & A. Pickert. (*T.F.T.*, March 1942, Vol. 31, No. 3, pp. 67–73.)

The equipment was developed primarily for measurements on projectiles, but it is useful also for tests on photographic shutters and on relays. The paper begins with a short survey of existing arrangements and their limitations. The basis of the new equipment is the combination of a time-linear horizontal line-deflection circuit giving equal forward and fly-back times (using Frühauf's early two-valve connection modified to take pentodes) and a simple single-valve frame-deflection circuit which draws out these double lines into a zig-zag of narrow Vs lying on their sides and forming an unbroken trace covering the whole screen.

The arrangement permits time measurements to be carried out with an accuracy within $\pm 5 \times 10^{-8}$ second.

134. ON THE SENSITIVITY OF A HIGH-RESISTANCE BOLOMETER.—G. Bauer. (*Physik. Zeitschr.*, 1st Sept. 1942, Vol. 43, No. 17, pp. 301–312.)

Hitherto, bolometers used as receivers of radiation have generally been made of metallic foils. It is an obvious step to examine the possibilities presented by materials of lower electrical conductivity: above all, semiconductors should be of interest because of their high resistance/temperature coefficients. The present full theoretical investigation leads to various conclusions, including the following:—For equal resistance/temperature coefficients, the lowest radiation density which can be measured with a mean error of 1% is about the same for a high-resistance bolometer as for a low-resistance type: if the coefficient is of the order of that of a metal foil (around 0.005 per degree), then for a receiving surface of 0.01 cm² this smallest density is about 1.8×10^{-7} w/cm².

Only by the use of materials with higher resistance/temperature coefficients can this density be reduced. Even in this direction it is useless to make the coefficient more than about 10 times greater, that is more than about 0.05 per degree, since with higher values the disturbing effects due to temperature fluctuations would supervene. With semiconductors, coefficients of this order are easily obtained, and bolometers about 10 times more sensitive than the metal-foil type can thus be made: with these, having the receiving-surface area mentioned above, the smallest measurable density becomes 2×10^{-8} w/cm². A capacitive bolometer (Moon & Steinhardt, 3339 of 1938) is subject to the same considerations, and presents no gain in sensitivity.

SUBSIDIARY APPARATUS AND MATERIALS

135. THE MEASUREMENT OF SHORT TIMES WITH THE CATHODE-RAY TUBE [using Zig-Zag Time Base covering Whole Screen: for Projectile, Shutter, & Relay Research].—Kömmnick & Pickert. (*See* 133.)

136. ON THE GENERATION OF THE HIGHEST TIME-BASE FREQUENCIES.—Johannsen. (*AEG-Mitteilungen*, May/Aug. 1942, No. 5/8, pp. 29–44.)

For previous work *see* 3344 of 1942. Author's summary:—"On the basis of a thorough discussion of the 'kipp' mechanism, the factors are investigated which determine the highest 'kipp' frequencies attainable with the different types of circuit. In contrast to the time-base circuits with thyratrons, hitherto most commonly used, the limit on the highest attainable frequency with hard-valve circuits is set predominantly by delays in the external circuit. It is shown how these delays can be diminished one by one by suitable steps and correct dimensioning. In this connection a specially valuable measure is the blocking of the charging valve during the discharge of the 'kipp' condenser, which allows charging currents of practically any desired strength, independent of the discharge current, to be worked with. The question of synchronisation at the highest frequencies is given particular attention, and a solution found which provides satisfactory synchronisation even at those frequencies.

"The highest speed of voltage-rise in the linear portion of the scanning stroke [using the circuit finally adopted: Fig. 31, with pentode charging valve R_L and discharging valve E, triode control valve S, and synchronising pentode Sy] was 6×10^9 v/s, and the highest 'kipp' frequency 14.4 Mc/s, the apparent 'kipp' frequency being twice as high. With a d.c. voltage of about 500 v the highest current consumed was 180 mA, so that the power taken was quite reasonable, especially in comparison with previous arrangements. The figures given above represent values considerably superior to those furnished by the earlier time-base generators."

The oscillogram seen in Fig. 32 was taken with the maximum voltage-rise speed mentioned above: it shows one cycle of a 24.4 Mc/s wave, and the actual "kipp" frequency in this case was 6.1 Mc/s, the apparent value being four times this (fly-back time, including switching times, three times as long as scanning-stroke time). The single 24.4 M/cs wave occupies 40 mm on the screen. Fig. 33 shows a 28.75 Mc/s wave recorded at the highest "kipp" frequency of 14.37 Mc/s instead of the highest time-extension of Fig. 32: the voltage-rise speed is now only 3.34×10^9 v/s, the apparent "kipp" frequency is equal to the test frequency, but the proportions of the times are now such that the actual "kipp" frequency is the 14.37 Mc/s mentioned.

137. ELECTROSTATIC DEFLECTION AND ITS IMAGE AND DEFLECTION ERRORS.—Himpan. (*T.F.T.*, Jan. 1942, Vol. 31, No. 1, pp. 20–21.) From a State Post Office colloquium: *cf.* previous papers, 3091 of 1941.

138. The Calculation of the Voltage Distribution in a Multiple Chain Network [and the Conditions for a Faithful Oscillographic Reproduction of Steep Surge Voltages].—Elsner. (*Wiss. Veröff. a. d. Siemens-Werken*, No. 2, Vol. 20, 1942, pp. 83–90.)

139. A Scanning Electron Microscope [including Equipment incorporating Electron Multiplier, Facsimile Recorder, & Mechanical Scanning (Object displaced by Rods mounted on Loudspeaker Voice Coils): Specimen Results].—Zworykin, Hillier, & Snyder. (*ASTM Bulletin*, Aug. 1942, No. 117, pp. 15–23.) *See* also 3346 of 1942.

140. On the Lenses of Electron-Microscopes of High Resolving Power [Exhaustive Survey of Electrostatic & Magnetic Lenses as at present developed: Possible Future Developments: General Superiority of Magnetic Lenses].—Ruska. (*Arch. f. Elektrot.*, 31st July 1942, Vol. 36, No. 7, pp. 431–454.)

141. Emission Electron-Microscopy with Magnetic Lenses.—Kinder. (*Naturwiss.*, 18th Sept. 1942, Vol. 30, No. 38/39, pp. 591–592.)

After Recknagel had shown theoretically that it must be possible, by the use of high field strengths in front of the cathode, to increase the resolving power of the emission electron-microscope to above the limit of the optical microscope (514 of 1942), various workers have achieved this result in practice: *see* for example Mahl, 3077 of 1942, and Boersch, 1773 [and 3347] of 1942. All these experiments, at 30–50 kv, had one thing in common—the use of a purely electrostatic lens, the Brüche-Johannson immersion objective. Now, however, experiments on a thoriated molybdenum ribbon have shown that similar results can be obtained with magnetic lenses. With the objective design seen in Fig. 1, embodying a special double-yoke lens, the image of the cathode given by 50 ekv electrons was brought by a second stage to an electron-optical magnification of 1800, with a resolving power down to below 150 mμ (points only 90 mμ apart could actually be distinguished): *see* Figs. 2 & 3.

142. The Usefulness and Practical Construction of a Film Carrier for Two Exposures with the Standard Design of Siemens Supermicroscope [eliminating the Normal Wait of 1–2 Minutes].—Frey. (*Zeitschr. f. tech. Phys.*, No. 7, Vol. 23, 1942, pp. 176–177.)

143. Supplement to the Paper "On the Intensity Relations in the Supermicroscope: I—The Blackening of Photographic Plates by Electron Rays."—von Borries. (*Physik. Zeitschr.*, 20th July 1942, Vol. 43, No. 13/14, p. 260.) *See* 3079 of 1942.

144. On Abbe's Microscope Theory and Its Related Coherence Problems.—Joos & Köhler. (*Naturwiss.*, 11th Sept. 1942, Vol. 30, No. 37, pp. 553–563.)

The writer sums up as follows:—"The elastic theory of light correctly represents all conditions in the propagation of light, just as in most cases of optical image-formation the simple theory of the self-luminous object is sufficient. Nevertheless the electromagnetic theory of light extends our horizon very greatly. That in our case also the more profound knowledge leads to progress has been shown by the discovery of the Zernike phase-contrast technique" [*cf.* 2066 of 1942 and back references].

145. On the Discoloration of Alkali-Halide Crystallites [and Possible Application to Cathode-Ray-Tube Screens for Special Purposes].—Kurzke & Rottgardt. (*See* 106.)

146. The Fluorescence of Manganese in Glasses and Crystals [with Sections on Zinc-Silicate & Other Phosphors with Manganese as Activator].—Linwood & Weyl. (*Journ. Opt. Soc. Am.*, Aug. 1942, Vol. 32, No. 8, pp. 443–453.)

147. Luminous Characteristics of Two Phosphorescent Materials [primarily for "Blackout" Purposes: Materials P-10 and P-11].—Taylor. (*Journ. Opt. Soc. Am.*, Sept. 1942, Vol. 32, No. 9, pp. 506–509.)

148. "Geryk" Vacuum Pumps [New Models].—Pulsometer Engineering. (*Journ. of Scient. Instr.*, Nov. 1942, Vol. 19, No. 11, pp. 172–173.)

149. On the Properties of Organic Working Substances for Practical Diffusion Pumps, and a New Design of Oil Diffusion Pump [Leybold Model Q3 (Fig. 2) & Its Advantages].—Jaeckel. (*Zeitschr. f. tech. Phys.*, No. 7, Vol. 23, 1942, pp. 177–186.)

150. On Voltage-Stabiliser Circuits.—Banerjee. (*Indian Journ. of Phys.*, April 1942, Vol. 16, Part 2, pp. 87–110.)

Author's summary:—"The paper describes several improved forms of voltage-stabiliser circuits. The single-valve and two-valve Neher–Pickering circuits have been improved by reducing the number of dry batteries used, without in any way sacrificing the performance. New principles are applied to the usual two-valve stabiliser circuit by which it is possible to have 'perfect' stabilisation and 'zero' or negative internal resistance. A circuit is described which is suitable for supplying a stabilised current to the heaters of the thermionic tubes used in sensitive valve-voltmeters. The performance of the circuit is very much superior to that of the stabilising transformers and barretter tubes as regards the stabilisation. The effect of source resistance on the performance of stabilisers has been studied. The analysis has the advantage of being not only more general but also more simple and straightforward."

151. The DT-5 Electronic Voltage Regulator for A.C. and D.C. Generators with Output Voltages exceeding 46 Volts.—Westinghouse. (*Review Scient. Instr.*, Sept. 1942, Vol. 13, No. 9, pp. 407–408.)

152. Paper on Non-Linear Circuits [with Iron-Cored Chokes] for Control and Supervision.—Steuernagel. (*See* 38.)

153. A 20-MILLION ELECTRON-VOLT BETATRON OR INDUCTION ACCELERATOR.—Kerst. (*Review Scient. Instr.*, Sept. 1942, Vol. 13, No. 9, pp. 387–394.) For previous references *see* 2796 of 1942 and back reference.

154. A CYCLOTRON MODEL FOR DEMONSTRATION AND STUDY [Glass Containers, with Lecher System and Electrons as Working Particles].—Dänzer. (*Ann. der Physik*, 13th Aug. 1942, Vol. 41, No. 7/8, pp. 485–500.)

155. REMARK ON H. WATZLAWEK'S PAPER "THE ELECTROSTATIC GENERATOR" [3355 of 1942]: AND REPLY.—Neubert: Watzlawek. (*Zeitschr. f. tech. Phys.*, No. 7, Vol. 23, 1942, pp. 187–188.)

156. CONDUCTIVITY OF GASES EXCITED BY HIGH-FREQUENCY DISCHARGES.—Mesnage. (*Génie Civil*, 15th Sept. 1942, Vol. 119, No. 21, p. 262: summary, from *Comptes Rendus* [Paris] of 8th April.)

157. ON THE STABILISATION OF THE GRID-CONTROLLED [Mercury-] VACUUM ARC AND THE CONSTANTS OF THE ARC [Analysis of the Processes of Stabilisation by the Use of Inductive & Capacitive Feedback Elements: including the Effect of Simultaneous Current & Voltage Feedback].—Schumann. (*Arch. f. Elektrot.*, 30th June 1942, Vol. 36, No. 6, pp. 362–377.) For Fetz's work, here mentioned, and other work, *see* references in 410 of 1942: *also* 1976 of 1942 and 158, below: *also* Schumann, 680 of 1942.

158. STABILITY CONSIDERATIONS IN MERCURY ARCS WITH GALVANIC [Ohmic] NEGATIVE FEEDBACK.—Fetz. (*Arch. f. Elektrot.*, 30th June 1942, Vol. 36, No. 6, pp. 378–381.)

Cf. Schumann, 157, above. Author's summary:—"In a mercury arc whose steady-state voltage can be controlled by a grid, the physical causes of the instability at the higher voltages are discussed, and it is shown that this stability can be cured by a galvanic negative feedback. The mathematical relations are derived between the value of the necessary feedback and the experimentally determined differential quotients D, S, and R_i ["durchgriff", slope, & internal resistance] which characterise the amplifying properties of the discharge."

159. PROBE INVESTIGATIONS ON "STABILISED" MERCURY-VAPOUR ARCS.—Wehner. (*See* 66.)

160. THE MERCURY-ARC CATHODE [New Concept of Emission, supported by Experiment and fitting in with Known Facts].—Smith. (*Phys. Review*, 1st/15th July 1942, Vol. 62, No. 1/2, pp. 48–54.)

161. ON THE FOCAL-SPOT FORMATION IN AN ARC.—Weizel & Rompe. (*Zeitschr. f. Phys.* 31st July 1942, Vol. 119, No. 5/6, pp. 366–373.)

162. SEALED-TUBE IGNITRON RECTIFIERS.—Morack & Steiner. (*Gen. Elec. Review*, Aug. 1942, Vol. 45, No. 8, pp. 459–466.)

163. BACK-FIRING AND SECONDARY EMISSION FROM A GRAPHITE ANODE IN MERCURY-VAPOUR RECTIFIERS.—Gabovich. (*Journ. of Tech. Phys.* [in Russian], No. 19, Vol. 10, 1940, pp. 1621–1629).

An experimental investigation of back-firing in mercury rectifiers, using the secondary emission from the graphite anode as an indication of the state of its surface. The effect on the phenomenon of various factors such as temperature, presence of air in the rectifier, etc., was investigated in detail.

164. THE DESIGN-CALCULATIONS OF SMOOTHING ARRANGEMENTS FOR THE L.F. INTERFERENCE SUPPRESSION OF RECTIFIER PLANT.—Moebes. (*See* 54.)

165. FURTHER ELECTROTECHNICAL BASES OF THE "CONTACT CONVERTER" [for Rectification of Polyphase Current].—Koppelmann. (*E.T.Z.*, 27th Aug. 1942, Vol. 63, No. 33/34, p. 398.) *See* 1780 of 1942: for a further paper see *Elektrot. u. Masch:bau*, 28th Aug. 1942, Vol. 60, No. 35/36, pp. 368–377.

166. A STUDY OF NON-STATIONARY PROCESSES IN COPPER-OXIDE RECTIFIERS CONNECTED TO AN IMPULSE CIRCUIT.—Tuchkevich. (*Journ. of Tech. Phys.* [in Russian], No. 22, Vol. 10, 1940, pp. 1849–1856.)

Experimental investigation of the change with time of the capacity and resistance (in the blocking direction) of a copper-oxide rectifier consisting of 20 plates connected in series. The Abraham-Bloch oscillator used for generating rectangular impulses of a given magnitude and duration is described (Fig. 1). A special cathode-ray oscillograph enabled processes of very short duration (of the order of 10^{-6} s) to be observed. The equivalent capacity of the rectifier was measured; the value measured at 11 v of blocking voltage coincides with that calculated by extrapolating the curve showing the variation of capacity with voltage, as obtained with a bridge circuit. It was also shown that the variation of the blocking resistance is subject to inertia.

167. VOLT/AMPERE CHARACTERISTICS OF COPPER-OXIDE RECTIFIERS FOR THE FORWARD DIRECTION.—Marchenko & Sharavski. (*Journ. of Tech. Phys.* [in Russian], No. 22, Vol. 10, 1940, pp. 1904–1907.)

Characteristics of copper-oxide rectifier discs of 41 mm diameter were taken for forward currents varying from 0.5 to 15 A. The results obtained seem to contradict Schottky's conception regarding the importance of contact potentials between the metal and the semiconductor.

168. A MOISTURE-PROOF HIGH-FREQUENCY RECTIFIER.—Renne. (*Journ. of Tech. Phys.* [in Russian], No. 22, Vol. 10, 1940, pp. 1883–1886.)

Humidity is one of the main factors affecting the stability of h.f. copper-oxide rectifiers with an aquadag contacting layer. Various methods for protecting the rectifiers were tried, but a satisfactory improvement was only obtained by building an entirely new model (shown in Fig. 3) consisting essentially of an ebonite tube containing the rectifier discs, with its ends sealed with bitumen, through which the leads are taken out. A small spiral spring inside the tube maintains the necessary pressure between the discs, and it was also found essential to introduce some deliquescent material into the tube. Satisfactory results were obtained with these rectifiers kept continuously for 6 months under conditions of 95% humidity. Experiments have also shown that the rise in the forward resistance of rectifiers is only partly due to the absorption of moisture by the aquadag layer. Thus there remains some other contributory causes whose nature is not yet fully understood, and it is suggested that the real solution of the problem lies in replacing the aquadag layer by a metallic layer.

169. COPPER-OXIDE RECTIFIERS WITH A SILVER CONTACTING LAYER.—Renne & Breydo. (*Journ. of Tech. Phys.* [in Russian], No. 22, Vol. 10, 1940, pp. 1871–1874.)

For previous work *see* 421 of 1942. Test results are published on American " Eclipse " type copper-oxide rectifiers, which have a metallic contacting layer (presumably gold). On the basis of these experiments it was decided to investigate rectifiers with a silver contacting layer. A method for depositing the silver layer on rectifier discs of 5 mm diameter is described, and results of tests given. It appears that no noticeable improvement in the volt/ampere characteristic or decrease in the temperature coefficient of the forward resistance is obtained if the aquadag contacting layer is replaced by a silver layer. On the other hand the stability of rectifiers with time, especially under conditions of high humidity, is greatly improved thereby (curves *C* and *B* in Fig. 1, as compared with curve *A*).

170. A SULPHIDE RECTIFIER.—Dunaev & Kurchatov. (*Journ. of Tech. Phys.* [in Russian], No. 22, Vol. 10, 1940, pp. 1857–1870.)

A sulphide rectifier developed at the Leningrad Institute of Physics & Technology is described, and a detailed test report is presented. A circuit for a.c. tests of the rectifier with a cathode-ray oscillograph (Fig. 6) is described, and a number of oscillograms so obtained are shown. The rectifier was also tested on d.c. and in an impulse circuit. On the basis of the results obtained, the mechanism of rectification is discussed and the authors accept the electron theory as expounded by Davydov and Schottky. Conditions necessary for series operation of rectifiers are also established.

171. THE MEASUREMENT OF THE CAPACITY OF SULPHIDE RECTIFIERS.—Dunaev & Tuchkevich. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 1, Vol. 11, 1941, pp. 89–92.)

Experiments are described in which the distortion, due to rectifier capacity, of rectangular current impulses applied to a sulphide rectifier from an Abraham-Bloch multivibrator were observed on a cathode-ray oscillograph. Calculations have shown that the capacity of a rectifier of this type, having a surface area of 4 cm^2, decreases from 0.8 μF to 0.1 μF when the voltage applied to the rectifier (in the blocking direction) is increased to 10 v. At the same time the resistance of the rectifier rises sharply. A theoretical interpretation of the results obtained is given.

172. THE TEMPERATURE DEPENDENCE OF THE RESISTANCE OF SELENIUM RECTIFIERS.—Sharavski. (*Journ. of Tech. Phys.* [in Russian], No. 22, Vol. 10, 1940, pp. 1843–1848.) A German version was dealt with in 533 of 1942.

173. SELENIUM RECTIFIERS.—Levinson & Pavlov. (*Journ. of Tech. Phys.* [in Russian], No. 22, Vol. 10, 1940, pp. 1887–1896.)

The manufacture of selenium rectifiers is described in detail under the following headings :—(1) The lower electrode ; (2) the selenium ; (3) deposition of selenium on the lower electrode ; (4) pressing of amorphous selenium and its crystallisation ; (5) depositing on upper electrode ; and (6) forming of rectifier discs. The characteristics of selenium rectifiers manufactured in Russia are compared with those of German rectifiers (produced by the S.A.F.). The ageing of the rectifiers and operation with forced air cooling are also discussed.

174. THE WORKING CHARACTERISTICS OF SELENIUM RECTIFIERS. — Komar. (*Journ. of Tech. Phys.* [in Russian], No. 22, Vol. 10, 1940, pp. 1897–1903.)

Tests of selenium rectifiers of Russian manufacture are described, mainly of high-power types employing discs of 120 mm diameter. Operating data are given of an experimental 2.7 kw rectifier.

175. ON THE DESIGN OF DRY-PLATE RECTIFIERS FOR OPERATION WITH OVERLOADS OF SHORT DURATION.—Nikiforovski. (*Journ. of Tech. Phys.* [in Russian], No. 22, Vol. 10, 1940, pp. 1875–1882.)

In many cases dry-plate rectifiers (copper-oxide and selenium) are operating for short duration only, as for example when used for controlling a h.t. oil switch. Under such conditions it is possible to increase the current density and raise the reverse voltage. In this paper a theoretical discussion is presented, the object of which is to determine the number of rectifier units, and their size, necessary for safe operation. Various factors affecting these parameters and the temperature conditions of the rectifier are discussed, and the advantage of three-phase over single-phase circuits is established. It is also shown that no advantage is gained by transforming the a.c. mains voltage before applying it to the rectifier. As an example, the design of a rectifier operating for periods of 10 to 20 seconds and giving an output of 12 kw is discussed.

176. THE ELECTRIC FIELD IN SEMICONDUCTORS DUE TO THE FLOW OF CURRENT, AND THE EJECTION OF ELECTRONS BY THIS FIELD.—Kosman & Ivanyuk. (*See* 69.)

177. A SOFT SILVER SOLDER [" Comsol " and Its Uses : Cost comparable with That of High-Grade Tin–Lead Solders].—(*Journ. of Scient. Instr.*, Nov. 1942, Vol. 19, No. 11, p. 174.)

178. Currency-Saving Welded and Soldered Joints for Conductors in Communications Technique.—Schulze. (*AEG-Mitteilungen*, Jan./April 1942, No. 1/4, pp. 17–20.)

179. The Manipulation of Wollaston Wire [Practical Hints, & the Usefulness as Micro-fuses: with Graph of Fusing Currents].—Bennett. (*Journ. of Scient. Instr.*, Nov. 1942, Vol. 19, No. 11, pp. 168–169.)

180. Contact Resistance: Temperature Rise in Switches.—Cockram. (*Elec. Review*, 21st Aug. 1942, Vol. 131, pp. 231–234.)

181. Beryllium as a Platinum-Alloy Material [replacing Iridium: Very Good for Contacts, etc.].—Fröhlich. (*Zeitschr. V.D.I.*, 3rd Oct. 1942, Vol. 86, No. 39/40, pp. 612–613: summary only.)

182. Platinum-Free High-Performance Contact Materials with a Gold Basis [Data of Three Gold Alloys, & Comparison with Pt–20Ir: Special Advantages of Gold–Zirconium Alloy].—Fröhlich. (*E.T.Z.*, 24th Sept. 1942, Vol. 63, No. 37/38, pp. 443–445.)

183. A New Equipment for Tests on the Fusing Behaviour of Contacts [and Some Results for Graphite, Silver, Copper, Iron, & a Silver Alloy].—Linckh & Krapf. (*E.T.Z.*, 10th Sept. 1942, Vol. 63, No. 35/36, pp. 405–409.)

184. Precision Variable Air Condenser [Type D-14-A].—Muirhead, Ltd. (*See* 115.)

185. Linear-Characteristic Rotary Condensers with Specially Large Range of Rotation [particularly needed for Selection of Ultra-High-Frequency Channels].—Leider & Zinke. (*E.T.Z.*, 24th Sept. 1942, Vol. 63, No. 37/38, pp. 433–436.)

Authors' summary:—"A new rotary condenser for a variation-range exceeding 180° is investigated with regard to the linear form of its characteristic $C = f(\alpha)$. Its development by experiment and measurement is described and then covered mathematically. Curves plotted for capacitance as a function of angle of rotation bring out clearly the importance of the use, for the first time, of a stator profile in the form of a spiral curve which bears a definite mathematical relation to that of the rotor. Although this new development was chiefly intended for u.s.w. purposes, the condenser described can well be used in general h.f. technique wherever it is desired to have a linear characteristic with a rotation exceeding 180° without any special gearing. Thus a condenser can be obtained with a full-scale adjustment covering 330°. For the spiral-shaped profile curves of rotor and stator there are an arbitrary number of possible pairs, but only one pair with a continuous, smooth course such as is suitable for manufacture: for this, the stator radius must increase with $\sqrt{\alpha}$, and the same holds good for the rotor radius."

As an example of the use of the design curves and tables provided, a 270° condenser for a max. capacitance of 10 pF is calculated. By eqn. 1a, applied to a condenser with 1 stator plate and 2 rotor plates ($n = 2$), and a plate-spacing $d = 0.06$ cm, the constant K (which has the dimensions of a surface) comes out at 1.4 cm²: from eqn. 5, $r_1^2 = r_0^2 + K \cdot \alpha/\alpha_{st}$ (α_{st} is the stator angle), and choosing r_0 as 1 cm, r_1 is given by Table 1, and the pattern for the stator is thus determined. Similarly the pattern for the rotor ($R^2 = R_0^2 + \alpha/\alpha_{st}$) is obtained from Table 2.

186. The Measurement of the Temperature Coefficient of Capacitance of Small Condensers.—Iorwerth Jones. (*See* 116.)

187. Standardisation of Paper Condensers for Communications Engineering [DIN Specifications].—(*E.T.Z.*, 13th Aug. 1942, Vol. 63, No. 31/32, p. 380.)

188. DIN Standardisation of Fixed Condensers [Electrolytic, Ceramic, etc.].—Linder. (*E.T.Z.*, 10th Sept. 1942, Vol. 63, No. 35/36, pp. 431–432.)

189. Electrolytic Condensers [and the True Reasons for Their Relatively High Power Factor].—Cozens. (*Wireless World*, Nov. 1942, Vol. 48, No. 11, p. 271.)

190. The Temperature Calculations in the Design of Electrolytic Condensers.—Zackheim. (*Journ. of Tech. Phys.* [in Russian], No. 21, Vol. 10, 1940, pp. 1762–1770.)

Formulae (20), (21) and (22) are derived from which the maximum temperature inside a dry electrolytic condenser of cylindrical shape can be determined for given operating conditions, dimensions of the condenser, and thermal conductivity of the materials used. The application of the formulae is illustrated by a number of practical examples in which low-voltage condensers both for d.c. and a.c. operation are considered.

191. Some Recent Advances in Industrial Plastics: Corrections.—Wearmouth. (*Journ. of Scient. Instr.*, Nov. 1942, Vol. 19, No. 11, p. 176.) *See* 3732 of 1942.

192. The Relation between Crystal Structure and Mechanical Properties in Moulded Plastics.—Siegfried. (*Schweizer Arch. f. angew. Wiss. u. Tech.*, Aug. 1942, Vol. 8, No. 8, pp. 255–262.)

193. Determining the Plasticizer Content of Plastics.—(*Bell Lab. Record*, Aug. 1942, Vol. 20, No. 12, p. 294.)

194. Progress in the Coating of Electrical Conductors, especially with Polyvinyl Chlorides [and the Latest Spraying Technique].—Beck & Rehbock. (*Zeitschr. V.D.I.*, 17th Oct. 1942, Vol. 86, No. 41/42, pp. 629–632.)

195. Insulating Materials in Cable and Line Technique [Survey, including Recent Developments: Relation between Chemical Stability, Mechanical Strength, & Dielectric Strength: between Low Water Absorption, Specific Insulation Resistance, & Dielectric Loss: etc.].—Heering. (*E.T.Z.*, 24th Sept. 1942, Vol. 63, No. 37/38, pp. 439–443.)

196. SUBSTITUTION AMONG MATERIALS USED FOR CABLE INSULATION. — Barron. (*G.E.C. Journal*, Aug. 1942, Vol. 12, No. 2, pp. 71–83.)

197. " KONSTRUIEREN IN NEUEN WERKSTOFFEN " [Special Pamphlet on the Designer's Use of New & Substitute Materials for Machines & Apparatus: Book Review]. —V.D.I. (*Zeitschr. f. Fernmeldetech.*, 15th June 1942, Vol. 23, No. 6, p. 96.)

198. " FORTSCHRITTE DER CHEMIE, PHYSIK, UND TECHNIK DER MAKROMOLEKULAR STOFFE: BAND 2 " [Book Review].—Röhrs & others. (*Zeitschr. V.D.I.*, 3rd Oct. 1942, Vol. 86, No. 39/40, p. 615.)

199. THE STUDY OF POLYMERS: PART VI [Crystallised Rubber].—Lysenko. (*Journ. of Tech. Phys.* [in Russian], No. 20, Vol. 10, 1940, pp. 1651–1674.)

Continuing 3098 of 1942, a survey is given of publications dealing with the physical properties of crystallised rubber and the effect of external conditions (temperature, pressure, tension, etc.) on the crystallisation and melting of rubber. The modern conceptions of the physical nature of the crystallisation process are also surveyed.

200. DISCUSSION ON " FACTORS INFLUENCING THE MECHANICAL STRENGTH OF CELLULOSE INSULATION." — Clark. (*Elec. Engineering*, Transactions Supplement, Dec. 1941, Vol. 60, pp. 1321–1323.) *See* 1172 of 1942.

201. IMPREGNATING VARNISHES [Advantages of Varnishes made with Synthetic Resins of Phenol-Aldehyde Type]. — Kiernan. (*Bell Lab. Record*, Aug. 1942, Vol. 20, No. 12, pp. 293–294.)

202. ON THE VOLUME AND SURFACE RESISTIVITIES OF SHELLAC MOULDED MATERIALS. — Bhattacharya. (*Indian Journ. of Phys.*, June 1942, Vol. 16, Part 3, pp. 147–154.)

203. THE DIELECTRIC STRENGTH OF INDIAN VEGETABLE OILS.—Chakravarty & Mahanti. (*Indian Journ. of Phys.*, April 1942, Vol. 16, Part 2, pp. 82–86.)

204. DIELECTRIC LOSSES IN BORIC GLASSES AT HIGH FREQUENCIES.—Walther, Gladkikh, & Martyushov. (*Journ. of Tech. Phys.* [in Russian], No. 19, Vol. 10, 1940, pp. 1593–1603.)

On the basis of previous investigations the following main propositions are formulated:—(1) Dielectric losses in a " pure glass " are very small (tan δ is of the order of 0.0008–0.001). (2) The addition of the oxide of a divalent metal increases the losses only slightly. (3) The addition of the oxide of a monovalent alkali metal may sharply increase the losses. (4) Losses in a glass containing an alkaline oxide may be reduced by the addition of the oxide of a heavy divalent metal or by the partial replacement of the alkaline oxide by a different alkaline oxide (neutralisation effect). (5) There is a certain parallelism between dielectric losses and electrical conductivity.

In the present paper a report is given on an experimental investigation in which the above propositions were studied in greater detail. Li_2O, K_2O, CaO, and BaO were used, and losses were measured at a frequency of 2 Mc/s and at temperatures varying from − 180° to + 600° C.

205. THE TEMPERATURE RISE DUE TO DIELECTRIC LOSSES IN THICK INSULATING LAYERS [and Its Rôle in the Proper Design of Insulation for Modern High-Voltage Apparatus and Transformers].—Elsner. (*Wiss. Veröff. a. d. Siemens-Werken*, No. 2, Vol. 20, 1942, pp. 74–82.)

206. ON THE PROBLEM OF SURFACE LEAKAGE [Survey of Recent Work (*e.g.* 2815 of 1942), and Some New Tests with a " Dipping " Equipment, & Their Results.—Pfestorf & Richter. (*E.T.Z.*, 10th Sept. 1942, Vol. 63, No. 35/36, p. 422: summary only.)

207. COMPREHENSIVE REVIEW OF [American, Italian, Japanese, & German] INVESTIGATIONS OF THE INFLUENCE OF ATMOSPHERIC HUMIDITY ON THE FLASHOVER VOLTAGE OF H.T. INSULATORS. — Weicker. (*Arch. f. Elektrot.*, 31st July 1942, Vol. 36, No. 7, pp. 418–430.)

208. ON THE COURSE OF THE REACTION AT THE TRANSITION OF PURE METALLIC FILMS FROM THE UNORDERED TO THE ORDERED STATE [with Accompanying Change in Resistance]. —Suhrmann & Schnackenberg. (*Zeitschr. f. Phys.*, 31st July 1942, Vol. 119, No. 5/6, pp. 287–317.)

209. RADIO DATA CHARTS: NO. 2 (3RD SERIES)—EFFECT OF A SCREENING CAN ON THE INDUCTANCE AND RESISTANCE OF A COIL.—Sowerby. (*Wireless World*, Nov. 1942, Vol. 48, No. 11, pp. 254–257.) Based on Bogle's equations (821 of 1941).

210. DISCUSSION ON " THE SHIELDING OF PERMANENT MAGNETS FROM TRANSIENT FIELDS ". —Wey. (*Elec. Engineering*, Transactions Supplement, Dec. 1941, Vol. 60, pp. 1338–1339.) *See* 1177 of 1942.

211. NEW KNOWLEDGE IN THE TECHNIQUE OF COMPRESSED-POWDER CORES [Discrepancies between Rayleigh–Jordan Theory & Actual Measurements (*e.g.* regarding Particle Sizes in Carbonyl Iron): Dependence of Magnetic & Thermal Stability on Method of Preparation & on Pressure: Anomalous Hysteresis Properties of Japanese " Sendust " : etc.].—Kiessling & Ludl. (*E.T.Z.*, 10th Sept. 1942, Vol. 63, No. 35/36, pp. 413–416.)

212. AN EQUIPMENT FOR THE QUICK PHOTOGRAPHIC RECORDING OF MAGNETOSTRICTION CURVES [Length-Variation transferred through Lever-System to Plate of Condenser supplied with 35 kc/s Voltage: Results for Various Iron–Cobalt Alloys, " Sendust " & " 1040 " High-Permeability Alloys]. — Kornetzki. (*Wiss. Veröff. a. d. Siemens-Werken*, No. 2, Vol. 20, 1942, pp. 48–53.)

213. ON THE THEORY OF TECHNICAL MAGNETISATION.—Vladimirski. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 2/3, Vol. 11, 1941, pp. 318–324.)

The statistical theory of spontaneous magnetisation is applied to the case of materials with low anisotropy, for calculating the relationship between magnetostriction and magnetisation by an external magnetic field.

214. RECRYSTALLISATION ANNEALING OF FINISHED PRODUCTS OF FERROSILICEOUS ALLOYS AS A MEANS FOR A MARKED IMPROVEMENT IN THEIR MAGNETIC PROPERTIES. — Shur, Drozhzhina, & Zhukova. (*Journ. of Tech. Phys.* [in Russian], No. 19, Vol. 10, 1940, pp. 1619–1620.)

The ferrosiliceous alloys used in the manufacture of electrical machines and apparatus are normally rolled into thin sheets which are then subjected to a prolonged annealing at a high temperature. It is often necessary to re-anneal the details manufactured from these sheets. In this paper it is suggested that only the finished details should be annealed and the first annealing operation omitted.

215. STRUCTURAL VARIATIONS IN THE Fe-Ni-Al ALLOYS RELATED TO COERCIVE FORCE.—Komar & Tarasov. (*Journ. of Tech. Phys.* [in Russian], No. 21, Vol. 10, 1940, pp. 1745–1755.)

An experimental investigation of the magnetic properties, and an X-ray investigation of the structure, of various Fe-Ni-Al alloys with different heat treatments. The relation between structure and coercive force is discussed.

216. THE EFFECT OF ELASTIC STRESSES ON THE MAGNETISATION OF FERROMAGNETIC BODIES IN WEAK FIELDS.—Drozhzhina & Shur. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 1, Vol. 11, 1941, pp. 116–121.) Experiments with samples of transformer steel, iron, and nickel: the results are discussed.

217. THERMAL EFFECTS AT THE HIGH-TEMPERATURE ANNEALING OF HARDENED STEEL: *also* THE CRYSTALLOGRAPHIC ORIENTATION OF α-PHASE WITH RESPECT TO β-PHASE IN Fe-Ni-Al ALLOYS: *and* STRUCTURE TRANSFORMATIONS IN Cu-Ni-Fe ALLOYS.—Abramovič & others. (*Journ. of Tech. Phys.* [in Russian], No. 12, Vol. 11, 1941, pp. 1083–1086: pp. 1087–1088: pp. 1098–1108.)

218. COLD-WORKED MANGANESE STEEL AS A NEW MAGNET MATERIAL.—Jellinghaus. (*E.T.Z.*, 30th July 1942, Vol. 63, No. 29/30, p. 358: summary only.)

219. THE DESIGN OF THE POLE PIECES OF ELECTROMAGNETS, AND THE FORCES ACTING ON SMALL BODIES PLACED IN THEIR MAGNETIC FIELDS.—Davy. (*Phil. Mag.*, Aug. 1942, Vol. 33, No. 223, pp. 575–593.)

220. SOFT AND HARD MAGNETIC MATERIALS FOR MEASURING AND COMMUNICATION TECHNIQUE [Survey]. — von Auwers. (*E.T.Z.*, 30th July 1942, Vol. 63, No. 29/30, pp. 341–348.)

221. A MAGNETIC FIELD OF GREAT HOMOGENEITY FOR THE WILSON CLOUD CHAMBER.—Sauerwein. (*Naturwiss.*, 7th Aug. 1942, Vol. 30, No. 32, pp. 494–495.)

STATIONS, DESIGN AND OPERATION

222. BUILDING WERS [War Emergency Radio Service] GEAR FROM SALVAGED BROADCASTING SETS [2½ Metre Transmitter-Receiver from Scrapped Receiver]. — Mix. (*QST*, Sept. 1942, Vol. 26, No. 9, pp. 15–18.)

223. COMMUNICATIONS EQUIPMENT FOR PRIVATE AIRCRAFT: SIMPLE TRANSMITTER AND RECEIVER FOR CIVIL AIR PATROL (CAP) WORK. —Mix. (*QST*, Aug. 1942, Vol. 26, No. 8, pp. 17–21 and 116..120.)

224. PLANNING AND ESTABLISHMENT OF A TRANSOCEANIC SINGLE-SIDEBAND RADIOTELEPHONIC LINK: *also* THE TELEFUNKEN SINGLE-SIDEBAND TRANSMITTER: THE TELEFUNKEN SINGLE-SIDEBAND RECEIVER FOR TWO SPEECH CHANNELS: THE I.F. EQUIPMENTS AT THE TRANSMITTING AND RECEIVING ENDS: *and* THE L.F. TERMINAL EQUIPMENTS.—Hahn & others. (*Telefunken-Mitteilungen*, Dec. 1941, Vol. 22, No. 86, pp. 11–71.)

Practically the whole of this issue is occupied by this symposium. A notice mentions that the previous issue, No. 85, was not published, for editorial reasons.

225. REDIFFUSION: A DEVELOPMENT OF BROADCASTING.—Adorjan. (*Endeavour*, Oct. 1942, Vol. 1, No. 4, pp. 161–165.)

GENERAL PHYSICAL ARTICLES

226. THE MAGNETIC ION [Letter on the Writers' Earlier & Latest Researches].—Ehrenhaft & Banet. (*Science*, 4th Sept. 1942, Vol. 96, pp. 228–229.)

227. THE LOSS OF ENERGY OF HYDROGEN IONS IN TRAVERSING VARIOUS GASES [Air, Water Vapour, etc.].—Crenshaw. (*Phys. Review*, 1st/15th July 1942, Vol. 62, No. 1/2, pp. 54–57.)

228. MOBILITIES IN SOME FREE ELECTRON GASES. —Bennett & Thomas. (*Phys. Review*, 1st/15th July 1942, Vol. 62, No. 1/2, pp. 41–47.)

"Mobility coefficients for free electrons and mobilities of positive ions are reported for hydrogen, deuterium, and some mixtures of hydrogen and nitrogen, and of hydrogen and helium, for field strengths between 1 and 2 volts per cm per mm of mercury gas pressure. The relation between free electron drift velocity and field strength is found to be parabolic in this range for all these gases. Discussion of these observations shows that they can be explained qualitatively if electrons excite rotations of the hydrogen molecules by collision, and the cross sections for this process are estimated . . ."

229. The Relativistic Problem of the Movement of an Electron in an Alternating Magnetic Field Parallel to, and Symmetrical with respect to, an Axis.—Terletski. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 1, Vol. 11, 1941, pp. 96–100.)

A particular solution of the above problem is found and it is shown that with the aid of such a field a very high acceleration of electrons can be obtained. As a practical example approximate data are calculated for an electron accelerator giving electrons with an energy of 30 Mev.

230. Note on the Transparency of a Potential Barrier [and the Full Use of Jeffreys' Approximation: Rectangular & Triangular Barriers].—Jeffreys. (*Proc. Cambridge Phil. Soc.*, Nov. 1942, Vol. 38, Part 4, pp. 401–405.)

231. Contact Potentials: Part V—The Metal-Electrolyte Volta Effect: Part VI—Single Potential Differences: Part VII—Chemical and Thermal Effects.—Chalmers. (*Phil. Mag.*, Aug. 1942, Vol. 33, No. 223, pp. 594–613.) For previous parts *see* 2848 of 1942.

232. Experimental Evidence for the Existence of a Neutrino.—Allen. (*Phys. Review*, 1st/15th June 1942, Vol. 61, No. 11/12, pp. 692–697.)

233. The Influence of Radiation Damping on the Scattering of Mesons: II—Multiple Processes.—Heitler & Peng. (*Proc. Cambridge Phil. Soc.*, July 1942, Vol. 38, Part 3, pp. 296–312.) Following on 3166 of 1941.

234. The Theoretical Values of the Physical Constants.—Eddington. (*Proc. Phys. Soc.*, 1st Nov. 1942, Vol. 54, Part 6, No. 306, pp. 491–504.)

235. On the Definition of Molecular Weight, of the Mol, and of the Loschmidt Number.—Westphal: Pohl. (*Physik. Zeitschr.*, 1st Sept. 1942, Vol. 43, No. 17, pp. 329–331.) Reply to 3415 of 1942.

236. "The Nature of Thermodynamics" [from the Writer's "Operational" Point of View: Book Review].—Bridgman. (*Proc. Phys. Soc.*, 1st Sept. 1942, Vol. 54, Part 5, No. 305, pp. 463–466.) Reviewed by Dingle.

237. A Generalised Electrodynamics: Part I—Non-Quantum.—Podolsky. (*Phys. Review*, 1st/15th July 1942, Vol. 62, No. 1/2, pp. 68–71.)

238. Discussion on Papers by C. W. Hansel entitled "Fundamental Laws and Definitions in Physics."—Hansel. (*Proc. Phys. Soc.*, 1st Nov. 1942, Vol. 54, Part 6, No. 306, pp. 509–526.)

239. Note on Some Recent Papers on Physical Quantities and Their Dimensions.—Duncanson. (*Proc. Phys. Soc.*, 1st Nov. 1942, Vol. 54, Part 6, No. 306, pp. 504–509.)

240. Dimensions and the Facts of Measurement.—Campbell. (*See* 132.)

MISCELLANEOUS

241. The Application of the Laplace Transformation to a Problem on Elastic Vibrations.—Tranter. (*See* 101.)

242. On Certain Expansions of the Solutions of the General Lame Equation.—Erdélyi. (*Proc. Cambridge Phil. Soc.*, Nov. 1942, Vol. 38, Part 4, pp. 364–367.)

243. Some New Values for the Exponential Integral.—Coulson & Duncanson. (*Phil. Mag.*, Oct. 1942, Vol. 33, No. 225, p. 754–761.)

244. Symmetric Relations between the Coefficients of Reversed Power Series.—Bleick. (*Phil. Mag.*, Aug. 1942, Vol. 33, No. 223, pp. 637–638.)

245. The Tensor Calculus, the Method of Dimensions, and the Per-Unit Method [and the Connections between the Three Methods].—Stigant. (*BEAMA Journal*, Oct. 1942, Vol. 49, No. 64, pp. 306–310.)

246. Concerning the Operational Calculus [Continued Correspondence].—Giorgi: Wagner. (*Alta Frequenza*, July 1942, Vol. 11, No. 7, p. 340.) *See* 3224 of 1942.

247. "Differentialgleichungen: Lösungsmethoden und Lösungen" [Book Review].—Kamke. (*Physik. Zeitschr.*, 20th Sept. 1942, Vol. 43, No. 18, p. 371.) An enthusiastic review.

248. A Machine for the Rapid Summation of Fourier Series.—Macewan & Beevers. (*Journ. of Scient. Instr.*, Oct. 1942, Vol. 19, No. 10, pp. 150–156.)

249. "Ultra-High-Frequency Techniques" [Text Book for Training Course planned by Convention at M.I.T: Book Review].—Brainerd & others. (*QST*, Sept. 1942, Vo. 26, No. 9, pp. 36 and 104.)

250. The Testing of Proposals for Inventions [Announcement of the National Socialist "Deutsche Arbeiterpartei"].—(*Zeitschr. f. tech. Phys.*, No. 7, Vol. 23, 1942, pp. 191–192.) *See* also 3791 of 1942.

251. The Physicist in the Factory [Discussion, at Royal Institution, of Lowery's Memorandum, 3804 of 1942].—Lowery. (*Engineering*, 23rd Oct. 1942, Vol. 154, p. 332.) *See* also *Nature*, 14th November. pp. 568–569.

252. The Physicist in Industry.—Buckley. (*Journ. of Scient. Instr.*, Oct. 1942, Vol. 19, No. 10, pp. 145–148.)

253. The Japanese Morse Telegraph Code: with Some Notes on the Japanese Language.—Millikin. (*QST*, Sept. 1942, Vol. 26, No. 9, pp. 23–25 and 120.)

254. Correspondence [between Editor of *Science* and Chief Postal Censor] in Regard to the Censorship of Scientific Journals.—(*Science*, 4th Sept. 1942, Vol. 96, pp. 216–221.) *See* also issue for 18th September, pp. 274–275.

255. Formation of the Netherland Committee for Scientific Documentation.—(*Electrician*, 6th Nov. 1942, Vol. 129, p. 492: paragraph only.)

256. The Technical Intelligence Bureau of the Imperial Institute, London, and Its Facilities.—(*Journ. of Scient. Instr.*, Nov. 1942, Vol. 19, No. 11, p. 176.)

257. Microfilm Photography [Some Brown University Projects, and the Necessity for Air Conditioning in Dark Room, Enlarging Room, & Camera Room].—(*Science*, 18th Sept. 1942, Vol. 90, p. 266.)

258. Medical Orthoepy [Letter urging Better Pronunciation of Technical Terms].—Craver. (*Science*, 18th Sept. 1942, Vol. 96, pp. 272–273.)

"It is true that a vital language is continually changing, but it is dubious if changes emerging from ignorance constitute progress. . . . The man who speaks with care arouses in his audience a greater feeling of confidence in the potential accuracy of his scientific conclusions."

259. A Session of the Department of Mathematics and Physics of the Academy of Sciences of the U.S.S.R.—Lifshits. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 1, Vol. 11, 1941, pp. 194–195.)

A brief report on a session held on 28th/29th October, 1940. Among other papers, two were read by Joffe, one on electrostatic generators and the other on semiconductors.

260. Publications from the Kaiser-Wilhelm Institutes, April 1941 to March 1942 [Titles, including Some which are Not Yet published].—(*Naturwiss.*, 9th Oct. 1942, Vol. 30, No. 41/42, pp. 620–641.) Preceded by a report on the Kaiser-Wilhelm Society.

261. Italo-German Electro-Physical Reunion at the I.E.N.G.F. [Galileo Ferraris Institute, Turin, May 1942: with Summaries of Papers].—(*Alta Frequenza*, July 1942, Vol. 11, No. 7, pp. 333–339.)

262. Activities of the "Galileo Ferraris" National Electrotechnical Institute in Its Seventh Year, 1940/1941.—Vallauri. (*La Ricerca Scient.*, Aug./Sept. 1942, Vol. 13, No. 8/9, pp. 361–406.)

263. Communications Technique at the 1942 Milan Fair.—Pirani. (*Zeitschr. f. Fernmeldetech.*, 15th July & 15th Aug. 1942, Vol. 23, Nos. 7 & 8, pp. 97–103 & 121–126.)

264. The *Wireless World* "Brains Trust" [Objects, & Invitation for Questions].—(*Wireless World*, Nov. 1942, Vol. 48, No. 11, p. 249.)

265. The Measurement of Short Times with the Cathode-Ray Tube [using Zig-Zag Time Base covering Whole Screen: for Projectile, Shutter, & Relay Research].—Kömmnick & Pickert. (*See* 133.)

266. Applications of the Cathode-Ray Oscillograph in Industry: VI—The Recording of Mechanical Pressure Fluctuations [particularly the Standard-Sunbury Indicating Equipment].—Wilson. (*BEAMA Journal*, Sept. 1942, Vol. 49, No. 63, pp. 254–258.)

267. Applications of the Cathode-Ray Tube in Industry: VII—The Electron Microscope and Diffraction Camera.—Wilson. (*BEAMA Journal*, Oct. 1942, Vol. 49, No. 64, pp. 300–305.) For further correspondence on the relative merits of the c.r.o. and the string galvanometer (3480 of 1942) *see* pp. 313–314.

268. Habit and Orientation in Electron Diffraction [Observations suggesting that Weighted Sampling of Crystallites, in place of Random Sampling, may occur rather generally in Surface-Layer Diffraction].—Johnson & Grams. (*Phys. Review*, 1st/15th July 1942, Vol. 62, No. 1/2, pp. 77–79.)

"We suggest, in view of the observations described here, that such patterns [*e.g.* from thin oxide films] may need to be interpreted cautiously."

269. Photoelectric Torsiograph [for Remote Measurement (by C.R. Oscillograph) of Torsional Vibrations in High-Speed Internal-Combustion Engines: Advantages, including Elimination of Slip Rings].—Spillmann. (*Schweizer Arch. f. angew. Wiss. u. Tech.*, Aug. 1942, Vol. 8, No. 8, pp. 252–255.)

270. Building-Up Processes and the Recording of Shocks [Theoretical & Experimental Investigation in Connection with the Design of Vibrometers, Seismographs, etc.].—Martin. (*Physik. Zeitschr.*, 20th July 1942, Vol. 43, No. 13/14, pp. 222–226.)

271. The Natural Frequencies of Elastically Mounted Machines [Method of Calculation].—de Gruben. (*Zeitschr. V.D.I.*, 17th Oct. 1942, Vol. 86, No. 41/42, pp. 633–637.)

272. Electrostatic Separator for Low-Grade Ores [also for purifying Foods, etc.].—Westinghouse Company. (*Scient. American*, Sept. 1942, Vol. 167, No. 3, p. 126.)

273. Electric Determination of Film-Volume and Film-Density [and Variations of Dielectric Constant of Soil in Western Desert].—Löwy. (*See* 22.)

274. High-Frequency Discharge in Oil Refining [Note on U.S.A. Patent on Improvement in "Voltolisation" by Use of Frequencies above 600 Mc/s: Dehydrogenation, Polymerisation, & Other Chemical Reactions].—(*Sci. & Culture* [Calcutta], July 1942, Vol. 8, No. 1, pp. 25–26.)

275. Papers on Heating by High-Frequency Induction, and Internal and External Surface Hardening.—Chestnut & others. (*Electronics*, June 1942, Vol. 15, No. 6, pp. 142–143: summaries only.)

276. Peculiarities of the Induction Heating of Steel.—Babat. (*Journ. of Tech. Phys.* [in Russian], No. 19, Vol. 10, 1940, pp. 1604–1618.)

The heating process is discussed in detail from both the theoretical and practical standpoints, and various particular cases are considered, such as when the magnetic field at the surface of the steel is non-uniform, when the steel is non-homogeneous, or when "ribbon" heating takes place (bright orange bands appear on the surface of the object, Fig. 10). *See* also Turlygin, 277, below.

277. On the Pamphlet by G. Babat and M. Lozinski on "Surface Strengthening of Steel by means of High-Frequency Currents."—Turlygin. (*Journ. of Tech. Phys.* [in Russian], No. 21, Vol. 10, 1940, p. 1831.) For other papers by Babat & Lozinski *see* 992 of 1941: and *cf.* 2200 of 1942, and 276, above.

278. Power-Circuit Instruments for the Higher Range of Audio-Frequencies [900–12 000 c/s, for Induction Furnaces, etc.].—Lunas & MacGahan. (*Elec. Engineering*, Transactions Supplement, Dec. 1941, Vol. 60, pp. 1230–1234.)

279. The Application of Ignitrons to Resistance-Welding Control.—Bivens. (*Elec. Engineering*, Transactions Supplement, June 1941, Vol. 60, pp. 471–478.) For Discussion *see* p. 655.

280. A Thyratron Circuit for Theatre Lighting.—Wischmeyer. (*Elec. Engineering*, Transactions Supplement, Dec. 1941, Vol. 60, pp. 1067–1072.)

281. The Behaviour of Moving-Coil Galvanometers to Periodic Currents [in Telemetering, etc.].—Fistl. (*See* 125.)

282. Paper on Non-Linear Circuits [with Iron-Cored Chokes] for Control and Supervision.—Steuernagel. (*See* 38.)

283. Experimental Investigations on Magnetic Amplifiers for Measuring and Control Technique.—Geyger. (*See* 123.)

284. The Laws governing Automatic Control Processes.—Görk. (*See* 39.)

285. Self-Excited Oscillation in Dynamical System possessing Retarded Actions [Special Case of the "Hysteresis-Type" System, with "Hysterodifferential" Equation, leading to Parasitic Oscillations & Hunting].—Minorsky. (*Journ. Roy. Aeron. Soc.*, Oct. 1942, Vol. 46, No. 382, p. 354: abstract only.)

286. Electronic Relay Control [Commercial Series, including Type working on about 2 μA and capable of starting ½ H.P. 230 V Motor, and Electronic "Stop Watch"].—(*Nature*, 19th Sept. 1942, Vol. 150, p. 345.)

287. Experiments in Audio-Frequency Induction and Earth-Current Communication.—(*QST*, June & July 1942, Vol. 26, Nos. 6 & 7, pp. 35–36 & 43–44.)

288. Conduction in Nerve as an Electron-Interaction Effect.—Schmidt. (*Naturwiss.*, 9th Oct. 1942, Vol. 30, No. 41/42, pp. 644–645.)

289. Electric Shock [Experimental Investigation of Effects: Max. Safe 60 c/s Current 8–9 mA: Muscular Reactions proportional to Peak Value: etc.].—Dalziel & others. (*Elec. Engineering*, Transactions Supplement, Dec. 1941, Vol. 60, pp. 1073–1078.) *See* also 343 of 1942: for Discussion *see* pp. 1295–1297.

290. The Geiger Counter Methods [and Their Origin & Development], *and* Biological Applications of the Counter Tube.—Bothe: Born & others. (*Naturwiss.*, 2nd Oct. 1942, Vol. 30, No. 40, pp. 593–599; pp. 600–603.)

291. The Coincidence Method [with Geiger-Müller Counters] and Its Application to Problems of Nuclear Physics [Comprehensive Survey].—Maier-Leibnitz. (*Physik. Zeitschr.*, 20th Sept. 1942, Vol. 43, No. 18, pp. 333–362.)

292. Applications of Geiger-Müller Counters to Inspection with X-Rays and Gamma Rays.—Friedman & others. (*Journ. Roy. Aeron. Soc.*, Oct. 1942, Vol. 46, No. 382, p. 357: abstract only.)

293. A Modified Patterson Function [in X-Ray Crystal-Structure Analysis: Criticism of Yü's Method].—Lu: Yü. (*Nature*, 3rd Oct. 1942, Vol. 150, p. 407.) *See* 2910 of 1942.

294. A Portable Indicating X-Ray Dosimeter.—Krebs & Kersten. (*Review Scient. Instr.*, Aug. 1942, Vol. 13, No. 8, pp. 332–334.)

295. Neutron Pictures in place of X-Ray Pictures [Patent for Compact Equipment for Production & Slowing-Down of Neutron Beams, and Protection of Operator].—Kallmann & Kuhn. (*Sci. News Letter*, 8th Aug. 1942, Vol. 42, No. 6, p. 89.)

296. A New High-Intensity Neutron Source.—Morand. (*Review Scient. Instr.*, July 1942, Vol. 13, No. 7, p. 301.)

297. X-Ray Cameras for High-Speed Photography.—Geller [Heller]. (*Journ. of Tech. Phys.* [in Russian], No. 19, Vol. 10, 1940, pp. 1643–1647.)

A description is given of two types of X-ray camera for industrial purposes in which a new method of focusing is used. This permits the exposure to be reduced to a few minutes only, as compared with several hours required in the case of ordinary cameras.

298. X-Ray Technique in the Industrial Laboratory.—Rooksby. (*Journ. Roy. Soc. Arts*, 2nd Oct. 1942, Vol. 90, pp. 673–706.) An abridged version was referred to in 2913 of 1942.

299. Industrial Micro-Radiography [New Technique supplementing Microscope & giving Three-Dimensional View without Elaborate Preparation of Specimen].—Clark & Gross. (*Electrician*, 30th Oct. 1942, Vol. 129, pp. 476–478.)

300. On the Sensitivity of a High-Resistance Bolometer [using Semiconducting instead of Metallic Foil].—Bauer. (*See* 134.)

301. Fundamental Considerations regarding Some Observations on Hollow Superconductors [leading to a New, "Structural" Theory of Superconductivity].—Koch. (*Zeitschr. f. Phys.*, 22nd Sept. 1941, Vol. 118, No. 1/2, pp. 1–21.)

302. On Simplified Calculations of Spectra.—Mayants. (*Journ. of Tech. Phys.* [in Russian], No. 21, Vol. 10, 1940, pp. 1811–1812.)

To determine the frequency of a line in a Raman spectrum or the position of a line of a given frequency, Hartmann's formula [$\nu = \nu_o - C/(l_o - l)$] is normally used. The difficulties connected with the use of this formula are pointed out and it is suggested that they could be avoided if certain tables based on Hartmann's formula were prepared.

303. An Infra-Red Spectrograph with Equipment for Direct Recording of the Absorption Ratios and with Linear Wavelength Distribution.—Lehrer. (*Zeitschr. f. tech. Phys.*, No. 7, Vol. 23, 1942, pp. 169–176.)

304. Tables for Calculating Refractive Indices [of Glass] for the Infra-Red Region of the Spectrum.—Slyusarev. (*Journ. of Tech. Phys.* [in Russian], No. 21, Vol. 10, 1940, pp. 1826–1830.)

305. On the Reduction of Reflection at Optical Glasses [Survey, from Carl Zeiss Works].—Smakula. (*Physik. Zeitschr.*, 20th July 1942, Vol. 43, No. 13/14, pp. 217–222.)

306. A Method for Investigating the Thickness, Chemical Properties, and Surface Structure of Thin Biological Objects ["Leptoscope", based on Modifications in Reflectivity of Glass Surface produced by Deposition of Thin Transparent Film].—Waugh. (*Journ. Opt. Soc. Am.*, Sept. 1942, Vol. 32, No. 9, pp. 495–502.)

307. A Long Optical Path in a Restricted Space [by Concave Spherical Mirror & Totally Reflecting Prism].—Kratz & Mack. (*Journ. Opt. Soc. Am.*, Aug. 1942, Vol. 32, No. 8, pp. 457–464.) *Cf.* 2926 of 1942.

308. Optical Fundamentals for Amateurs [for Light-Beam Communication].—Bourne. (*QST*, June 1942, Vol. 26, No. 6, pp. 19–21 and 84, 86.) *See* also pp. 34–35 for a light-gate and a light-gatherer.

309. Theory of the Effects of Light Intensity and Duration in determining Visual Responses.—Bartlett & Hudson. (*Proc. Nat. Acad. Sci.*, July 1942, Vol. 28, No. 7, pp. 289–292.)

310. Direct-Reading Densitometer [with Linear Phototube & Logarithmic Amplifier: successfully used in Commercial Testing of Photographic Films].—Sweet. (*Electronics*, July 1942, Vol. 15, No. 7, p. 68.) Based on a paper in *Journ. Soc. Mot. Pic. Eng.*

311. Additional Control for Amplifier for measuring Stellar Photoelectric Currents.—Wilson: Heidelberg & Rense. (*See* 3528 of 1942.)

312. A Current Detector of High Sensitivity [for Photoelectric Currents] and the Measurement of Colour Temperatures.—Garelli. (*See* 124.)

313. Photometric Study of the Profiles of the Fraunhofer Lines in the Solar Spectrum: Part I [and the Improvements to the Direct-Reading Photoelectric Spectrophotometer (2029 of 1941)].—Rao & Ananthasubrahmanyam. (*Indian Journ. of Phys.*, June 1942, Vol. 16, No. 3, pp. 177–186.)

314. A Simple Photoelectric Relay [for combining with Mirror Galvanometer for Control of Various Systems where Null Condition is to be maintained: Simplified Circuit made possible by Use of 117L7GT Valve, which cuts out Preliminary Stage & supplies D.C. Bias].—Working. (*Science*, 18th Sept. 1942, Vol. 96, p. 281.)

315. How the "Electric Eye" helps Production: Types of Light Cells and Their Circuits.—Gilbert. (*BEAMA Journal*, Oct. 1942, Vol. 49, No. 64, p. 311: summary only.)

316. Note on "Direct Pen Recording of Galvanometer Deflections."—Pompeo & Penther. (*See* 127.)

317. Photoelectric Railway-Signalling System [in Tunnel under Construction, where Blasting Charges might be Ignited by Sparking].—(*Engineering*, 18th Sept. 1942, Vol. 154, p. 227.)

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Printed in England for the Publishers, Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1,
by The Cornwall Press Ltd., Paris Garden, Stamford Street, London, S.E.1.