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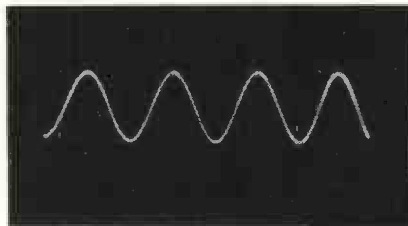

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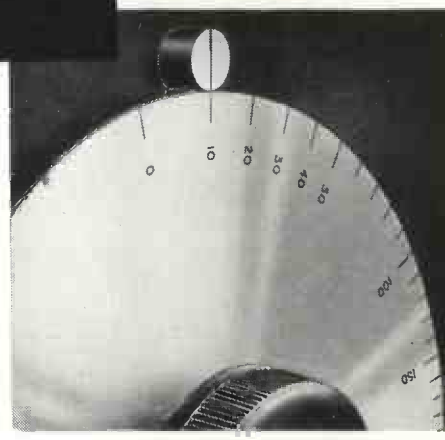

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WIRELESS ENGINEER

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VOL. XXII — JULY, 1945 — No. 262

EDITORIAL

A Dummy Dipole Network

IN the *Proceedings of the Institute of Radio Engineers* of February 1944, Hans Salinger describes an interesting circuit arrangement which could be used instead of the actual dipole aerial in testing radio transmitters for output over a range of frequencies above and below the resonant frequency. A theoretical investigation of the impedance of a symmetrical aerial over such a range of frequencies had been made by King and Blake* for different values of the ratio of the diameter to the length, and it was these results that Salinger tried to simulate by means of a simple arrangement of resistance, inductance and capacitance. The arrangement finally adopted is shown in Fig. 1. Fig. 2 shows the values in ohms of the resistance R and the reactances $X_L = \omega_0 L$, $X_{c1} = 1/\omega_0 C_1$ and $X_{c2} = 1/\omega_0 C_2$ for a wide range of the ratio of the diameter d to the length l of the dipole. It will be seen that all the values decrease rapidly as the dipole is made shorter and thicker. The value of $\omega_0 = 2\pi f_0$ used in calculating the reactances is that corresponding to a wave-length λ exactly twice the length of the dipole; this is not exactly the same as the resonant frequency. The table on the next page gives a comparison of the impedance of the actual dipole as calculated by King and Blake with that of the dummy network for three values of d/l and for values of f from f_0/π to $2f_0$, mainly in multiples of f_0/π.

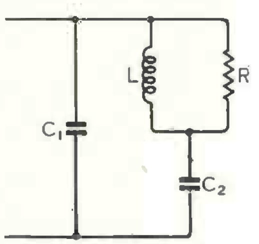

Fig. 1 (left).

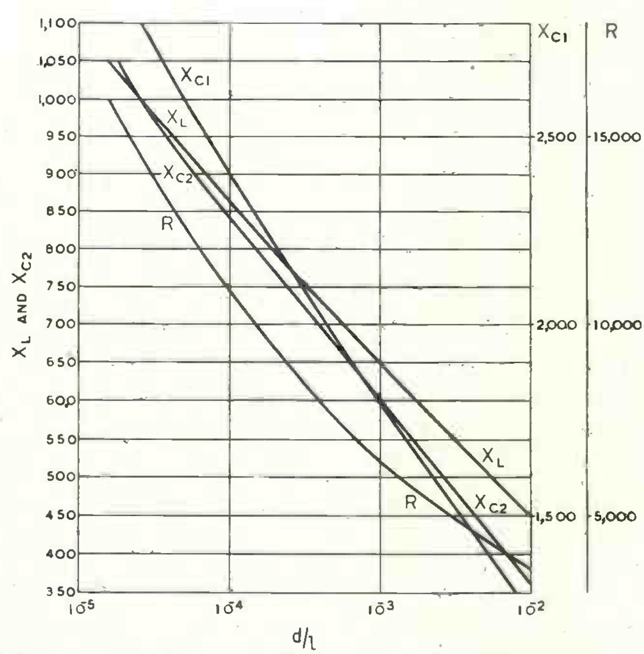

Fig. 2 (right).

These results are plotted in Figs. 3, 4 and 5 for the two values $d/l = 4 \times 10^{-5}$ and $d/l = 4 \times 10^{-3}$. For values of d/l greater

* *Proc. I.R.E.*, Vol. 30, pp. 335–349, July 1942.

than this the approximations made by King and Blake become more and more invalid

d/l	f/f_0	Z of dipole	Z of network
4×10^{-5}	0.318	$5 - j\,2050$	$4.0 - j\,1938$
	0.637	$22 - j\,750$	$19.3 - j\,728$
	0.955	$61 - j\,47$	$59.4 - j\,82$
	1.000	$69 + j\,36$	$69.2 + j\,2$
	1.273	$157 + j\,540$	$182.3 + j\,591$
	1.591	$550 + j\,1650$	$778.5 + j\,1792$
	1.910	$7040 + j\,2160$	$6740 + j\,1302$
	2.000	$5720 - j\,3800$	$6180 - j\,2790$
4×10^{-4}	0.318	$5 - j\,1550$	$4.1 - j\,1509$
	0.637	$22 - j\,540$	$18.9 - j\,532$
	0.955	$60 - j\,28$	$58.4 - j\,42.2$
	1.000	$68 + j\,38$	$68.1 + j\,22.1$
	1.273	$155 + j\,440$	$180.7 + j\,465$
	1.591	$540 + j\,1250$	$757.5 + j\,1340$
	1.910	$4740 + j\,660$	$4410 + j\,273$
	2.000	$3450 - j\,2400$	$3860 - j\,1791$
4×10^{-3}	0.318	$5 - j\,1050$	$3.8 - j\,988$
	0.637	$22 - j\,350$	$18.1 - j\,327$
	0.955	$58 - j\,12$	$56.7 + j\,17.4$
	1.000	$66 + j\,32$	$66 + j\,62.8$
	1.273	$149 + j\,340$	$175 + j\,380$
	1.591	$520 + j\,800$	$715 + j\,944$
	1.910	$2600 - j\,200$	$2600 - j\,241$
	2.000	$1900 - j\,1350$	$2180 - j\,1129$

as the dipole is made shorter and thicker.

It is easy to see that in the case of a short dipole of considerable diameter an element of uncertainty is introduced by the electrostatic capacitance between the inner ends of the two halves which will depend upon the length of the gap between them.

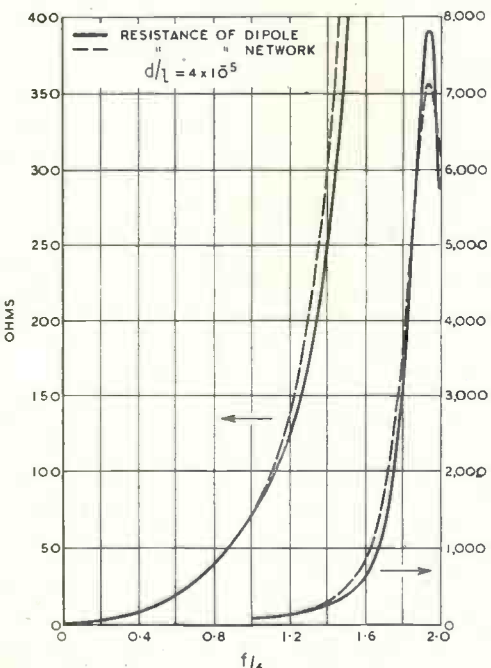

Fig. 3.

It is seen from the curves that the dummy network gives a very good approximation to the resistance and reactance of the actual dipole over a wide range of frequencies on either side of the resonant frequency. By plotting to a larger scale the reactances in the neighbourhood of resonance it is found that for exact resonance, *i.e.*, for zero reactance, the values of f/f_0 are as follows for the dipole:

$d/l =$	4×10^{-5}	4×10^{-4}	4×10^{-3}
$f/f_0 =$	0.98	0.975	0.9675

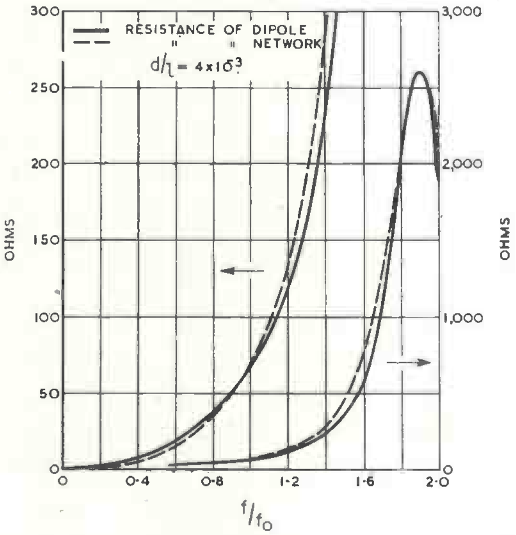

Fig. 4.

This means that the fundamental wavelengths are longer than $2l$ by 2.0, 2.5 and 3.25 per cent. The exact resonant frequencies of the dummy network do not agree very well with these values, the corresponding differences being 0.1, 1.5 and 4 per cent., but this is regarded as an unimportant detail and not worth correction. Salinger draws attention to the various sources of error that must be guarded against and, if necessary, taken into account, *e.g.*, the self-capacitance of the resistance R which, being perhaps of several thousand ohms, may have a self-capacitance which is by no means negligible at the high frequency employed. For accurate results the losses

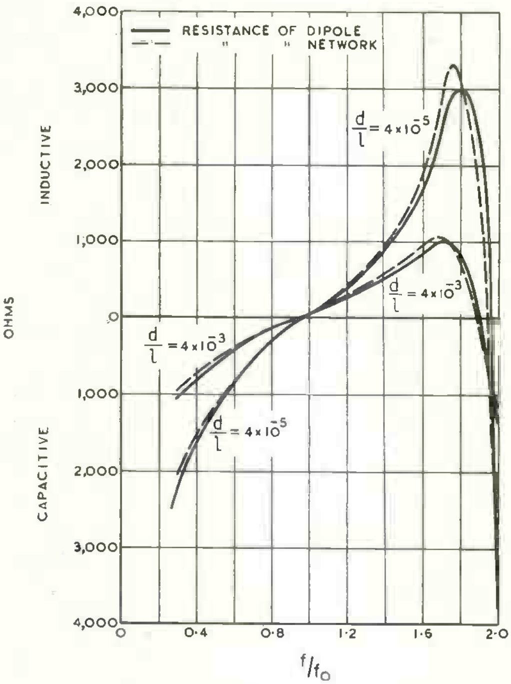

Fig. 5.

in the coil L will also have to be computed and taken into account.

The device is interesting and may prove of considerable value but very great care will be necessary to ensure accurate results.

There is one point to which Salinger does not refer but which appears to need some explanation. In the April Editorial we showed that the radiation resistance of a tuned dipole is 73.2 ohms. Expressing the input impedance of the aerial as $R+jX$, the imaginary term jX vanishes at resonance, leaving R which should be equal to the radiation resistance. In the above Table, whether one takes resonance as being when $f/f_0 = 1$ or when $X = 0$, the corresponding values of R are always less than 73.2, and vary between 60 and 69, being less for short thick aerials than for long thin ones. This raises the interesting point whether the radiation resistance of an aerial of a given length decreases as its diameter is increased and, if so, to what extent and why. If Salinger's figures are correct the radiation resistance is only 82 per cent. of its theoretical value when the length is 250 times the diameter, which sounds improbable.

G. W. O. H.

A Strange Convention

In an article recently submitted for publication in *Wireless Engineer*, we were surprised to find that the P.D. or voltage between the two ends of a resistance was always represented in the circuit diagrams by an arrow pointing in the opposite direction to the current through it. On pointing out to the author that there seemed to be something wrong, we were told that this was in accordance with the convention adopted at the educational establishment with which the author was associated. According to this convention the arrow always pointed from the negative to the positive terminal. We have noticed this same misuse of the arrow in several recent publications (*see* for example p. 60 of the current number of *The Marconi Review*).

It would be interesting to know if there is anything that can be said in favour of such a convention; there are obviously many reasons against it. If two insulated spheres or wires are charged, the one positively and the other negatively, the electric field between them is universally regarded as in the direction from positive to negative, and if a resistance were connected between them everyone would agree that current would flow from positive to negative. Why then should the electrical condition, potential difference, or voltage, be represented by an arrow pointing from negative to positive? If it be maintained that the arrow is merely intended to indicate which is the positive terminal and not to indicate the direction of any field, force or current, then it seems a flagrant misuse of the arrow.

The recognised method of indicating positive and negative is by means of the + and − signs, and if arrows are used they should certainly indicate the direction of the electric field between the two points. If a battery of resistance R were connected between the two points and its electromotive force E adjusted until the current through it was zero, we should write $(V - E)/R = 0$ and represent V and E by two equal and opposite arrows. This surely leaves no room for doubt as to the direction in which the V arrow should be drawn.

G. W. O. H.

A SPACE CHARGE PROBLEM*

Its Application to Cathode-Ray Tube Design

By Hilary Moss, Ph.D., B.Sc., A.M.I.E.E., A.M.Brit.I.R.E.

(*A. C. Cossor, Ltd.*)

SUMMARY.—A solution is obtained for the problem of a focused electron beam of circular symmetry emerging from an anode hole and moving subsequently in a region of constant axial field. This problem is an extension of the simpler one first treated by Watson,[1] and later more fully by Thompson and Headrick,[2] in which the electron beam is moving in a region free from external fields. Several numerical examples of the two solutions are compared with particular reference to cathode-ray tubes using post acceleration.

List of Symbols Used

z = distance measured along beam axis from anode as origin.

r = radial distance from beam axis.

R = radius of anode hole.

v_z = axial velocity of electron at any point.

V_z = initial axial velocity of electrons emerging from anode hole.

V_r = initial radial velocity of electrons emerging from anode hole.

I = current in beam.

ρ = total electron charge in portion of beam of length δz at point where velocity is v_z.

ϕ_a = anode voltage referred to cathode.

Grad ϕ = uniform axial field between anode and target.

e = electronic charge.

m = electron mass.

t = time measured from instant when electron emerges from anode hole.

A, B, K — parameters defined by $A = \frac{e}{m} \cdot \text{grad}\ \phi$, $B = V_z$, $K = 2 \cdot I \cdot e/m$

λ = auxiliary variable defined by $\lambda = ln\,(A \cdot t + B)$

β = auxiliary variable defined by $r = \beta \cdot \exp \lambda/2$

μ = auxiliary variable defined by $\mu = d\beta/d\lambda$

Note.—The suffix o attached to λ, β, or μ denotes nitial values.

Introduction

In investigating the limiting current density in the focused spot of an ordinary cathode-ray tube, one encounters the problem of a circular electron beam emerging from a circular anode hole, and moving between there and the screen in a region free from external fields. The effect of the previous focusing field is allowed for by assuming that on emerging from the hole, each electron has an inward radial velocity component proportional to its distance from the beam axis. This problem was first rigorously solved by Thompson and Headrick,[2] their most important additional postulate being a neglect of the spread in velocities among the electrons due to thermal emission energies. A discussion of the bearing of their solution on general cathode-ray tube design has been given by the present author[3]. From this it is clear that space charge limitation at the screen is a serious restriction on the performance of low-voltage electrostatically-deflected tubes of certain types.

Similarly when considering the design of the post accelerator type of cathode-ray tube it is necessary to pay regard to space

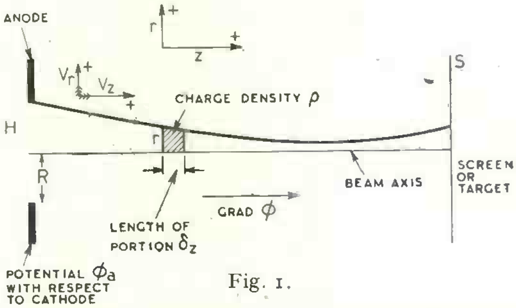

Fig. 1.

charge limitation. The theory advanced by Thompson and Headrick does not cover this case, as in this class of tube the electron beam is moving in an external applied field after emerging from the final anode hole. The precise nature of this field is rather complex, but a useful approximation can be obtained by assuming it to be uniform. This assumption implies zero radial field.

The problem we shall now solve, can be stated then in the following terms. Referring to Fig. 1, an electron beam homogeneous in initial axial velocity and density emerges from the final anode hole H. Between this hole and the screen S is a uniform accelerating field of strength grad ϕ. On emerging

* MS. accepted by the Editor, March 1945.

from the anode hole, each electron has an inward velocity component V_r which is proportional to its distance from the axis. What is the shape of the envelope of the resulting beam? In the solution which follows we shall neglect the electro-kinetic force due to the fields produced by the electron motion and shall treat only the Coulomb repulsive force as present between static charges.

Consider a small portion of the beam (shown shaded in Fig. 1) bounded by two parallel planes normal to the beam axis and spaced an infinitesimal distance δz apart. The surface area of the periphery of the section of the beam between these two planes is thus $2 . \pi . r . \delta z$ since δz is vanishingly small. By definition of what is meant by beam current, it follows that $I = \rho v_z/\delta z$ where ρ is the total charge contained in length δz of the beam at the point where the velocity is v_z. By Gauss's theorem the total flux emerging from the periphery* of the beam between the two planes is $4 . \pi . \rho$. The surface potential gradient is therefore found by dividing by the surface area and is thus $2 . \rho/r . \delta z$. Substituting the meaning of ρ in terms of the beam current I gives the surface potential gradient as $2 . I/r . v_z$. The radial force exerted on any outer surface electron is then given by:

$$F = 2 . I . e/r . v_z \quad \ldots \quad (1)$$

Using Newton's law, the fundamental equations of motion are then:

$$\frac{d^2r}{dt^2} = 2 . I . e/m . r . v_z \quad \ldots \quad (2)$$

[radial direction]

$$\frac{d^2z}{dt^2} = \frac{e}{m} . \text{grad } \phi \quad \ldots \quad (3)$$

[axial direction]

The signs of equations (2) and (3) have regard to the fact that e is inherently negative. The sign convention for the co-ordinates is indicated in Fig. 1.

* This statement is justified by the following reasoning:—

(a) Since we are considering only that portion of the flux due to the electrons themselves, we neglect the external applied field due to the post accelerator.

(b) Then the axial velocity of the electrons is constant and equal to V_z, so that by energy conservation principles, the potential is independent of z and depends only on r.

(c) Therefore no work is done in transferring unit charge from any point (r, z_1) to any point (r, z_2); the flux due to the electrons is wholly radial, and in applying Gauss's theorem to the portion of the beam shown in Fig. 1, the ends of the disc make no contribution to the surface integral.

Integrating (3) and inserting the initial condition $dz/dt = V_z$ when $t = 0$ yields:

$$dz/dt = e/m . t . \text{grad } \phi + V_z \quad \ldots \quad (4)$$

Integrating (4) and inserting the initial condition $z = 0$ when $t = 0$ gives:

$$z = \frac{e}{2 . m} t^2 . \text{grad } \phi + V_z . t \quad \ldots \quad (5)$$

Substituting from (4) into (2) gives:

$$d^2r/dt^2 = 2 . I . e/m . r(\frac{e}{m} . t . \text{grad } \phi + V_z)^* \quad \ldots \quad (6)$$

Equations (6) and (5) provide a complete solution for the shape of the beam profile.

For the solution of (6) I am indebted to Lionel Jofeh of the Myra Research Department of A. C. Cossor, Ltd.

Setting $A = e/m . \text{grad } \phi$, $K = 2 . I . e/m$, $B = V_z$, (6) has the form:

$$r . d^2r/dt^2 - K/(A . t + B) = 0 \quad \ldots \quad (7)$$

The substitution $\lambda = ln(A . t + B)$ reduces (7) to the form:

$$d^2r/d\lambda^2 - dr/d\lambda = \frac{K . \exp \lambda}{A^2 . r} \quad \ldots \quad (8)$$

Setting $r = \beta . \exp \lambda/2$ where $\beta = f(\lambda)$ throws (8) into

$$(\exp \lambda/2) . d^2\beta/d\lambda^2 - (\beta/4) . \exp \lambda/2 = (\exp \lambda/2) . K/A^2 . \beta$$

and since by hypothesis $\exp \lambda/2 \neq 0$ this yields:

$$d^2\beta/d\lambda^2 = \beta/4 + K/A^2 . \beta \quad \ldots \quad (9)$$

We now put $\mu = d\beta/d\lambda$ whence $d^2\beta/d\lambda^2 = \mu . d\mu/d\beta$ and this substitution transforms (9) into $\mu . d\mu/d\beta = \beta/4 + K/A^2 . \beta$ integrating with regard to β gives

$$\mu^2/2 = \beta^2/8 + (K/A^2) . ln \beta + \text{constant.}$$

If $\mu = \mu_0$ when $\beta = \beta_0$ this becomes:

$$\mu^2 - \mu_0{}^2 = (\beta^2 - \beta_0{}^2)/4 + (2 . K/A^2) . ln \beta/\beta_0 \quad \ldots \quad (10)$$

On putting back the value of μ, (10) gives:

$$d\beta/d\lambda = \sqrt{\frac{\beta - \beta_0{}^2}{4} + \frac{2 . K}{A^2} ln \frac{\beta}{\beta_0} + \mu_0{}^2}$$

integrating with regard to λ then yields:

$$\lambda = \int_{\beta_0}^{\beta} \frac{d\beta}{\sqrt{\frac{\beta^2 - \beta_0{}^2}{4} + \frac{2 . K}{A^2} ln \frac{\beta}{\beta_0} + \mu_0{}^2}} + \lambda_0 \quad \ldots \quad (11)$$

* When no post accelerating field is applied, grad $\phi = 0$, and (6) reduces to $d^2r/dt^2 = 2 . I . e/m . r . v_z$ as treated in references 1 and 2.

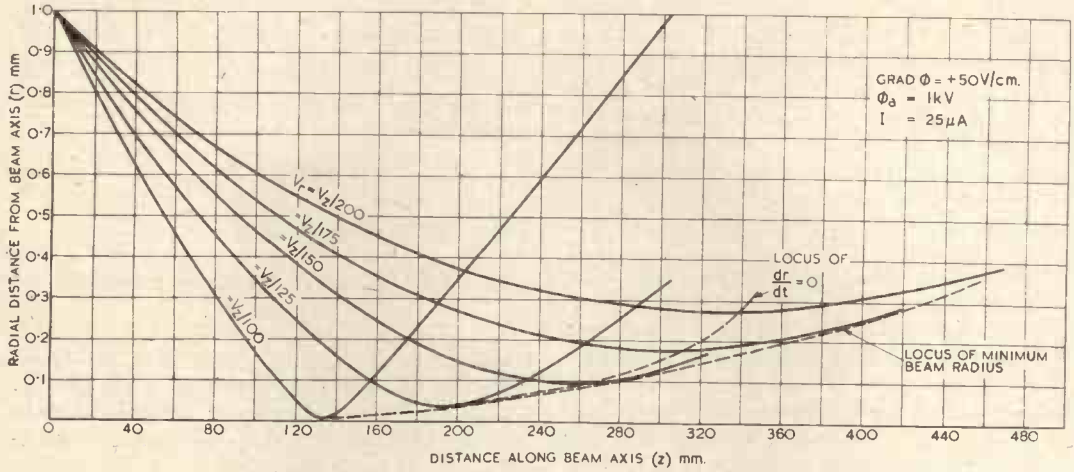

Fig. 2.

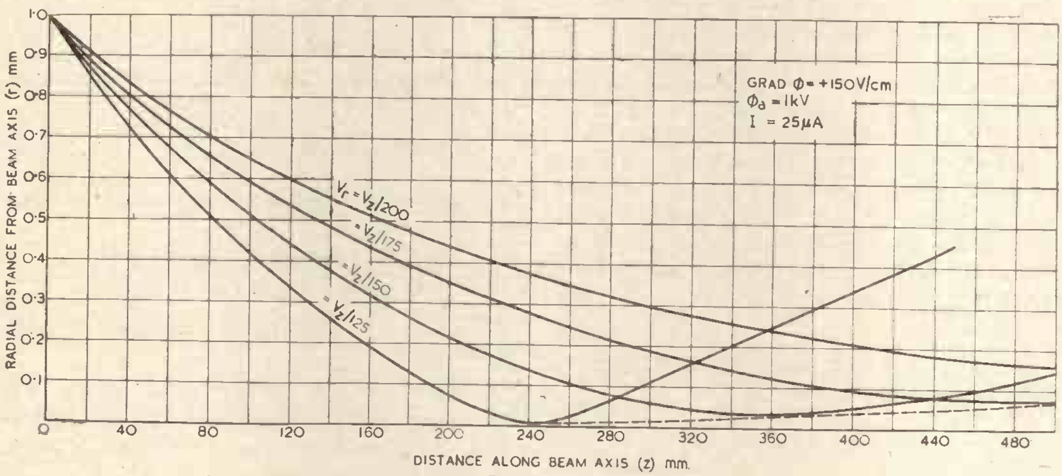

Fig. 3.

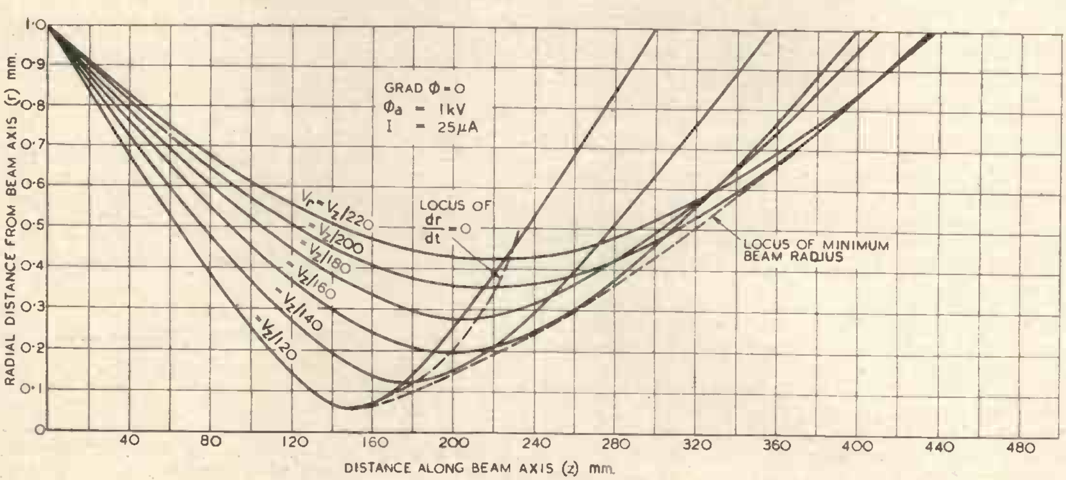

Fig. 4.

This is the formal solution reached by Jofeh. To obtain the values of the various parameters introduced to effect the solution we proceed as follows: Insertion of the simultaneous initial conditions $t = 0$, $r = R$, $\lambda = \lambda_0$, $\beta = \beta_0$ in the substitution $\lambda = ln(A \cdot t + B)$ yields $\lambda_0 = lnB$, i.e., $B = \exp \lambda_0$, hence it follows that $\sqrt{B} = \exp \lambda_0/2$. Again β was defined by $r = \beta \cdot \exp \lambda/2$ so that $R = \beta_0 \cdot \exp \lambda_0/2 = \beta_0 \cdot \sqrt{B}$. Thus:

$$\beta_0 = R/\sqrt{B} \quad \ldots \quad (12)$$

Again from the substitution $r = \beta \cdot \exp \lambda/2$ it follows:

$$dr/d\lambda = (\exp \lambda/2) \cdot d\beta/d\lambda + (\exp \lambda/2) \cdot \beta/2$$

whence

$$\frac{dr}{dt} \cdot \frac{dt}{d\lambda} \equiv dr/d\lambda = (\mu + \beta/2) \cdot \exp \lambda/2$$

since $\mu = d\beta/d\lambda$.

Putting in the initial conditions $dr/dt = -V_r$ when $\lambda = \lambda_0$, $\mu = \mu_0$ and remembering that $dt/d\lambda = (\exp \lambda)/A$ gives:

$$(\exp \lambda_0) \cdot V_r/A = (\mu_0 + \beta_0/2) \cdot \exp \lambda_0/2$$

whence

$$\mu_0 = -\frac{V_r}{A} \cdot \sqrt{B} - \beta_0/2 \quad \ldots \quad (13)$$

This completes the formal solution. The practical method of solution adopted was to assign an arbitrary series of values to β inside the range $\alpha < \beta \leqslant \beta_0$ where $\alpha = (\beta^2/4) + (2 \cdot K/A^2) \ln\beta$ and $\alpha = (\beta_0^2/4) + (2 \cdot K/A^2) \cdot \ln \beta_0 - \mu_0^2$, thus obtaining a series of values of the integrand in (11), for various values of β. The integral was then evaluated by planimeter, so that by (11), $\beta = f(\lambda)$ was found. But by definition $r = \beta \cdot \exp \lambda/2$, so that r, the beam radius, was also determined. Again by definition $\lambda = ln (A \cdot t + B)$, so that t, the time of flight corresponding to radius r, was calculated. Finally, knowing t, equation (5) permits the corresponding value of z, the axial distance to radius r, to be evaluated.

The evaluation of (11) by planimeter is necessary since this function has no integral in terms of elementary functions. It is, however, worth while to consider whether it might be integrated by some method of approximations. One obvious possibility is to expand $ln\ \beta/\beta_0$, but this series does not converge rapidly unless $\beta/\beta_0 \simeq 1$, and, unfortunately, this latter condition does not obtain except at the commencement of the electron flight. The value of β/β_0 in the region of most interest (i.e., at the minimum beam radius) depends on numerous parameters but for typical conditions is of the order of 0.2 to 0.1. The resulting series for $ln\ \beta/\beta_0$ is here so slowly convergent that its use would not be helpful, and it is very doubtful if it would be worth while splitting up the range of integration and using an expansion in one region and planimeter methods in another.

Other possibilities, such as a binomial expansion of the whole term under the root sign, have also been investigated, but again the resulting series are too slowly convergent to make the method of use, at least over the whole range of values of β.

Results

In all cases treated, the beam current emerging from the anode hole has been taken to be 25 μA, and the hole radius has been set at 1 mm. These values have been taken as typical of cathode-ray tubes for oscillography. The anode potential has been assumed to be 1 kV.

Fig. 2 shows a numerical solution based on the above constants and with a subsequent uniform axial potential gradient of 50 volts/cm. The various curves are the beam profiles (top half only) for various initial inward radial velocities. It is especially important to be clear as to the underlying postulates on which these curves are based. They are similar to those set out by Thompson and Headrick[2] so far as conditions on emergence are concerned. Each electron is supposed to have the same axial velocity. The electron density in the hole is supposed uniform. Each electron has an initial inward velocity component proportional to its distance from the beam axis when passing through the hole. It will be evident from a study of equation (6) which is a consequence of these postulates, that they result in a beam which has a uniform density distribution over its cross section. Thus the conditions in the beam are completely specified by a determination of its profile.

In a practical cathode-ray tube, the third postulate relating to the initial inward velocity components, cannot be closely satisfied, even if lens aberrations are neglected. For the electrons are emitted with a spread in velocities of the order of a volt. The resulting *fractional* spread in velocity in an *axial* direction is usually negligible, since the accelerating voltages are relatively very high. But in a radial direction, the focusing field

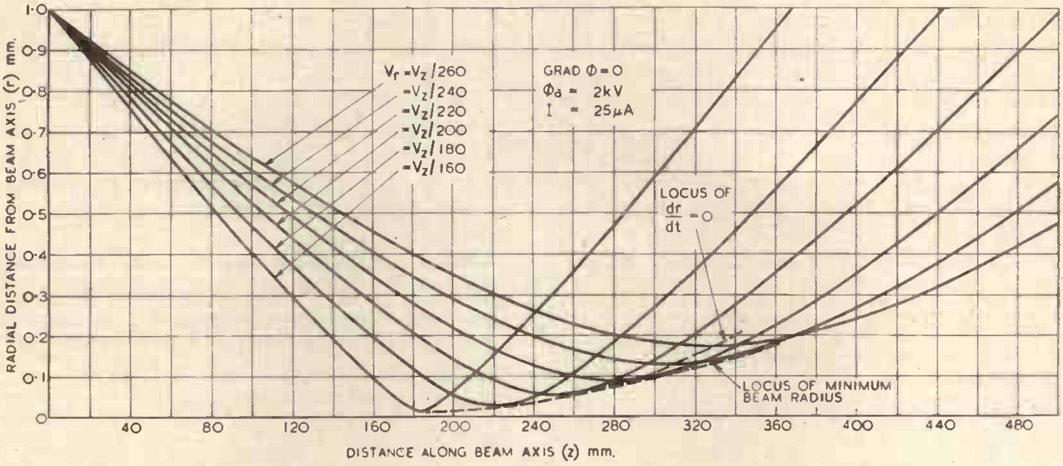

Fig. 5.

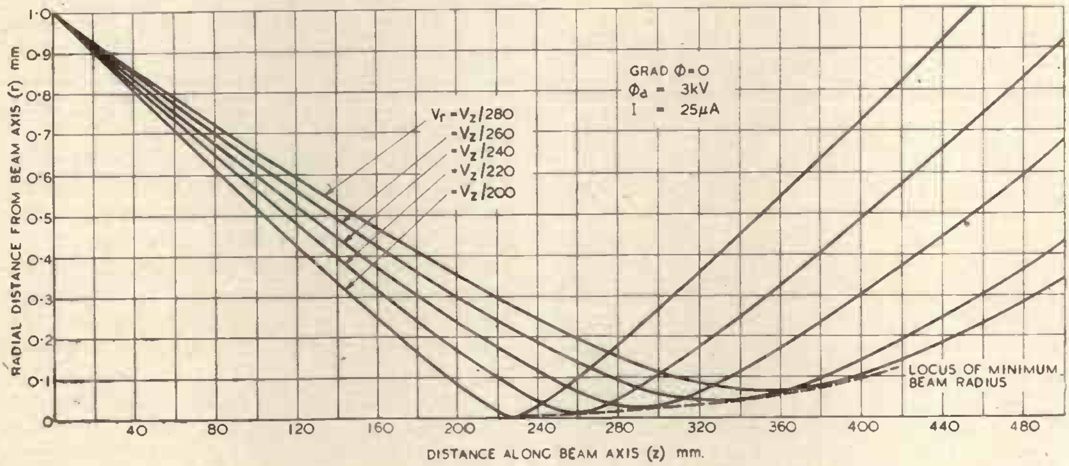

Fig. 6.

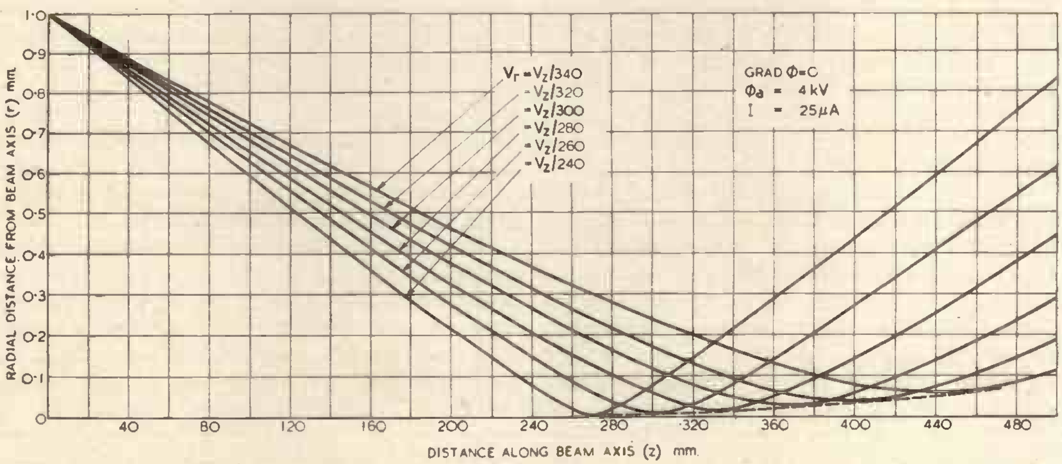

Fig. 7.

imparts only a relatively small volt velocity* and the spread of emission energies plays a dominant part. This has some complex effects which the author hopes to treat in a later paper, but the digression is given here as a warning against reading more into the curves presented than the postulates justify.

Reverting to Fig. 2, it will be noted that the beam profiles there given are rigorously valid for an infinite number of parallel plate accelerating fields, provided always that the actual plate spacings and voltages are so related as to give a field of strength 50 volts/cm. The axial field in a practical post accelerator cathode-ray tube is certainly not strictly uniform, but the curves will give some idea of the space charge limitations obtaining in such a tube when the voltage difference between the final anode and post accelerator divided by the anode to screen distance is 50 volts/cm.

Fig. 3 is similar to Fig. 2, but relates to an axial potential gradient of 150 volts/cm.

For the purpose of making the desired comparisons, Figs. 4 to 7, inclusive, show conditions obtaining when the axial field is zero. These curves are thus similar to those presented by Thompson and Headrick,[2] but are interesting in themselves since they represent numerical conditions which are more typical of oscillograph cathode-ray tubes.

Comparison of Two Cases

(1) When no axial field is applied, the beam profile is symmetrical about the point of minimum radius. This is apparent because the time scale along the z axis is now uniform, and in addition the radial force is a function of beam radius only. Neither of these conditions obtain when the accelerating field is applied, and the curve is thus no longer symmetrical.

(2) With increase in axial field, the increase in minimum beam radius with increase in distance from the focusing lens, is more gradual. When the axial field is quite high, as in Fig. 3, the " depth of focus due to space charge " becomes large.

(3) Both sets of conditions show the interesting effect that to obtain maximum beam density at a given plane, the lens power should be increased somewhat beyond that value giving $dr/dt = 0$ at the plane considered. This means that when the lens conditions are such as to produce the smallest spot on the screen, the beam has a plane of still smaller radius between the screen and the lens.

(4) Consider the following problem. Given that the screen in the two cases is to have the same potential (so that for equal currents the light outputs are equal) do we obtain a smaller limiting spot size due to space charge, by applying all the potential to the final anode so that no post acceleration is used, or by applying some of this voltage to the anode and the remainder to the post accelerator? Suppose for example that the screen potential is to be 3 kV. If we put 1 kV on the anode and use an axial gradient of 50 volts/cm. this implies an anode to screen distance of 400 mm. and Fig. 2 gives the limiting beam radius as approximately 0.25 mm. Fig. 6, showing the conditions when the whole 3 kV is applied to the anode, indicates a minimum beam radius at 400 mm. from the lens of under 0.1 mm.—a considerable improvement. Any similar tests made on the curves presented show that the post accelerator gives a lower beam density, and there is no reason to doubt the generality of the result. It is reasonable to expect the result merely from a consideration of eqn. (1) Thus it appears that the space charge restriction in a post accelerator tube is likely to prove more troublesome than in the conventional design of tube, on the basis of equal electron impact velocities at the screen. This result is, however, only one feature in the many interesting comparisons between these rival systems of tube construction, and it is to be hoped that no far reaching and perhaps unwarranted conclusions will be drawn from it.

* In the example given, the anode voltage is 1 kV and the initial inward radial velocity is of the order of 1/200 of the corresponding axial velocity. Since velocity is proportional to the root of the voltage, it follows that the inward volt velocity is only 1/40 volt, which is quite small in relation to the emission spread.

Acknowledgments

In addition to Lionel Jofeh, to whom I am indebted for the solution of eqn. (6), it is a pleasure to record my appreciation of the help of my personal assistant, Miss M. Webb, in the rather laborious numerical calculations. I am also indebted to A. C. Cossor, Ltd., for the facilities provided.

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SINGLE CRYSTAL FILTERS*

By K. R. Sturley, Ph.D., M.I.E.E.

SUMMARY.—This article shows that generalised selectivity curves can be constructed for two identical tuned circuits coupled by a single fully neutralised crystal, and also for the condition arising when the two formerly identical tuned circuits are mistuned an equal amount in opposite directions from the crystal frequency. Increased selectivity due to mistuning is accompanied by reduced amplification at the crystal frequency (generalised curves are given to estimate this loss), and the appearance of secondary humps at the resonant frequencies of the mistuned circuits with loss of selectivity at the "skirts" of the curves. At frequencies very much off-tune from the crystal resonant frequency mistuning has little effect. Numerical examples are given to illustrate the method of using the generalised curves.

Introduction

SELECTIVITY curves of general application to a pair of identical coupled tuned circuits were developed some years ago by R. T. Beatty,[1] and the author[2] has shown that they can also be used to give the frequency response of a pair of dissimilar tuned circuits. Filters consisting of a pair of tuned circuits coupled by a crystal are being increasingly used to provide a much higher degree of selectivity than is possible from circuits coupled by a fixed value of inductance, capacitance or resistance, and generalised selectivity curves can be derived for these types of crystal coupled circuits. The scope of this article is not confined to the simple form of crystal coupling between two identical circuits but is expanded to include the case of two formerly identical tuned circuits mistuned equally in opposite directions from the crystal resonant frequency.

Theory

1. *Two identical tuned circuits coupled by a crystal*

The schematic diagram of the simple form of single crystal filter is shown in Fig. 1. The capacitance C_3 has a comparatively high value, about 0.001μF, and is to isolate the D.C. voltage from the grid of the succeeding valve. The capacitance C_4 and inductance L_4 induce a voltage into the secondary circuit which is in opposition to, and neutralises the effect of, the crystal holder capacitance. The equivalent circuit is that of Fig. 2(a), the valve being shown as a constant current generator of $I = g_m E_g$, where g_m is its mutual conductance, and E_g, the R.F. input voltage to its grid. The neutralising circuit L_4C_4 and crystal electrode capacitance have been omitted from the figure since it may be assumed that they cancel each other. The voltage and current relationships of the simplified circuit of Fig. 2(b) are

$$I = g_m E_g = E_1\left(\frac{1}{R_a} + \frac{1}{Z_1} + \frac{1}{Z_c + Z_2}\right)$$

where Z_c is the crystal impedance.

$$E_0 = \frac{E_1 Z_2}{Z_g + Z_2}$$

Transfer impedance,

$$Z_T = \frac{E_0}{I} = \frac{Z_2}{Z_c + Z_2} \Big/ \left(\frac{1}{R_a} + \frac{1}{Z_1} + \frac{1}{Z_c + Z_2}\right)$$

$$Z_T = \frac{Z_2}{\left(\frac{1}{R_a} + \frac{1}{Z_1}\right)\left(Z_c + Z_2\right) + 1}$$

$$= \frac{Z_1' Z_2}{Z_1' + Z_c + Z_2} \quad \ldots \quad \ldots \quad (1a)$$

where $Z_1' = \dfrac{R_a Z_1}{R_a + Z_1}$

Assuming that the tuned circuits are identical,

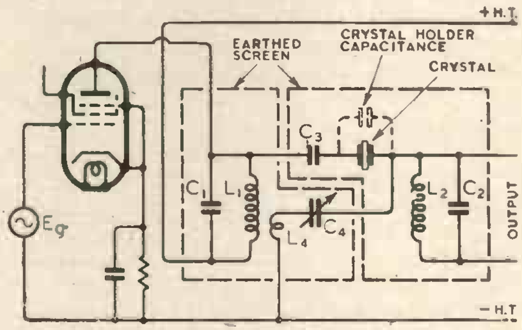


Fig. 1. *A schematic diagram of a single-crystal filter.*

that R_a can be neglected in comparison with Z_1, or that Z_2 is damped by an equal resistance,

$$Z_T = \frac{Z^2}{2Z + Z_c} \quad \ldots \quad \ldots \quad (1b)$$

* MS. accepted by the Editor, December, 1944.

It is shown in Appendix I that the impedances of the identical tuned circuits may be written as

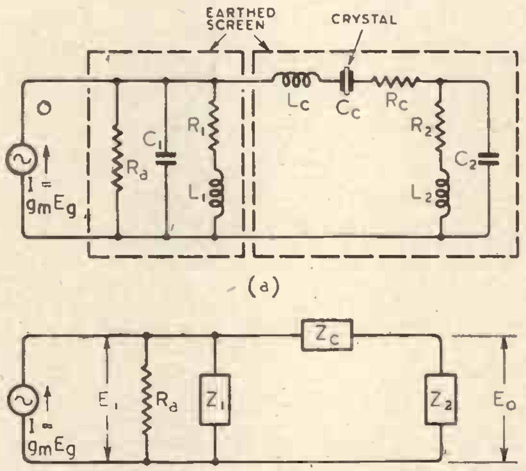
$$Z = \frac{R_D}{1 - jQF} \quad \cdots \quad \cdots \quad (2)$$

where R_D = resonant resistance of either circuit $= \frac{(\omega_r L)^2}{R} = \frac{L}{CR}$

Q = magnification of either tuned circuit $= \frac{\omega_r L}{R}$

$F = \frac{2\Delta f}{f_r}$

Δf = off-tune frequency from the resonant frequency, f_r



(a) (b)

Fig. 2. *(a) The circuit equivalent of Fig. 1 (b) A simplified equivalent of Fig. 1.*

In Appendix II the expression for the crystal impedance is given as

$$Z_c = R_c(1 + jQ_cF) \quad \cdots \quad \cdots \quad (3)$$

where R_c = the series resistance equivalent of the crystal

Q_c = magnification of the crystal $= \frac{\omega_r L_c}{R_c}$

L_c = inductance equivalent of the crystal.

Replacing Z and Z_c in (1b) by their values from (2) and (3)

$$Z_T = \frac{R_D^2}{2R_D(1 + jQF) + R_c(1 + jQ_cF)(1 + jQF)^2}$$

$$= \frac{R_D^2}{[1 + jQF][2R_D + R_c(1 + jQ_cF)(1 + jQF)]} = \frac{R_D^2}{[1 + jQF][2R_D + R_c - R_cQ_cQF^2 + jR_c(Q_c + Q)F]} \quad \cdots \quad \cdots \quad (4)$$

At the resonant frequency f_r, $\Delta f = 0$, $F = 0$, and

$$Z_{T_r} = \frac{R_D^2}{2R_D + R_c} \quad \cdots \quad \cdots \quad \cdots \quad (5)$$

This expression (5) determines overall amplification, to which it is directly proportional. Rewriting (5) as

$$Z_{T_r} = \frac{R_D}{2 + \frac{R_c}{R_D}}$$

it is clear that maximum amplification calls for a large value of R_D and small value of R_c.

As a rule $\frac{R_c}{R_D}$ is much less than 2, and maximum amplification is approximately proportional to $\frac{1}{2}R_D$, the value of Z_T for critically coupled circuits with pure reactance (L or C) coupling.

The selectivity characteristic, expressed in ratio form, is

$$\frac{Z_T}{Z_{T_r}} = \frac{1}{(1 + jQF)\left[1 - \frac{R_cQ_cQF^2}{2R_D + R_c} + j\frac{R_c(Q_c + Q)F}{2R_D + R_c}\right]}$$

$$= \frac{1}{(1 + jQF)(D + jAQF)} \quad \cdots \quad \cdots \quad (6)$$

where $D = 1 - \frac{R_cQ_cQF^2}{2R_D + R_c} \quad \cdots \quad \cdots \quad (7a)$

and $A = \frac{R_c(Q_c + Q)}{(2R_D + R_c)Q} \quad \cdots \quad \cdots \quad (8a)$

Alternatively selectivity may be written

$$\text{loss (db)} = -20 \log_{10} \frac{Z_{T_r}}{|Z_T|}$$

$$= -10 \log_{10} [1 + (QF)^2][D^2 + (AQF)^2] \quad \cdots \quad \cdots \quad (9)$$

In order to obtain selectivity curves of general application it is important to try and reduce the number of variables to two instead of three, QF, D and A, as in (9). This can be done if certain simplifying assumptions, which are in most practical cases admissible, are made. Thus

$$D = 1 - \frac{R_cQ_c(QF)^2}{(2R_D + R_c)Q}$$

$$\simeq 1 - A(QF)^2 \quad \cdots \quad \cdots \quad (7b)$$

when $Q_c \gg Q$, and rewriting (9) we have

$$\text{Loss (db)} = -10 \log_{10}[1 + (QF)^2] \; [(1 - A(QF)^2)^2 + (AQF)^2] \quad \ldots \quad (10)$$

which leaves only two variables QF and A.

$$A = \frac{R_c(Q_c + Q)}{(2R_D + R_c)Q} = 5.06 \simeq 5$$

$$\Delta f = \frac{465}{200} = 2.325 \text{ kc/s.}$$

Hence the logarithmic off-tune frequency

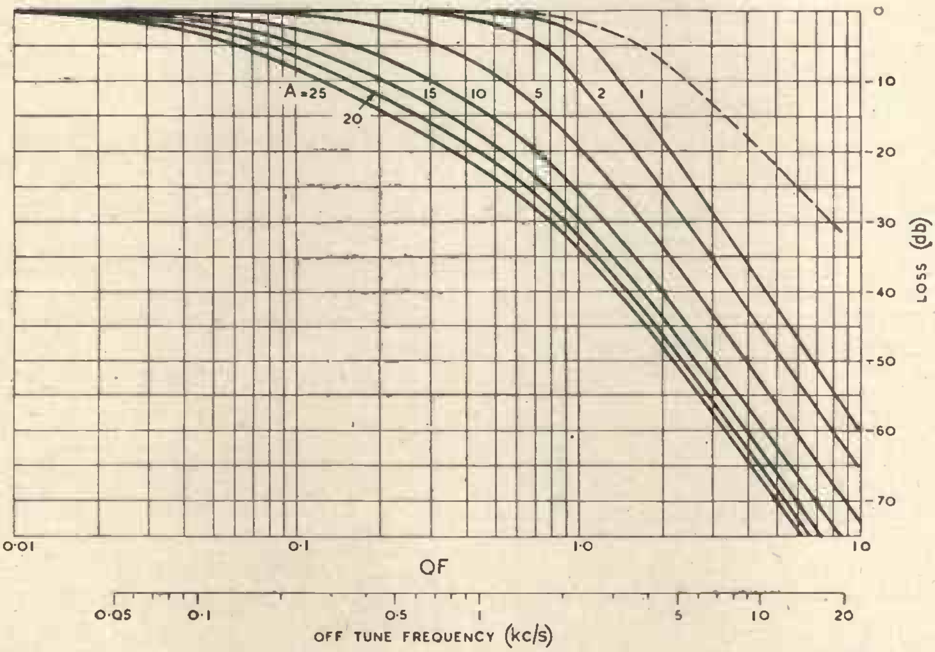


Fig. 3. *Generalised selectivity curves for correctly tuned crystal-coupled circuits.* $A = \frac{R_c(Q_c + Q)}{(2R_D + R_c)Q}$; R_c = *series resistance of crystal*; Q_c = *magnification of crystal*; R_D = *parallel resonant impedance of either tuned circuit.* Q = *magnification of either tuned circuit. Dashed line—selectivity curves for critically coupled tuned circuits with reactance coupling.*

From (10) a series of generalised selectivity curves of loss against QF can be plotted for different values of A, and the result is illustrated in Fig. 3. A logarithmic scale is chosen for QF because it allows the selectivity characteristic for any particular set of component values to be found by suitably positioning an identical logarithmic scale marked in off-tune frequency underneath the QF scale. The point on the frequency scale corresponding to

$$\Delta f = \frac{f_r}{2Q} \text{ (kc/s)}$$

is registered immediately underneath $QF = 1$ As an example consider a crystal filter of the following component values:

$f_r = 465$ kc/s, $L = 300\ \mu$H,
$C = 379\ \mu\mu$F, $Q = 100$,
$L_c = 31$H, $R_c = 12{,}500\ \Omega$, $Q_c = 7500$
$R_D = \omega_r LQ = 87{,}500\ \Omega$

scale is adjusted with 2.325 kc/s against $QF = 1$, and frequency response loss is read from the curve $A = 5$, i.e., there is a loss of -7.5 and -16.5 db. at off-tune frequencies of 1 and 2 kc/s respectively.

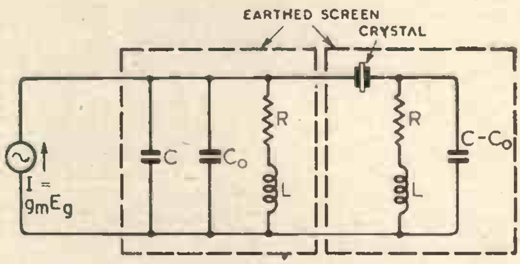


Fig. 4. *Equivalent circuit for mistuned crystal-coupled circuits.*

It is interesting to note that all the loss curves tend to become parallel to each other and separated by a vertical interval of

$-20 \log_{10} \frac{A_2}{A_1}$ db. Thus the curve for $A = 10$ is very nearly -20 db. below the curve for $A = 1$. This is to be expected since is increased expression (10) approaches

$$\text{loss} = -10 \log_{10} A^2 [1 + (QF)^2]^2 (QF)^2$$

The following approximate value for A may be useful for a rapid estimate of crystal filter response.

$$A = \frac{R_c(Q_c + Q)}{(2R_D + R_c)Q} = \frac{1 + \frac{Q_c}{Q}}{1 + \frac{2R_D}{R_c}}$$

$$\simeq \frac{Q_c R_c}{2R_D Q} = \frac{\omega_r L_c}{2\omega_r L Q^2} = \frac{L_c}{2LQ^2} \quad .. \quad \text{(8b)}$$

This approximate expression gives 5.16 for A in the example quoted above, so that the error involved in using (8b) instead of (8a) is unlikely to be serious as long as A exceeds 5.

2. *Two oppositely Mistuned Circuits coupled by a Crystal.*

Increased selectivity may be obtained from a crystal filter by mistuning the circuits in opposite directions by an equal amount. Equal mistuning is achieved practically by transposing a small fixed capacitance from the secondary to the primary or *vice versa*, and the equivalent circuit is that of Fig. 4, the crystal holder capacitance and its neutralising circuit are omitted from the diagram.

In Appendix III the impedance of the primary, the resonant frequency of which has been reduced by adding C_0, can be written.

$$Z_1 = \frac{R_D}{1 + jQ(F + F_1)} \quad .. \quad .. \quad \text{(11a)}$$

where R_D, Q and F have the meanings already assigned to them and

$F_1 = \frac{2\Delta f_1}{f_r}$ = constant for a given degree of mistuning, i.e. of C_0.

$\Delta f_1 = f_r - f_1$

f_1 = resonant frequency of the primary.

The secondary resonant frequency is increased by subtracting C_0 and its impedance is

$$Z_2 = \frac{R_D}{1 + jQ(F - F_2)} \quad .. \quad .. \quad \text{(11b)}$$

where $F_2 = \frac{2\Delta f_2}{f_r}$

$\Delta f_2 = f_2 - f_r$

f_2 = resonant frequency of the secondary

But $\Delta f_2 = \Delta f_1$ so that $F_1 = F_2$ and

$$Z_2 = \frac{R_D}{1 + jQ(F - F_1)}$$

Transfer impedance is from (1a)

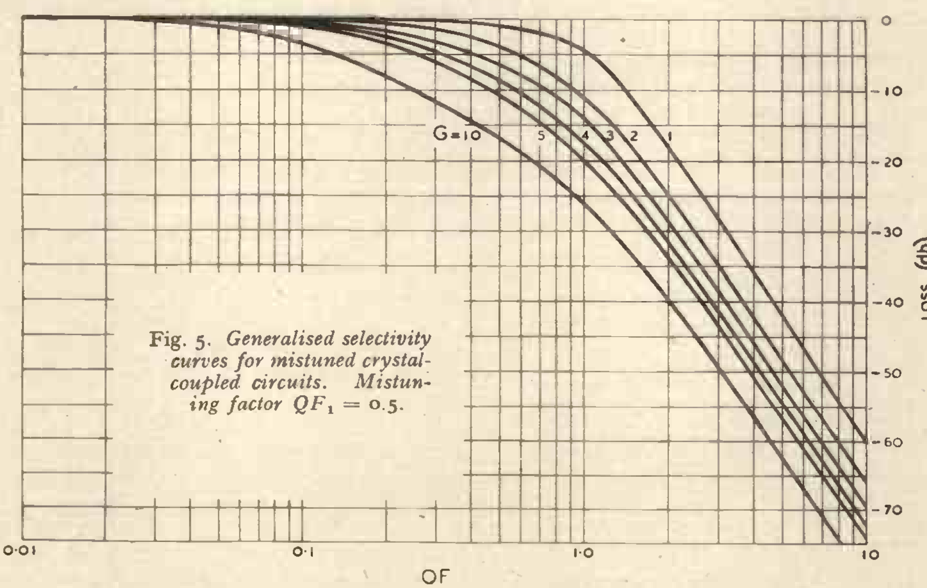


Fig. 5. *Generalised selectivity curves for mistuned crystal-coupled circuits. Mistuning factor $QF_1 = 0.5$.*

$$Z_T = \frac{Z_1 Z_2}{Z_1 + Z_2 + Z_c}$$

$$= \frac{R_D^2}{R_D[1+jQ(F-F_1)]+R_D[1+jQ(F+F_1)] + R_c[1+jQ_cF]\,[1+jQ(F-F_1)]\,[1+jQ(F+F_1)]}$$

$$= \frac{R_D^2}{2R_D[1+jQF] + R_c[1+jQ_cF]\,[1-Q^2(F^2-F_1^2)+2jQF]}$$

$$= \frac{R_D^2}{[1+jQF]\,[2R_D + R_c(1+jQ_cF)\,(1+jQF+\frac{(QF_1)^2}{1+jQF})]} \quad \ldots \quad \ldots \quad (12a)$$

Transfer impedance at resonance ($F = 0$) is

$$Z_{T_r} = \frac{R_D^2}{2R_D + R_c[1+(QF_1)^2]} \quad \ldots \quad (12b)$$

and G, and they cannot be reduced to two as was the case for the identical tuned circuits. Series of curves of loss against QF have therefore to be drawn for a fixed value of QF_1 and different values of G, or vice versa. It is preferable to adopt the former method because G is itself a variable dependent on QF_1, and a series of curves for $QF_1 = 0.5$, 1, 1.5, 2, 2.5 and 3 (likely practical values) are shown in Figs. 5, 6, 7, 8, 9 and 10 for values of G varying from 1 to 10.

For any particular value of QF_1, it may be noted that the curves of Figs. 5 to 10 are, above certain minimum values of QF, almost parallel and separated by an interval of $-20 \log_{10} \frac{G_1}{G_0}$, where G_1 is the actual and G_0 the reference value of G. Thus, the curve in Fig. 5 ($QF_1 = 0.5$) for $G_1 = 2$ is very nearly 6 db. below that for $G = 1$ when

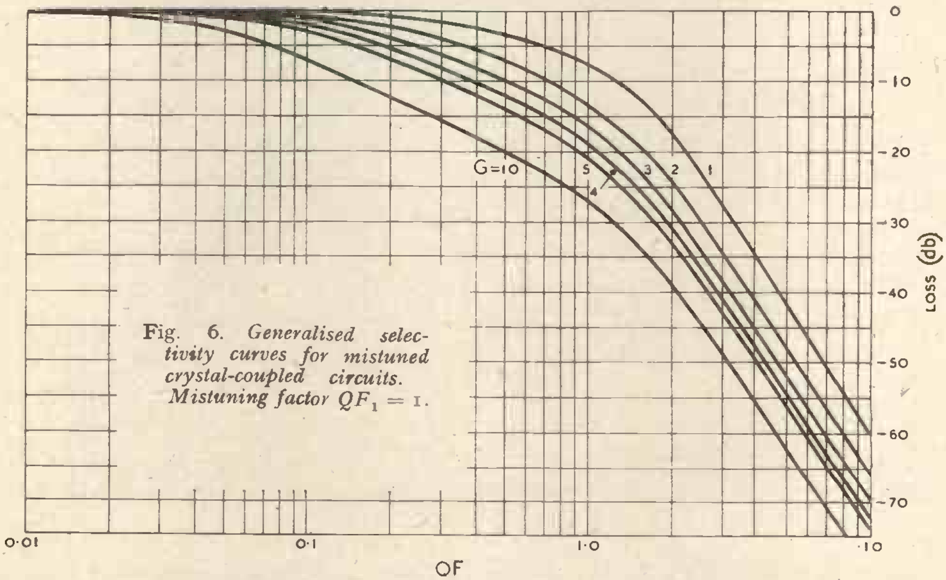


Fig. 6. *Generalised selectivity curves for mistuned crystal-coupled circuits. Misluning factor* $QF_1 = 1$.

Referring to Appendix IV, the selectivity characteristic is seen to be

$$\text{loss (db)} = -10 \log_{10} \frac{Z_{T_r}}{|Z_T|}$$

$$= -10 \log_{10}[1+(QF)^2]\left[[1-G(QF)^2 (1-\frac{(QF_1)^2}{1+(QF)^2})]^2 + [GQF(1+\frac{(QF_1)^2}{1+(QF)^2})]^2\right] \quad \ldots \quad \ldots \quad (13)$$

where $G = \dfrac{R_cQ_c}{\left[2R_D + R_c[1+(QF_1)^2]\right]Q}$

There are therefore three variables, QF, QF_1

$QF > 1$. The minimum value of QF, above which this relationship is true, depends on G and QF_1, and increase of either reduces QF (min). For example the curves in Fig. 5 ($QF_1 = 0.5$) for $G = 5$ and 10 are separated by 6 db. from approximately $QF = 0.3$, whereas the curves in Fig. 10 ($QF_1 = 3$) for $G = 1$ and 2, 5 and 10 are separated by 6 db. from approximately $QF = 0.15$, and 0.05 respectively. This result is to be expected because when

$$G(QF)^2\left[1 - \frac{(QF_1)^2}{1+(QF)^2}\right] \gg 1$$

expression (13) becomes

$$\text{loss (db.)} = -10 \log_{10}[1 + (QF)^2] \left[(QF)^4 \left(1 - \frac{(QF_1)^2}{1 + (QF)^2}\right)^2 + (QF)^2\left(1 + \frac{(QF_1)^2}{1 + (QF)^2}\right)\right] G^2$$

$$= -20 \log_{10}G - 10 \log_{10}[1 + (QF)^2] \left[(QF)^4\left(1 - \frac{(QF_1)^2}{1 + (QF)^2}\right)^2 + (QF)^2\left(1 + \frac{(QF_1)^2}{1 + (QF)^2}\right)\right]^2$$

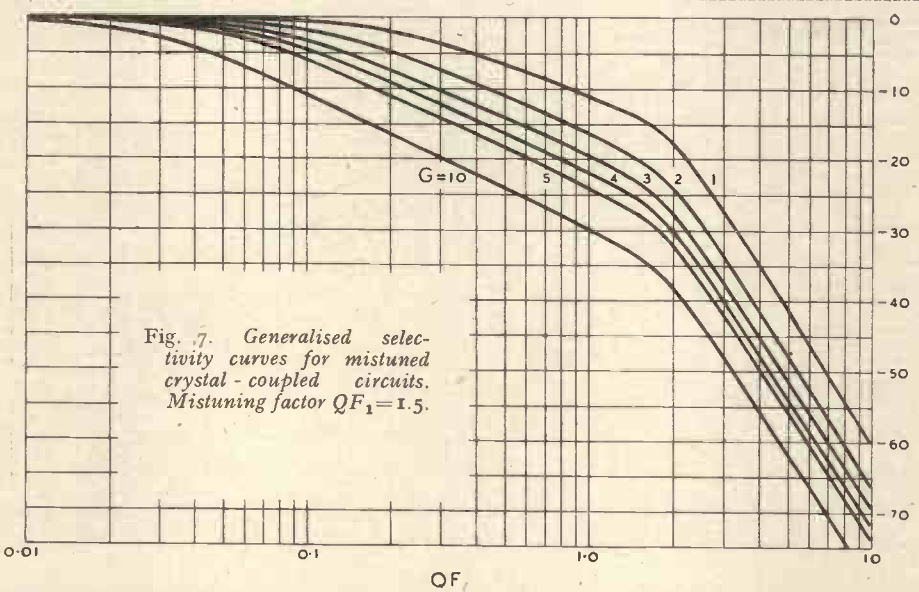


Fig. 7. *Generalised selectivity curves for mistuned crystal-coupled circuits. Mistuning factor* $QF_1 = 1.5$.

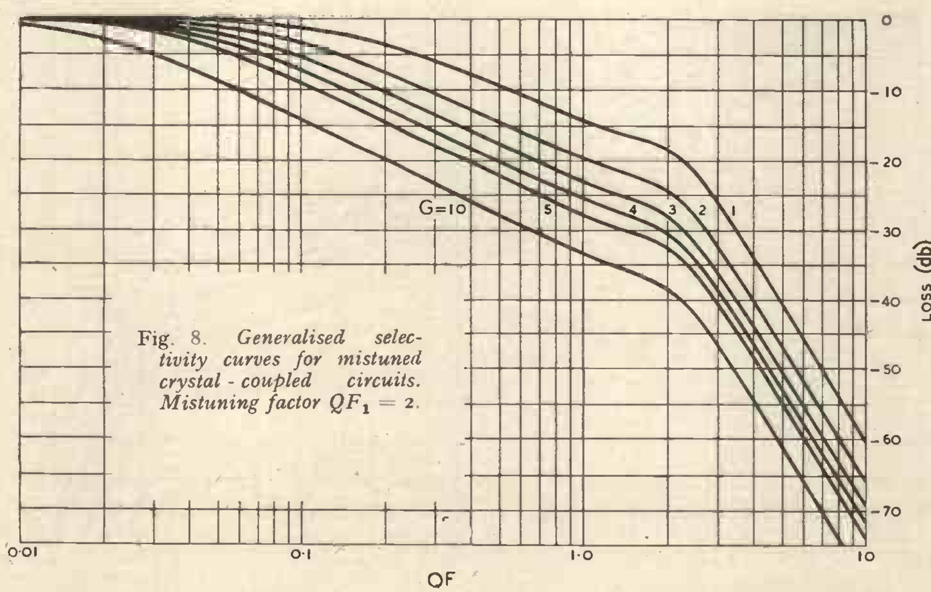


Fig. 8. *Generalised selectivity curves for mistuned crystal-coupled circuits. Mistuning factor* $QF_1 = 2$.

Another interesting feature of the curves is that when QF is large (>5), the factor G determines the loss. This is to be expected because (13) becomes

$$\text{loss (db)} = -10 \log_{10}[1 + (QF)^2] [(1 - G(QF)^2)^2 + (GQF)^2]$$

which is identical with expression (10). Hence the outer regions of the loss curves for the mistuned circuits are unaffected by mistuning except in so far as G itself is altered by change of QF_1. This is shown up more clearly in Fig. 11, where loss curves are plotted for a fixed value of $G = 5$, and QF_1 is varied from 0 to 5. In all cases the loss curves start underneath the curve for $QF_1 = 0$, cross over this curve and then become asymptotic to it as QF is increased. Increase of QF_1 leads eventually to secondary side peaks (*see* the curve for $QF_1 = 5$ in Fig. 11) at approximately $QF = QF_1$.

Since Fig. 11 is drawn on the assumption that G is independent of QF_1 it does not give an exact picture of what happens when a given crystal coupled circuit is mistuned. Actually G decreases as QF_1 is increased—an example given later shows the extent of the decrease—and the effect of mistuning is to render the circuit less selective at a given value of QF_1 than shown by Fig. 11 for $QF < 1$, and to prevent it merging into the $QF_1 = 0$ curve at high values of QF.

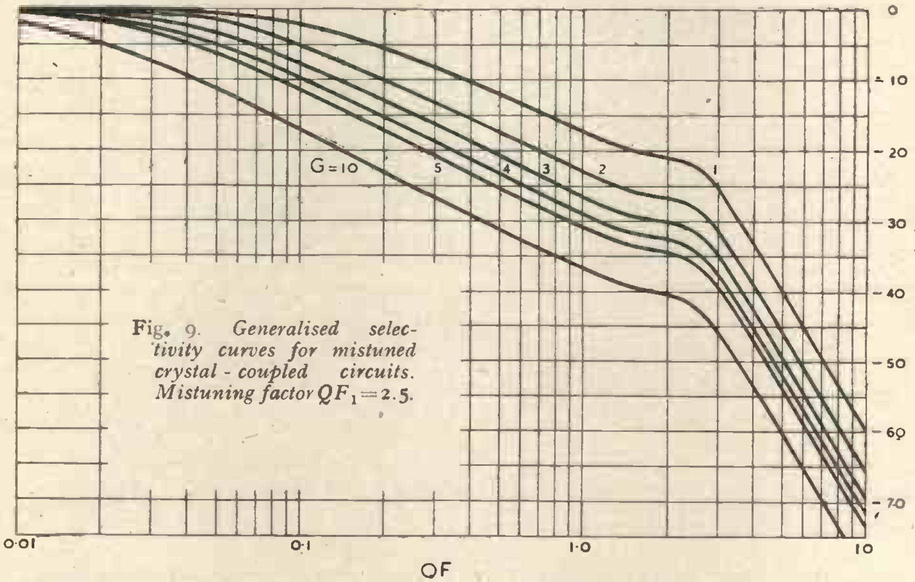


Fig. 9. *Generalised selectivity curves for mistuned crystal-coupled circuits. Mistuning factor* $QF_1 = 2.5$.

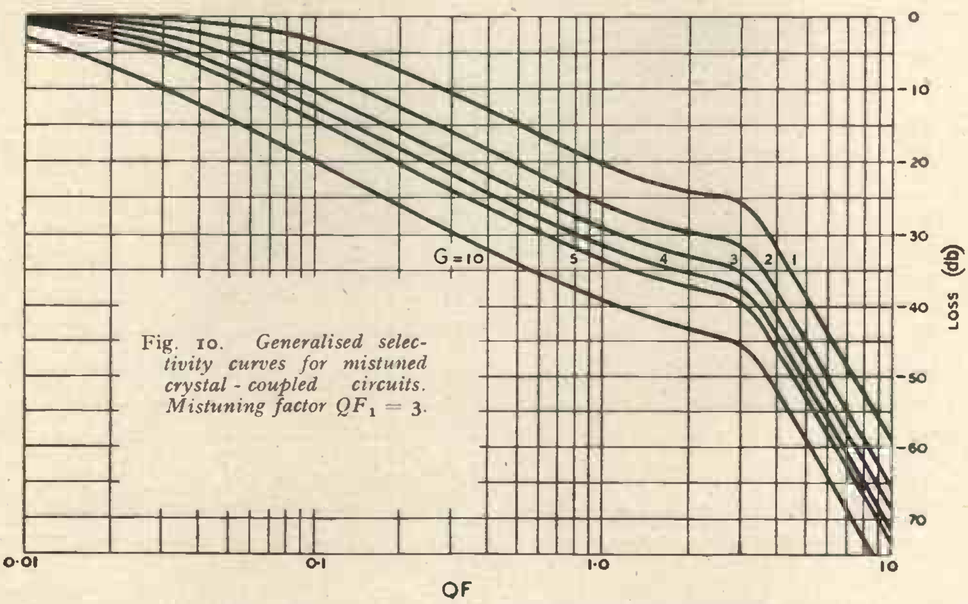


Fig. 10. *Generalised selectivity curves for mistuned crystal-coupled circuits. Mistuning factor* $QF_1 = 3$.

The loss curves of Fig. 11 are all drawn relative to zero loss at the crystal resonant frequency ($QF = 0$), but overall amplification at this point is proportional to transfer impedance, which is reduced (*see* 12b) as

QF_1 is increased. The reduction in overall amplification at the crystal resonant frequency due to mistuning is dependent on the ratio $\frac{R_c}{2R_D}$ as well as QF_1, and is given by

Loss (db) at crystal resonance

$$= -20\log_{10}\frac{Z_{T_r}\text{ (correct tuning)}}{Z_{T_r}\text{ (mistuned)}}$$

$$= -20\log_{10}\frac{1+\frac{R_c}{2R_D}[1+(QF_1)^2]}{1+\frac{R_c}{2R_D}} \quad \ldots \quad \ldots \quad (14)$$

This expression (14) is plotted against QF_1 for selected values of $\frac{R_c}{2R_D}$ in Fig. 12.

To illustrate the use of the generalised curves for mistuned circuits, the circuit constants quoted above will again be taken, viz.,

$$f_r = 465\text{ kc/s}, L = 300\ \mu\text{H}, C = 379\ \mu\mu\text{F}, Q = 100, R_D = 87{,}500\,\Omega$$

$$L_c = 31\text{H}, R_c = 12{,}500\,\Omega, Q_c = 7{,}500.$$

$QF_1 = 0.5$, 1, 1.5, 2, 2.5 and 3.

Values of C_0 to give these selected values of QF_1 can be calculated as follows.

Thus $$QF_1 = Q\frac{C_0}{C}$$

or $$C_0 = \frac{C}{Q}\cdot QF_1$$

$= 1.89$, 3.79, 5.7, 7.58, 9.48 and 11.37 $\mu\mu$F.

$$\frac{R_c}{2R_D} = \frac{12{,}500}{175{,}000} = 0.0715$$

$$G = \frac{\frac{Q_c}{Q}}{\frac{2R_D}{R_c}+1+(QF_1)^2}$$

$= 4.82$, 4.6, 4.27, 3.89, 3.48, 3.09 respectively at $QF_1 = 0.5$, 1, 1.5, 2, 2.5, 3.

By extrapolating from Figs. 5 to 10, selectivity curves against frequency can be drawn as shown in Fig. 13. The curve for $QF_1 = 0$ is taken from Fig. 3, assuming A to be 5. The improvement in selectivity in the neighbourhood of the crystal resonant frequency due to mistuning the circuits is clearly indicated in Fig. 13. Fig. 14 shows the reduction in selectivity at the "skirts" of the curve, the appearance of secondary humps at the resonant frequencies of the tuned circuits, and the loss of amplification (obtained from the curve for $\frac{R_c}{2R_D} = 0.07$ in

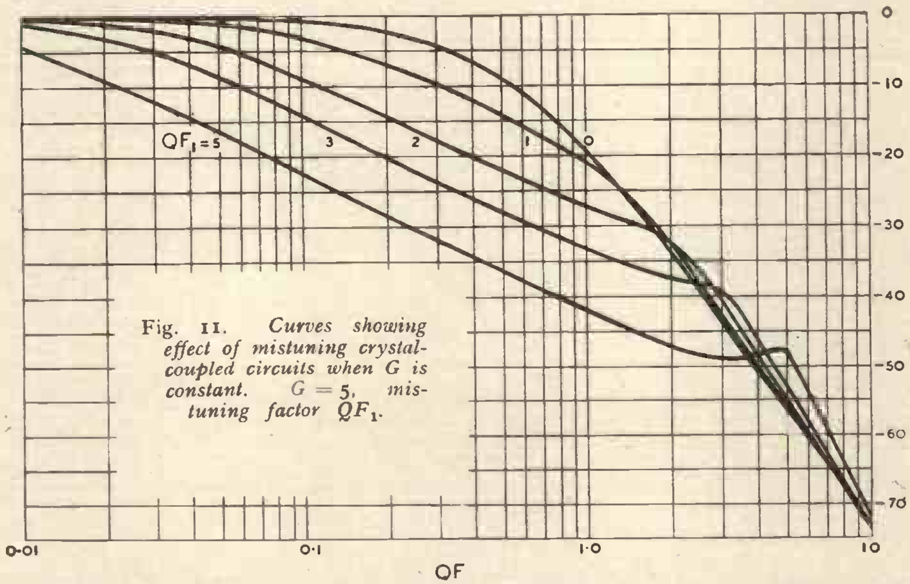


Fig. 11. *Curves showing effect of mistuning crystal-coupled circuits when G is constant. G = 5, mistuning factor QF_1.*

$$F_1 = \frac{2\Delta f_1}{f_r} = \frac{2(f_r - f_1)}{f_r} = 2\left(1-\frac{f_1}{f_r}\right) = 2\left(1-\frac{1}{\sqrt{1+\frac{C_0}{C}}}\right) \simeq 2\left(1-\left(1-\frac{C_0}{2C}\right)\right) = \frac{C_0}{C}$$

when $$\frac{C_0}{2C} \ll 1.$$

Fig. 12) at the crystal resonant frequency. Only one-half of the curves is given because they are symmetrical about the crystal resonant frequency.

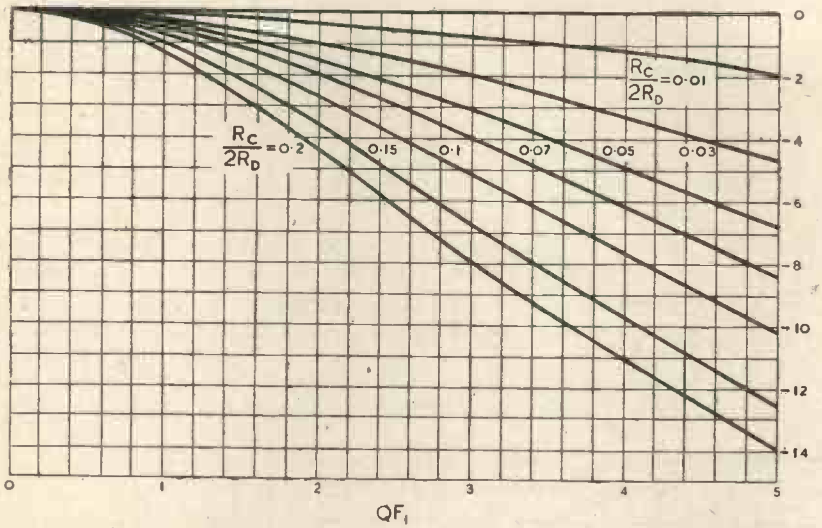
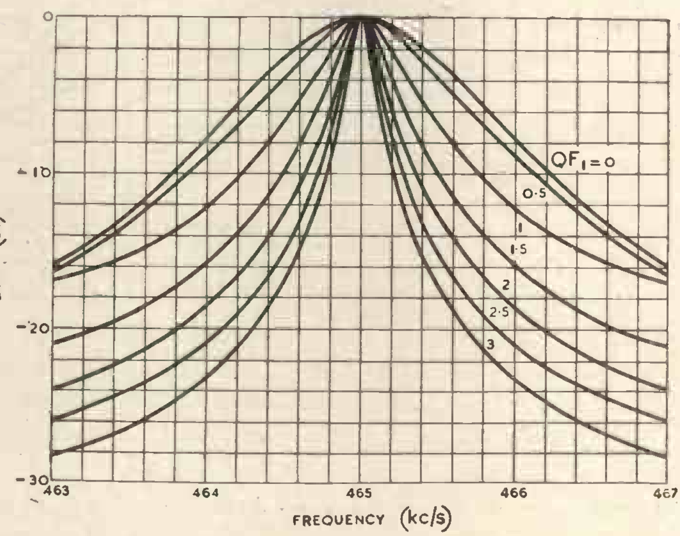


Fig. 12 (Above). *The loss of amplification at the crystal resonant frequency due to mistuning. Mistuning factor* QF_1. Q = *magnification of either tuned circuit;* $F_1 = \frac{2\Delta f_1}{fr}$; $\Delta f_1 = f_r - f_1$; f_r = *resonant frequency of crystal;* f_1 = *resonant frequency of one tuned circuit;* R_D = *resonant impedance of one tuned circuit;* R_c = *series resistance of crystal.*

Fig. 13 (Right) *Selectivity curves for special crystal-coupled circuits for different degrees of mistuning.* $L = 300\ \mu$H, $C = 379\ \mu\mu$F, $Q = 100$, $L_c = 31$ H, $R_c = 12{,}500\ \Omega$, $Q_c = 7500$.



product of the inductance of the tuned circuit and the square of its Q value. Increase of the factor A increases selectivity at all off-tune frequencies above a frequency corresponding to a minimum value of QF, and the loss is increased by $-20 \log_{10} A$ compared with the curve for $A = 1$ for all values of

$$QF \geqslant \frac{1}{\sqrt{A}}.$$

With all the curves in Fig. 3 this is true when $QF > 1$. Overall amplification is slightly lower than that obtained from a pair of critically coupled tuned circuits coupled by inductance or capacitance; the reduction is $-20 \log_{10} (1 + \frac{R_c}{2R_D})$, where R_c and R_D are respectively the series resistance equivalent of the crystal and the parallel resonant resistance of either tuned circuit. For comparison the selectivity characteristic of a pair of critically coupled circuits is shown as the dashed curve in Fig. 3.

Conclusion

Analysis of a pair of identically tuned circuits and a pair of oppositely mistuned circuits coupled by a crystal, the holder capacitance of which is neutralised, shows that generalised selectivity curves can be produced for both types. The selectivity of the identically tuned circuits depends on the crystal and tuned circuit constants, and, to a good degree of approximation, it is directly proportional to a factor A, which is equal very nearly to half the equivalent inductance of the crystal divided by the

Selectivity in the case of the oppositely mistuned circuits is a function of the mistuning, represented by a factor $QF_1(F_1 = \frac{2\Delta f_1}{f_r}$, where Δf_1 is the frequency mistune of either circuit from the crystal resonant frequency, f_r). Mistuning increases selectivity up to $QF = QF_1$, but decreases it when $QF > QF_1$. This decrease in selectivity is due to a tendency to produce secondary side peaks

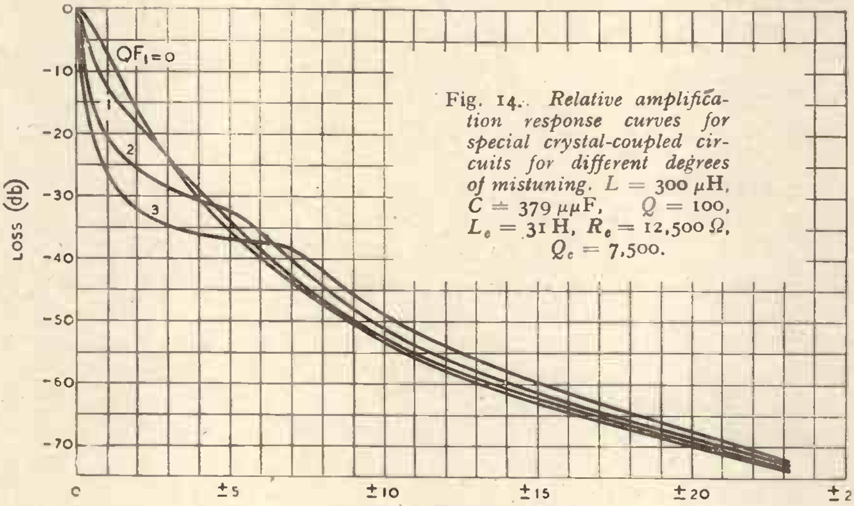


Fig. 14. *Relative amplification response curves for special crystal-coupled circuits for different degrees of mistuning.* $L = 300\ \mu H$, $C \doteq 379\ \mu\mu F$, $Q = 100$, $L_e = 31\ H$, $R_e = 12{,}500\ \Omega$, $Q_c = 7{,}500$.

at the resonant frequencies ($f_r \pm \Delta f_1$) of the tuned circuits, i.e. when $QF = QF_1$. The side peaks become more pronounced as QF_1 is increased, but loss of selectivity is practically negligible when $QF \gg QF_1$, and mistuning has very little effect at the "skirts" of the selectivity curve. The increase in selectivity due to mistuning is obtained at the expense of overall amplification at the crystal resonant frequency. The loss of amplification compared with that for the identical tuned circuits is

$$-20 \log_{10}\left(1 + \frac{(QF_1)^2}{1 + \frac{2R_D}{R_c}}\right) \text{db}$$

For a given degree of mistuning (QF_1 is constant), selectivity, except very near to the crystal resonant frequency, is increased by approximately $-20 \log_{10} G$ compared with the curve for $G = 1$, where

$$G = \frac{\frac{Q_c}{Q}}{\frac{2R_D}{R_c} + 1 + (QF_1)^2}.$$

The factor G acts in the same manner as the factor A of the identical tuned circuits.

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APPENDIX I

The Impedance of a Parallel Tuned Circuit

The parallel tuned circuit is assumed to consist of two branches in parallel, one the tuning capacitance C and the other the coil equivalent to an inductance L in series with a resistance R. The circuit impedance is

$$Z = \frac{\frac{R + j\omega L}{j\omega C}}{R + j\omega L + \frac{1}{j\omega C}}$$

$$= \frac{\frac{L}{CR}}{1 + \frac{j\omega L}{R} + \frac{1}{j\omega CR}} \text{ if } R \lessdot \omega L$$

$$= \frac{\frac{L}{CR}}{1 + \frac{j\omega_r L}{R}\left(\frac{\omega}{\omega_r} - \frac{1}{\omega\omega_r LC}\right)}$$

By noting that $\frac{L}{CR} = R_D$, the resonant resistance of the tuned circuit, $\frac{\omega_r L}{R} = Q$, its magnification, and $\omega_r = \frac{1}{\sqrt{LC}}$, we have $Z = \frac{R_D}{1 + jQ\left(\frac{\omega}{\omega_r} - \frac{\omega_r}{\omega}\right)}$

Now $\frac{\omega}{\omega_r} - \frac{\omega_r}{\omega} = \frac{f}{f_r} - \frac{f_r}{f} = \frac{f^2 - f_r^2}{ff_r} = \frac{(f - f_r)(f + f_r)}{ff_r}$

Replacing f by $f_r + \Delta f$ where Δf = the frequency off-tune from the resonant frequency f_r,

$$\frac{\omega}{\omega_r} - \frac{\omega_r}{\omega} = \frac{\Delta f(2f + \Delta f)}{(f + \Delta f)f_r} \doteq \frac{2\Delta f}{f_r} = F \text{ when } \Delta f \ll f_r$$

Therefore $Z = \dfrac{R_D}{1 + jQ\dfrac{2\Delta f}{f_r}} = \dfrac{R_D}{1 + jQF}$

APPENDIX II

The Impedance of the Crystal Circuit

Assuming the crystal to be represented by a series circuit of L_c, C_c and R_c of magnification Q_c, and that its holder capacitance is neutralised, we have for its impedance at any frequency

$$Z_c = R_c + j\omega L_c + \frac{1}{j\omega C_c}$$

$$= R_c[1 + jQ_c(\frac{\omega}{\omega_r} - \frac{\omega_r}{\omega})] = R_c(1 + jQ_cF)$$

where f_r is the crystal resonant frequency.

APPENDIX III

The Impedance of a Parallel Tuned Circuit referred to a Frequency other than its Resonant Frequency

From Appendix I the impedance of a parallel tuned circuit referred to its resonant frequency f_1 is

$$Z_1 = \frac{R_{D1}}{1 + jQF'} \quad \text{where} \quad F' = \frac{2\Delta f'}{f_1}$$

and $\Delta f'$ = frequency off-tune from f_1

If the reference frequency is to be f_r and $f_1 < f_r$

$$\frac{2\Delta f'}{f_1} = \frac{2(\Delta f + \Delta f_1)}{f_1}$$

where Δf = frequency off-tune from f_r

and $\Delta f_1 = f_r - f_1$

This is checked by noting that at the resonant frequency, f_1,

$$\Delta f' = 0, \Delta f = -(f_r - f_1) = -\Delta f_1$$

When Δf_1 is small compared with f_r, $f_1 \simeq f_r$ so that

$$\frac{2(\Delta f + \Delta f_1)}{f_r} \simeq \frac{2\Delta f}{f_r} + \frac{2\Delta f_1}{f_r}$$

$$= F + F_1$$

Hence $Z_1 = \dfrac{R_{D1}}{1 + jQ(F + F_1)}$

When $f_2 > f_r$

$$\frac{2\Delta f''}{f_2} = \frac{2(\Delta f - \Delta f_2)}{f_2} \simeq \frac{2\Delta f}{f_r} - \frac{2\Delta f_2}{f_r}$$

$$= F - F_2 = F - F_1$$

if $\Delta f_2 = f_2 - f_r = f_r - f_1 = \Delta f_1$.

Hence $Z_2 = \dfrac{R_{D2}}{1 + jQ(F - F_2)} = \dfrac{R_{D1}}{1 + jQ(F - F_1)}$

APPENDIX IV

The Expression for the Selectivity Characteristic of Mistuned Crystal Coupled Circuits

From expressions (12a) and (12b)

$$\frac{Z_{T_r}}{Z_T} = \frac{[1 + jQF]\,[2R_D + R_c(1 + jQ_cF)(1 + jQF + \frac{(QF_1)^2}{1 + jQF})]}{2R_D + R_c(1 + (QF_1)^2)}$$

Writing α_c for Q_cF, α_1 for QF_1 and α for QF, the second part of the numerator in the above expression is

$$2R_D + R_c(1 + j\alpha_c)(1 + j\alpha + \frac{\alpha_1^2}{1 + j\alpha})$$

$$= 2R_D + R_c(1 + j\alpha_c)(1 + j\alpha + \frac{\alpha_1^2(1 - j\alpha)}{1 + \alpha^2})$$

$$= 2R_D + R_c(1 + j\alpha_c)\Big[1 + \frac{\alpha_1^2}{1 + \alpha^2} + j\alpha(1 - \frac{\alpha_1^2}{1 + \alpha^2})\Big]$$

$$= 2R_D + R_c\Big[1 + \frac{\alpha_1^2}{1 + \alpha^2} - \alpha_c\alpha(1 - \frac{\alpha_1^2}{1 + \alpha^2}) + j\alpha_b(1 + \frac{\alpha_1^2}{1 + \alpha^2}) + j\alpha(1 - \frac{\alpha_1^2}{1 + \alpha^2})\Big]$$

$$= 2R_D + R_c(1 + \alpha_1^2) - R_c\Big[\frac{\alpha_1^2\alpha^2}{1 + \alpha^2} + \alpha_c\alpha(1 - \frac{\alpha_1^2}{1 + \alpha^2}) - j\alpha_c(1 + \frac{\alpha_1^2}{1 + \alpha^2}) - j\alpha(1 - \frac{\alpha_1^2}{1 + \alpha^2})\Big]$$

$$= 2R_D + R_c(1 + \alpha_1^2) - \frac{R_c\alpha_c}{\alpha}\alpha^2\Big[1 - \frac{\alpha_1^2}{1 + \alpha^2}(1 + \frac{\alpha}{\alpha_c})\Big] + jR_c\alpha_c\Big[1 + \frac{\alpha_1^2}{1 - \alpha^2} + \frac{\alpha}{\alpha_c}(1 - \frac{\alpha_1^2}{1 + \alpha^2})\Big]$$

Now $\dfrac{\alpha}{\alpha_c} = \dfrac{Q}{Q_c}$, and it may be neglected in comparison with unity.

Similarly $\dfrac{\alpha}{\alpha_c}\Big[1 - \dfrac{\alpha_1^2}{1 + \alpha^2}\Big]$ can be neglected in comparison with $1 + \dfrac{\alpha_1^2}{1 + \alpha^2}$. The above expression for the second part of the numerator therefore reduces to

$$2R_D + R_c(1 + \alpha_1^2) - \frac{R_c\alpha_c}{\alpha}\alpha^2\Big[1 - \frac{\alpha_1^2}{1 + \alpha^2}\Big] + j\frac{R_c\alpha_c}{\alpha}\alpha\Big[1 + \frac{\alpha_1^2}{1 + \alpha^2}\Big]$$

and replacing this in $\dfrac{Z_{T_r}}{Z_T}$ we have

$$\frac{Z_{T_r}}{Z_T} = \Big[1 + j\alpha\Big]\Big[1 - \frac{R_c\alpha_c\alpha^2}{\alpha[2R_D + R_c(1 + \alpha_1^2)]}\Big(1 - \frac{\alpha_1^2}{1 + \alpha^2}\Big) + j\frac{R_c\alpha_c\alpha}{\alpha[2R_D + R_c(1 + \alpha_1^2)]}(1 + \frac{\alpha_1^2}{1 + \alpha^2})\Big]$$

or

$$\frac{Z_{T_r}}{|Z_T|} = \Big[1 + \alpha^2\Big]^{\frac{1}{2}}\Big[\Big[1 - G\alpha^2(1 - \frac{\alpha_1^2}{1 + \alpha^2})\Big]^2 + \Big[G\alpha(1 + \frac{\alpha_1^2}{1 + \alpha^2})\Big]^2\Big]^{\frac{1}{2}}$$

$$= \Big[1 + (QF)^2\Big]^{\frac{1}{2}}\Big[\Big[1 - G(QF)^2(1 - \frac{(QF_1)^2}{1 + (QF)^2})\Big]^2 + \Big[G\,.\,QF(1 + \frac{(QF_1)^2}{1 + (QF)^2})\Big]^2\Big]^{\frac{1}{2}}$$

where $G = \dfrac{R_c\,\alpha_c}{\alpha(2R_D + R_c(1 + \alpha_1^2))}$

$$= \frac{R_cQ_c}{Q(2R_D + R_c(1 + Q^2F_1^2))}$$

LINEAR SINGLE-STAGE VALVE CIRCUITS*

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(Communication from the Research Staff of the M-O. Valve Company, Limited, at the G.E.C. Research Laboratories, England)

§ 1. IN this paper we give general formulae that permit an important class of linear single-stage valve circuit problems to be solved by mere substitution of numerical values for algebraic symbols. However complicated the circuit, no element need be ignored ; but of course those whose numerical values prove to be insignificant when the substitution is made can be neglected. The formulae are also useful in the discussion of multistage circuits in which each stage belongs to this class ; but their application in this field is not considered in this paper.

The method of deriving the formulae consists in treating the circuit as a multi-terminal network. The properties of such a network are completely defined by a set of simultaneous equations, whose constant terms are made up of the imposed e.m.f.s and certain impedances intimately associated with them. The solution of any problem can then be stated in terms of the determinant of these equations and the co-factors of its elements together with the constant terms. The individual impedances are contained in the elements of the determinant ; the formulae relating the elements to the impedances turn out to be very simple.

§ 2. The circuit has $n + 1$ terminals, which will be denoted by the numerals 0 to n. Most of these will be directly connected to electrodes of the valves, and every electrode will be directly connected to a terminal. But there may be some terminals not so connected. We shall assume that there is one such non-electrode terminal (earth) and denote it by 0 ; it will usually be the common terminal of the input and output circuits. The primary cathode will be denoted by 1. But these conventions are not essential ; the formulae would remain true even if there were many non-electrode terminals and if earth and cathode were denoted by other numerals ; but the significance of some of the quantities would be changed. The letters k, l, p, q, u, v, x, y will be used in various contexts to denote any one (or nearly any one) of the terminals. Σ with a suffix of one of them denotes summation over *all* the numerals, unless the contrary is explicitly stated. The changes to be made, if there is no earth separate from the electrodes, will be considered later.

§ 3. Let V_{lk} be the amount by which terminal k is positive to terminal l. The omission of a time-factor may be taken to indicate that we confine our attention to variations of a single frequency $\omega/2\pi$, so that all time-factors cancel out.

When the solution of the circuit is obtained as a function of ω, application of the usual Fourier analysis or of operational methods will give the results for any kind of disturbance. $V_{lk} = -V_{kl}$. The characteristic of a valve circuit is that a part of the currents flowing in the circuit consists of an electron current $\alpha_k I$ to (i.e. a current in the conventional sense from) each electrode k, when I is a linear function of the V_{lk}, and α_k is characteristic of the electrode and the valve geometry but independent of the V_{lk}. Since $V_{lk} = V_{l1} - V_{k1}$, I is a linear function of the V_{k1}'s and we may write

$$I = g_2 V_{21} + g_3 V_{31} + \ldots + g_n V_{n1}$$
$$= \sum_l g_l V_{l1} (l \neq 0 \text{ or } 1) \quad \ldots \quad (1)$$

where the g_k's are the usual valve conductances. No g_1 appears in (1) ; our formulae will be simplified, if we write

$$g_2 + g_3 + \ldots + g_k = -g_1 \quad \ldots \quad (2)$$

a reasonable convention, since the effect on I of changing the cathode potential is the same as that of changing the potentials of all the other electrodes by an equal and opposite amount. The term in g_0 is omitted ; for, earth, in order that it may be distinguished

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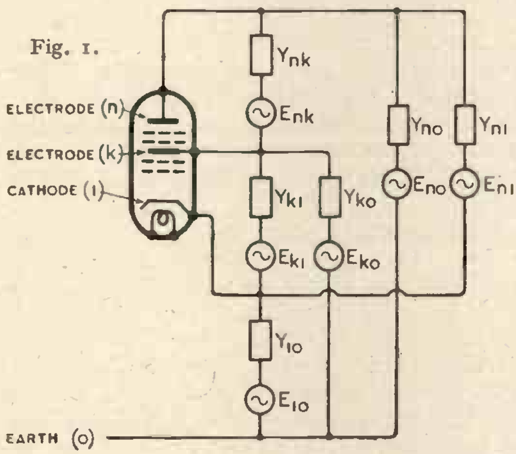
† Late member of the staff of the G.E.C. Research Laboratories.

from a negative grid, which also neither receives nor emits electrons, must be defined as a terminal whose potential relative to the cathode does not effect I. Of course other g_k may actually be zero.

$$\sum_l \alpha_k = 0 \quad \ldots \quad (3)$$

This involves assigning to α_1 a negative value which, if the g_k's have their usual significance, is -1. If there is secondary emission some of the other α_k may be negative, since more electrons may leave an electrode than arrive at it ; but this does not affect the formulae. If in (3) the summation includes $l = 0$, α_0 must be defined as zero.

Fig. 1.



§4. In addition to the electron currents, there will be currents flowing through the external paths connecting the terminals. We shall suppose that terminals k, l are connected by a single path consisting of a generator of e.m.f. E_{lk} in series with an impedor of admittance Y_{kl} (Fig. 1). E_{lk} is the amount by which the generator would make k positive to l if there were no other path between them ; we shall write E_{kl} for $-E_{lk}$. Of course some E_{lk} may be zero.

This assumption excludes circuits in which there is mutual inductance between one impedance connecting one pair of electrodes and another impedance connecting another pair of electrodes. This restriction will be partially removed later. It also excludes circuits in which the path between one pair of electrodes includes an impedance which is common to a path between another pair of electrodes. It does not exclude circuits in which the E_{lk} is part of a complicated two terminal network each terminal of which is connected to an electrode, for by a well-known theorem any more complicated path is equivalent to a generator in series with an impedor. In particular, if the actual path (as often happens) consists of two branches (Fig. 2), one containing no e.m.f. and of admittance Y_{klt}, the other containing a generator of e.m.f. E_{kls}, whose internal admittance is Y_{kls}, the arrangement is equivalent, as shown by the dotted line, to E_{kl} in series with Y_{kl} where

$$Y_{kl} = Y_{klt} + Y_{kls} \; ; \; E_{kl}Y_{kl} = E_{kls}Y_{kls} \quad \ldots \quad (4)$$

§5. The equations of this section are derived by equating to zero the sum of all currents arriving at and leaving each terminal. At the outset we shall assume that there is no mutual inductance between any pair of the impedors Y_{kl}. Then for the kth terminal, we have

$$\alpha_k I + (V_{k0} - E_{k0}) Y_{k0} + \ldots + (V_{k,k-1} - E_{k,k-1})Y_{k,k-1} + (V_{k,k+1} - E_{k,k+1})Y_{k,k+1} + (V_{kn} - E_{kn}) Y_{nk} = 0 \quad (5)$$

$$\text{or} \quad \alpha_k I + \sum_l V_{kl}Y_{kl} = \sum_l E_{kl}Y_{kl} (l \neq k) \quad \ldots \quad (6)$$

There are $n + 1$ such equations, but they sum identically to zero, so that only n of them are independent and we may omit any one of them. Further, in virtue of the relations

$$V_{kl} = V_{km} - V_{lm} \quad \ldots \quad (7)$$

there are only n independent V's. We therefore omit the equation referring to terminal 0 and express all V_{kl}, in virtue of (7), as V_{k0}. Substituting for I from (1), the remaining n equations (6) for the electrodes $l, \ldots k, \ldots n$, then become

$$\left.\begin{aligned} V_{10}(11) + \ldots + V_{k0}(k1) + \ldots + V_{n0}(n1) &= \sum_l E_{1l}Y_{1l} \\ &\vdots \\ V_{10}(1k) + \ldots + V_{k0}(kk) + \ldots + V_{n0}(nk) &= \sum_l E_{kl}Y_{kl} \\ &\vdots \\ V_{10}(1n) + \ldots + V_{k0}(kn) + \ldots + V_{n0}(nn) &= \sum_l E_{nl}Y_{nl} \end{aligned}\right\} \quad \ldots \quad (8)$$

where

$$(xx) = \alpha_x g_x + \sum_l Y_{xl}\,(l \neq x) \quad .. \quad (9)$$

$$(xy) = \alpha_y g_x - Y_{xy}\,(y \neq 0 \text{ or } x) \quad .. \quad (10)$$

No coefficient (00) or $(0k)$ or $(k0)$ occurs in (8).

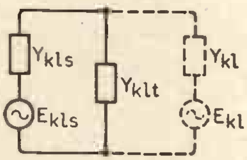


Fig. 2.

When coefficients involving 0 occur in any of the formulae given below, they are to be made zero. In interpreting (9), (10) it must be remembered that g_1 is defined by (2) and that $\alpha_1 = -1$. It is well to observe that, since $\sum_k \alpha_k = 0$ the sum of the coefficients of each V_{k0}, i.e. $\sum_l (kl)$, is Y_{k0} and, since $\sum_k g_k = 0$ so is the sum of the coefficients in each equation, i.e. $\sum_l (lk)$.

Let Δ be the determinant of equations (8) i.e.

$$\Delta = \begin{vmatrix} (11) \ldots (k1) \ldots (n1) \\ \vdots \\ (1k) \ldots (kk) \ldots (nk) \\ \vdots \\ (1n) \ldots (kn) \ldots (nn) \end{vmatrix} \quad .. \quad (11)$$

and let Δ_{kl} be the co-factor of (kl) in the determinant. Then, solving the simultaneous equations by means of determinants,

$$V_{k0} \cdot \Delta = \Delta_{k1} \sum_l E_{1l} Y_{1l} + .. + \Delta_{kk} \sum_l E_{kl} Y_{kl} + .. + \Delta_{kn} \sum_l E_{nl} Y_{nl} \quad .. \quad (12)$$

or $$V_{k0} \cdot \Delta = \sum_q \Delta_{kq} \sum_p E_{qp} Y_{qp} \quad .. \quad (13)$$

In (13) both E_{pq} and E_{qp} occur on the right hand side. If, as is more convenient, we decide that only one of them shall occur, and denote by $\sum_{pq}$ a summation over the combination pq without permutations, we have

$$V_{k0} = \sum_{pq} E_{pq} Y_{pq} \cdot \frac{\Delta_{kp} - \Delta_{kq}}{\Delta} \quad .. \quad (14)$$

In (13) p includes zero in its range of values but q does not. We may add zero to the range of values of q by adding a term $\Delta_{k0} \sum_l E_{0l} Y_{0l}$ to the right-hand side of (12) with the convention that $\Delta_{k0} = 0$. Then in (14) both p and q include zero in their range of values and when Δ_{k0} occurs in formulae it is to be put equal to zero. It is unnecessary to include the combinations pp and qq for $E_{pp} = E_{qq} = 0$.

§6. Equation (14) is the fundamental formula from which most others of importance can be derived. Thus if we want the "gain" between terminal pairs k, l and p, q, i.e. the ratio V_{kl}/E_{pq}, when E_{pq} is the only generator in the network, we have

$$V_{kl}/E_{pq} = \frac{\Delta_{kp} - \Delta_{kq} - \Delta_{lp} + \Delta_{lq}}{\Delta} Y_{pq} \quad .. \quad .. \quad (15)$$

If the input and output circuits share the terminal 0, i.e. if $l = q = 0$, this becomes

$$V_{k0}/E_{p0} = \frac{\Delta_{kp}}{\Delta} \cdot Y_{p0} \quad .. \quad .. \quad (16)$$

If we want the input impedance Y_{kli} at the terminals k, l, we may argue thus (Fig. 3). If the generator of e.m.f. E_0 in series with an impedor of admittance Y_0 is connected across a network of input impedance Y, the voltage across the terminals of the network is $E_0 Y_0/(Y + Y_0)$. Hence if Y_{klj} is the part of Y_{kli} that does not reside in Y_{kl}.

$$V_{kl}/E_{kl} = Y_{kl}/(Y_{klj} + Y_{kl}) \quad .. \quad (17)$$

But $$Y_{klj} + Y_{kl} = Y_{kli} \quad .. \quad .. \quad (18)$$

Hence $$Y_{kli} = Y_{kl} \cdot E_{kl}/V_{kl} \quad .. \quad .. \quad (19)$$

and from (15)

$$Y_{kli} = \frac{\Delta}{\Delta_{kk} + \Delta_{ll} - \Delta_{kl} - \Delta_{lk}} \quad (20)$$

If $l = 0$, we have

$$Y_{k0i} = \Delta/\Delta_{kk} \quad .. \quad .. \quad .. \quad (21)$$

If there are many electrodes, and if many of the Y_{kl} are complex and of comparable magnitude, the labour of calculating Δ and its co-factors will be considerable, since it involves the troublesome arithmetic of complex quantities.

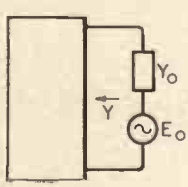


Fig. 3.

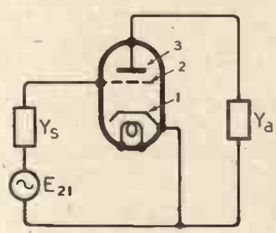


Fig. 4.

§7. We now consider circuits in which there is no separate earth. One of our n suffixes $1 \ldots n$, say u, becomes identical with the suffix 0. If we use the potential V_{ku} relative to the electrode u we have n equations instead of the $(n + 1)$ in (6). These equations are not independent since they sum identically to zero. We may therefore omit any one of them say u and obtain $(n - 1)$ equations in $V_{ku}(k_1 \neq 0, u)$

$$\left.\begin{array}{l} V_{1u}(11) + \ldots + V_{u-1,u}(u-1,1) + V_{u+1,u}(u+1,1) + \ldots + V_{nu}(n1) = \sum_l E_{1l}Y_{1l} \\ \vdots \\ \text{The uth equation missing.} \\ \vdots \\ V_{1u}(1n) + \ldots + V_{u-1,u}(u-1,n) + V_{u+1,u}(u+1,n) + \ldots + V_{nu}(nn) = \sum_l E_{nl}Y_{nl} \end{array}\right\} \quad \ldots \quad (22)$$

where l ranges over the values 1 to n.

Δ becomes the minor of (uu) in (11) and (14) remains true with V_{ku} replacing V_{k0}; the summation in (14) extending over all suffixes $1 \ldots n$; any minor in (14) involving a suffix u must be put equal to 0.

§8. We will illustrate these conclusions by considering the simplest possible valve circuit, the common cathode-triode (Fig. 4). Here there is no earth, u is the cathode 1, and the only other electrodes are the control grid 2 and the anode 3. Then

$$\Delta = \begin{vmatrix} (22) & (32) \\ (23) & (33) \end{vmatrix}$$

$\alpha_2 = 0$; $\alpha_3 = 1$; $g_2 = g_m$ (mutual conductance); $g_3 = g_a$ (anode conductance) Y_{12} is internal admittance of signal generator Y_s; $Y_{13} = Y_a$ (anode load); $Y_{23} = 0$

$$(22) = \alpha_2 g_2 + Y_{12} + Y_{23} = Y_s;$$

$$(32) = \alpha_2 g_3 - Y_{23} = 0$$

$$(23) = \alpha_3 g_2 - Y_{23} = g_m;$$

$$(33) = \alpha_3 g_3 + Y_{13} + Y_{23} = g_a + Y_a$$

$$\Delta = (22)(33) - (32)(23) = Y_s(g_a + Y_a)$$

$\Delta_{31} = \Delta_{12} = \Delta_{11} = 0$ (because suffix 1 does not occur in Δ).

$$\Delta_{32} = -(23)$$

Therefore

$$\frac{V_{31}}{E_{21}} = Y_s \cdot \frac{\Delta_{32} - \Delta_{31} - \Delta_{21} + \Delta_{11}}{\Delta}$$

$$= \frac{-g_m}{g_a + Y_a}$$

which is right; the negative sign indicates the change of phase.

$$Y_{12i} = \frac{\Delta}{\Delta_{22}} = (22) = Y_s$$

$$Y_{13i} = \frac{\Delta}{\Delta_{33}} = (33) = g_a + Y_a$$

$$Y_{23i} = \frac{\Delta}{\Delta_{22} + \Delta_{33} - \Delta_{23} - \Delta_{32}}$$

$$= \frac{Y_s(g_a + Y_a)}{Y_s + g_m + Y_a + g_a}$$

which are also right.

§9. We now consider the case of mutual inductances. The general case, when every circuit that can be formed in the network is coupled to every other, is very complicated and of little practical importance. Accordingly we shall go to the other extreme and consider in detail only the simplest case, when the impedors Y_{uv} and Y_{xy} alone are coupled.

Let us consider the simplest circuit (Fig. 5) in which Y_{uv} and Y_{xy} consist of admittances Y_{uv}' and Y_{xy}' respectively in series with the inductances which are coupled so that a current i_{uv} in the former produces an e.m.f. $-j\omega M_{uvxy}i_{uv}$ in the latter and a current i_{xy} in the latter produces an e.m.f. $-j\omega M_{xyuv}i_{xy}$ in the former. We have then

$$M_{uvxy} = M_{xyuv} = -M_{vuxy} = -M_{uvyx} \quad \ldots \quad \ldots \quad (23)$$

The negative sign is prefixed to the e.m.f. in order that, when $xy = uv$ the "coupling" may be represented in the ensuing formulae by the self-inductance of Y_{uv}; since the effects of this self-inductance have been included already, we must adopt the convention that $M_{uvuv} = 0$

Now

$$\left.\begin{array}{l} i_{uv} = (V_{uv} - E_{uv} + j\omega M_{uvxy}i_{xy})Y_{uv} \\ i_{xy} = (V_{xy} - E_{xy} + j\omega M_{xyuv}i_{uv})Y_{xy} \end{array}\right\} \quad (24)$$

which give:

$$\left.\begin{array}{l} i_{uv} = \dfrac{(V_{uv} - E_{uv})Y_{uv} + j\omega M_{xyuv}Y_{uv}Y_{xy}(V_{xy} - E_{xy})}{1 + \omega^2 M^2 Y_{xy}Y_{uv}} \\ i_{xy} = \dfrac{(V_{xy} - E_{xy})Y_{xy} + j\omega M_{uvxy}Y_{xy}Y_{uv}(V_{uv} - E_{uv})}{1 + \omega^2 M^2 Y_{xy}Y_{uv}} \end{array}\right\} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (25)$$

Consequently the effect of the mutual inductance is that E_{xy} on the right-hand side of equations (8) or (22) is replaced by

$$E_{xy} - j\omega M_{uvxy} i_{uv} \qquad \ldots \qquad (26)$$

that is by

$$E_{xy} - \frac{j\omega M_{uvxy}(V_{uv} - E_{uv})Y_{uv} - \omega^2 M_{xyuv} M_{uvxy} Y_{uv} Y_{xy}(V_{xy} - E_{xy})}{1 + \omega^2 M^2 Y_{xy} Y_{uv}} \qquad \ldots \qquad (27)$$

E_{yx}, E_{uv}, E_{vu} will be replaced by similar expressions. We may drop the suffixes of the M after paying due attention to (23).

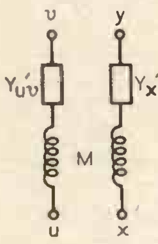


Fig. 5.

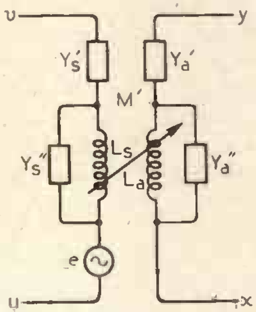


Fig. 6.

Thus if $(ux)'$ is the modified value of (ux) due to the effect of the mutual inductance, changing v's or u's and x's or y's the u, v should be changed as a pair with x, y without change of sign of M and then the interchange of x and y and of u and v should be made with any necessary change of sign of M. This will be quite clear if in (27) M is written with its set of suffixes.

In addition to these changes in the coefficients, new terms appear on the right-hand side of the xth, yth, uth and vth equations. Accordingly we must add on the right-hand side of the xth equation

$$\frac{j\omega M E_{uv} Y_{uv} - \omega^2 M^2 Y_{uv} Y_{xy} E_{xy}}{1 + \omega^2 M^2 Y_{xy} Y_{uv}} \qquad (29)$$

and similar terms for the other three equations.

Then in place of (14) we obtain :—

$$V_{k0} = \sum_{pq} E_{pq} Y_{pq} \frac{\Delta_{kp}' - \Delta_{kq}'}{\Delta'} + Y_{uv} Y_{xy} \frac{j\omega M E_{uv} - \omega^2 M^2 Y_{xy} E_{xy}}{1 + \omega^2 M^2 Y_{xy} Y_{uv}} \cdot \frac{\Delta_{kx}' - \Delta_{ky}'}{\Delta'}$$
$$+ Y_{xy} Y_{uv} \frac{j\omega M E_{xy} - \omega^2 M^2 Y_{uv} E_{uv}}{1 + \omega^2 M^2 Y_{uv} Y_{xy}} \cdot \frac{\Delta_{ku}' - \Delta_{kv}'}{\Delta'} \qquad \ldots \qquad (30)$$

and in place of (15) when the only generator is in one of the coupled circuits

$$\frac{V_{kl}}{E_{xy}} = \frac{Y_{xy}}{\Delta'} \Bigg[(\Delta_{kx}' - \Delta_{ky}' - \Delta_{lx}' + \Delta_{ly}') + \frac{j\omega M Y_{uv}}{1 + \omega^2 M^2 Y_{xy} Y_{uv}} \cdot (\Delta_{ku}' - \Delta_{kv}' - \Delta_{lu}' + \Delta_{lv}')$$
$$- \frac{\omega^2 M^2 Y_{uv} Y_{xy}}{1 + \omega^2 M^2 Y_{xy} Y_{uv}} (\Delta_{kx}' - \Delta_{ky}' - \Delta_{lx}' + \Delta_{ly}') \Bigg] \qquad \ldots \qquad (31)$$

we have for coefficients occurring in the xth equation :—

$$(ux)' = (ux) + \frac{j\omega M Y_{uv} Y_{xy}}{1 + \omega^2 M^2 Y_{xy} Y_{uv}}$$
$$(vx)' = (vx) - \frac{j\omega M Y_{uv} Y_{xy}}{1 + \omega^2 M^2 Y_{xy} Y_{uv}}$$
$$(xx)' = (xx) - \frac{\omega^2 M^2 Y_{uv} Y_{xy}^2}{1 + \omega^2 M^2 Y_{xy} Y_{uv}}$$
$$(yx)' = (yx) + \frac{\omega^2 M^2 Y_{uv} Y_{xy}^2}{1 + \omega^2 M^2 Y_{xy} Y_{uv}} \qquad \ldots \qquad (28)$$

There will also be four coefficients to be modified in a similar way in the yth, uth and vth equations. These may be obtained by interchange of the suffixes. In doing this (22) should be remembered. In inter-

where Δ' indicates that the determinant contains the dashed terms from (28).

§ 10. Let us apply these results to the triode of § 8 the coupling being between (21) and (31). We have then

$x = 2$; $y = 1$; $u = 3$; $v = 1$; $k = 3$; $l = 1$

From (28)

$$(22) = Y_s - \frac{\omega^2 M^2 Y_a Y_s^2}{1 + \omega^2 M^2 Y_a Y_s}$$
$$(32) = \frac{j\omega M Y_a Y_s}{1 + \omega^2 M^2 Y_a Y_s}$$
$$(23) = g_m + \frac{j\omega M Y_a Y_s}{1 + \omega^2 M^2 Y_a Y_s}$$
$$(33) = g_a + Y_a - \frac{\omega^2 M^2 Y_a^2 Y_s}{1 + \omega^2 M^2 Y_a Y_s} \qquad \ldots \qquad (32)$$

$$\Delta' = (22)\ (33) - (32)\ (23)$$
$$= \frac{Y_s(g_a + Y_a - j\omega M Y_a g_m}{1 + \omega^2 M^2 Y_a Y_s)}$$

and from (30)

$$\frac{V_{31}}{E_{21}} = \frac{Y_s}{\Delta'}\left[-(23) + \frac{j\omega M Y_a}{1 + \omega^2 M^2 Y_a Y_s}\cdot(22) + \frac{\omega^2 M^2 Y_a Y_s}{1 + \omega^2 M^2 Y_a Y_s}\cdot(23)\right]$$
$$= \frac{-g_m}{g_a + Y_a - j\omega M Y_a g_m}$$

which is correct.

§ 11. The cases dealt with above (which cover a large proportion of the practically important circuits) have a common property, namely, that it is possible always to put the circuit into an equivalent form of the type shown in Fig. 1 in which the E_{xy} do not involve the valve input admittances Y_{klj} (§ 6). In the circuit of Fig. 6 however, it will be found that the elimination of the mutual inductance by the addition of appropriate e.m.f.s in series with admittances in the path uv and the path xy involves a knowledge of Y_{xyj} and Y_{uvj}. These can be obtained by the method of § 6 but the formulae corresponding to (30) and (31) become much more complicated. A similar difficulty arises with the other type of circuit excluded from § 4 namely that in which an admittance is common in two branches each connecting a pair of electrodes. The complication involved in an attempt to apply the methods of this paper suggests that in these cases some other form of analysis is more suitable.

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

Book Review—An Explanation

IN the September 1944 issue of *Wireless Engineer* we reviewed on p. 429 a doctorate thesis* by Dr. E. Metzler on forced oscillations in aerials and we drew attention to the fact that the formula

$$J_B = J_{eff}\frac{X}{\sqrt{R^2 + X^2}}$$

was followed on the next line by the formula

$$\frac{d}{dz}J_{eff} = \frac{X}{\sqrt{R^2 + X^2}}\frac{d}{dz}J_B.$$

We said that this was obviously upside down.

We have received a letter from the author explaining that this is not so. His explanation is as follows.

"The actually measured current (RMS) at any point along the aerial is given by

$$J_{eff} = \sqrt{J_W^2 + J_B^2},$$

both components J_W (watt) and J_B (wattless) being functions of z.

Then

$$\frac{d}{dz}J_{eff} = \frac{d}{dz}\sqrt{J_W^2 + J_B^2} = \frac{1}{J_{eff}}\left(J_W\frac{dJ_W}{dz} + J_B\frac{dJ_B}{dz}\right)$$

The difference $\frac{d}{dz}J_{eff}\Big|_{z-\Delta}^{z+\Delta}$ for arbitrary values of z tends to zero as $\Delta \to 0$. If however, $z = \zeta$ (the point at which the aerial is energised) the derivative of the wattless component J_B is discontinuous and therefore for $z = \zeta$

$$\frac{d}{dz}J_{eff}\Big|_{\zeta-0}^{\zeta+0} = \frac{J_B}{J_{eff}}\cdot\frac{d}{dz}J_B\Big|_{\zeta-0}^{\zeta+0}$$

but J_B at the feeding point ($z = \zeta$) may be put in the form $J_B = J_{eff}\frac{X_A}{\sqrt{R_A^2 + X_A^2}}$

Substituting this expression in the foregoing formula and making use of (67) leads to the final statement in formula (68). [The formula that we said was obviously upside down.]

It should be well noted that the expression

$$J_B = J_{eff}\frac{X_A}{\sqrt{R_A^2 + X_A^2}}$$

is to be introduced only after the differentiation has been carried out.

This condition apparently has not been taken care of when the remarks in *Wireless Engineer* referring to this part of my thesis were written down."

In the review we also said that if the correct formula were employed the calculations would agree more closely with the observations. The author says "there is in fact a marked disagreement between measured and calculated values for the amount of discontinuity in the feeding zone. A difference of this order was to be expected because the calculations were based on a cylindrical shape of conductor, whereas the practical measurements refer to a self-supporting antenna tower."

We regret having misinterpreted the author's mathematical treatment and are very pleased to publish this explanation. G. W. O. H.

* "Erzwungene Elektrische Schwingungen an Rotations-symmetrischen Leitern bei Zonaler Anregung." Gebr. Leemann & Co., Zürich.

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.

ACOUSTICS AND AUDIO-FREQUENCY CIRCUITS AND APPARATUS

567 021.—Multi-stage low-frequency amplifier in which the usual decoupling resistance-capacitance shunts are replaced by suitable impedances in the H.T. supply line.

Furzehill Laboratories Ltd.; F. R. Milsom; and S. Smith & Sons (Motor Accessories) Ltd. Application date 27th July, 1943.

567 152.—Apparatus for recording speech magnetically on a tape, for subsequently reproducing it at high or low speed.

Telephone Manufacturing Co. Ltd.; S. J. Smith; and R. S. G. Terry. Application date 30th November, 1942.

567 222.—Relay or switching device which is automatically operated at pre-determined time intervals by a thermally-sensitive resistance, or Thermistor.

Standard Telephones and Cables Ltd. and S. C. Shepard. Application date 30th July, 1943.

567 225.—Time-operated relay, controlled by a thermally-sensitive resistance, or Thermistor, in which provision is made for adjusting the thermal coefficient of the sensitive element. (Divided out of 567 222 and Patent of addition to 557 707).

Standard Telephones and Cables Ltd. and S. C. Shepard. Application date 30th July, 1943.

567 238.—Gramophone pick-up in which provision is made for offsetting the falling amplitude of records made at constant velocity.

Philco Radio and Television Corpn. (assignees of F. R. Farrow Jr.). Convention date (U.S.A.) 2nd April, 1942.

AERIALS AND AERIAL SYSTEMS

567 201.—Method of coupling a crossed pair of dipole aerials to a coaxial feed-line so as to radiate a circularly-polarised wave.

The British Thomson-Houston Co. Ltd. and B. A. C. Tucker. Application date 5th March, 1943.

TRANSMITTING CIRCUITS AND APPARATUS

(*See also under Television*)

567 080.—Tuning inductance with a movable roller contact which is constrained to rotate separately at a speed sufficient to ensure a good wiping contact.

Radio Transmission Equipment Ltd. and C. E. Payne. Application date 22nd June, 1943.

567 083.—Valve oscillator coupled through a cathode-follower valve to a low-impedance load, and arranged to offset impedance variations.

Standard Telephones and Cables Ltd (assignees of T. L. Wilson). Convention date (U.S.A.) 20th July, 1942.

567 189.—Circuit device for automatically stabilising the voltage across a tuned circuit as the frequency is varied, as in frequency modulation.

The General Electric Co. Ltd. and J. M. W. McBride. Application date 18th June, 1943.

567 251.—Transmitting circuit, including a blocking oscillator which produces interim pulses, so that the installation can be used for radiating signals on any one of a plurality of harmonically-related carrier waves.

Marconi's W. T. Co. Ltd. (assignees of W. van B. Roberts). Convention date (U.S.A.) 1st July, 1942.

567 256.—Motor-driven device for the remote control of the tuning of a transmitting or receiving set.

Standard Telephones and Cables Ltd.; S. Smith and Sons (Motor Accessories) Ltd.; and E. C. Klepp. Application date 29th July, 1943.

SIGNALLING SYSTEMS OF DISTINCTIVE TYPE

567 011.—Thermionic switching device for interrupting a series of pulsed signals at predetermined times, or automatically upon the arrival of a second signal.

E. L. C. White; G. S. P. Scantlebury; and R. T. Clayden. Application date 22nd June, 1943.

CONSTRUCTION OF ELECTRONIC-DISCHARGE DEVICES

566 969.—Method of manufacturing valves for use at very-high frequencies of the kind where the grid is connected to an annular disc sealed into the walls of the tube.

Standard Telephones and Cables Ltd. and W. T. Gibson. Application date 16th July 1943.

567 111.—Construction and assembly of an electron-discharge tube in which two or more of the electrons are so closely spaced as to be almost in contact.

The Mullard Radio Valve Co. Ltd. and H. J. L. Herne. Application date 10th May, 1943.

567 190.—Electrode arrangement for increasing the effective electron emission from a discharge tube with a light-sensitive cathode.

F. J. G. Van Den Bosch; E. T. J. Tapp; and Vacuum Science Products Ltd. Application date 14th July, 1943.

567 220.—Method of sealing a lead-in wire to the heating filament of an evacuated glass tube.

The British Thomson-Houston Co. Ltd. Convention date (U.S.A.) 24th July, 1942.

567 228.—Cathode-ray tube wherein the beam is divided into two parts, which are deflected in opposite directions, by a pair of interleaved grids.

O. E. H. Klemperer, commonly known as O. Klemperer. Application date 12th September, 1940.

ABSTRACTS AND REFERENCES

Compiled by the Radio Research Board and published by arrangement with the Department of Scientific and Industrial Research

Comparative Length of the Abstracts.—*It is explained to new readers that the length of an abstract is no sign, by itself, of the importance of the work concerned. An important paper in English may be dealt with by a short abstract, or even, if it is in a journal readily obtainable, by a square-bracketed addition to the title; while a paper of similar importance in a language other than English may be given a long abstract. In addition to these questions of language and accessibility, the nature of the work has, of course, a great effect on the useful length of its abstract.*

PROPAGATION OF WAVES

2132. A STUDY OF GUIDED HERTZIAN WAVES: APPLICATION TO THE FILTERING OF DECIMETRIC WAVES.—Gutton & Ortusi. (*See* 2154.)

2133. CIRCULAR WAVE GUIDE FIELDS.—Cooper. (*See* 2158.)

2134. THE RADIAL FIELD IN A SPHERICAL ELECTROMAGNETIC WAVE [Sequel to Editorial dealt with in 1802 of June].—G.W.O.H. (*Wireless Engineer*, May 1945, Vol. 22, No. 260, pp. 209–211.)

2135. THE QUESTION OF F-LAYER INTERFERENCE AT SUNSPOT MAXIMUM, IN CONNECTION WITH FREQUENCY-MODULATION WAVELENGTH ALLOCATION.—K. A. Norton & others. (*See* Editorial, 2356, below.)

2136. WINDS IN THE IONOSPHERE INDICATED BY RADIO-REFLECTING "CLOUDS" OF HIGH IONIC DENSITY.—P. Ferrell, Jr. (*Bull. Am. Met. Soc.*, No. 9, Vol. 25, 1944, p. 371: brief excerpt from a letter.) Mentioned in *Terr. Mag. & Atmos. Elec.*, March 1945, Vol. 50, No. 1, p. 87. For other work by this writer *see* 1105 of 1944 and 391 of February.

2137. RADIO PROGRESS DURING 1944: WAVE PROPAGATION [Ionosphere: Troposphere: Effect of Ground Shape & Properties: Propagation through the Earth: Transmission Lines, Wave Guides: etc.: Short Comments followed by Bibliographies].—I.R.E. Committee. (*Proc. I.R.E.*, March 1945, Vol. 33, No. 3, pp. 152–155.)

2138. FREQUENCY ALLOCATION: NEEDS OF LONG-DISTANCE COMMUNICATION SERVICES.—Smith-Rose. (*See* 2371.)

2139. RECOMBINATION PROCESSES IN THE E LAYER OF THE IONOSPHERE.—Ta-You Wu. (*Terr. Mag. & Atmos. Elec.*, March 1945, Vol. 50, No. 1, pp. 57–62.)

Author's summary:—"It is shown that photo-ionisation of the negative ion of oxygen leads to a low value for the ratio λ of the concentrations of the negative ion and the electron, $[O^-]/e$. Hence the observed high value of the order of 10^{-8} cm³/s (compared with the theoretical value of the order of 10^{-12} cm³/s) for the daytime effective recombination-coeffieient α' in the E layer cannot be ascribed to a high value of λ, of the order of 10^2–10^3" [as was done by Bates & his colleagues, 3038 of 1939].

"It is suggested that in order to explain the observed α', one abandons the usual assumption that the E layer is electrically neutral and postulates instead a preponderance of positive over negative charge so that $[O^+]$ or $[O_2^+]$ is of the order of $10^3[e]$ [the O_2^+ alternative is included because Bhar's approximate calculations (1348 of 1939) seem to indicate that the E layer is due to the ionisation of O_2 by radiations below 660 AU]. Such a concentration of positive ions is consistent with what is demanded by the Stewart-Schuster-Chapman theory for the diurnal variation of terrestrial magnetism. Night-time conditions in the E layer are also discussed. The rise of electron-density before sunrise is explained" [eqn. 24 and subsequent lines]. For other recent work by this writer *see* 2846 of 1944, 722 of March, and 1385 of May.

2140. RECENT ZURICH PAPERS ON SUNSPOTS.—W. Brunner: W. Brunner-Hagger. (Quoted in *Terr. Mag. & Atmos. Elec.*, March 1945, Vol. 50, No. 1, p. 87.)

2141. Harmonic Analysis of the Annual Variation of Magnetic Declination and Horizontal Intensity at Oslo, 1843–1930.—K. F. Wasserfall. (*Terr. Mag. & Atmos. Elec.*, March 1945, Vol. 50, No. 1, pp. 37–45.)

2142. Some Early Contributions to the History of Geomagnetism: VIII—The Haven-Finding Art, by Simon Stevinus.—H. D. Harradon. (*Terr. Mag. & Atmos. Elec.*, March 1945, Vol. 50, No. 1, pp. 63–68.)

2143. Solar Activity and Magnetism [Extract from "Survey of the Year's Work at Mount Wilson"].—W. S. Adams. (*Terr. Mag. & Atmos. Elec.*, March 1945, Vol. 50, No. 1, pp. 79–80.)

2144. Maris and Hulburt's Ultra-Violet-Light Theory of Aurorae and Magnetic Storms.—Ta-You Wu. (*Proc. Indian Ac. of Sci.*, Series A, Vol. 18, 1943, p. 345 onwards.) Mentioned in *Terr. Mag. & Atmos. Elec.*, March 1945, p. 86, where a *Chem. Abstr.* abstract is referred to (No. 5727 of 1944).

2145. Infra-Red Auroral Display in the Night Sky [Far More Intense than the Ordinary Persistent Aurora, and probably due to the Large Number of Nitrogen Atoms: Need for Further Research for Estimation of Height, etc.].—J. Stebbins, A. E. Whitford & P. Swings. (*Science*, 16th March 1945, Vol. 101, No. 2620, Supp. p. 10: Sci. News Letter, 17th March 1945, Vol. 47, No. 11, p. 169.)

2146. New Measurements of Wavelength in the Blue and Violet Regions of the Spectrum of the Night Sky.—J. Cabannes & J. Dufay. (*Comptes Rendus* [Paris], Nov. 1943, Vol. 217, p. 433 onwards.) Mentioned in *Review Scient. Instr.*, March 1945.

2147. Colour-Temperature Index of the Sky Zenith at Low Positions of the Sun over the Horizon.—N. N. Kalitin. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URSS*, 20th Sept. 1944, Vol. 44, No. 8, pp. 317–320: in English.)

Among other conclusions, it is deduced that "the value of the colour temperature may serve to evaluate the thickness of the cloud layer (or the mass of the fog) as well as the changes in their thickness. . .": thus if successive observations made in the fog show an increase in colour temperature, this may serve as an indication that the fog is thinning out and is likely to vanish soon. The observations are made with a photoelectric equipment with filters.

2148. "Methods in Climatology" [Book Review].—V. Conrad. (*Science*, 16th March 1945. Vol. 101, No. 2620, pp. 273–275.)

2149. Shutter in front of an Object Lens always working at Full Aperture [Defects in Existing Shutters used for Photographing the Sun (when Duration of Opening & Closing is Comparable with That of the Exposure): Designs using Optical Wedges].—G. A. Tikhov. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URSS*, 30th Aug. 1944, Vol. 44, No. 6, pp. 238–240: in English.)

For a previous Note, "Development of Photographic Photometry without Objectives" (outline of two new lens-less cameras, with prisms or system of small mirrors), *see* issue for 10th July 1944, No. 1, pp. 15–17.

2150. "The Velocity of Light" [Review of Part I, Vol. 34, 1944, *Transactions Am. Phil. Soc.*].—N. E. Dorsey. (*Current Science* [Bangalore], Feb. 1945, Vol. 14, No. 2, p. 48.) The writer is on the staff of the National Bureau of Standards.

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY

2151. Justifying "Static" [Suggestion that B.S.I. should canonise Use of Term "Static" for Noise due to Corona on Aerials having D.C. Path to Earth, and for Effects in Rubber-Tyred Vehicles].—T. Roddam. (*Wireless World*, March 1945, Vol. 51, No. 3, p. 93.) Prompted by Bennington's denunciation of the term as a substitute for "atmospherics."

PROPERTIES OF CIRCUITS

2152. The Field Between Equal Semi-Infinite Rectangular Electrodes or Magnetic Pole-Pieces.—N. Davy. (*Phil. Mag.*, Dec. 1944, Vol. 35, No. 251, pp. 819–840.)

"The two-dimensional problem of finding the properties of the electrostatic field between two equal semi-infinite rectangular electrodes, with a gap between them, is commenced in Riemann-Weber's 'Differentialgleichungen der Physik' . . . The discussion stops when the differential equation of the transformation and the modulus of the elliptic functions to be used are obtained. Any reader wishing to obtain numerical results will find that much remains to be done thereafter. In the present paper the differential equation is integrated and a number of consequences are deduced from the solution. Experimental tests of the theory are also described."

The application of the theory to a corresponding magnetic system is dealt with; thus §9 considers the electric resistance or magnetic reluctance of the gap, § 10 the mechanical forces on the conductors in both cases.

2153. On the Theorem of Reciprocity for Hertzian Waves.—H. Gutton & J. Ortusi. (*Comptes Rendus* [Paris], 27th Dec. 1943, Vol. 217, pp. 677–679.)

Lorentz showed the relation existing, at each point in space, between the electric and magnetic vectors associated with two electromagnetic fields with indexes 1 and 2: namely $\text{div}\,(E_2 \wedge H_1) = \text{div}\,(E_1 \wedge H_2)$. This condition assumes, at each point in space, the existence of a definite dielectric constant, magnetic permeability, and conductivity. By this relation he demonstrated the reciprocity of the electric fields created by two Hertz dipoles. Sommerfeld extended the proof to two radiotelegraphic aerials: Carson showed that Sommerfeld's reasoning was faulty, and that Rayleigh's reciprocity theorem (which applied to quasi-stationary fields) could be extended to electromagnetic fields.

Carson deduced that, if an e.m.f. is applied to a transmitting aerial A_1 and produces a current in a receiving aerial A_2, a current equal in amplitude and phase is generated in the aerial A_1 by the application of the same e.m.f. to aerial A_2. In the present Note "we shall set ourselves to find what assertion of the reciprocity theorem may be deduced from the Lorentz relation in the very general case where two sources O_1 and O_2 radiate by the intermediation of an electromagnetic guide of arbitrary nature. The sources O_1 and O_2, since they do not radiate directly, may be considered as enclosed in two conducting boxes, S and S′ respectively: these boxes communicate with the external medium by means of the guides G and G′," whose cross-sections are Σ and Σ'.

The following two theorems are derived: (i) the time taken by a Hertzian wave to cover the distance which separates Σ from Σ' is equal to the time taken by the wave to cover the distance separating Σ' from Σ, whatever obstacles may be interposed, on condition that there exists throughout the medium a definite dielectric constant, magnetic permeability, and electric conductivity: (b) in the above conditions, the ratio of the power received to the power emitted remains unchanged when the rôles of the two arrangements are exchanged.

2154. A STUDY OF GUIDED HERTZIAN WAVES: APPLICATION TO THE FILTERING OF DECIMETRIC WAVES.—H. Gutton & J. Ortusi. (*Bull. de la Soc. Franç. des Élec.*, Feb. 1944, No. 34: a 12-page paper.)

Two *Comptes Rendus* Notes were dealt with in 3081 & 3107 of 1944. The present paper has the following sections and subsections:—General properties of a guided wave: the guided wave considered as a special case of the wave-propagating system: definition of the coefficient of reflection: definition of the apparent impedance at a point: longitudinal current in the guide (power transported by a progressive wave: obstacle interposed in a guide—transmission coefficient—the reciprocity theorem (2153, above]): different types of obstacle (obstacle introduced by diffraction phenomena at the extremity of guides and horns—use of Kottler's formulae, based on the Huyghens principle applied to the electromagnetic field [de Broglie's book, cited here and in so many recent French researches, was referred to in 3083 of 1944: it is published by Gauthier-Villars, Paris]: obstacle composed of an interposed slit: of an interposed insulating block of variable length: obstacle constituted by a change of curvature of the wave surfaces at a plane of junction of guides and horns, and by the eventual curvature of the direction of propagation of the guide in executing junctions).

Study of the filtering of waves: resonator arranged in series (theorem derived: "When a cell is such that the moduli of the reflection coefficients of each component obstacle are equal, the transmission coefficient is equal to unity if the cell is tuned. The coefficient of reflection is then zero. The characteristic impedance is realised. . . . This theorem is very important in practice . . ."): resonators arranged in shunt (two types).

The writers stress the result that the employment of reflection coefficients is essential in guide theory. These coefficients have been measured successfully, "but we cannot describe in this Note the experimental arrangements employed." The theory has led to the solving of a large number of problems connected with matching, filtering, and the accurate measurement of dielectric constants and losses at very high frequencies.

2155. PRINCIPLE OF EQUIVALENCE BETWEEN AN ELECTROMAGNETIC CAVITY AND A CIRCUIT WITH LOCALISED CONSTANTS.—J. Bernier. (*Comptes Rendus* [Paris], 3rd Nov. 1943, Vol. 217, pp. 424–426.)

"To study electrical systems involving electromagnetic cavities as resonators, it is convenient to establish as a preliminary step a correspondence between these and certain *equivalent* oscillatory circuits with localised constants, in order to be able to use, in the calculations, the results already obtained for the ordinary circuits. But for such an equivalent scheme to be practical, it must be simple and the quantities appearing in it must be easily calculable or accessible by test. These considerations have led me to the following principle of equivalence:

"(i) Given, in the interior of a cavity, a path Γ joining two points in the wall, it is possible to find corresponding, in a univocal way at each fundamental mode of vibration ν of the cavity, an antiresonant cell K_ν composed of a resistance, a capacitance, and an inductance in parallel which shall possess the same natural frequency ω_ν and the same overvoltage S_ν as the cavity excited at its resonance of order ν, and shall moreover be such that the potential difference $U\nu$ at the terminals of the cell is equal to the integral $\int_\Gamma \vec{E_\nu} \cdot \vec{ds}$ of the fundamental electric field. The constants of the cell will be called *constants of the cavity looking from Γ, for the natural vibration considered. The cavity is equivalent to the chain of cells K_ν, connected in series.*

"(ii) If the cavity is effectively excited by a current i circulating along the path Γ, it is this current that should figure in the equivalent scheme as excitation current.

"(iii) If the cavity is coupled to an external circuit by a loop γ enclosing a magnetic flux, the coefficient of mutual induction M_ν of each of the cells K_ν with the external circuit will be defined as being the quantity which makes M_ν/L_ν, the ratio of the e.m.f.s of induction and of excitation, equal to the ratio of the integrals of the electric field E_ν along γ and along Γ. In these conditions, there will again be equality between the current circulating in the loop and the current appearing in the equivalent scheme. Moreover, the M_νs make it easy to pass from the constants of the cavity looking from Γ to those of the cavity looking from γ . . ."

The Note continues by assuming the dielectric to be a vacuum and gives, in eqn. 1, expressions for the constants of the cavity looking from Γ, and in eqn. 2 the expression for S_ν on the assumption that the only losses are those due to the Joule effect in the highly conductive walls.

2156. PRINCIPLES FOR THE CALCULATION OF ELECTROMAGNETIC CAVITIES.—J. Bernier. (*Comptes Rendus* [Paris], Nov. 1943, Vol. 217, p. 530 onwards.) Mentioned in *Review Scient. Instr.*, March 1945. For further development *see* 2157, below.

2157. A "RACCORDEMENT" [Piecing-Together] METHOD FOR THE CALCULATION OF ELECTROMAGNETIC CAVITIES.—J. Bernier. (*Comptes

Rendus [Paris], 31st Jan. 1944, Vol. 218, pp. 186–188.)

"To calculate the constants of electromagnetic cavities and to trace their field-charts (2156, above) it is convenient to derive the electric and magnetic fields of a vector potential $Ae^{j\omega t}$ which must fulfil the conditions of eqn. 1: $\text{div}\,\vec{A} = 0$ and $\Delta\vec{A} + k^2\vec{A} = 0$, with $k = \omega/c$." This system, however, with the condition fixing the proper values k_ν and the corresponding normal solutions $\vec{A}_\nu$, namely the condition of nullity of the tangential component of E at the wall S of the cavity, is capable of solution by ordinary methods only in cases where the cavity is of simple geometrical form. The present Note therefore describes a method of resolution by "raccordement" when the domain of the cavity can be resolved into two or more elementary domains, for each of which a general solution of eqn. 1 can easily be obtained.

The method has been used, for example, to calculate the fundamental vibration (electric type) of a cavity of revolution of re-entrant form whose semi-meridian is represented in Figs. 1 and 2. Empirical formulae have been deduced, accurate within about 5%: the natural wavelength can be obtained within 2% by a simplified equation which is suitable for numerical calculation thanks to the rapid convergence of its second term.

2158. Circular Wave Guide Fields.—G. R. Cooper. (*Electronics*, Feb. 1945, Vol. 18, No. 2, pp. 106–109.)

"To facilitate the design of exciting elements and grids for filtering particular modes, field patterns for five modes having the lowest cut-off frequencies are plotted. Diagrams show direction and relative magnitude of fields in the transverse plane."

2159. Quarter-Wavelength Insulators [Use of Short-Circuited $\lambda/4$ Stub as Support for Inner Conductor to Coaxial Line: the Single-Stub Support: Two Special Cases of the Double-Stub Support].—L. A. Ware. (*Communications*, Nov. 1944, Vol. 24, No. 11, pp. 51..54 and 84..88.)

"It is shown that by making appropriate adjustments in these elements, 'broad-banding' is improved, *i.e.* a broader band of frequencies may be transmitted with less loss due to mis-matching. As an illustration, a design of a double-stub support to operate at 750 Mc/s is presented."

2160. Proof of the Foster Reactance-Curve Theorem for the Case of a Loss-less Electromagnetic Enclosure [Cavity Resonator: Short Summary of Rochester Fall Meeting Paper].—W. R. MacLean. (*Communications*, Dec. 1944, Vol. 24, No. 12, p. 42.)

2161. Correspondence on Bell's "Transient Response in Frequency Modulation" [2514 of 1944: Some Corrections].—P. K. Chatterjea: H. E. Curtis: D. A. Bell. (*Phil. Mag.*, Dec. 1944, Vol. 35, No. 251, pp. 851–853.)

2162. Transient Response [as the Criterion for the Quality of a Television Amplifier: Accurately Calculated Curves, Procedures for Synthesis, etc.].—Kallmann & Spencer. (*See* 2268.)

2163. Single-Inductor Coupling Networks [and Their Advantages over Inter-Stage Transformers in Wide-Band R.F. & Video Amplifiers: Analysis of Performance: Expressions for Total Voltage Gain, Band Width, & Skirt-Steepness Ratio: Design Curves for Band Widths up to 5 Mc/s].—C. T. McComb & A. P. Green. (*Electronics*, Sept. 1944, Vol. 17, No. 9, pp. 132–137.) From the Naval Research Laboratory, Washington.

2164. Balanced Amplifiers.—F. Offner. (*Proc. I.R.E.*, March 1945, Vol. 33, No. 3, p. 202.)

"Several articles (895 of 1939; 695, 1512, & 3425 of 1944; and 1680 of May) have recently appeared on amplifiers employing cancellation of in-phase signals. These include differential-input amplifiers; d.c. phase-inverters; and *R-C*-coupled push-pull amplifiers . . . All three types of amplifier are merely special uses of in-phase signal degeneration. Perhaps the failure to recognise this fact may in part account for the frequent republishing, as original, of several of the circuits the writer developed for this purpose (1713 of 1937 and 1038 of 1941). These have been used in most of the equipment we have built since 1936, and because of their apparent wide usefulness were made available to many workers in biophysics in private communications, in advance of publication . . ." Some of the applications made do not appear to recognise, for example, the effect of small variations in components. Such points, as well as several new applications, will be covered in a forthcoming article.

2165. Low-Frequency Amplification: Part IV—Cathode Self-Bias and Attenuation Distortion: Part V—The Anode Decoupling Circuit: Part VI—The Screen Decoupling Circuit.—K. R. Sturley. (*Electronic Eng:g.*, Feb., March, & April, 1945, Vol. 17, Nos. 204/206, pp. 378–381, 429–431, & 470–472.) For previous parts *see* 1756 of June.

2166. Negative Feedback in Hearing-Aid Amplifiers.—Planer & Marland. (*See* 2248.)

2167. Protest Against the Use of the Term "Amplitude Distortion" when "Non-Linear (or Harmonic) Distortion" is Meant [Letter prompted by Sturley's Article, 1756 of June].—J. R. Hughes: K. R. Sturley. (*Electronic Eng:g*, Feb. 1945, Vol. 17, No. 204, p. 390.) For Sturley's reply *see* March issue, No. 205, p. 426.

2168. Mathematical Analysis of Random Noise: Part III—Statistical Properties of Random Noise Currents.—S. O. Rice. (*Bell S. Tech. Journ.*, Jan. 1945, Vol. 24, No. 1, pp. 46–108.)

For previous parts *see* 440 of February. "In this section we use the representations of the noise currents given in section 2.8 to derive some statistical properties of $I(t)$. The first six sections are concerned with the probability distribution of $I(t)$ and of its zeros and maxima. Sections 3.7 and 3.8 are concerned with the statistical properties of the envelope of $I(t)$. Fluctuations of integrals involving $I^2(t)$ are discussed in section 3.9 [Thiede's paper (2690 of 1936) is specially praised, and his results are extended]. The probability distribution of a sine wave *plus* a noise current is given in 3.10, and in 3.11 an alternative method of deriving the results of Part III is mentioned [with the shot-effect representation used in Part I as a starting point]. Prof. Uhlenbeck has pointed out that much of the material in this part is closely connected with the theory of Markoff processes. Also S. Chandrasekhar has written a review of a class of physical problems which is related, in a general way, to the present subject (2866 of 1943)." For Part IV *see* 2169, below.

2169. Mathematical Analysis of Random Noise: Part IV—Noise through Non-Linear Devices.—S. O. Rice. (*Bell & Tech. Journ.*, Jan. 1945, Vol. 24, No. 1, pp. 109–156.)

For previous parts *see* 2168, above. "We shall consider two problems which concern noise passing through detectors or other non-linear devices. The first deals with the statistical properties of the output of a non-linear device, that is, with its average value, its fluctuation about this average, and so on. The second problem may be stated more definitely: Given a non-linear device and an input consisting of noise alone, or of noise *plus* a signal. What is the power spectrum of the output?

"There does not seem to be much published material on the first problem. However, from conversation with other people, I have learned that it has been studied independently by several investigators. The same is probably true of the second problem, although here the published material is somewhat more plentiful . . . Help was obtained from a recent paper by Bennett (1883 & 3110 of 1944) and also from the manuscript of a forthcoming paper by Middleton."

The section headings are as follows:—l.f. output of a square-law device: l.f. output of a linear rectifier: some statistical properties of the output of a general non-linear device: output power spectrum: noise through square-law device: two correlation-function methods: linear detection of noise—the Van-Vleck–North method: the characteristic-function method: noise *plus* sine wave applied to non-linear device: miscellaneous results obtained by correlation-function method: appendices (table of non-linear devices specified by integrals; the hypergeometric function $_1F_1(a; c; x)$, in problems concerning a sine wave *plus* noise; the power spectrum corresponding to $\psi_r{}''$).

2170. Intermittent Behaviour in Oscillators [Motor-Boating, Squegging].—Edson. (*See* 2187.)

2171. A Note on Diode Modulation.—Bailey & Fett. (*See* 2185.)

2172. A Stabilised Pulse Generator [Output-Pulse Amplitude given by Simple Triode Circuit depends on Amplitude of Applied Pulses & on Valve Constants: Modified Circuit ensuring Constancy of Output Pulses].—E.M.I. Laboratories. (*Electronic Eng:g*, March 1945, Vol. 17, No. 205, p. 438.)

2173. Microsecond Pulse Generator [Reduction of Deionisation Time of Thyratrons].—Kiernan. (*See* 2233.)

2174. Filter Design for Grid-Controlled Rectifiers [Gas Triodes (Thyratrons): taking into account the Variations in Harmonic Content with Conduction Angle, which renders Unsuitable the Usual Filter-Design Equations for High-Vacuum or Gas-Diode Rectifiers].—H. A. Thomas. (*Electronics*, Sept. 1944, Vol. 17, No. 9, pp. 142-145.)

2175. A Compilation of Transducer Formulae Relations between Pi-Section Elements, T-Section Elements, Open-Circuit Impedances, Short-Circuit Impedances, Iterative & Image Parameters and Others, are Tabulated in All Possible Combinations so that Any Set can be found from Any Other Set].—W. R. MacLean. (*Communications*, Nov. 1944, Vol. 24, No. 11, pp. 58..66.)

2176. Coupled Circuit Design [Notes from "Radio Engineering II," a Course developed for E.S.M.W.T. Programme (2025 of June)].—J. E. Maynard. (*Communications*, Jan. 1945, Vol. 25, No. 1, pp. 38..43 and 68, 74, 92.) With special attention to discriminator circuits and their analysis.

2177. Determination of Resonance-Curve Maxima for a Symmetric Homogeneous Recurrent Circuit [by the Method dealt with in 1768 of June].—P. L. Kalantarov & L. A. Zeitlin. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URSS*, 30th Sept. 1944, Vol. 44, No. 9, pp. 369–371: in English.)

2178. Resistive Attenuator, Pad and Network Theory and Design [with Tabulated Functions of a Real Variable over the Range 0.01 to 150.0 db]: Parts I, II, and III.—P. B. Wright. (*Communications*, Aug. & Oct. 1944, Vol. 24, Nos. 8 & 10, pp. 49..56 and 70..78: pp. 62..76: Jan. 1945, Vol. 25, No. 1, pp. 50..60 and 72, 73, 82..89.) To be concluded by one more instalment.

2179. Valve Vectors: Relationship between Input and Output A.C. Voltages and Currents and the D.C. Supply.—K. R. Sturley. (*Wireless World*, May 1945, Vol. 51, No. 5, pp. 140–141.)

Attempts made by various writers to clear up the student's mental picture of this vector relationship "have not, in the author's opinion, proved entirely successful because they appear either to violate Ohm's law or to ignore the d.c. conditions in the output circuit. . . This short article is offered as a solution to the impasse . . ."

TRANSMISSION

2180. Papers on Velocity-modulated and Other U.H.F. Valves.—Warnecke, Bernier & others. (*See* 2214/9.)

2181. Power Supply for U.H.F. Velocity-Modulated Tubes [3000 Mc/s Klystron: for Continuous Operation for 4–6 Hours].—I. Eachus, Jr. (*Communications*, Dec. 1944, Vol. 24, No. 12, pp. 62 and 97, 99: Jan. 1945, Vol. 25, No. 1, p. 96.)

2182. ENERGY DISTRIBUTION IN THE SPECTRUM OF A FREQUENCY-MODULATED WAVE: Part I.—A. S. Gladwin. (*Phil. Mag.*, Dec. 1944, Vol. 35, No. 251, pp. 787–802.)

Author's summary:—"A method is derived of calculating the distribution of energy in the frequency spectrum of a frequency-modulated wave when the distribution of energy in the frequency spectrum of the modulating wave is known, and the modulating wave consists of a very large number of sinusoidal components of unrelated frequencies and small amplitudes [the validity of this assumption will be examined more closely in Part II].

"The spectra for two particular cases of frequency modulation by telephonic signals are calculated." The final paragraphs deal with a comparison of the relative sideband energy distribution for a f.m. wave with that for an a.m. wave of the same unmodulated carrier power.

2183. FREQUENCY AND PHASE MODULATION [Letter prompted by "Unfortunate Statements" in Hund's Letter, 39 of January: *see* also 1451 of May].—D. L. Jaffe & D. Pollack. (*Proc. I.R.E.*, March 1945, Vol. 33, No. 3, pp. 200–201.)

"It is unfortunate that few people have attempted to arrive at the properties of modulated waves through the use of vectors and words . . ." "We cannot emphasise this point—phase and frequency are interdependent—strongly enough. Many writers, Dr. Hund is among them, have strayed because, while they surely know that phase and frequency are knotted solidly together, they sometimes ignore this principle . . ." Early writers "gave different names, frequency and phase modulation, to two types of modulation, identical except for the frequency response of the modulating system. In f.m., the frequency excursion is independent of the frequency of the modulating wave; in p.m., the frequency excursion is directly proportional to the modulating frequency. This is the sole distinction between the terms as they are classically used . . . Present usage is fortunately tending to ignore these classical distinctions between f.m. and p.m. This is because the most widely used angular-velocity system, the Armstrong system, is neither classical f.m. nor classical p.m. . . . For low notes the frequency deviation is independent of modulating frequency —classical f.m.—while for high notes the frequency deviation is directly proportional to modulating frequency—classical p.m." Thus f.m. is now coming to be used, rightly, for any type of angular-velocity modulation.

2184. PULSE-TIME MODULATION.—Labin. (*See* 2354.)

2185. A NOTE ON DIODE MODULATION.—A. D. Bailey & G. H. Fett.—(*Proc. I.R.E.*, April 1945, Vol. 33, No. 4, pp. 254–256.)

A summary was dealt with in 1743 of June. "While the applications of diode modulation are not as numerous as other methods of producing amplitude modulation, there are certain advantages in its use in certain types of carrier telephone equipment and in instruction."

2186. AUTOMATIC AMPLITUDE CONTROL FOR VARIABLE-FREQUENCY OSCILLATORS.—M. Lévy, (*Electronics*, Sept. 1944, Vol. 17, No. 9. pp. 252..265.) From the paper dealt with in 3123 of 1944.

2187. INTERMITTENT BEHAVIOUR IN OSCILLATORS [Intermittent Oscillation, Motor-Boating, Squegging].—W. A. Edson. (*Bell S. Tech. Journ.*, Jan. 1945, Vol. 24, No. 1, pp. 1–22.)

See 3429 of 1944. The following sections are included:—Criterion of self-modulation: analogy of the oscillator to the feedback amplifier: analysis of an oscillator having automatic output control: analysis of the Hartley oscillator: the lamp-stabilised oscillator: the varistor-stabilised oscillator: negative feedback in oscillators: design of a controlled oscillator [for 1 Mc/s]: auxiliary control of thermally limited oscillators: a self-modulated oscillator.

2188. THE PRINCIPLES AND DESIGN OF VALVE OSCILLATORS: PART I—SEPARATION OF FUNCTIONS: PART II—FREQUENCY STABILITY: PART III—THE HETERODYNE OSCILLATOR.—A. C. Lynch & J. R. Tillman. (*Electronic Eng:g*, Feb., March, & April 1945, Vol. 17, Nos. 204/6, pp. 382–383, 414–416, & 465–469: Corrections p. 469.) From the P.O. Research Station.

2189. ARMY SET TYPE 76: CRYSTAL CONTROL OF OPERATION BETWEEN 2 AND 12 Mc/s ON PRE-SELECTED SPOT FREQUENCIES [primarily for Commando Formations: "Stark Simplicity & Ruggedness"].—(*Wireless World*, May 1945, Vol. 51, No. 5, pp. 137–139.)

2190. A GERMAN KEY [captured in Italy: Several Good Points, including Concave Knob, Plastic Dust-Cover, & Rubber "Pimples" to prevent Slipping].—(*QST*, Jan. 1945, Vol. 29, No. 1, p. 18.)

RECEPTION

2191. JUSTIFYING [the Use of the Term] "STATIC".—Roddam. (*See* 2151.)

2192. RADIO SPECTROSCOPY: WHAT IT IS, AND HOW IT WORKS [and Its Many Possible Applications: Easily Constructed from Basis of Communications Receiver & C.R. Oscilloscope: More Advanced (Purely Electronic) Equipment embodying Ganging Oscillator (with Modulation by Saw-Tooth or Pyramid Wave)].—T. Roddam. (*Wireless World*, May 1945, Vol. 51, No. 5, pp. 145–148.)

"The radio spectroscope seems to have made its first public appearance in 1938" [*cf.* Wallace, "Panoramic Reception", 3975 & 4386 of 1938; 3385 & 3888 of 1940; 1088 of 1941; 1702 of 1942: and *cf.* also Hull, "Etherscope", 2556 of 1944].

2193. CORRESPONDENCE ON BELL'S "TRANSIENT RESPONSE IN FREQUENCY MODULATION" [2514 of 1944: Some Corrections].—P. K. Chatterjea: H. E. Curtis: D. A. Bell. (*Phil. Mag.*, Dec. 1944, Vol. 35, No. 251, pp. 851–853.)

2194. DISCUSSION ON THE DESIGN OF BROADCAST AND TELEVISION RECEIVERS FOR THE POST-WAR MARKET [L. H. Bedford & others].—I.E.E. Radio Section. (*Elec. Review*, 4th May 1945, Vol. 136, No. 3519, p. 661: *Electrician*, 4th May 1945, Vol. 134, No. 3492, p. 405: summaries only.)

2195. Mathematical Analysis of Random Noise Part III—Statistical Properties of Random Noise Currents: Part IV—Noise through Non-Linear Devices.—Rice. (*See* 2168/9.)

2196. More about "Scale Distortion" and Visual Analogies.—"Cathode Ray": Stevenson. (*See* 2244.)

2197. Oscillator-Circuit Calculations [Superheterodyne Tracking Calculations described in Recent Articles cannot be evaluated easily on Slide-Rule: Two Simple Empirical Formulæ giving Results accurate to 10% (and Reasons why This is Adequate)].—H. P. Staunton. (*Wireless World*, May 1945, Vol. 51, No. 5, pp. 149–150.)

2198. A Volume Limiter for Leased-Line Service [to prevent Crosstalk due to Excessive Current: a Hybrid-Coil Arrangement embodying Thermistor & Tungsten Lamps, developed primarily for Leased Lines to Radio Receivers used in Aircraft/Ground Communication].—J. A. Weller. (*Bell Lab. Record*, March 1945, Vol. 23, No. 3, pp. 73–75.)

2199. On the Curves of Longitudinal Magnetisation of a Ferromagnetic Wire traversed by a Continuous Current.—Gorelik, Goronina, & Joukova. (*See* 2322.)

2200. A Dual-Input Receiver for WERS Local Controls: Constant District-Control Monitoring with a Resistance-Coupled Superhet.—F. Craven. (*QST*, Jan. 1945, Vol. 29, No. 1, pp. 16–18.)

To avoid the extravagance and difficulties of two receivers and operators. One input is tuned permanently to the district-control frequency (for "shut-down" orders, etc.) while the other is operated as usual for local-net control.

2201. Pubradio [Present Use of Ordinary Domestic Sets leads to Breakdowns & Bad Publicity for the Maker: Suggestions for "Pub" Model with Special Features].—"T. Buvant." (*Wireless World*, May 1945, Vol. 51, No. 5, p. 149.)

2202. Sets for Export [Letter from New Delhi supporting Hallows' and "Diallist's" Views on Post-War Broadcast Receivers (787 of March): India "virtually a Lost Market" as regards Pre-War British Receivers—Three Main Mistakes: Recommendations].—H. K. L. Arora. (*Wireless World*, May 1945, Vol. 51, No. 5, p. 149.)

2203. Developing a General-Purpose Commercial Aircraft Receiver [with Eighteen Different Functions].—C. A. Harvey. (*Communications*, Oct. 1944, Vol. 24, No. 10, pp. 48..54 and 76, 88.)

Namely, to receive on three variable bands, on fourteen fixed frequencies, and to operate with a loop aerial and supplementary amplifier when desired. From Harvey-Wells Communications Inc.

2204. Dust-Free Electronic Equipment [Time has now Come when More Attention should be paid to Protection from Dirt: Replacement of Usual Back Panel of Broadcast Receiver by a Filter: etc.].—C. G. Vokes. (*Electronic. Eng:g*, March 1945, Vol. 17, No. 205, pp. 413 and 416.) From Messrs. Vokes, Ltd., Guildford.

AERIALS AND AERIAL SYSTEMS

2205. On the Theorem of Reciprocity for Hertzian Waves.—Gutton & Ortusi. (*See* 2153.)

2206. The Radial Field in a Spherical Electromagnetic Wave [Sequel to Editorial dealt with in 1802 of June].—G.W.O.H. (*Wireless Engineer*, May 1945, Vol. 22, No. 260, pp. 209–211.)

2207. Experimentally Determined Impedance Characteristics of Cylindrical Aerials.—G. H. Brown & O. M. Woodward, Jr. (*Proc. I.R.E.*, April 1945, Vol. 33, No. 4, pp. 257–262.)

Author's summary:—"Measurements of resistance and reactance of cylindrical antennas operating against ground have been made, with a wide variation of both antenna length and diameter [both expressed in electrical degrees: thus "antenna length" A (degrees) = $360a/\lambda$]. These data are displayed by means of a series of graphs. The maximum values of resistance encountered are displayed. The 'shortening effect' near the quarter-wave resonance point is also shown.

"Terminal conditions, such as capacitance of the base of the antenna to ground, are briefly considered, and a series of measurements shows the wide variation in impedance for varying terminal conditions. Measurements made in the course of the investigation show that the impedance of the antenna is independent of whether the top of the radiator is open or closed [contrary to suggestions by other workers: *cf.* Brillouin, 2899 of 1944]. The measured impedance data are also directly applicable to the case of a centre-fed dipole." The measurements were carried out on 60 and 540 Mc/s.

2208. Rebuilding Broadcast Directional-Antenna Systems [without Interruption of Service: Experience at WMBG, Richmond, Virginia].—W. H. Wood. (*Communications*, Oct. 1944, Vol. 24, No. 10, pp. 36–38 and 76.)

2209. Broadcast Antenna and Arrays: Calculation of Radiation Patterns.—W. Pritchett. (*Communications*, Aug. 1944, Vol. 24, No. 8, pp. 42..48.) Part I of the paper dealt with in 1803 of June.

2210. Calculator for Directive Arrays [Supplement to Paper dealt with in 1470 of May: Reply to Enquiries regarding the Additional Scales necessary to provide Information on the Vertical Pattern: and a Correction to a Typographical Error].—J. G. Rountree. (*Proc. I.R.E.*, March 1945, Vol. 33, No. 3, p. 202.)

2211. Voltage/Decibels Conversion Device [Two-Piece Transparent-Plastic Device for Interpretation of Aerial-Radiation Patterns, etc.].—E. Dyke. (*Electronics*, Sept. 1944, Vol. 17, No. 9, p. 146.)

2212. Aerial-Coupling Circuits: a Series of Data Sheets [and Discussions] Part I—Introduction: Part II—Series-Capacitance Aerial Coupling: Part III—Shunt-Capacitance Aerial Coupling.—S. W. Amos. (*Electronic Eng:g*, Feb., March & April 1945, Vol. 17, Nos. 204/206, pp. 373–375, 417–420, & 461–464.)

2213. Graphical Determination of the Sag of Over-Head Wires [of Given Cross-Section, as a Function of Span & Temperature].—H. Wettstein. (*Bull. Assoc. Suisse des Élec.*, 31st May 1944, Vol. 35, No. 11, pp. 294–297: in German.)

VALVES AND THERMIONICS

2214. Contribution to the Theory of Velocity-Modulation Valves and Other Transit-Time Valves.—R. Warnecke & J. Bernier. (*Rev. Gén. de l'Élec.*, Jan. & Feb. 1942, Vol. 51, pp. 43–58 & 117–139: for Errata *see* Vol. 52, 1943, p. 320, and end of this abstract.)

This is the paper referred to in 3337 of 1943. The results obtained complete and make more precise those given, in a deliberately simplified form, by the first writer in his study of the Hahn–Metcalf velocity-modulated valves and the Varian klystrons, in the same journal, June 1941, Vol. 49, p. 381 onwards. Part I gives the mathematical analysis of the kinetic bunching of the electrons in a straight beam, initially homogeneous but then velocity-modulated by a limited u.h.f. field acting parallel to its axis (between electrodes A, B in Fig. 1), and then allowed to drift in a field-free space. Part II deals with the exchange of energy between the density-modulated beam and a limited u.h.f. energy-collecting field at the end of the drift space (between electrodes M, N in Fig. 1); here, since calculation will not give a general solution which is both simple and accurate, a graphical method of treatment is developed, the results being confirmed in two important special cases by calculation.

Among the conclusions reached are the following: If only the internal electronic phenomena are considered, it is not necessary to have h_1 (the distance between the modulating electrodes A, B) very small in order to produce a strong bunching effect in the drift tube. But a footnote points out that a small value of h_1 is desirable from the point of view of the modulating power; and also that in the complete problem h_1 acts in general in an important way on the constants of the modulation circuit; these external considerations have to be taken into account.

On the other hand, the length h_2 between the energy-collecting electrodes M, N may have a considerable influence on the conversion efficiency: *see* Part II, section III, where the efficiencies for a "narrow" and a "wide" field are calculated. The results of Part II show the possibility of the conception of u.h.f. generators using only a single limited field: a footnote mentions that this agrees with the independent results of Müller & Rostas, 406 P 1010 of 1942.

It is to be noted that the diagram Fig. 27 is incorrect. The correct diagram may be found in Fig. 8, of the paper by Bernier, Guénard, & Lortie dealt with in 2219, below.

2215. Grouping and Degrouping in the Interior of a Cathode Ray injected into a Space free from External Fields, after having been Velocity-Modulated: Parts I and II.—R. Warnecke, J. Bernier, & P. Guénard. (*Journ. de Phys. et le Radium*, May & June 1943, Vol. 4, Nos. 5 & 6: an 18-page paper.)

The theory given in 2214, above, and completed in Part I of the present paper, owes its interest to the simplicity of its bases and to its clear physical representation: it is, however, obviously insufficient to account for experimental facts since it neglects all space-charge effects and, particularly, those which result from the formation of "electron packets" in the beam. To obtain a more correct image of the phenomenon, it should at least be completed or corrected: this is done in the second part of the present paper.

"After having calculated by successive approximations the forces exerted on the electrons and the consecutive modifications of their motion, we determine, for a certain number of practically important cases, the amplitude and the phase of the first harmonics of the wave of conduction current transported by the beam." Part I deals with the kinetic bunching of electrons in a beam after velocity modulation, and the optimum bunching: the first section considers a sinusoidal modulation, the second an improved bunching due to non-sinusoidal modulation ("object of an important work by Borgnis & Ledinegg": 2109 of 1943): the remainder deal with the efficiency of conversion as various factors are changed. Part II, as already mentioned, is devoted to the study of the effects of space charge: sinusoidal modulation is assumed.

2216. On the Efficiency of Electronic Valves with Velocity Modulation and Bunching by Drift.—R. Warnecke. (*Comptes Rendus* [Paris]), 27th Dec. 1943, Vol. 217, pp. 679–680.)

"In the theories published before the one developed by myself and Bernier at the beginning of 1942 (2214, above), account was taken only very incompletely of the angles of transit of the electrons across the organs serving as 'buncher' of electrons and 'collector' of h.f. energy. Although the study in question could only be carried through with the help of hypotheses to some extent restrictive, two of the results to which it leads are extremely important and ought to be noted: (a) when the angle of transit of the electrons in the collector, $\theta_2 = \omega h_2/v_0$, has an appreciable value, the optimum value of the efficiency of energy exchange, η, between the velocity-modulated beam and the h.f. field of the collector is obtained for a value of U_2/U_0 [U_0 is the accelerating voltage of the electrons corresponding to the velocity $v_0 = \sqrt{(2e/m)U_0}$] which is greater than unity, while smaller than that corresponding to a reflection of the electrons in the field of the collector. (b) In spite of this, the efficiency in question cannot exceed the value 0.58, the value found in the most favourable case when $\theta_2 = 0$ and $U_2/U_0 = 1$."

Discussion of the theory in question brings out the possibility that in certain cases the efficiencies obtained will be well below those predicted by the simple theory based on the hypothesis that $\theta_2 = 0$, and also indicates the important influence of the spacing h_2 of the collector electrodes (*cf.* Warnecke & Bernier, *loc. cit.* above).

2217. On Some New Conceptions in the Domains of the Physics and Technique of Transmitting Valves for Very High Frequencies [Survey, with 77 Literature References].—R. Warnecke. (*Ann. de la Radiodiffusion*, Jan. 1944, Vol. 4, No. 1: a 37-page paper.)

Chapter I: Effects of electron inertia in the interelectrode spaces: (a) induction current circulating in the external circuits of a vacuum tube as a result of the electron movement in the interelectrode spaces: (b) exchange of energy by induction between an oscillatory circuit connected to a system of electrodes and an electron beam traversing that system: (c) dynamic characteristics of a diode at ultra-high frequencies: (d) principal effects of the current induced in valves with space-charge grids: (e) ultilisation of the effects of induction due to electron motion for the generation of oscillations (valves with non-modulated beam and uniform h.f. field—the "wide-field" generator of Müller & Rostas [*see* end of 2214, above]): valves with non-modulated beam and h.f. field whose intensity depends on the abscissa—"Monotron" of Stanford University: valves with beam density-modulated by direct control of the space charge, and a uniform h.f. field—Haeff's "inductive-output" valve: velocity-modulated valves): (f) other electron-inertia effects: magnetrons and "spatial oscillation" valves (B-K).

Chapter II: Replacement of the usual oscillatory circuits by new systems: (a) quasi-stationary and non-quasi-stationary circuits: (b) transmission-line sections: (c) oscillatory pot-circuits and the Kolster spheres: (d) electromagnetic cavities and guides (and their "lumped-constants" equivalent circuits: works by Webster [968 of 1940], Clavier & Leboiteux [ref. "63"], and Bernier, Guérnard, & Lortie [2219, below] are referred to here): association of a cavity with the electrodes of a valve: cavities suitable for association with a density-modulated beam: "circuit limits" of valves using cavities as oscillatory circuits: theoretical bases of the direct study of the coupling of a cavity to a beam.

2218. Electronic Generation of Electromagnetic Waves in a Hollow Resonator.—R. Warnecke & J. Bernier. (*Comptes Rendus* [Paris], 10th Jan. 1944, Vol. 218, pp. 73–75.)

"Following a method employed in quantum theory, applied already by Condon (4240 of 1940 [for later work *see* 1319 of 1941]) and recently taken up again by one of the writers (Bernier, 2155, above) the phenomenon of the maintenance of electromagnetic oscillations in a hollow resonator by a beam of electrons may be analysed directly, starting from Maxwell's equations . . ."

The final equation (6), $\ddot{q}_\nu + (\omega_\nu/S_\nu)\dot{q}_\nu + \omega_\nu^2 q_\nu = 4\pi c \iiint_{\text{volume of beam}} \rho\vec{v} \,.\, a_\nu d\tau$, where S_ν is the overvoltage coefficient of the cavity, corresponding to the oscillation of order ν, "formally resolves the problem of the forced oscillations of a cavity excited by an electron beam and justifies, by its form, the simple image of the induced current which is habitually used (Warnecke, 1865 of 1943, where the volume number should be "11") to represent the excitation of the cavity by the electrons in motion. Made more precise and explicit, it can serve as a basis for the direct study of electronic valves containing cavities whose fields react with the electrons. In such a study it is no longer necessary to make use of the image of localised-constants circuits equivalent to the cavities (Bernier, *loc. cit.*), although this image remains a very convenient intermediary for most of the theoretical problems."

2219. Theoretical Study of the Auto-Oscillator Klystron.—J. Bernier, P. Guénard, & Marthe Lortie. (*Bull. de la Soc. Franç. des Élec.*, Feb. 1944, No. 34: a 15-page paper.)

Using the first writer's derivation of an equivalent scheme for a resonant cavity, 2155, above, "The following results are obtained from the simple theory here developed:—(i) the particular form of the curves of modulation by variation of the current i_0 or the voltage V_0. In the case of modulation by i_0, this leads either to a judicious choice of the control grid or to the adoption of a special method of modulation [section VIII: Modulation by square wave signals of constant amplitude but varying length or spacing, especially suitable for multiplex working: "gives excellent results" when applied to the klystron].

"(ii) The possibility of obtaining, at any rate in the case of small powers, a high stability of frequency. (iii) The interest presented by klystrons with cavities having variable wavelength, which permit on the one hand the variation of the length of the wave obtained and, on the other, the attainment of the adjustment corresponding to the aim desired [*i.e.* the obtaining of maximum efficiency: section XIII]. This simple theory may be considered as a good approximation for klystrons working with a small current and a high voltage. We have outlined, in conclusion [section XV], the way in which this theory should be modified in other cases." A final footnote mentions some outputs obtained with valves developed in the T.S.F. Company's laboratories.

2220. Disc-Seal Tubes.—E. D. McArthur. (*Electronics*, Feb. 1945, Vol. 18, No. 2, pp. 98–102.)

See also 1479 of May. The section headings include:—Union of tube and tank: controllable feedback: electromagnetic shielding provides heat radiation: design requirements: manufacturing tolerances.

2221. A "Starlight" Tube [with Application to Astronomy, Electro-Chemical Analysis of Steel, Detection of Impurities in Explosives, etc.: Unorthodox Design].—W. A. Hayes. (*Science*, 23rd Feb. 1945, Vol. 101, No. 2617, Supp. p. 10.) *See* 1486 of May. A Westinghouse development.

2222. Space-Charge Effects Between a Positive Grid and Anode of a Beam Tetrode: Part II.—G. B. Walker. (*Wireless Engineer*, May 1945, Vol. 22, No. 260, pp. 212–222: to be concluded.)

Part I, dealt with in 1807 of June, investigated the formation of a potential minimum between screen and anode for the particular case that all electrons are just able to cross to the anode: this occurs when the potential minimum has the value V_T, at which electrons receiving the greatest deflection on crossing the screen lose their forward velocity component. "This is perhaps the most important case in the normal usage of the valve, for it determines the anode voltage below which a marked drop in anode current occurs; but if we are properly to understand the behaviour of space charge in the valve, and other effects arising therefrom, it is necessary to develop the analysis to include all the possible potential distributions which can arise."

The present part therefore considers the potential minimum for the case where its value $V_m > V_T$ (the case of the virtual potential minimum follows directly from the result) and the more complex problem when $V_m < V_T$. Curves showing the screen/anode potential distribution for different values of the potential minimum are given and discussed, and the last section deals with "the instability phenomenon," finding an explanation for the discontinuity sometimes observed at the knee of the I_a/V_a curve of a beam tetrode when the curve is traced on a c.r. oscillograph.

2223. MATHEMATICAL ANALYSIS OF RANDOM NOISE: PART III—STATISTICAL PROPERTIES OF RANDOM NOISE CURRENTS: PART IV—NOISE THROUGH NON-LINEAR DEVICES.—Rice. (*See* 2168/9.)

2224. PRACTICAL APPLICATIONS OF SIMPLE MATHEMATICS: PART IX—AMPLIFIER - TUBE OPERATING CONDITIONS IN RELATION TO CIRCUIT VALUES [in Audio-Amplifier Design: Finding the Operating Point (including the "Bias-Line" Method)].—E. M. Noll. (*QST*, Jan. 1945, Vol. 29, No. 1, pp. 42–43.) *See* also 2225, below.

2225. DETERMINATION OF THE QUIESCENT OPERATING POINT OF AMPLIFIERS EMPLOYING CATHODE BIAS [Objections to Usual Cut-&-Try Method: the "Grid-Bias-Line Method" and Its Convenience].—J. N. Thurston: Saylor. (*Proc. I.R.E.*, Feb. 1945, Vol. 33, No. 2, pp. 135–136.)

2226. CONDENSERS IN SERIES-HEATER CIRCUITS [Six Advantages & Four Disadvantages of the Series Capacitor compared with the Series Resistor].—G. S. Light. (*Electronic Eng:g*, April 1945, Vol. 17, No. 206, pp. 454–455.)

2227. EQUIVALENT-PLATE-CIRCUIT THEOREM [Long Letter on the Preisman and Stockman Letters dealt with in 819 of March & Back Reference].—H. J. Reich. (*Proc. I.R.E.*, Feb. 1945, Vol. 33, No. 2, pp. 136–138.)

2228. EXTERNAL-ANODE TRIODES: CHARACTERISTICS AND APPLICATIONS [Dissipations ranging from 1.2 to 250 kW: for Radio Transmitters, H.F. Heating Technique, etc.].—A. J. Ebel. (*Communications*, Jan. 1945, Vol. 25, No. 1, pp. 44, 46, and 104, 105.) Part I of a four-part paper.

2229. DEVELOPMENT OF ELECTRONIC TUBES [Survey].—I. E. Mouromtseff. (*Proc. I.R.E.*, April 1945, Vol. 33, No. 4, pp. 223–233.)

"The main types of modern electronic tubes are briefly surveyed in this paper, together with their general uses. Tubes are classified according to electronic mechanism, and their origin is traced to three independent sources and several independent lines of development. . . ."

2230. A PENTODE FOR THE BATTLE FRONT IN THREE DAYS [Special German Pentode needed for Repeaters in Abandoned Strategic Telephone Communications System successfully Reproduced].—J. O. McNally & others. (*Bell Lab. Record*, March 1945, Vol. 23, No. 3, pp. 78–79.)

2231. A NOTE ON GRID CONTROL CHARACTERISTICS OF GAS-FILLED RELAYS [and the Two Classes of Behaviour of Commercially Available Types].—D. W. Gillings. (*Electronic Eng:g*, Feb. 1945, Vol. 17, No. 204, p. 372.)

2232. GAS-FILLED TUBES AS PULSE GENERATORS [Part of Paper read before Institution of Electronics, March 1945].—F. J. G. van den Bosch. (*Electronic Eng:g*, April 1945, Vol. 17, No. 206, pp. 474–476.)

"In conclusion, three distinct possibilities have been found during the examination of the design requirements for a gas-discharge tube made with the specific purpose of generating a perfect square wave-form coupled with absence of striking time [these three designs are the "neotron type A", "neotron type B, and the "pulsatron": Figs. 2, 3 & 4]. There is no doubt that these may lead to other types of tube, but even they will be influenced by the three different methods we have introduced, either jointly or individually. . . ." Being gas-filled tubes, it must be realised that their frequency response is limited.

2233. MICROSECOND PULSE GENERATOR: RESULTS OF INVESTIGATION TO REDUCE THE DEIONISATION TIME OF [Standard] THYRATRONS USED IN A CIRCUIT PROVIDING PULSE-TYPE SIGNALS OF VARIABLE DURATION AT HIGH REPETITION RATES [up to 400 per Second].—E. F. Kiernan. (*Electronics*, Sept. 1944, Vol. 17, No. 9, p. 141.)

2234. PAPER ON THE PRECALCULATION OF CARBONISED THORIATED TUNGSTEN AND PURE TUNGSTEN FILAMENTS [Summary of Rochester Fall Meeting Paper].—H. J. Dailey. (*Communications*, Dec. 1944, Vol. 24, No. 12, pp. 40–41.)

DIRECTIONAL WIRELESS

2235. "INSTRUMENT FLYING AND RADIO NAVIGATION" [Book Review].—H. L. Redfield. (*Proc. I.R.E.*, Jan. 1945, Vol. 33, No. 1, pp. 68–69.) "There has been a definite need for a book of this kind for several years. . . ."

2236. DEVELOPING A GENERAL-PURPOSE COMMERCIAL AIRCRAFT RECEIVER [with Eighteen Different Functions].—Harvey. (*See* 2203.)

2237. THE C.A.A. INSTRUMENT-LANDING SYSTEM: PART I [Theoretical Aspects & Runway Localiser Circuits]: PART II [Technical Details, and Sections on Effects of Hills & Buildings, etc.].—P. Caporale. (*Electronics*, Feb. 1945, Vol. 18, No. 2, pp. 116–124: March, No. 3, pp. 128–135.)

"First complete technical details of blind-landing system officially adopted for civil aviation in U.S. Installation programme is under way and will be accelerated after the war. . . ."

2238. GRAPHICAL SOLUTION FOR C.A.A. COURSE ALIGNMENT [for the Four Courses of Radio-Range Stations employing Modified Adcock Aerial System].—G. L. Brewer. (*Communications*, Nov. 1944, Vol. 24, No. 11, pp. 38–40 and 81: Dec. 1944, No. 12, pp. 52–53 and 56.)

2239. PRE-FLIGHT INSTALLATION TESTS OF AUTOMATIC RADIO COMPASSES.—C. W. McKee. (*Communications*, Aug. 1944, Vol. 24, No. 8, pp. 33–35 and 64..69.) From the Supervisor of Aircraft Radio, Eastern Air Lines, Inc.

2240. AERONAUTICAL COMMUNICATIONS IN THE POST-WAR ERA.—McM. Silver. (*Communications*, Jan. 1945, Vol. 25, No. 1, pp. 48, 76, and 90..92.)

ACOUSTICS AND AUDIO-FREQUENCIES

2241. A SMALL ROCHELLE-SALT MICROPHONE [in Spherical Housing of 4.8 cm. Diameter: Response very Uniform from 50 c/s to 10 kc/s: Sensitivity 1 mV/bar].—Telefunken. (*Zeitschr. V.D.I.*, 26th June 1943, Vol. 87, No. 25/26, p. 406: paragraph only.)

2242. A HIGH-GAIN A.C.–D.C. AUDIO AMPLIFIER: CONSTRUCTIONAL DETAILS OF A COMPACT MULTI-PURPOSE UNIT [for Crystal Microphone ("Radio Nurse" Application), etc.: Power Drain under 40 Watts].—P. S. Rand. (*QST*, Jan. 1945, Vol. 29, No. 1, pp. 32–33 and 84.)

2243. A HOME-MADE INTERCOMMUNICATING SYSTEM: USING JUNK-BOX PARTS IN A MULTIPLE-STATION CIRCUIT.—E. H. Hartnell. (*QST*, Jan. 1945, Vol. 29, No. 1, pp. 46–47.)

2244. MORE ABOUT "SCALE DISTORTION" AND VISUAL ANALOGIES [Reply to Stevenson's Article, 1839 of June].—"Cathode Ray": Stevenson. (*Electronic Eng:g*, March 1945, Vol. 17, No. 205, pp. 432 and 433.)

The conclusion reached is that "the size of the portrait (or the output from the loudspeaker) may be what we will, within reasonable limits, provided that the distance away is such that the image subtends the same angle at the eye (or the sound is of the same intensity at the ear) as the original. Any other distance results in a more or less out-of-balance effect, which in extreme cases it is no exaggeration to describe as distortion."

2245. A VOLUME LIMITER FOR LEASED-LINE SERVICE [to prevent Crosstalk due to Excessive Current].—Weller. (*See* 2198.)

2246. CERTAIN APPLICATIONS OF PHYSICAL PRINCIPLES TO THE PLAYING OF MUSICAL INSTRUMENTS.—W. F. G. Swann. (*Journ. Franklin Inst.*, Feb. 1945, Vol. 239, No. 2, pp. 79–85: to be contd.)

Continued from 1846 of June. Certain characteristics of the ear: the carrying power of stringed instruments (including a footnote giving C. Weyl's conclusions from his own investigations).

2247. HEARING AIDS [Letter prompted by Questions in House of Lords and Subsequent Reports & Correspondence: the True Situation, including an Account of the Four Technical Committees & Their Functions].—A. Poliakoff. (*Wireless World*, May 1945, Vol. 51, No. 5, p. 150.) From the Chairman, Technical Committee, H.A.M.A. (Hearing Aid Manufacturers' Association).

2248. NEGATIVE FEEDBACK IN HEARING-AID AMPLIFIERS.—F. E. Planer & E. A. Marland. (*Electronic Eng:g*, April 1945, Vol. 17, No. 206, pp. 450–453 and 455.)

Discussion leading up to a description of a frequency-corrected negative-feedback hearing aid designed by the writers. The amplifier "affords maximum possible gain over the whole of the frequency spectrum, when used for low sound intensities where there is little danger of exceeding the threshold of pain. As the sound intensity from the source is increased and the volume control is turned down, a gradual change is effected in the shape of the frequency curve, which finally approaches the conjugate of the individual hearing-loss curve. A simple control is provided, and use is made of negative feedback at the lower settings of this control."

2249. LOW-FREQUENCY AMPLIFICATION: PARTS IV, V, AND VI.—Sturley. (*See* 2165.)

2250. VOLTAGE/DECIBELS CONVERSION DEVICE [Two-Piece Transparent-Plastic Device].—Dyke. (*See* 2211.)

2251. A PRECISION METHOD FOR THE DETERMINATION OF THE VELOCITY OF SOUND IN AIR.—R. W. Leonard. (*Communications*, Aug. 1944, Vol. 24, No. 8, pp. 38 and 88, 89: illustrated summary.) Another summary was dealt with in 96 of January.

2252. NOTE ON THE LATEST FORM OF "ECHOLOCATION": SUPERSONIC METHOD OF MEASURING THE THICKNESS OF METAL PLATES AND TESTING FOR FLAWS.—Firestone. (*See* 2469.)

2253. THE "SONIGAGE": SUPERSONIC SOUND MEASUREMENT OF METAL THICKNESS.—Erwin. (*See* 2470/1.)

PHOTOTELEGRAPHY AND TELEVISION

2254. TELEVISION COMMITTEE'S REPORT: ARE THEY FLOGGING A DEAD HORSE?—R. W. Hallows. (*Wireless World*, May 1945, Vol. 51, No. 5, pp. 130–132.)

The "almost dead horse" is 405-line television, which can never allow the proper close partnership with the cinema. Other objections to the Report include the selection of the witnesses (all "transmitters," not one "receiver"—*i.e.*, owner or would-be owner) and the acceptance of wrong reasons for the crawling, instead of galloping, into public favour in the years before the war: two very potent reasons were a dislike of the small screen and a doubt as to the entertainment value of the programmes [*cf.* Harmon, 1860 of June]: another was the fear of the cost of re-valving and re-tubing. For a "Monthly Commentary" *see* p. 129.

2255. SHOULD TELEVISION PAY ITS WAY? *and* HIGH FIDELITY SOUND [from Television Broadcasting Stations: Two Notes on the Television Committee's Report].—"Diallist." (*Wireless World*, May 1945, Vol. 51, No. 5, p. 156: p. 157.)

"I dislike the sharp distinction between sound-only and sound-and-vision broadcasting; I should like to see the two included under the one heading of broadcast entertainment": these sentiments influence both the Notes, the second of which also discusses the absence, from the Report, of all mention of frequency modulation.

2256. RADIO-RELAY-SYSTEMS DEVELOPMENT BY THE RADIO CORPORATION OF AMERICA [Historical: Present Status: Phase or Frequency Modulation preferred to Amplitude Modulation: Relay-System Signal/Noise Ratio Requirements: the Over-All Problem of Television Radio Relaying: Symbols & Formulæ: Summary of Calculations: Couplings between Directional Aerials: Band-Widths required: Guard Bands between Channels working in Same Direction & in Opposite Directions: Design of Television Tower: Probable Future Uses of Radio-Relay Systems].—C. W. Hansell. (*Proc. I.R.E.*, March 1945, Vol. 33, No. 3, pp. 156–168.)

2257. *QST* LOOKS AT TELEVISION—1944: THE "STATE OF THE ART" FROM AN AMATEUR VIEWPOINT [and Future Prospects for Commercial Television].—C. T. Read. (*QST*, Jan. 1945, Vol 29, No. 1, pp. 11–15 and 92, 94.)

The writer envisages television broadcasting taking place only for a few hours in the afternoon (mainly educational) and from 7 to 11 p.m. or perhaps midnight (entertainment). If, on the contrary, "we find that the 'viewies' run night and day without even time out to polish our glasses, we will have to admit that we grossly underestimated both the commercial possibilities of this new art and the ability of the American public to 'take it.'"

2258. A REPORT ON THE TECHNICAL PANEL SESSION AT THE TELEVISION BROADCASTERS' ASSOCIATION CONFERENCE.—M. A. Trainer: J. E. Keister: W. S. Lemmon. (*Communications*, Jan. 1945, Vol. 25, No. 1, pp. 34–35 and 75, 76.) Camera and picture-tube developments: satellite television stations: the relay and satellite problem: summaries only.

2259. TELEVISION AS SERVICE TO THE PUBLIC: *and* LOOKING AHEAD TO COLOUR AND U.H.F. TELEVISION: *also* TELEVISION NETWORKS.—E. W. Engstrom: P. C. Goldmark: R. F. Guy. (*Proc. I.R.E.*, March 1945, Vol. 33, No. 3, pp. 204–205: p. 205: pp. 205–206: summaries of recent Addresses.)

2260. A REPORT ON THE F.C.C. ALLOCATION HEARINGS ON TELEVISION: HIGH-LIGHTS OF STATEMENTS PRESENTED BY E. W. ENGSTROM, DR. P. C. GOLDMARK, AND G. L. BEERS.—L. Winner. (*Communications*, Nov. 1944, Vol. 24, No. 11, pp. 42, 44, and 78, 80.)

2261. SIGNAL-INTENSITY TESTS ON A MOUNTAIN TOP [Mt. Greylock (3505 Ft.) Measurements of Sound & Video Signals from Five Television Stations].—D. Phillips. (*Communications*, Dec. 1944, Vol. 24, No. 12, pp. 36, 38, and 88.) Extracts from a DuMont report presented to F.C.C. during the recent allocation hearings.

2262. SCANNING SYSTEMS FOR COLOUR TELEVISION [Critical Survey].—L. C. Jesty. (*Electronic Eng:g*, April 1945, Vol 17, No. 206, pp. 456–460.)

"Summing up, it appears that there is only one method of scanning a colour television picture which is practicable, in the light of present published knowledge and experience, bearing in mind the need for the use of electronic scanners at transmitter and receiver. The basic principle of this method is to scan each picture-frame successively in each of the three primary colours. This method is likely to suffer from colour fringing on fast-moving objects, but this price may be worth paying for the addition of colour . . . It is desirable to replace the colour-filter disc or drum, rotating in front of the cathode-ray tube in the receiver, with some more compact, preferably electronic device for producing the necessary colour-scanning sequence. This may impose certain limitations on the scanning sequences available. The commercial solution of these problems must be achieved if colour is to be ready for inclusion in an improved television system."

2263. COLOUR TELEVISION: DISCUSSION ON WAYS AND MEANS [Informal Discussion, introduced by L. C. Jesty].—I.E.E. Radio Section. (*Wireless World*, May 1945, Vol. 51, No. 5, pp. 154–155.) *See* also 2262 above, and *Electrician*, 30th March 1945, Vol. 134, No. 3487, p. 283.

2264. RADIO PROGRESS DURING 1944: TELEVISION AND FACSIMILE [Short Comments followed by Bibliographies]. — I.R.E. Committee. (*Proc. I.R.E.*, March 1945, Vol. 33, No. 3, pp. 147–151.)

2265. DISCUSSION ON THE DESIGN OF BROADCAST AND TELEVISION RECEIVERS FOR THE POST-WAR MARKET [L. H. Bedford & others].—I.E.E. Radio Section. (*Elect. Review*, 4th May 1945, Vol. 136, No. 3519, p. 661: *Electrician*, 4th May 1945, Vol. 134, No. 3492, p. 405: summaries only.)

2266. CATHODE-RAY TUBES: SPECIAL DESIGNS [for Television: Comparison between Direct-Viewing, Lens, & Schmidt Optical Systems: etc.].—J. R. Beers. (*Communications*, Nov. 1944, Vol. 24, No. 11, pp. 46, 48, and 80, 81.) For previous articles *see* 1867 & 1900 of June.

2267. SOME NOTES ON THE DESIGN OF ELECTRON GUNS [to give Reasonably High Currents

& High Current-Densities without the Sacrifices in Beam Current which are Normally Accepted in Cathode-Ray-Tube Guns].—A. L. Samuel. (*Proc. I.R.E.*, April 1945, Vol. 33, No. 4, pp. 233–240.)

Author's summary :—" A method is outlined for the design of electron guns, based on the simple theory first published by J. R. Pierce (4393 of 1940). This method assumes that the electrons are moving in a beam according to a known solution of the space-charge equation, and requires that electrodes exterior to the region of space charge be shaped so as to match the boundary conditions at the edge of the beam. An electrolytic-tank method is used to obtain solutions for cases which are not amenable to direct calculation. Attention is given to some of the complications ignored by the simple theory and to some of the practical difficulties which are encountered in constructing guns according to these principles. An experimental check on the theory is described, together with some information as to the actual current distribution in a beam produced by a gun based on this design procedure."

The writer concludes : " As mentioned earlier, there appears to be a practical limit to the beam perveance [defined as the ratio of the beam current in amperes to the 3/2 power of the voltage] which can be obtained with a point-focused beam of the simple type which has just been discussed. The gun shown in Fig. 19 was constructed in an effort to obtain a still higher perveance . . . "

The cathode surface was made in the form of an axially symmetric section of the surface of a toroid. With such designs a measured perveance up to 66×10^{-6} was obtained. " If still higher perveances are required, accelerating grids can be used without invalidating the fundamental correctness of the design method."

2268. Transient Response. H. E. Kallmann & R. E. Spencer : C. P. Singer. (*Proc. I.R.E.*, March 1945, Vol. 33, No. 3, pp. 169-195.)

" The criterion for the quality of a television amplifier is its transient response, but little is known about the factors which contribute to the steepness and shape of transients and about their deterioration in the passage through electrical filters. Such knowledge, including quantitative details, must form the basis of any efficient filter design.

" In this paper we have aimed at picturing the kinetics of transients in filters, *i.e.*, the sudden discharge of energy into condensers, through coils and resistances, and we have only as a second line of attack resorted to Fourier analysis and the resulting amplitude response of the filters. All curves shown are based on calculations, most equations being worked out with the aid of Heaviside calculus. The analysis involved some very intricate mathematical problems, for the solution of which we are much indebted to C. P. Singer. A survey of the mathematical procedure is given in Appendix I. Some of the curves for two amplifier stages and all curves for more stages have been obtained by numerical point-to-point integration and differentiation ; this process increases the possible error from 0.01 to about 0.02 (more, in a few particularly complex cases)."

Section I deals with the transient response of single filters, proceeding from the shunt-peaking and series-peaking coils to filters without and with *m*-derived section. Section II describes the deterioration of transients in cascades of equal or different, electrical or ideal, filter systems. Section III describes a family of ideal transitions of uniform stretch [the " stretch " modulus *s* gives the increase in the transition time each time the number of stages is doubled : *see* p. 177, l–h column], their even cases corresponding to ideal filters with flat time-response and steadily dropping amplitude response, and representing the ultimate shapes of transients in filter cascades. Section IV gives various procedures for synthesising well-shaped transient-response curves. Appendix II deals with the carrier-frequency analogues of the series- and shunt-peaking circuits.

2269. The L.F. Compensation of Multi-Stage Video-Frequency Amplifiers [Long Summary of Rochester Fall Meeting Paper].—M. J. Larsen. (*Communications*, Dec. 1944, Vol. 24, No.12, pp. 41–42.)

2270. The Mervyn Reactance-Alignment Comparator [for Television & Other Equipment].—Saw. (*See* 2282.)

2271. Comments on " A Note on Photocell Nomenclature " [1869 of June].—H. T. Stott : Sommer. (*Electronic Eng:g*, Feb. 1945, Vol. 17, No. 204, p. 390.) For a letter from A. S. Trask giving the practice in U.S.A. *see* March issue, No. 205, p. 426.

2272. Quantum Yield and Photoelectric Threshold of Cuprous Iodide.—J. Mattler. (*Comptes Rendus* [Paris], Nov. 1943, Vol. 217, p. 447 onwards.) Mentioned in *Review Scient. Instr.*, March 1945. For Mattler's work on CuI photocathodes for ultra-violet sensitivity *see* 2446 & 2919 of 1944.

2273. The Effect of Electric Field on the Depolarisation of Light Scattering in Colloidal Systems [Quantitative Study].—Narayana Rao. (*Current Science* [Bangalore], Feb. 1945, Vol. 14, No. 2, pp. 43–44.)

2274. Electro-Optical Properties of Colloids : II [Development of a Relaxation Theory].—B. W. Sakmann. (*Journ. Opt. Soc. Am.*, Jan. 1945, Vol. 35, No. 1, pp. 66–85.) The full paper, summaries of which were dealt with in 1870 of June and back reference. For I *see* 3044 of 1942.

MEASUREMENTS AND STANDARDS

2275. Paper on the Measurement of Dielectric Properties at Frequencies 50–1000 Mc/s by the Use of Re-entrant Cylindrical Cavities (tan δ measured within 0.00005, ϵ' within $\pm$ 1%, in Routine Measurements : Summary of Rochester Fall Meeting Paper].—T. W. Dakin. (*Communications*, Dec. 1944, Vol. 24, No. 12, pp. 46 and 48.) *See* also 2276, below.

2276. A Resonant-Cavity Method for Measuring Dielectric Properties at Ultra-High Frequencies.—C. N. Works, T. W.

Dakin, & F. W. Boggs. (*Proc. I.R.E.*, April 1945, Vol. 33, No. 4, pp. 245-254.)

See Dakin, 2275, above. " The chief advantages of this method are that the operation of the apparatus is simple, very rapid, and similar to the susceptance-variation technique [Hartshorn & Ward, 351 of 1937] now used at lower radio frequencies. Also, the involved computations usually found in other methods operative in this frequency range are eliminated." Because of the high Q values (> 2000) the method is much more sensitive to low-power-factor samples than any conventional coil-&-capacitor resonant circuit. The frequency range mentioned is covered by several cavities each with a ratio of about 1.5 : 1. Fine adjustment is by a differential-screw assembly.

2277. ULTRA-HIGH-FREQUENCY OSCILLATOR [100–500 Mc/s Power Source for Laboratory Measurements, with " Butterfly " as Frequency-Determining Element (Single-Knob Simultaneous Variation of Inductance & Capacitance) : Type 857–A].—General Radio (*Review Scient. Instr.*, Feb. 1945, Vol. 16, No. 2, p. 44.) For the " Butterfly " elements *see* 1411 of May.

2278. AUTOMATIC AMPLITUDE CONTROL FOR VARIABLE-FREQUENCY OSCILLATORS.—M. Lévy. (*Electronics*, Sept. 1944, Vol. 17, No. 9, pp. 252..265.) From the paper dealt with in 3123 of 1944.

2279. TERMINOLOGY OF INTERPENETRATING TWINS IN α-QUARTZ [and Some Existing Confusion : Suggested Terminology].—L. A. Thomas. (*Nature*, 7th April 1945, Vol 155, No. 3936, p. 424.) From the General Electric laboratories, Wembley.

2280. HISTORIC FIRSTS : ZERO-TEMPERATURE - COEFFICIENT QUARTZ CRYSTALS.—W. A. Marrison : W. P. Mason. (*Bell Lab. Record*, March 1945, Vol. 23, No. 3, pp. 70–71.)

2281. TUBELESS PROBE FOR VACUUM-TUBE VOLTMETER.—H. L. Daniels. (*Electronics*, Feb. 1945, Vol. 18, No. 2, p. 125.)

" Users of vacuum-tube voltmeters who have struggled with necessarily bulky vacuum-tube probes in confined spaces " will appreciate the value of this arrangement, in which the r.f. circuit loading due to the input admittance of the measuring instrument is reduced by the use of a cathode-follower, fed through a shielded conductor ; the shield is not grounded but is connected directly to the valve cathode.

2282. THE MERVYN REACTANCE-ALIGNMENT COMPARATOR [primarily for Tests on Television Equipment, applicable also to Radio Receiver Testing or Component Checking].—P. D. Saw. (*Electronic Eng:g*, April 1945, Vol. 17, No. 206, p. 473.)

From a Television Society paper. The instrument matches or checks capacitances, inductances, or combinations of the two, " to a high degree of accuracy," and adjusts complete tuned circuits to some exact frequency. A stable oscillator circuit is loosely coupled to a high-Q resonator circuit whose natural frequency is varied by a moving vane (forming one plate of a small condenser) carried on a reed kept vibrating at 50 c/s by a mains-energised coil. The end of the reed forms a pointer ; the scale over which this moves is illuminated 50 times a second by a light-flash, always at the moment when the natural frequency of the resonator equals that of the oscillator. At a working frequency of ½ Mc/s a difference of about 1/10th picofarad can be observed easily.

2283. A SQUARE-WAVE ANALYSER [for testing Networks, Amplifiers, etc.]. C. C. Eaglesfield. (*Wireless Engineer*, May 1945, Vol. 22, No. 260, pp. 223-232.)

From the Mullard laboratories. "It is difficult to make direct measurements on the screen of a c.r. tube, and it takes a long time to take photographs or tracings, and measure them. It therefore seems logical to look for an instrument that will give directly the 'descriptive numbers,' as a substitute for, or as a supplement to, the oscillograph. In effect this means some type of voltmeter, and several considerations suggest the peak voltmeter. It is the most convenient form of voltmeter at high frequencies, and its readings will be associated with definite points on the wave-form."

The writer shows how the response of the network under test can be defined by two " descriptive figures," the "speed " *s* (merely the reciprocal of the time t_1 from the initial to the final state, supposing that the slope were constant and equal to the max. slope of the actual curve : *see* Fig. 2) and the "overshoot " δ (Fig. 2) measured as a percentage of the final value. Both these figures are directly measurable by the instrument whose general principles, possible errors (errors in the peak voltmeter : in the differentiating network), and experimental design are here discussed : photographs of the final instrument are included. Tests on a 3-stage video amplifier indicate that the instrument gives reliable results with multi-stage networks.

2284. IMPEDANCE MEASUREMENTS WITH SQUARE WAVES.—F. Rockett. (*Electronics*, Sept. 1944. Vol. 17, No. 9, pp. 138–140 and 336, 338.)

Describes " the test equipment and procedures for determining capacitance and inductance, as well as the natural frequency, distributed capacitance, resistance, and Q of inductors, by oscillographic observation of square-wave decay rates. Results of actual measurements are given, showing accuracy."

2285. IMPEDANCE BRIDGE WITH A BILLION-TO-ONE RANGE [Type W–10135 for Audio-Frequencies (20–10 000 c/s) and W–10125 for Carrier Frequencies (200 – 150 000 c/s), Both for Resistances & Inductances : also in Types for Capacitance as well].—H. T. Wilhelm. (*Bell Lab. Record*, March 1945, Vol. 23, No. 3, pp. 89–92.) Measuring, for example, inductances from 1 μH to 1000 H. *See* also 2286, below.

2286. A CATHODE-RAY BRIDGE DETECTOR [designed primarily for the Wide-Range Impedance Bridge dealt with in 2285, above, to give the Required High Sensitivity over the Wide Frequency Range and yet to be Suitable for Use in Manufacturing Plants].—E. H. Eveland. (*Bell Lab. Record*, March 1945, Vol. 23, No. 3, pp. 93–96.)

2287. ELECTRICAL SORTING MACHINES AS A MEANS FOR INCREASED OUTPUT IN MASS-PRODUCTION TESTING.—P. K. Hermann. (*Zeitschr. V.D.I.*, 26th Dec. 1942, Vol. 86, No. 51/52, pp. 769–774.)

2288. CONSTRUCTION AND EQUIPMENT OF ROOMS FOR TROPICAL TESTS OF MATERIALS AND APPARATUS.—L. Metz & others. (*Zeitschr. V.D.I.*, 6th March 1943, Vol. 87, No. 9/10, pp. 132–136.) From the Chem.-Techn. Reichsanstalt.

2289. MAGNETIC FLUXMETER [Model 256: with Electronic Circuit so connected that when Exploring Inductor is placed in Magnetic Field, Indication is Proportional to Field: Built-In Voltage Regulation against Mains Fluctuations].—Hickok Elec. Instr. Company. (*Review Scient. Instr.*, March 1945, Vol. 16, No. 3, p. 60.)

2290. MEASUREMENT OF SMALL MOTIONS [in Relays, between Carbon Granules in Microphones, etc.].—G. F. Hull, Jr. (*Bell Lab. Record*, March 1945, Vol. 23, No. 3, pp. 86–88.) *See* also 1548 of May.

2291. FIXED MICA CAPACITORS IN THE ARMY–NAVY ELECTRONICS STANDARDISATION PROGRAMME.—G. A. Osmundsen. (*Communications*, Aug. 1944, Vol. 24, No. 8, pp. 36–37 and 90, 91.)

SUBSIDIARY APPARATUS AND MATERIALS

2292. ELECTRONIC OSCILLOGRAPH [Self-Contained Industrial Cold-Cathode-Type Equipment, including Photoelectric Control enabling Oscillogram to be taken in One Revolution of Film-Drum].—Westinghouse. (*Review Scient. Instr.*, Feb. 1945, Vol 16, No. 2, pp. 44.) *See* also 1134 of April.

2293. CATHODE-RAY TUBE TESTING [and the Two Dozen or So Characteristics that require Careful Checking: the Various Tests].—Beers. (*Communications*, Oct. 1944, Vol. 24, No. 10, pp. 56..60 and 89, 102.) For other work by this writer *see* 2266, above.

2294. CATHODE-RAY-TUBE TRACES: PART II—STRAIGHT-LINE TIME BASES.—Moss (*Electronic Eng:g*, Dec. 1944 & Jan. 1945, Vol. 17, Nos. 202 & 203, pp. 285–288 & 329–332: Corrections, Feb. 1945, Vol. 17, No. 204, p. 377.) Continuation of the series referred to in 1896 of June. For a letter from R. H. Frazier on Bowditch's pre-Lissajous curves, and an editorial note mentioning Suardi's still earlier traces, *see* March issue, No. 205, p. 426.

2295. DEVELOPMENT OF ELECTRONIC TUBES [Survey].—Mouromtseff. (*See* 2229.)

2296. THE "MINISCOPE", A MINIATURE CATHODE-RAY OSCILLOSCOPE.—Michaelis. (*Electronic Eng:g*, Feb. 1945, Vol. 17, No. 204, pp. 360–362.) From the laboratories of the General Electric Company, England.

2297. SOME NOTES ON THE DESIGN OF ELECTRON GUNS [including the Obtaining of High Beam Perveances].—Samuel. (*See* 2267.)

2298. HIGH-ENERGY ELECTRONS FROM A GLOW-DISCHARGE TUBE [worked at High Voltage & Low Pressure, so that the Discharge Current confines Itself to a Fine Axial Thread, yielding Electron Beam of High Current Density through Minute Aperture at Centre of Anode: Stability maintained by Accurate Pressure-Regulation (Fixed Leak, Variable Pumping Speed): Successfully Used in Electron-Diffraction Camera: Discharge operated at 60 kV without Attention].—Schulz. (*Review Scient. Instr.*, Feb. 1945, Vol. 16, No. 2, pp. 35–36.)

2299. "CLIX" SHROUDED CATHODE-RAY-TUBE SOCKET [giving Protection for All Live Leads].—(*Wireless World*, May 1945, Vol. 51, No. 5, p. 142: photograph & caption only.)

2300. ON THE POLARISED LUMINESCENCE OF DYE-STUFFS IN RIGID [Vitreous] SOLUTIONS.—Feofilov. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URSS*, 10th Aug. 1944, Vol. 44, No. 4, pp. 147–151: in English.)

"Comparing the polarisation of the instantaneous fluorescence with that of the luminescence of long duration, one arrives at certain conclusions important for the characteristic of the metastable states of organic molecules, as well as for the entire theory of polarised luminescence . . ."

2301. THE ELECTRICAL CHARGING OF ELECTRON-DIFFRACTION SPECIMENS [of Poorly Conducting Material: Practical Elimination by Irradiation by Auxiliary Electron Gun: Discussion of Results]. Brubaker & Fuller. (*Journ. Applied Phys.*, March 1945, Vol. 16, No. 3, pp. 128–130.)

"An explanation of these results solely in terms of secondary-electron emission seems impossible. It is suggested that a major part of the action of the [auxiliary] 400 V electron beam lies in ionisation of residual gas in the neighbourhood of the specimen surface."

2302. SOME STRUCTURAL DETAILS OF DIATOM *Pleurosigma elongatum* AS REVEALED WITH THE AID OF ELECTRON MICROSCOPE [and Their Interest as Criterion of Resolving Power].—Werzner. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URSS*, 30th July 1944, Vol. 44, No. 3, pp. 118–119: in English.)

2303. PHOTOGRAPHIC MATERIALS FOR THE ELECTRON MICROSCOPE [Extracts from Paper read at Joint Meeting, Royal Photographic Society & Association for Scientific Photography].—Chilton, Crook, & Sheffield. (*Electronic Eng:g*, Feb. 1945, Vol. 17, No. 204, pp. 363–366.) In a subsequent issue it is mentioned that the captions of Figs. 2 and 3 should be interchanged. A summary was referred to in 1902 of June.

2304. RESOLVING POWER OF THE MICROSCOPE USING POLARISED LIGHT.—Hopkins: Stump. (*Nature*, 3rd March 1945, Vol. 155, No. 3931, p. 275.)

2305. A 100 kV ELECTRON MICROSCOPE [at Stanford University: "Differs in Many Respects from Previous Instruments"].—Marton. (*Journ. Applied Phys.*, March 1945, Vol. 16, No. 3, pp. 131–138.) For some features *see* 1558 of May.

2306. ADDITIONAL STABILISATION FOR THE BEAM CURRENT IN THE R.C.A. TYPE B ELECTRON MICROSCOPE [acting as Time Saver in Reducing the Necessary Frequency of Cleaning & Aligning the Aperture Diaphragms to avoid Fuzziness in the Photograph: Fluctuations in Filament Emission reduced by Factor of at least Ten by a One-Valve Circuit].—Crane. (*Review Scient. Instr.*, March 1945, Vol. 16, No. 3, p. 58.) In this type of microscope the filament is heated by r.f. current.

2307. ELECTRONIC ALTERNATING-CURRENT POWER REGULATOR [for the Supply of Electronic Apparatus, etc.].—Cherry & Wild. (*Proc. I.R.E.*, April 1945, Vol. 33, No. 4, pp. 262–267.)

A summary was referred to in 1324 of April. "The theory and design considerations governing a conventional circuit using gaseous-discharge tubes are presented. The effect of the extent of voltage-limiting by the gas tubes on the degree of regulation is discussed.

"A bridge-type circuit is described and its theory developed. The effect of the degree of unbalance of the bridge circuit on the degree of regulation is discussed. The application of these circuits for regulation of low power, particularly the use in electronic apparatus, is treated, and performance data on both circuits are given."

2308. POWER SUPPLY FOR U.H.F. VELOCITY-MODULATED TUBES. Eachus. (*See* 2181.)

2309. FILTER DESIGN FOR GRID-CONTROLLED RECTIFIERS [Thyratrons].—Thomas. (*See* 2174.)

2310. GAS-FILLED TUBES AS PULSE GENERATORS.—van den Bosch. (*See* 2232.)

2311. A NOTE ON GRID CONTROL CHARACTERISTICS OF GAS-FILLED RELAYS [and the Two Classes of Behaviour of Commercially Available Types].—Gillings. (*Electronic Eng:g*, Feb. 1945, Vol. 17, No. 204, p. 372.)

2312. AN A.C.-OPERATED LEAK DETECTOR AND IONISATION GAUGE [based on Change in Temperature-Limited Thermionic Emission of Tungsten Filament in the Vacuum, as Oxygen is blown over the Leak: Full-Scale Deflection of Meter given by Variation of 1% Total Emission Current: "Control Diode" Method of Stabilising the Filament Supply against Mains Fluctuations].—Nelson. (*Review Scient. Instr.*, March 1945, Vol. 16, No. 3, pp. 55–57.)

2313. THERMOCOUPLE VACUUM GAUGE AND CONTROL UNIT [suitable also for locating Leaks].—Nat. Research Corporation. (*Review Scient. Instr.*, March 1945, Vol. 16, No. 3, p. 59.)

2314. ON THE MAXIMAL ENERGY ATTAINABLE IN A BETATRON.—Iwanenko & Pomeranchuk. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URSS*, 20th Sept. 1944, Vol. 44, No. 8, pp. 315–316: in English.) Already dealt with in 3961 of 1944.

2315. ON A NEW METHOD OF ACCELERATION OF RELATIVISTIC PARTICLES.—Veksler [Wechsler]. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URSS*, 30th Sept. 1944, Vol. 44, No. 9, pp. 365–368: in English.)

"As was shown in a preceding paper (1913 of June), acceleration of relativistic particles can be attained by applying a constant magnetic field. We hope to prove below that, due to automatic phasing, resonance acceleration is possible not only in a constant magnetic field but also in those in which the intensity increases with time. In contrast to the Wideröe–Kerst betatron, in this case the magnetic field is designed to control the paths of the particles, while the acceleration is a result of the variable electric field." The advantages of this arrangement are mentioned.

2316. THE FIELD BETWEEN EQUAL SEMI-INFINITE RECTANGULAR ELECTRODES OR MAGNETIC POLE-PIECES.—Davy. (*See* 2152.)

2317. APPLICATION OF THE FOURIER TRANSFORM TO PROBLEMS OF THE MAGNETIC FIELD.—Raymond. (*Comptes Rendus* [Paris], Nov. 1943, Vol. 217, p. 499 onwards.) Mentioned in *Review Scient. Instr.*, March 1945.

2318. THINNER TRANSFORMER LAMINATIONS [" Ultra-Thin, Grain-Oriented Hipersil " for H. F. Applications: 2-mil Laminations instead of the Previous Thinnest 5-mil: also (on Experimental Basis at present) a 1-mil Hipersil].—Westinghouse. (*Review Scient. Instr.*, March 1945, Vol. 16, No. 3, pp. 61–62.)

The 2-mil material makes possible transformers in which iron cores have not been used previously because of intolerably high eddy-current losses: *e.g.* in television, for high-power pulses lasting only a fraction of a microsecond.

2319. RECENT TRANSFORMER DEVELOPMENT (Drastic Size Reductions, Frequency-Range Extensions, Complete Elimination of Transformers, & Hitherto Impossible Uses of Transformers, obtained by New Steel (Hypersil), New Insulation (Fosterite), & New Circuits (Cathode Follower)].—Lee. (*Proc. I.R.E.*, April 1945, Vol. 33, No. 4, pp. 240–245.) *See* also 2747 of 1944, and *cf.* 2318, above.

2320. MAGNETIC MATERIALS: II — THE MAGNETISATION PROCESS: III—RECENT DEVELOPMENTS [including Effect of Impurities and Cooling in a Magnetic Field].—Brailsford. (*Electronic Eng:g*, Oct. & Nov. 1944, Vol. 17, Nos. 200 & 201, pp. 192–194 & 248–250.) For I *see* 169 of January.

2321. PERMANENT MAGNETS [Note on Circular C 448 (R. L. Sanford) giving Summary of Data available in the Literatures and Brief Discussion of Design & Testing].—Nat. Bureau of Standards. (*Journ. Franklin Inst.*, Dec. 1944, Vol. 238, No. 6, p. 456.)

2322. ON THE CURVES OF LONGITUDINAL MAGNETISATION OF A FERROMAGNETIC WIRE TRAVERSED BY A CONTINUOUS CURRENT.—Gorelik, Goronina, & Joukova. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URRS*, 30th Aug. 1944, Vol. 44, No. 6, pp. 235–237: in French.) Continuation of the work dealt with in 1942 of June.

2323. THE THERMISTOR [30–40 Types now in Manufacture: Characteristics of the 1C Type: Applications of the Thermistor].—Western Electric. (*Journ. Franklin Inst.*, Feb. 1945, Vol. 239, No. 2, pp. 158–159.)

2324. NON-OHMIC RESISTORS [Some Data & Applications of Metrosil Material & Its Modifications].—Metropolitan-Vickers. (*Journ. of Scient. Instr.*, April 1945, Vol. 22, No. 4, p. 77.) For an earlier note *see* 3184 of 1940.

2325. CARBON-PILE CONTINUOUSLY ADJUSTED RHEOSTATS.—Stackpole Carbon. (*Review Scient. Instr.*, Jan. 1945, Vol. 16, No. 1, p. 18.)

2326. LIQUI-JECTOR [on "Revolutionary Principle" of separating Liquid & Gas Phases by virtue of Surface Tension of the Liquid] FOR CONTINUOUS REMOVAL OF DROPLETS, MIST, ETC., FROM COMPRESSED AIR OR GAS LINES.—Selas Corporation. (*Review Scient. Instr.*, Jan. 1945, Vol. 16, No. 1, pp. 16–17.)

2327. TROPICAL FAILURES OF ELECTRONIC COMPONENTS [Notes on Behaviour of Transformers, Capacitors, Resistors, Meters, Wiring, etc., in the "Wet Tropics," and the Necessary Precautions].—Anon. (*Electronics*, Sept. 1944, Vol. 17, No. 9, pp. 198..222.)

2328. FLASH-OVER AT HIGH ALTITUDES.—Jacottet. (*Electronic Eng:g*, Nov. 1944, Vol. 17, No. 201, p. 235.) Abstract of the survey referred to in 3135 of 1943.

2329. THE EFFECT OF CORONA ON SOLID INSULATING MATERIALS [Cellulose-Acetate Films & Varnished Cloth].—Morris Thomas. (*Journ. I.E.E.*, Part II, Dec. 1944, Vol. 91, No. 24, pp. 549–562.)

2330. HIGH-VOLTAGE RADIO-FREQUENCY INSULATOR DESIGN NOTES [Calculation of Design to give Negligible Heating of Dielectric at Normal Working Voltage of the Part, and to avoid Corona and Spark-Over until about Twice That Voltage is applied].—Wald. (*Communications*, Oct. 1944, Vol. 24, No. 10, pp. 40..46.)

2331. CHEMICALLY STABILISED PAPER CAPACITORS.—McLean. (*Bell Lab. Record*, March 1945, Vol. 23, No. 3, pp. 65–69.)

When operated at room temperatures, capacitors with paper dielectrics impregnated with chlorinated diphenyl or chlorinated naphthalene have a satisfactory life. "At high d.c. potentials, however, and at temperatures from 50–100° C, which are common in much modern equipment for our Armed Forces, rapid degradation of the dielectric material results.

"The Laboratories discovered that there are a number of compounds which substantially increase the life of capacitors on accelerated d.c. tests, when added in small amounts to the chlorinated impregnant. These stabilisers also maintain the leakage current during tests at low and relatively stable values in contrast with the rapidly increasing leakage current in unstabilised capacitors. Among the stabilisers used, the quinones were the most satisfactory, and of them anthraquinone was chosen for commercial use owing to its high effectiveness, ready availability in pure form, low volatility, and lack of toxicity." Details are given, in connection first with linen paper and then with kraft paper. Kraft paper exerts a stabilising action of its own, but the improvement due to the anthraquinone is still great.

2332. DIELECTRICS IN U.H.F. FLEXIBLE COAXIAL CABLES [and the Influence of Molecular Configuration on the Properties of Suitable Plastic Materials].—Warner. (*Communications*, Dec. 1944, Vol. 24, No. 12, pp. 33–35 and 54, 90, 91.) From the Intelin Division, Federal Telephone & Radio Corporation.

2333. SYNTHETIC RUBBERS AND PLASTICS: IX—MECHANICAL PROPERTIES IN RELATION TO MOLECULAR STRUCTURE.—Pollett. (*Distribution of Elec.*, April 1945, Vol. 17, No. 158, pp. 384–387.) For previous parts in this series *see* 215 of January and 1180 of April.

2334. LOW-TEMPERATURE SYNTHETIC RUBBER ["Thiokol" Type ST, a Polysulphide Synthetic Rubber flexible at Low Temperatures, with Other Special Properties].—Thiokol Corporation. (*Review Scient. Instr.*, Feb. 1945, Vol. 16, No. 2, p. 46.)

2335. RESEARCH DEVELOPS NEW COATING MATERIAL [New Type of Resinous Coating Material looking like Varnish, withstanding High Temperatures & Most Chemicals & Solvents: "Especially Valuable in preparation of Lacquers, Varnishes, Cements, & Impregnating Compounds": "Allyl Starch" & other Allyl Carbohydrates, from Surplus Starches & Sugars].—Nichols & Hamilton. (*Journ. Franklin Inst.*, Feb. 1945, Vol. 239, No. 2, pp. 160–161.)

2336. TAPPED THREADS IN SYNTHETIC-RESIN MOULDING MATERIALS [Tests on Mechanical Strength, etc., and Practical Deductions].—Thum & Boden. (*Zeitschr. V.D.I.*, 7th Aug. 1943, Vol. 87, No. 31/32, pp. 506–507: summary, from *Kunststoffe*, 1942.)

2337. SILICONES [and Their High Thermal Stability & Other Properties: Summary of Rochester Fall Meeting Paper].—Bass. (*Communications*, Dec. 1944, Vol. 24, No. 12, pp. 48..51.) From the director of research, Dow Corning Corporation.

2338. POLYMERISED SILICONES PRODUCE NEW SUBSTANCES [Silicones polymerised with Addition of Other Chemical Elements yield Resin-like Substances of Remarkable Physical Properties, including High Resistance to Heat & Electricity: *e.g.* Phenyl Ethyl Silicon, used as Impregnating Agent in Glass-Fibre Cloth].—Hyde. (*Sci. News*

Letter, 17th March 1945, Vol. 47, No. 11, p. 169.) From the Corning laboratories.

2339. A New Journal, *Journal für makromolekulare Chemie*.—Staudinger (Editor). (*Zeitschr. V.D.I.*, 16th Oct. 1943, Vol. 87, No. 41/42, p. 660.)

2340. Fixed Mica Capacitors in the Army–Navy Electronics Standardisation Programme. — Osmundsen. (*Communications*, Aug. 1944, Vol. 24, No. 8, pp. 36–37 and 90, 91.)

2341. New Ceramic for Fused Plug ["Alorite," with "Unprecendented Physical & Mechanical Properties"].—Dorman & Smith, Ltd. (*Electrician*, 13th April 1945, Vol. 134, No. 3489, p. 331.)

2342. Glass: a Summary of Its Development as an Art and as a Science.—Flint. (*ASTM Bulletin*, Jan. 1945, No. 132, pp. 19–24.)

2343. Protecting Joints [Use of Plaster-of-Paris Bandage to give Rigidity & Extra Protection].—"Diallist." (*Wireless World*, April 1945, Vol. 51, No. 4, p. 127.)

2344. Sealed Zippers [" Pressure-Sealing Zippers," with Rubber Construction making them "Completely Waterproof & preventing Escape of Air or Gas"].—Goodrich Company. (*Review Scient. Instr.*, Dec. 1944, Vol. 15, No. 12, pp. 355–356.)

2345. Gallium [Its Abundance (compared with Silver & Mercury) and Probable Valuable Industrial Uses].—(*Electronic Eng:g*, April 1945, Vol. 17, No. 206, p. 460: a note from *Monthly Science News*.)

2346. The Mechanical Properties of Zinc-Alloy Die Castings.—Street. (*Engineering*, 29th Dec. 1944, Vol. 158, No. 4120, pp. 514–515.) "Far too many potential users still base their judgment of these alloys on the properties of die castings of twenty years ago. . . ."

2347. Equipment and Techniques for Evaporation of Metals *and* The Evaporation of Metals from Crucibles [for Metals which alloy readily with Those ordinarily used as Filaments].—Olsen, Smith, & Crittenden. (*Phys. Review* 1st/15th Dec. 1944, Vol. 66, No. 11/12, p. 357: summaries only.) Supplementing Caldwell's work, 856 of 1942.

2348. Some Modern Components and Accessories [Rotary Stud Switch (to give Two Sine-Wave Potentials spaced 90°): "Actograp" Electric Pen & "Lorsol" Carbon-Electrode Tool for Spot Soldering: etc.].—(*Electronic Eng:g*, Oct. 1944, Vol. 17, No. 200, p. 209–212.)

2349. An Interesting Tool [Note on the "Biobas" Electric Soldering Iron, with "Several Interesting Features," including a Novel & Effective Method of Temperature Control].—"Diallist." (*Wireless World*, March 1945, Vol. 51, No. 3, p. 94.)

2350. Solderless Terminals.—Wells & Balsbaugh. (*Elec. Engineering*, Dec. 1944, Vol. 63, No. 12, Transactions pp. 933–938.) A Summary was dealt with in 563 of February.

2351. Electrostatic Spraying and De-Tearing [and Its Advantages over Ordinary Methods of applying Metal Finishes by Dipping or Spraying].—Forsberg. (*Electronic Eng:g*, March 1945, Vol. 17, No. 205, p. 436: summary, from *Iron Age*, 1944.)

2352. "Ferrotoning," a New Chemical Blackening Finish for Ferrous Parts.—Turco Products. (*Review Scient. Instr.*, Jan. 1945, Vol. 16, No. 1, p. 19.)

2353. Electroplating Facilities at Murray Hill.—Ehrhardt. (*Bell Lab. Record*, Dec. 1944, Vol. 22, No. 16, pp. 609–613.)

STATIONS, DESIGN AND OPERATION

2354. Pulse-Time Modulation [Summary of Rochester Fall Meeting Paper].—Labin. (*Communications*, Dec. 1944, Vol. 24, No. 12, pp. 42 and 46.) From the Federal Telephone & Radio laboratories. *See* also 1947 of June.

2355. Multi-Channel Radio Link [Norfolk/Cape Charles]. — Peterson. (*Electronics*, Sept. 1944, Vol. 17, No. 9, pp. 186..198.) *See* also 1945/6 of June.

2356. Proposed Raising of the Frequency Band for Frequency-Modulated Broadcasting in America [F.C.C's Proposal to raise from Present 42–50 to 84–102 Mc/s: Protests at Enquiry: Opposition to Norton's Prediction of Serious F-Layer Interference (at Peak of Sunspot Cycle) on the Lower Frequencies asked for (48–66 Mc/s): Secret Session to be held under Military Supervision].—G.W.O.H. (*Wireless Engineer*, May 1945, Vol. 22, No. 260, pp. 210–211.)

2357. U.S. Frequency Proposals: American and International Allocations above 25 Mc/s [including the New "Citizens' Radio Communications Service" (Proposed Band 460–470 Mc/s: Simplified Licensing Procedure) & Amateur Allocations].—F.C.C. (*Wireless World*, May 1945, Vol. 51, No. 5, pp. 142–143.)

2358. Radio Progress during 1944: Frequency Modulation [Comments and Bibliography]. —I.R.E. Committee. (*Proc. I.R.E.*, March 1945, Vol. 33, No. 3, pp. 144–145.)

2359. Planning an F.M. Station [Notes on Selection of Sites, Estimation of Coverage, Determination of Required Transmitter Power, Choice of Aerials, & Building Lay-Outs].—Laeser. (*Electronics*, Feb. 1945, Vol. 18, No. 2, pp. 92–97.)

2360. Radio-Relay-Systems Development by the Radio Corporation of America.—Hansell. (*See* 2256.)

2361. Aeronautical Communications in the Post-War Era.—Silver. (*Communications*, Jan. 1945, Vol. 25, No. 1, pp. 48, 76, and 90..92.)

2362. Radioteletype in the Army Airways Communications System.—Hart. (*QST*, Nov. 1944, Vol. 28, No. 11, pp. 12–15.)

2363. Police Communication Problems facing Engineers Today.—Boss. (*Communications*, Jan. 1945, Vol. 25, No. 1, pp. 53 and 77..81.)

2364. Compact Gear for 224 Mc/s WERS: One Way to Solve the 112 Mc/s QRM Problem [Ultra-Audion Transmitter using "Doorknob"-Type WE 316-A: Receiver with Self-Quenched Super-Regenerative Circuit & Audio Amplifier (for Use in Transmitter also)].—Semel. (*QST*, Nov. 1944, Vol. 28, No. 11, pp. 9–11 and 94.)

2365. A Versatile WERS Mobile Station: District-Wide Communication by means of Dual Installation [Transceiver *plus* Separate Transmitter of Somewhat Higher Power].—Rand. (*QST*, Nov. 1944, Vol. 28, No. 11, pp. 33–38.)

2366. WERS in the Florida State Guard: Operation of the State-Wide WKRW Net.—Hazelton. (*QST*, Nov. 1944, Vol. 28, No. 11, pp. 45–47.)

2367. A Mobile Installation for WERS: Separate Receiver and Transmitter in One Compact Unit.—Carter. (*QST*, Dec. 1944, Vol. 28, No. 12, pp. 9–13.)

"A receiver refinement in the form of an acorn r.f. stage takes a long step toward the reduction of two common receiver weaknesses—super-regenerative radiation and antenna tuning effects. . . ."

2368. A Midget Transmitter–Receiver: the Permanent-Magnet Speaker does Double Duty in a WERS Rig.—Clemens. (*QST*, Jan. 1945, Vol. 29, No. 1, pp. 38–40.)

2369. A Miniature Ham-Band C.W. Station: Compact Construction for Three-Band Portable Work.—Gates. (*QST*, Jan. 1945, Vol. 29, No. 1, pp. 25–27.)

2370. Office of War Information's 200 kW H.F. Transmitters at Bethany, Ohio.—Rockwell. (*Communications*, Nov. 1944, Vol. 24, No. 11, pp. 33–36 and 56, 66, 70..77: Dec. 1944, No. 12, pp. 58, 60 and 66, 67, 70..76.)

2371. Frequency Allocation: Needs of Long-Distance Communication Services.—Smith-Rose. (*Wireless World*, May 1945, Vol. 51, No. 5, pp. 133–136.)

Our knowledge of the propagation of radio waves around the surface of the earth and through the ionosphere "is now considerably in advance of that available when the current distribution of frequencies was drawn up by the Conference at Cairo in 1938, and it is to be expected that any revision of the allocations will have due regard to the known suitability of the various frequencies from a wave-propagation standpoint. . . ."

With the help of Tables I & II, showing the limits of useful distances of communication from Great Britain at various seasons, for sunspot minimum and maximum conditions respectively, "a suggested broad allocation of frequencies may be drawn up for communication circuits with one terminal in this country. This has been done in Tables III & IV. . . ." Such conclusions, derived from our scientific knowledge of radio wave propagation, "should naturally be used in a complementary manner to the results of the experience of all those who are, and have been responsible for the practical design and operation of such communication circuits, and who will undoubtedly have already formed certain opinions as to the efficacy and limitations of the present distribution of radio frequencies. . . ."

2372. "International Telecommunications" [Book Review].—Mance & Wheeler. (*Proc. I.R.E.*, Jan. 1945, Vol. 33, No. 1, pp. 67–68.) This is the book mentioned in 3284 of 1944.

2373. The Western Union Varioplex Telegraph System.—Pierson. (*Elec. Communication*, No. 2, Vol. 22, 1944, pp. 101–109.) *See* also 3781 of 1942 and 608 of 1944.

GENERAL PHYSICAL ARTICLES

2374. Is the Particle's "Self-Field" a Physically Observable Quantity?—Markov. (*Comptes Rendus* (*Doklady*) *de l'Ac. des Sci. de l'URSS*, 10th Oct. 1943, Vol. 41, No. 1, p. 14–17: in English.)

2375. Cohesion of the Electron.—Bryliński. (*Comptes Rendus* [Paris], No. 1943, Vol. 217, p. 478 onwards.) Mentioned in *Review Scient. Instr.*, March 1945. Further development of the work dealt with in 1228 of April.

2376. Classical Theory of the Point Electron, *and* The Radiation Field of a Point Electron.—Schönberg: Lopes & Schönberg. (*Phys. Review*, 1st/15th Feb. 1945, Vol. 67, No. 3/4, p. 122: pp. 122–123.)

The writers conclude: "A consistent theory of the radiation field of the electron that will be given elsewhere by one of us shows that all the difficulties of the classical theory of the electron can be overcome without any subtraction processes of the kind involved in the theories of Dirac and Pryce."

2377. The Magnetic Current [Survey of Ehrenhaft's Results & Some "Duplications" with Negative Results (1235/6 of April & 1610 of May)].—Chatterjee: Ehrenhaft. (*Sci. & Culture* [Calcutta], Feb. 1945, Vol. 10, No. 8, pp. 315–317.) For new experiments not reported in this survey *see* Kane & Reynolds, 1633 of May and 2378, below.

2378. New Evidence for the Magnetic Current: *also* Magnetic Saturation of Microscopic Particles: *and* The Rotation of Electrolytes under the Influence of a Magnetic Field.—Ehrenhaft: Kane: Reynolds. (*Phys. Review*, 1st/15th Jan. 1945, Vol. 67, No. 1/2, p. 63: p. 63: pp. 63-64: summaries only.)

The third writer (of F.C.C.) shows that the rotations are not explained by the Lorentz force, concentration gradient, or pure electrochemical action. "A satisfactory explanation can be shown if the existence of a magnetic current is assumed." *See* also 1633 of May.

2379. " ELECTROMAGNETICS " [Book Review].—O'Rahilly. (*Electronic Eng:g*, March 1945, Vol. 17, No. 205, p. 433.)

" An attitude reminiscent of a bull in a china shop . . . " " I like this book for its insistence on exact thinking." " One must be grateful that the Maxwellian equations still survive, although the underlying theory is attacked . . ."

2380. TRANSFORMATIONS OF THE FUNDAMENTAL EQUATIONS OF THERMODYNAMICS.—Buckley. (*Journ. of Res. of Nat. Bur. of Stds.*, Sept. 1944, Vol. 33, No. 3, pp. 213–233.)

2381. ON THE THEORY OF THE SURFACE TENSION OF METALS.—Dorfman. (*Comptes Rendus (Doklady) de l'Ac des Sci. de l'URSS*, 30th Dec. 1943, Vol. 41, No. 9, pp. 372–374 : in English.)

The theory here given, though a rough approximation, agrees well with experimental data and may be used " as a point of departure for further investigations of the superficial properties of metals and alloys."

MISCELLANEOUS

2382. NUMERICAL SOLUTION OF ORDINARY AND PARTIAL DIFFERENTIAL EQUATIONS BY MEANS OF EQUIVALENT CIRCUITS [Methods for Calculation of Initial-Value, Boundary-Value, & Characteristic-Value Problems].—Kron. (*Journ. Applied Phys.*, March 1945, Vol. 16, No. 3, pp. 172–186.) For previous work *see*, for example, 1008 of April & 1980/2 of June. A paper by Prebus, Zlotowsky, & Kron on the application to electron-optical problems is scheduled to appear in *Phys. Review*.

2383. THE FOURIER INTEGRAL AND FUNCTIONALLY INVARIANT SOLUTIONS OF THE WAVE EQUATION [of the Theory of Elasticity] in n-DIMENSIONAL SPACE.—Gogoladze. (*Comptes Rendus (Doklady) de l'Ac. des Sci. de l'URSS*, 20th Sept. 1944, Vol. 44, No. 8, pp. 307–310 : in English.)

2384. " A TREATISE ON THE THEORY OF BESSEL FUNCTIONS : SECOND EDITION " [Book Review].—Watson. (*Science*, 2nd Feb. 1945, Vol. 101, No. 2614, pp. 117–118.) " This excellent book was written at a time when the author was much interested in the propagation of electromagnetic waves over the surface of the earth . . ."

2385. THE TABULATION OF SOME BESSEL FUNCTIONS $K_\nu(x)$ and $K_\nu'(x)$ OF FRACTIONAL ORDER.—Carsten & McKerrow. (*Phil. Mag.*, Dec. 1944, Vol. 35, No. 251, pp. 812–818.)

2386. MATHEMATICS AT THE NATIONAL PHYSICAL LABORATORY [Scope of Project to establish a Mathematics Division].—Nat. Physical Laboratory. (*Nature*, 7th April 1945, Vol. 155, No. 3936, p. 431.)

2387. ON THE RELATION OF MATHEMATICS AND PHYSICS.—Lindsay. (*Scient. Monthly*, Dec. 1944, Vol. 59, No. 6, pp. 456–460.)

2388. " METHODS OF ADVANCED CALCULUS " [with Special Attention to Physical & Engineering Applications : Book Review].—Franklin. (*Science*, 19th Jan. 1945, Vol. 101, No. 2612, pp. 64–65.) Based on teaching experience at M.I.T.

2389. " ENGINEERING MATHEMATICS " [Book Review].—Sohon. (*Proc. I.R.E.*, March 1945, Vol. 33, No. 3, p. 207.) Favourably reviewed by F. W. Grover.

2390. THE DUODECIMAL SOCIETY OF AMERICA [Formation of New Society for Mathematical Research & Education of the Public].—(*Journ. Franklin Inst.*, Feb. 1945, Vol. 239, No. 2, p. 126.)

2391. " SAMPLING INSPECTION TABLES : SINGLE AND DOUBLE SAMPLING " [Book Review].—Dodge & Romig. (*Proc. I.R.E.*, Jan. 1945, Vol. 33, No. 1, p. 68.) A notice was dealt with in 1250 of April.

2392. QUALITY-CONTROL ENGINEERING [" will in the Future be a ' Must ' to Radio & Parts Manufacturers "].—Purnell. (*Proc. I.R.E.*, March 1945, Vo. 33, No. 3, p. 202.)

" How it works," summarised in four short paragraphs. Conclusion : that the quality-control department " keeps everyone on the alert from incoming inspection to engineering because of its continued spot checks from any paint : therefore, a high-quality unit is assured." From Philco Radio.

2393. THE " ZED-THETA " CALCULATOR [Patented Device giving Impedance & Phase-Displacement Angle when Resistance & Reactance are Known, and *vice versa* : Other Applications].—Ivtcher. (*Distribution of Elec.*, April 1945, Vol. 17, No. 158, pp. 399–402.)

2394. NEW ROTATING SLIDE-RULE WITH 24 SCALES ON SLIDER [The " Rota-Vec-Trig " Rule with Wide Range of Applications for Electronic & Electrical Engineers].—Ailinger. (*Electronics*, Sept. 1944, Vol. 17, No. 9, p. 252.)

2395. THE LATE SIR AMBROSE FLEMING, PIONEER OF THE THERMIONIC VALVE.—(*Wireless Engineer*, May 1945, Vol. 22, No. 260, p. 211.)

Among the literary works mentioned there is no reference to his " Principles of Electric Wave Telegraphy ", first published in 1906 and running into several editions ; a bulky volume of nearly 700 pages which for many years formed the wireless engineer's bible.

2396. JUBILEE OF WIRELESS COMMUNICATION.—Marconi's Wireless Telegraph Company. (*Engineering*, 2nd March 1945, Vol. 159, No. 4129, p. 173.)

2397. AMATEUR RADIO, 1905 MODEL [Replica of Transmitter & Receiver (" Frequency given rather vaguely as ' above 30 Mc/s ' ") sold for Home Use].—Gernsback. (*Wireless World*, May 1945, Vol. 51, No. 5, p. 148.)

2398. RADIO-TELEPHONE TRANSMITTER DESIGN YESTERDAY AND TODAY [New York Tests in 1920].—McNicol. (*Communications*, Dec. 1944, Vol. 24, No. 12, pp. 64 and 89.)

2399. THE WHIPPLE COLLECTION OF INSTRUMENTS AND BOOKS.—Whipple. (*Engineering*, 2nd March 1945, Vol. 159, No. 4129, pp. 161–163 and 170 : to be contd.)

2400. RADIO PROGRESS DURING 1944 [Transmitters, Frequency Modulation, Receivers, Electronics, Television & Facsimile, Piezoelectricity, Electroacoustics, Propagation, Symbols].—I.R.E. Committee. (*Proc. I.R.E.* March 1945, Vol. 33, No. 3, pp. 143–155.) Comments and bibliographies.

2401. COMPONENTS FOR POST-WAR RADIO [Photographs & Notes on Components at the Second Radio Components Manufacturers' Association].—(*Electronic Eng:g*, April 1945, Vol. 17, No. 206, p. 449.)

2402. RADIO AND REHOUSING [Note on Report "Post-War Building Studies No. 11, Electrical Installations"].—I.E.E. Committee. (*Wireless World*, May 1945, Vol. 51, No. 5, p. 136.)

2403. RADIO SPECTROSCOPY : WHAT IT IS, AND HOW IT WORKS [and Its Many Possible Applications].—Roddam. (*See* 2192.)

2404. TWENTY-FIVE INVENTIVE PROBLEMS SET BY THE U.S. NAVY DEPARTMENT.—Nat. Inventors Council. (*Review Scient. Instr.*, March 1945, Vol. 16, No. 3, pp. 65–67.)

Including a device for transmitting rotary motion (*e.g.* control knobs on radio equipment) through moisture-proof barrier : small portable field-strength meter (walkie-talkie size) : aerials up to 300 ft. for unskilled ground crews : precision twin-triode valve with additional features : and a small, fast-acting, double-action solenoid.

2405. HAMS IN THE F.B.I.S. : THE WORK OF F.C.C.s FOREIGN BROADCAST INTELLIGENCE SERVICE.—Read. (*QST*, Jan. 1945, Vol. 29, No. 1, pp. 34–37.) For the same writer's article on the Radio Intelligence Division *see* 1652 of May.

2406. DEVELOPMENTS IN THE FIELD OF CABLE AND RADIO TELEGRAPH COMMUNICATIONS [Story of the American Cable & Radio Corporation's Group of Companies].—Pratt & Roosevelt. (*Elec. Communication*, No. 2, Vol. 22, 1944, pp. 147–153.)

2407. C. A. A. WORLD-WIDE ACTIVITIES IN COMMUNICATIONS.—Richelieu. (*Communications*, Oct. 1944 Vol. 24, No. 10, pp. 33–35 and 80..87.)

2408. "INTERNATIONAL TELECOMMUNICATIONS" [Book Review].—Mance & Wheeler. (*Proc. I.R.E.*, Jan. 1945, Vol. 33, No. 1, pp. 67–68.) This is the book mentioned in 3284 of 1944.

2409. ELECTRICAL RESEARCH IN THE U.S.S.R. [Semiconductor & Insulation Research : Non-Linear Oscillations : Electronics & Radio : Magnetism].—Oster. (*Journ. Applied Phys.*, March 1945, Vol. 16, No. 3, pp. 21–124.) A short survey, with 27 literature references.

2410. SCIENTIFIC INTERCHANGE BETWEEN THE UNITED STATES AND SOVIET RUSSIA.—Dunn. (*Science*, 23rd Feb. 1945, Vol. 101, No. 2617, pp. 200–201.)

2411. INSTRUMENTS AND APPLIED RESEARCH [Extracts from Presidential Address on "Applied Research"].—Ricardo. (*Journ. of Scient. Instr.*, April 1945, Vol. 22, No. 4, p. 80.)

"By all means, let us spend large sums of money, but let it be spent on the production and training of skilled research workers rather than on the equipment of large laboratories. We hear much of the costly and magnificent equipment of the research laboratories in other lands, but not so much of their meagre output. . . ."

2412. REMARKS BY DR. O. H. CALDWELL, EDITOR OF *Electronic Industries*, IN ACKNOWLEDGING I.R.E. FELLOW AWARDS TO TWELVE RADIO ENGINEERS INCLUDING HIMSELF.—Caldwell. (*Proc. I.R.E.*, April 1945, Vol. 33, No. 4, p. 274.)

Rejecting Webster's definition of "fellow" as "a man of low breeding or of little worth" in favour of the alternative "a sharer, a partner", the writer develops the thesis that "these great industries [created by radio engineers] must be officered by radio men, from top executive posts on down to the design rooms and production departments. This is absolutely necessary, for the good of the radio industries and the public they serve. . . ."

2413. LETTER ON THE DANGERS OF THE "DILETTANTE" ATTITUDE IN PHYSICS, ESPECIALLY THE NEGLECT OF FIELDS WHICH HAVE LOST THEIR NOVELTY.—Lyons. (*Journ. Applied Phys.*, March 1945, Vol. 16, No. 3, p. 187.)

"Shall we expect to read, say twenty years hence, that the cyclotron is the contribution and special care of the 'cyclotronic engineers', banded together in an independent institute, and read perhaps, on the next page, that physicists are meeting to discuss means of initiating a professional attitude in physics?"

2414. INTERDEPARTMENTAL COOPERATION IN RESEARCH [Leading Article].—(*Nature*, 7th April 1945, Vol. 155, No. 3936, pp. 407–408.)

"Competition between university departments may create a barrier to interdepartmental work". Two other barriers are mentioned : as a result, "the young scientific worker is poorly prepared to participate in the activities of a committee or a research team. . . ."

2415. GUIDING LINES IN THE CHOICE OF YOUNG RESEARCH WORKERS.—McDonald. (*Journn. Franklin Inst.*, Feb. 1945, Vol. 239, No. 2, pp. 88–92.)

"The first requirement is that they should want to work. . ." To be super-rational is a characteristic of genuis (Hervey Allen) : "it may be that the research worker is not so extreme, but the good ones are tarred with this brush. He must pursue his aim relentlessly, although that aim may be changed with changing conditions, that is, with greater knowledge and vision, the result of his own experiments or those of others . ."

2416. OLIVER LODGE SCHOLARSHIP [founded to commemorate 25th Jubilee of Radio Section].—I.E.E. (*Wireless World*, May 1945, Vol. 51, No. 5, p. 151: Wireless Engineer, May 1945, Vol. 22, No. 260, p.235.)

2417. THE SCIENCE TALENT SEARCH [Westinghouse Scheme now in Its Fourth Year: Doubts as to the Discovery of Science Talent by the Methods used].—Brandwein: Westinghouse. (*Science*, 2nd Feb. 1945, Vol. 101, No. 2614, p. 117.) For a reply by Edgerton & Britt *see* issue for 9th March, No. 2619, pp. 247–248.

2418. HEADS OR HANDS? [Note on Discussion Meeting on Apprenticeship & Training].—I.E.E. Radio Section. (*Wireless World*, May 1945, Vol. 51, No. 5, p. 132.)

2419. "SANDWICH" TRAINING [Letter regarding Recent Suggestions on Alternation of Technical Study with Periods of Practical Work in Industry: Note on Current Practice in Canada].—Sherwood. (*Wireless World*, May 1945, Vol. 51, No. 5, p. 149.)

2420. SCIENTIFIC EDUCATION AND RESEARCH IN RELATION TO NATIONAL WELFARE: I.—(*Sci. & Culture* [Calcutta]. Feb. 1945, Vol. 10, No. 8, pp. 313–315: leading article.)

2421. ORGANISATION OF INDUSTRIAL RESEARCH [Summary of Opening Address & Discussion, Institute of Physics, Branch Meeting].—Slade & Others. (*Nature*, 3rd March 1945, Vol. 155, No. 3931, pp. 280–281.)

2422. "COOPERATIVE RESEARCH" [Review of Brochure]. — E.R.A. (*BEAMA Journ.* March 1945, Vol. 52, No. 93, pp. 73–74.)

2423. EXPORT MARKET RESEARCH: FORMATION OF COOPERATIVE ORGANISATION [British Export-Trade Research Organisation].—Betro. (*Electrician*, 30th March 1945, Vol. 134, No. 3487, p. 277: *Wireless World*. May 1945, Vol. 51, No. 5, p. 155.)

2424. RADIO IN GREECE: Brief Summary of Situation. (*Wireless World*, May 1945, Vol. 51, No. 5, p. 148.)

2425. INAUGURATION OF THE RADIO INDUSTRIES' COUNCIL [Federation of Four Independent Associations]. — R.I.C. (*Electronic Eng:g*, Feb. 1945, Vol. 17, No. 204, p. 359.)

2426. PRIZES FOR SCIENTIFIC INSTRUMENT MANUFACTURE [Fund presented by W. Bowen: Conditions of Entry].—Scientific Instr. Manufacturer's Association. (*Nature*, 7th April 1945, Vol. 155, No. 3936, p. 423.)

2427. "STRONG" DESIGN: SOME ADDITIONS TO THE PREVIOUS PAPER [2856 of 1942].—Kesselring. (*Zeitschr. V.D.I.*, 12th Dec. 1942, Vol. 86, No. 49/50, pp. 749–752.)

2428. SCIENCE IN PEACE: OPEN CONFERENCE [and the *Leitmotiv* recurring through the Three Sessions (Science & Production, The Future Development of Science, & Science in Everyday Life)].—Assoc. of Scient. Workers. (*Nature*, 3rd March 1945, Vol. 155, No. 3931, pp. 260–262.)

2429. POPULAR SCIENCE [Misrepresentation of Scientific Matters in the Lay Press (Survival of Stephen Leacock's Reporter): Editorial].—(*Electronic Eng:g*, March 1945, Vol. 17, No. 205, p. 403.)

2430. THE SOCIETY FOR FREEDOM IN SCIENCE [and the Complete Untruth of Statements that It is partly a Political Organisation].—Society for Freedom in Science. (*Science*, 16th March 1945, Vol. 101, No. 2620, p. 273.)

2431. THE THREAT TO PURE SCIENCE [Further Correspondence: *see* 2001 of June].—Moore: Robin: Stern.—(*Science*, 19th Jan. 1945, Vol. 101, No. 2612, p. 62.)

2432. LITERATURE AND SCIENCE: A STUDY IN CONFLICT.—Glicksberg. (*Scient. Monthly*, Dec. 1944, Vol. 59, No. 6, pp. 467–472.) *Cf.* Johnson, 2014 of June.

2433. "THE IMPACT AND VALUE OF SCIENCE" [Book Review].—Hill. (*Phil. Mag.*, Dec. 1944, Vol. 35, No. 251, p. 854.)

"The author does not believe that there is a widespread appreciation of science, or a desire for the help it can give, except in technical application. He is concerned to show that, beyond this, science has a most important contribution to make, through the application of scientific thought in every sphere of human activity. . ."

2434. "RADIO'S 100 MEN OF SCIENCE" [Book REVIEW].—Dunlap. (*Proc. I.R.E.*, Feb. 1945, Vol. 33, No. 2, p. 138.)

2435. "MEET THE ELECTRON" [Book Review].—Grimes. (*Proc. I.R.E.*, Feb. 1945, Vol. 33, No. 2, p. 138.) "Suitable for recommendation by engineers to those who ask questions about the electron" as a result of the publicity campaign the latter is receiving at present.

2436. "MARINE RADIO MANUAL" [from the Operator's Viewpoint: Book Review].—Strichartz (Edited by). (*Proc. I.R.E.*, March 1945, Vol 33, No. 3, p. 208.)

2437. REPRODUCTIONS OF GERMAN SCIENTIFIC AND TECHNICAL BOOKS [List].—Alien Property Custodian. (*Proc. I.R.E.*, March 1945, Vol. 33, No. 3, pp. 208–209.)

2438. TECHNICAL JOURNALS [Functions of Technical & Trade Journals of This Country in relation to Post-War Industry: Need for Prompt Removal of Handicaps (especially Paper Rationing) and for Release of Information on War-Time Developments: etc.].—Council of Tech. & Trade Press. (*Wireless Engineer*, May 1945, Vol. 22, No. 260, p. 235: summary of memorandum.)

2439. GAPS IN CURRENT FILES OF SCIENTIFIC PERIODICALS.—Cunningham. (*Science*, 19th Jan. 1945, Vol. 101, No. 2612, pp. 62–64.) From the International Federation of Library Associations.

2440. "SOME NOTES ON THE WRITING OF SCIENTIFIC PAPERS" [Editorial Note calling

Attention to Pre-War Pamphlet].—(*Journ. of Scient. Instr.*, April 1945, Vol. 22, No. 4, p. 80.)

2441. "THE LOOM OF LANGUAGE: A GUIDE TO FOREIGN LANGUAGES FOR THE HOME STUDENT" [Book Review].—Bodmer: Hogben (Edited by). (*Sci. & Culture* [Calcutta], Feb. 1945, Vol. 10, No. 8, p. 346.) This is the book referred to in 2043 of June.

2442. "BILDWORT DEUTSCH: TECHNISCHE SPRACHHEFTE" [Illustrated: No. 8—Terms in Telecommunication Technique: Book Review].—Herrmann. (*Zeitschr. V.D.I.*, 4th Sept. 1943, Vol. 87, No. 35/36, p. 576.)

2443. REPLY TO "ETYMOLOGY OF THE WORD MICRORADIOGRAPH" [343 (and 342) of January].—Chilton: Maddigan. (*Journ. Applied Phys.*, Jan. 1945, Vol. 16, No. 1, pp. 55–56.)

2444. PROTEST AGAINST THE USE OF THE TERM "AMPLITUDE DISTORTION" WHEN "NON-LINEAR (or Harmonic) DISTORTION" IS MEANT.—Hughes: Sturley. (*See* 2167.)

2445. BALANCED AMPLIFIERS [for Biophysical Purposes, etc.: the Usefulness of In-Phase Signal Degeneration].—Offner. (*See* 2164.)

2446. CUP-ELECTRODE TECHNIQUE IN ELECTROENCEPHALOGRAPHY.—Greville & St. John-Loe. (*Electronic Eng:g*, Feb. 1945, Vol. 17, No. 204, p. 377.)

2447. THE COSSOR–ROBERTSON ELECTROCARDIOGRAPH.—Richards. (*Electronic Eng:g*, Feb. 1945, Vol. 17, No. 204, pp. 385 and 386.) *See* also 2061 of June.

2448. A STRAIN-GAUGE RECORDER FOR PHYSIOLOGICAL VOLUME, PRESSURE, AND DEFORMATION MEASUREMENTS [Application of the Resistance-Wire Strain Gauge].—Grundfest, Hay, & Feitelberg. (*Science*, 9th March 1945, Vol. 101, No. 2619, pp. 255–256.)

2449. DIFFUSION IN SPHERICAL SHELLS, AND A NEW METHOD OF MEASURING THE THERMAL DIFFUSIVITY CONSTANT.—Barrer. (*Phil. Mag.*, Dec. 1944, Vol. 35, No. 251, pp. 802–811.)

2450. DISCUSSION ON "DESIGN OF ELECTRONIC HEATERS FOR INDUCTION HEATING" [Jordan, 4068 of 1944: Transformer *versus* the Use of Multi-Turn Coils connected Directly in the Tank Circuit].—Brown: Jordan. (*Proc. I.R.E.*, April 1945, Vol. 33, No. 4, pp. 267–268.).

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2457. MEASURING THE ELASTICITY OF SYNTHETIC YARNS [and Plastic Films, Wires, etc.: Simple, Direct, & Rapid Method using 10 kc/s Excitation].—Silverman & Ballou. (*Electronics*, Feb. 1945, Vol. 18, No. 2, pp. 103–105.) From the du Pont de Nemours Company. *See* also 512 of February.

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Thus providing industrial engineers "with a new, sensitive, non-destructive test, a method of measuring the thickness of a metal plate whose rear surface may be inaccessible, or for exploring the interior for hidden flaws."

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2492. Resolving Power of the Microscope using Polarised Light.—Hopkins: Stump. (*Nature*, 3rd March 1945, Vol. 155, No. 3931, p. 275.)

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2494. Effect of Electric Field on Depolorisation of Light Scattering in Colloidal Systems, *and* Electro-Optical Properties of Colloids.—Rao: Sakmann. (*See* 2273 & 2274.)

2495. The Mechanism of Bioluminescence [New Hypothesis in Agreement with All Known Properties].—McElroy & Ballentine. (*Proc. Nat. Acad. Sci.*, 15th Dec. 1944, Vol. 30, No. 12, pp. 377–382.)

2496. Energy Minimum for Chromatic Vision [Results referring to Mercury Line 546 mu, near Maximum of Photopic Sensitivity].—Pinegin. (*Comptes Rendus* (*Doklady*) *de l'Ac. des Sci. de l'URSS*, 20th July 1944, Vol. 44, No. 2, pp. 60-61: in English.)

"So it is necessary for the stimulation of chromatic vision that a cone have 100 quanta per second falling on it, as an average, provided the neighbouring cones are stimulated." This result is some 17 times larger than those given by Monroe and by Goodeve: a reason for this large discrepancy is given.

2497. "The Velocity of Light" [Review of Part I, Vol. 34, 1944, *Transactions Am. Phil. Soc.*].—Dorsey. (*Current Science* [Bangalore], Feb. 1945, Vol. 14, No. 2, p. 48.) The writer is on the staff of the National Bureau of Standards.

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"The improvements concern a bridge-type vacuum-tube voltmeter to read the voltage on the condenser and an arrangement to compensate parasitic potentials developed in the rectifier for the pulses"; the circuit is particularly suitable for portable instruments, and is independent of a.c. mains fluctuations.

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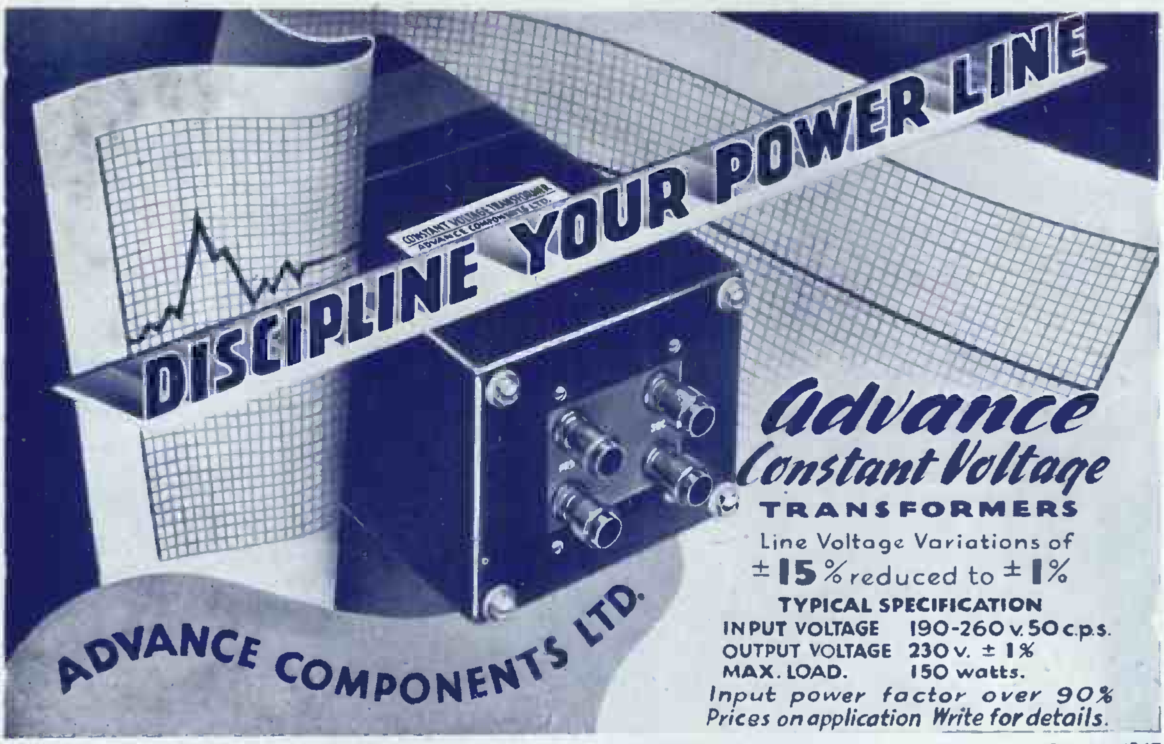

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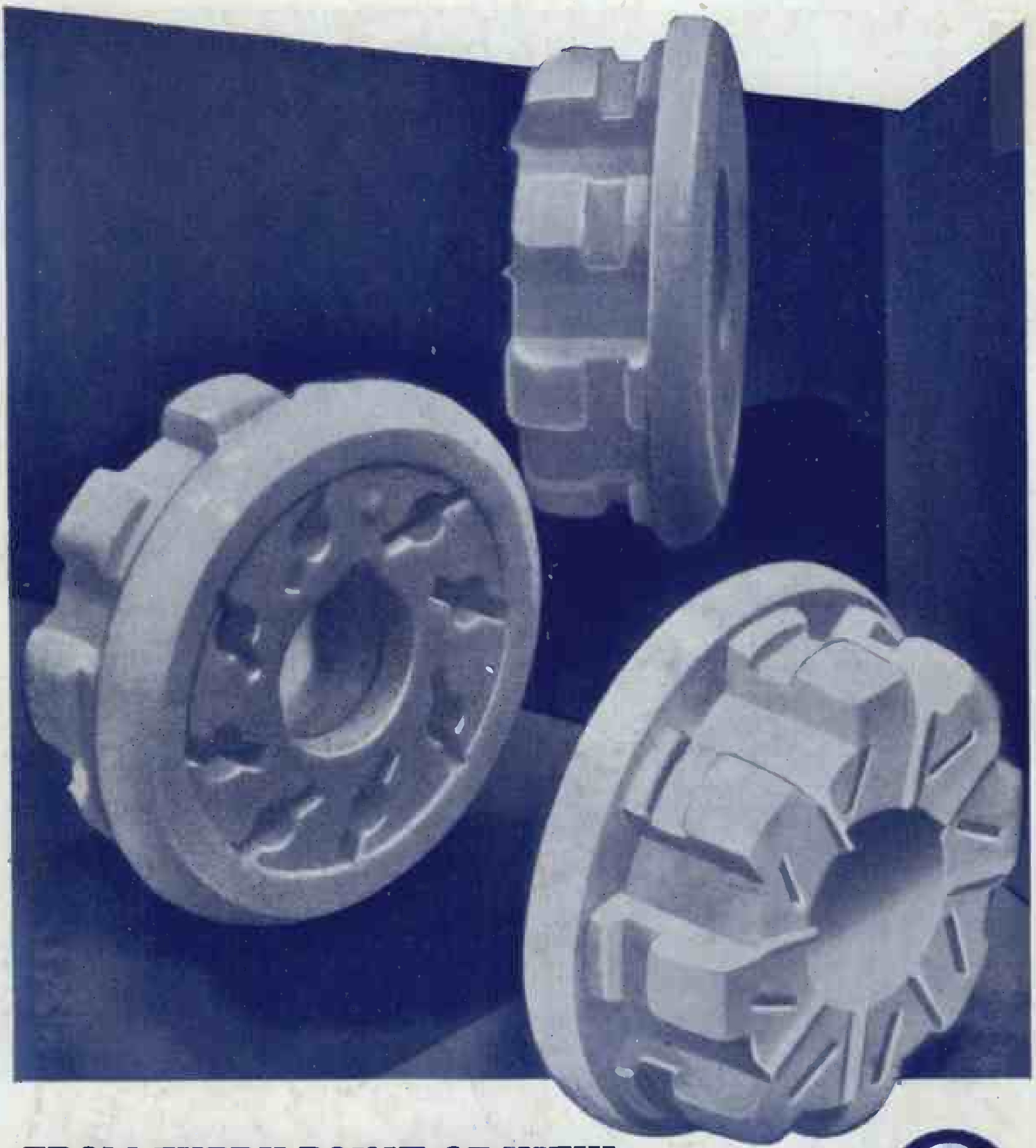

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