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CONTENTS

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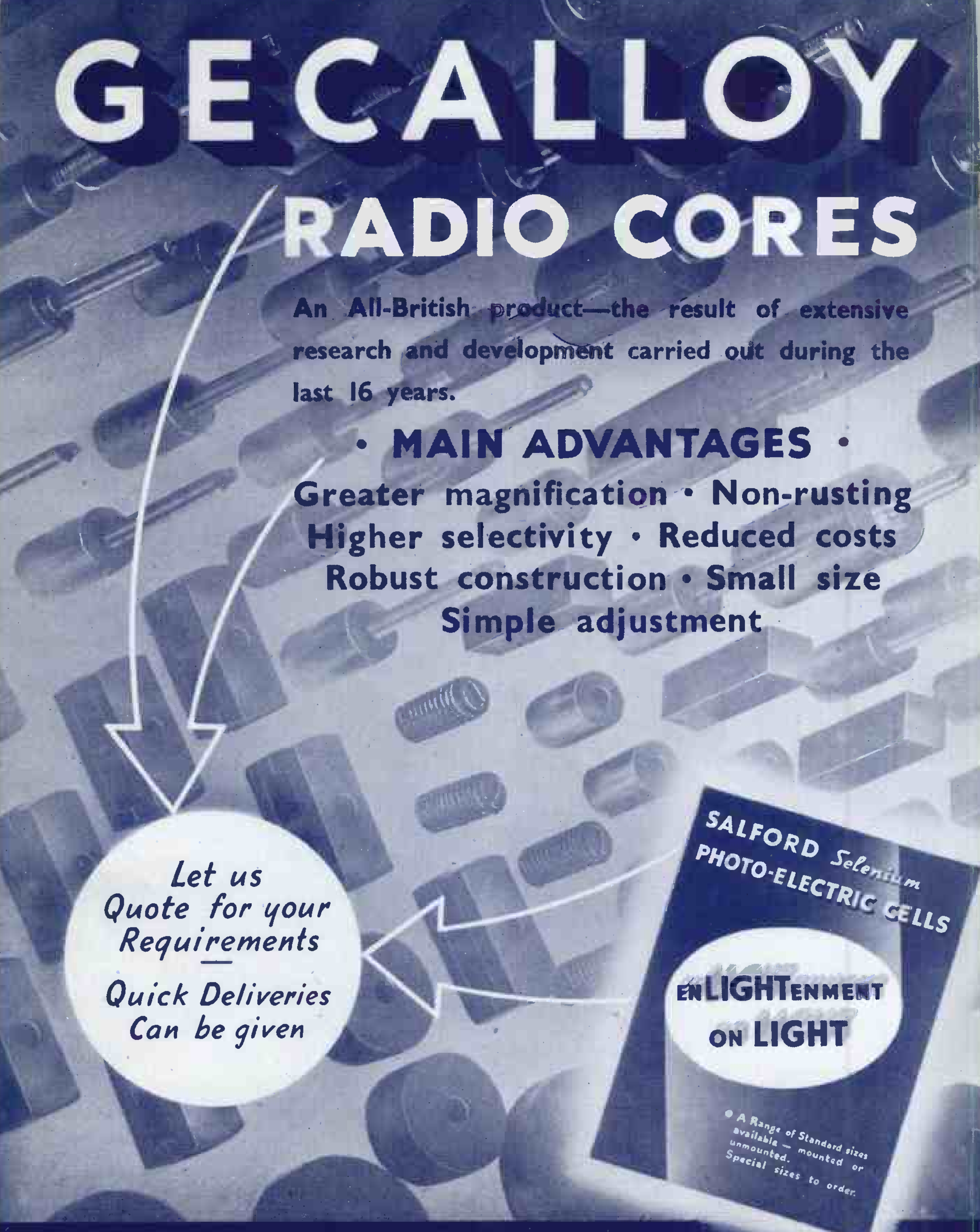

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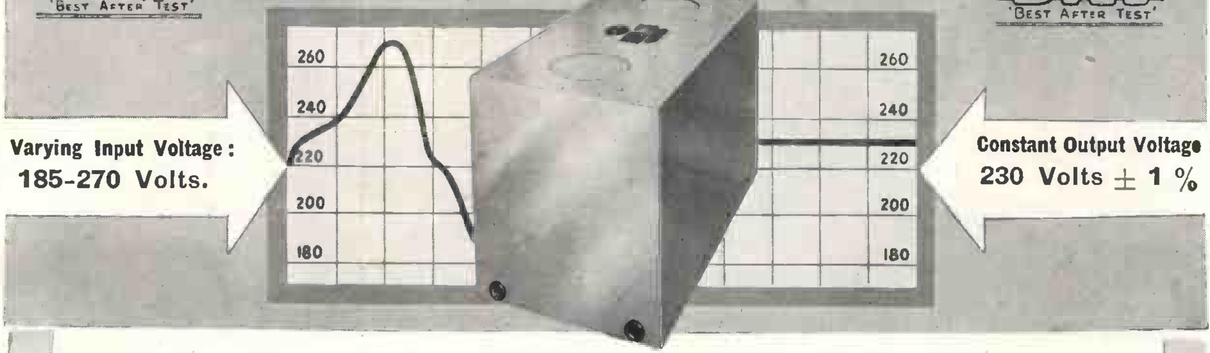

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Constant A.C. input voltage is essential for the effective operation of many electrical devices, both Industrial and laboratory patterns. Examples : X-ray apparatus, Incandescent-lamp light sources (photometers, photo-printing, colour comparators, photo-electric cell applications, spectrography, etc.), laboratory test-gear (VTVM's, signal generators, amplifiers, oscillators, signal generators, standards of frequency, etc.) : the larger patterns for stabilizing a complete laboratory room or test-bench : the smaller units as integral components of equipment.

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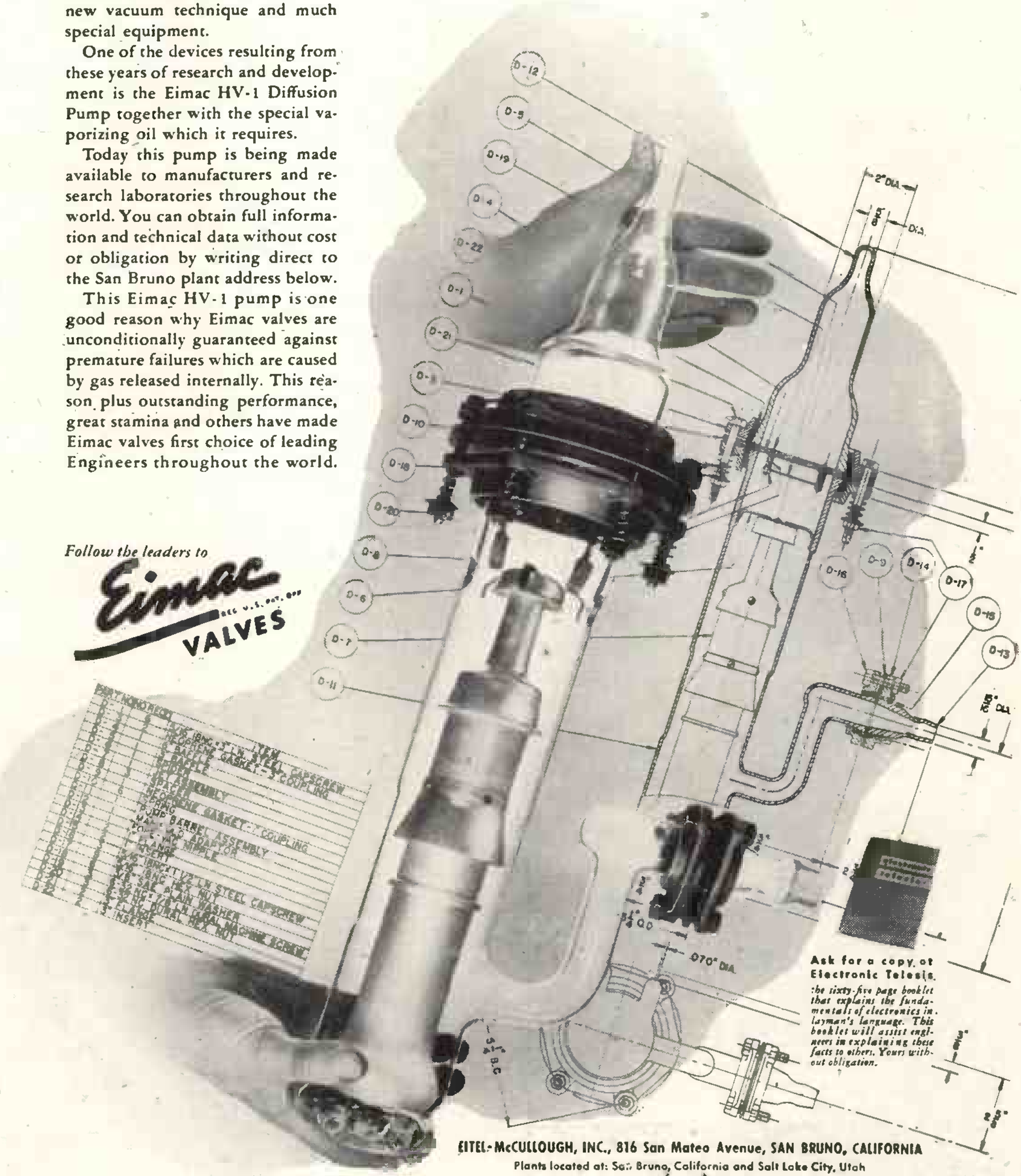

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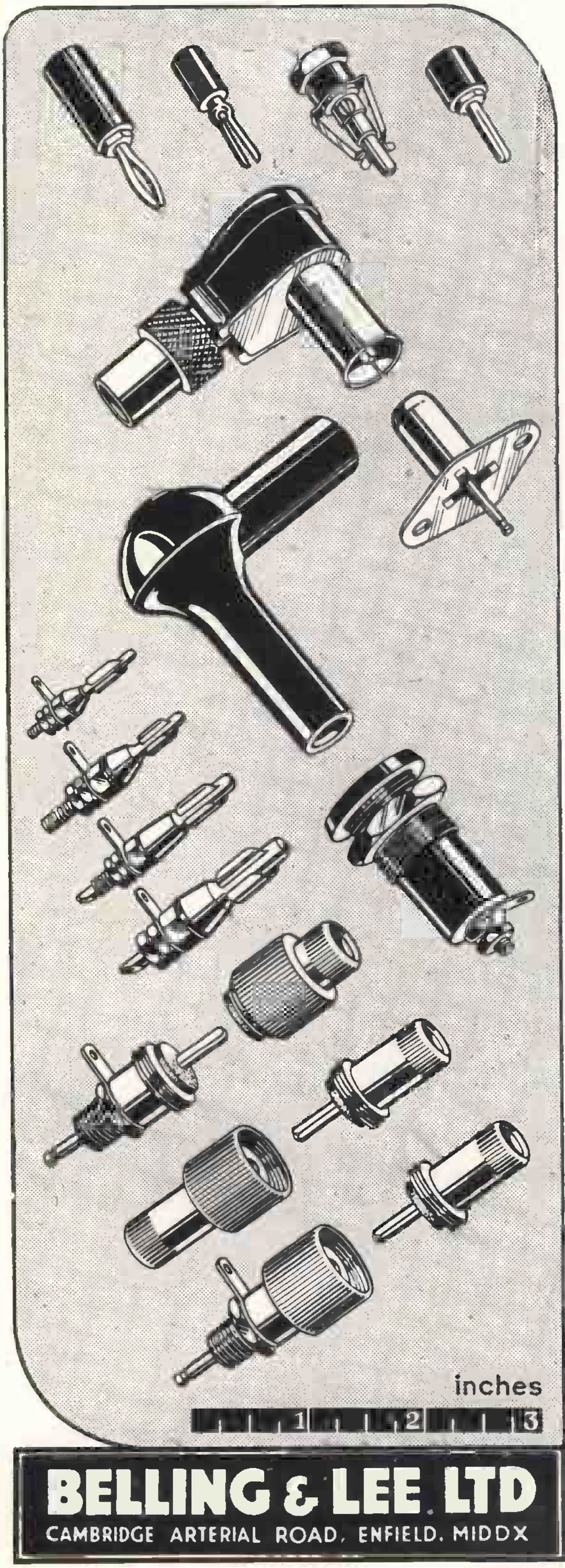
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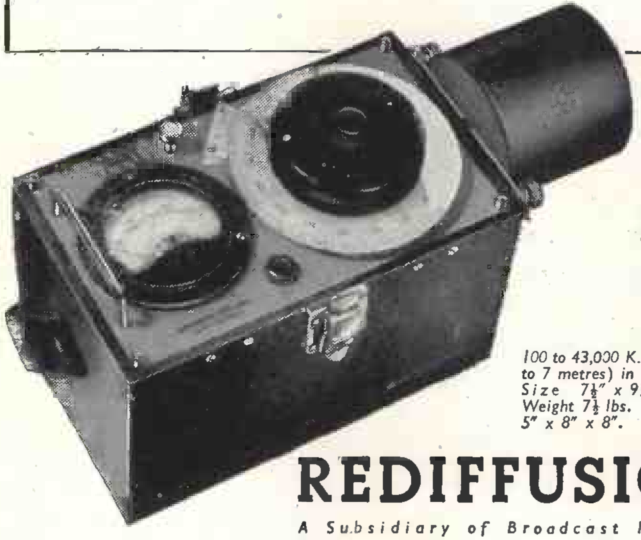

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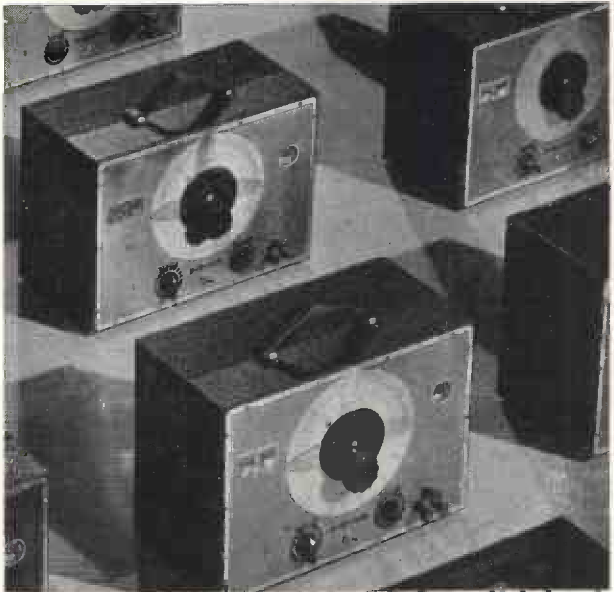

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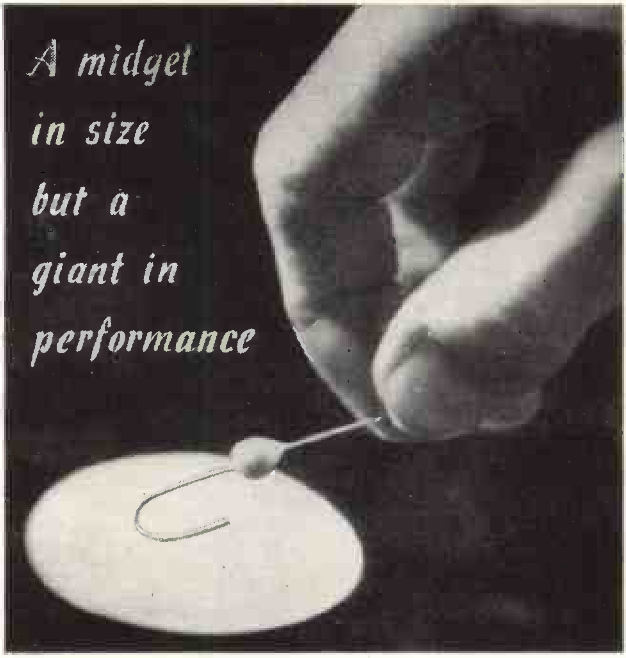
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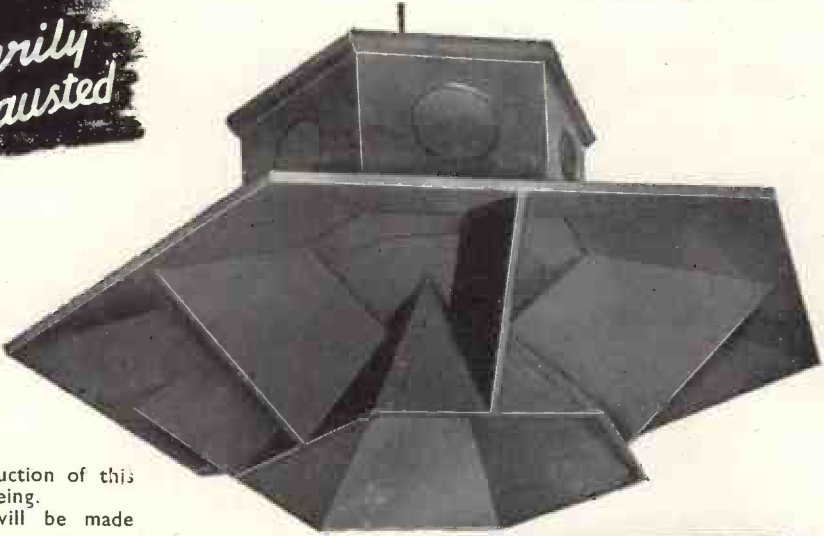

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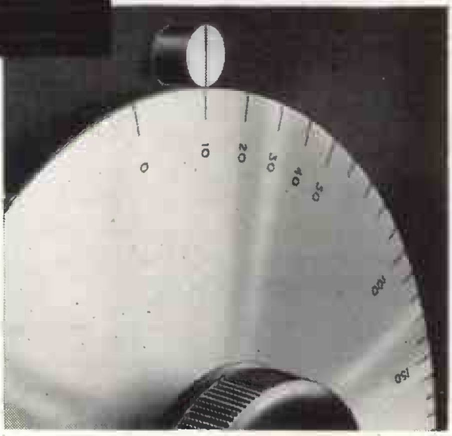

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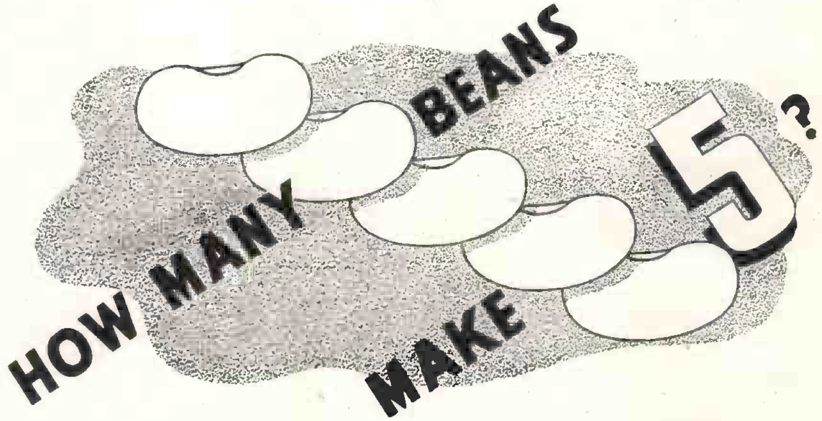

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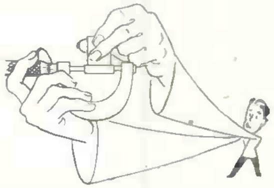

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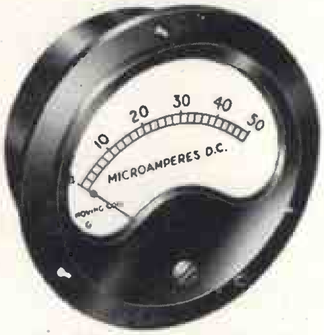

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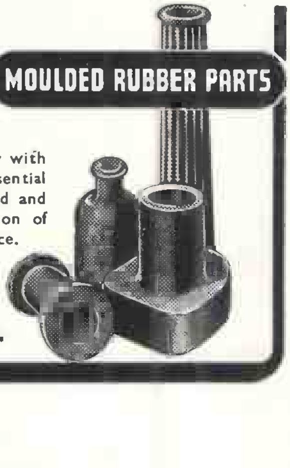

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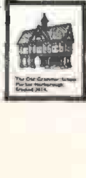

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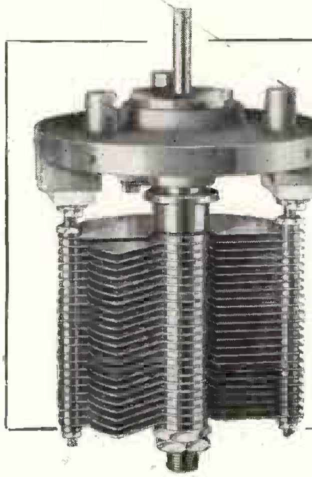

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WHY ERSIN MULTICORE

the Solder wire with 3 cores of non-corrosive ERSIN FLUX is preferred by the majority of firms manufacturing the best radio and electrical equipment under Government Contracts.

WHY THEY USE CORED SOLDER

Cored solder is in the form of a wire or tube containing one or more cores of flux. Its principal advantages over stick solder and a separate flux are :

(a) it obviates need for separate fluxing (b) if the correct proportion of flux is contained in cored solder wire the correct amount is automatically applied to the joint when the solder wire is melted. This is important in wartime when unskilled labour is employed.

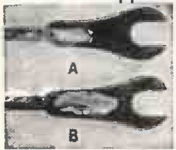
WHY THEY PREFER MULTICORE SOLDER. 3 Cores—Easier Melting Multicore Solder wire contains 3 cores of flux to ensure flux continuity. In Multicore there is always sufficient proportion of flux to solder. If only two cores were filled with flux, satisfactory joints are obtained. In practice, the care with which Multicore Solder is made means that there are always 3 cores of flux evenly distributed over the cross section of the solder, so making thinner solder walls than single cored solder, thus giving more rapid melting and speeding up soldering.

ERSIN FLUX

For soldering radio and electrical equipment non-corrosive flux should be employed. For this reason either pure resin is specified by Government Departments as the flux to be used, or the flux residue must be pure resin. Resin is a comparatively non-active flux and gives poor results on oxidised, dirty or "difficult" surfaces such as nickel. The flux in the cores of Multicore is "Ersin"—a pure, high-grade resin subjected to chemical process to increase its fluxing action without impairing its non-corrosive and protective properties. The activating agent added by this process is dissipated during the soldering operation and the flux residue is pure resin. Ersin Multicore Solder is approved by A.I.D., G.P.O., and other Ministries where resin cored solder is specified.

PRACTICAL SOLDERING TEST OF FLUXES

The illustration shows the result of a practical test made using nickel-plated spade tags and bare copper braid. The parts were heated in air to 250° C, and to identical specimens were applied ½" lengths of 14 S.W.G. 40/60 solder. To sample A, single cored solder with resin flux was applied. The solder fused only at point of contact without spreading. A dry joint resulted, having poor mechanical strength and high electrical resistance. To sample B, Ersin Multicore Solder was applied, and the solder spread evenly over both nickel and copper surfaces, giving a sound mechanical and electrical joint.



ECONOMY OF USING ERSIN MULTICORE SOLDER

The initial cost of Ersin Multicore Solder per lb. or per cwt. when compared with stick solder is greater. Ordinary solder involves only melting and casting, whereas high chemical skill is required for the manufacture of the Ersin flux and engineering skill for the Multicore Solder incorporating the 3 cores of Ersin Flux. However, for the majority of soldering processes in electrical and radio equipment Multicore Solder will show a considerable saving in cost, both in material and labour time, as compared either with stick solder or single cored solder. Cored solder ensures that the solder and flux are put just where they are required, and by choice of suitable gauge, economy in use of material is obtained. The quick wetting of the Ersin flux as compared with resin flux in single core resin solder ensures that with the correct temperature and reasonably clean surface, immediate alloying will be obtained, and no portions of solder will drop off the job and be wasted. Even an unskilled worker, provided with irons of correct temperature, is able to use every inch of Multicore Solder without waste.

ALLOYS

Soft solders are made in various alloys of tin and lead, the tin content usually being specified first, i.e. 40/60 alloy means an alloy containining 40% tin and 60% lead. The need for conserving tin has led the Government to restrict the proportion of tin in solders of all kinds. Thus, the highest tin content permitted for Government contracts without a special licence is 45/55 alloy. The radio and electrical industry previously used large quantities of 60/40 alloy, and lowering of tin content has meant that the melting point of the solder has risen. The chart below gives approximate melting points and recommended bit temperatures.

ALLOY Tin Lead	Equivalent B.S. Grade	Solidus C.°	Liquidus C.°	Recommended bit Temperature C.°
45/55	M	183°	227°	267°
40/60	C	183°	238°	278°
30/70	D	183°	257°	297°
18.5/81.5	N	187°	277°	317°

VIRGIN METALS—ANTIMONY FREE

The wider use of zinc plated components in radio and electrical equipment has made it advantageous to use solder which is antimony free, and thus Multicore Solder is now made from virgin metals to B.S. Specification 219/1942 but without the antimony content.

IMPORTANCE OF CORRECT GAUGE

Ersin Multicore Solder Wire is made in gauges from 10 S.W.G. (.128″—3.251 m/ms) to 22 S.W.G. (.028″—.711 m/ms). The choice of a suitable gauge for the majority of the soldering undertaken by a manufacturer results in considerable saving. Many firms previously using 14 S.W.G. have found they can save approximately 33⅓%, or even more by using 16 S.W.G. The table gives the approximate lengths per lb. in feet of Ersin Multicore Solder in a representative alloy, 40/60.

S.W.G.	10	13	14	16	18	22
Feet per lb.	23	44.5	58.9	92.1	163.5	481

CORRECT SOLDERING TECHNIQUE

Ersin Multicore Solder Wire should be applied simultaneously with the iron, to the component. By this means maximum efficiency will be obtained from the Ersin flux contained in the 3 cores of the Ersin Multicore Solder Wire. It should only be applied direct to the iron to tin it. The iron should not be used as a means of carrying the solder to the joints. When possible, the solder wire should be applied to the component and the bit placed on top, the solder should not be "pushed in" to the side of the bit.

ERSIN MULTICORE SOLDER WIRE is now restricted to firms on Government Contracts and other essential Home Civil requirements. Firms not yet using Multicore Solder are invited to write for fuller technical information and samples.

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WIRELESS ENGINEER

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

VOL. XXI AUGUST, 1944 No. 251

Editorial

Effect of Stray Capacitance on Coupling Coefficient

THE February Editorial was devoted to simple methods of calculating the coupling coefficient and the resonant frequencies of various arrangements of coupled circuits. A matter of some interest in such circuits is the effect of stray capacitance between the coupling coils. It is not easy to say offhand whether such stray capacitance will increase or decrease the effective coupling; as we shall see, it may do one or the other depending on circumstances.

Fig. 1a shows two similar circuits coupled by the mutual inductance M between the coils which, although drawn side by side, are really co-axial.

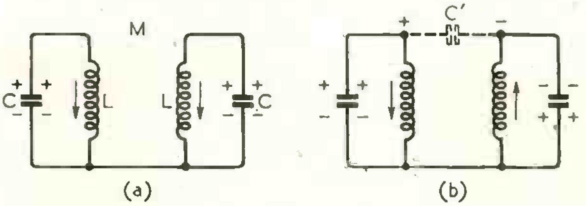
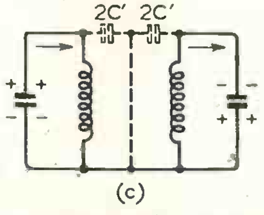


Fig. 1.



We shall assume in the first place that the two coils are wound in the same direction so that when the two condensers are charged as shown in Fig. 1a and simultaneously discharged, the effective inductance of each circuit is increased from L to $L + M$. If the two circuits are connected as shown, the upper ends of the coils are always at the same potential and therefore any capacitance between them will have no effect. For the lower resonant frequency we have therefore

$$\omega_2^2 = 1/C(L+M) = \omega_0/\left(1 + \frac{M}{L}\right).$$

If, however, the condensers are charged as shown in Fig. 1b and simultaneously discharged, the effective inductance of each circuit is reduced from L to $L - M$. Now, however, there is a difference of potential between the upper ends of the coils and the stray capacitance between the coils must be taken into account. Let this be represented by a capacitance $C' = \alpha C$ between the upper ends of the coils. If C' be replaced by two condensers each of $2C'$ in series, their midpoint is obviously always at zero potential and can be connected to the lower ends of the coils as shown in Fig. 1c. It is seen that the effect of the stray capacitance is to increase the effective capacitance of the circuits from C to $C + 2C'$, i.e. to $C(1 + 2\alpha)$. For the higher resonant frequency we therefore have the formula

$$\omega_1^2 = \frac{1}{C(1+2\alpha)(L-M)}$$

$$= \frac{1}{CL\left(1+2\alpha\right)\left(1-\frac{M}{L}\right)} = \frac{\omega_0^2}{\left(1+2\alpha\right)\left(1-\frac{M}{L}\right)}$$

It can be seen at once that the effect of the stray capacitance is to decrease the difference between ω_1^2 and ω_2^2 which is equivalent to a decrease in the coupling. Putting the magnetic coupling $\frac{M}{L} = k_m$ we have for the effective coupling

$$k = \frac{\omega_1^2 - \omega_2^2}{\omega_1^2 + \omega_2^2}$$

$$= \frac{1 + k_m - (1-k_m)(1+2\alpha)}{1 + k_m + (1-k_m)(1+2\alpha)} = \frac{k_m - \alpha(1-k_m)}{1 + \alpha(1-k_m)}$$

If the coils are wound in opposite directions, then when the currents are flowing as in Fig. 1a the effect of the mutual inductance will be to decrease the effective inductance of each circuit from L to

$L - M$, and the higher resonant frequency will be given by the formula $\omega_1{}^2 = \omega_0{}^2/(1 - k_m)$. When the currents are flowing as in Fig. 1b the effective inductance will now be increased to $L + M$ and the lower resonant frequency will be given by the formula $\omega_2{}^2 = \dfrac{\omega_0{}^2}{(1 + 2\alpha)(1 + k_m)}$.

For the effective coupling we now have

$$k = \frac{\omega_1{}^2 - \omega_2{}^2}{\omega_1{}^2 + \omega_2{}^2}$$
$$= \frac{(1 + k_m)(1 + 2\alpha) - (1 - k_m)}{(1 + k_m)(1 + 2\alpha) + (1 - k_m)} = \frac{k_m + \alpha(1 + k_m)}{1 + \alpha(1 + k_m)}$$

In this case the effective coupling is increased. If as a numerical example we take k_m as 0.1 and α as 0.05, then with the coils wound in the same direction the coupling is reduced from 0.1 to 0.053, whereas with the coils wound in opposite directions it is increased from 0.1 to 0.147. Thus if α be expressed as a percentage of k_m the effective coupling is increased or decreased by the same percentage to a close degree of approximation. If, instead of being connected or earthed at the lower end as in Fig. 1, or the upper end, the two coils are connected as shown in Fig. 2 conditions are entirely different. Representing the capacitance between the coils by a condenser C' between them at each end, it is seen that each of these condensers is in parallel with one of the tuning condensers and the two resonant frequencies are given by the formulae

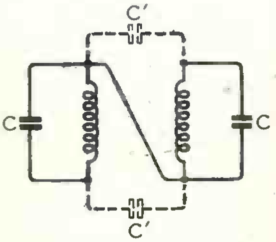


Fig. 2.

$$\omega_1{}^2 = \frac{\omega_0{}^2}{(1 - k_m)(1 + \alpha)} \text{ and } \omega_2{}^2 = \frac{\omega_0{}^2}{(1 + k_m)(1 + \alpha)}$$

where $C' = \alpha C$.

For the effective coupling we have

$$k = \frac{\omega_1{}^2 - \omega_2{}^2}{\omega_1{}^2 + \omega_2{}^2} = k_m$$

since the term $(1 + \alpha)$ cancels out. Hence in this case the stray capacitance decreases both resonant frequencies in the same ratio, and thus leaves the coupling coefficient unaffected.

These simple examples bring out clearly the fact that the stray capacitance between the coils may increase or decrease the coupling or have no effect on it, depending on the connections and the way the coils are wound. G. W. O. H.

Specific Resistance, Volume Resistivity and Mass Resistivity

In the Editorial on this subject in the July number Mr. Brockelsby was quoted as saying that the definition [of mass resistivity] makes the term apply to the column "ohms/lb" often found in wire tables. Readers will, however, search his letter on p. 328 in vain for any reference to this point. This is due to the fact that he deleted this sentence when checking the proof of his letter.

Correspondence

"Deflected Electron Beams"

To the Editor, "Wireless Engineer"

Sir,—In his discussion, in the July issue, of Mr. Harries' paper (June), Dr. Gabor states that the analysis on p. 268 amounts to an admirably concise derivation of Recknagel's formula. Now this analysis is along similar lines to that given by myself in December, 1939 (pp. 598 and 599). Since neither derivation purports to cover the effect of the exit or stray field of the condenser they should therefore yield the same result.

In his original paper in the March issue, Dr. Gabor refers in a footnote to a slip which he considers I made and corrected. Perhaps Dr. Gabor will be good enough to refer again to my 1939 paper and compare the analysis step for step with that of Mr. Harries. I should then be glad if he would tell readers exactly where the divergence occurs between the two analyses, exactly where the mistake lies, and who makes it.

Chipperfield, Herts. W. E. Benham.

To the Editor, "Wireless Engineer"

Sir,—In his article in the June issue of *Wireless Engineer*, J. H. Owen Harries gives a new expression for the current in a length o to l of an infinitely long deflector plate system. The expression is derived from the form

$$i_d = \frac{I_b}{v_b d}\int_o^l v_y dx \quad .. \quad .. \quad .. \quad .. \quad .. \quad (1)$$

but the integration appears to be performed incorrectly, as it should lead to Benner's equation. However (1) is itself in error, the correct form of Ramo's equation for the length o to l being

$$i_d = \frac{I_b}{d}y(t,t) - \frac{I_b}{d}y(t,t-\tau) + \frac{I_b}{v_b d}\int_o^l v_y dx \quad .. \quad .. \quad (2)$$

where y is a function $y(t,t_o)$ of t and t_o.

$y(t,t)$, $y(t,t-\tau)$ are the y displacements at time t for electrons at the planes $x = o$, $x = l$ respectively.

The expression (2) applies even if l is less than the deflector plate length.

London, N.21. J. A. Jenkins.

"Screened Loop Aerials"

To the Editor, "Wireless Engineer"

Sir,—I have noted a typographical error in my paper on "Screened Loop Aerials" which appeared in the May, 1944, issue of *Wireless Engineer*. In Fig. 2, on p. 215, the left-hand label of the abscissa axis should be r_1/r_2 and not P/r_2.

Slough, Bucks. R. E. Burgess

TEMPERATURE COEFFICIENT OF AIR-CORED SELF-INDUCTANCES*

The Case of a "Thin" Current-Carrying Layer

By A. Bloch, Dr.-Ing., M.Sc.

(Communication from the Staff of the Research Laboratories of The General Electric Company, Limited, England)

SUMMARY.—In Section 1 of the paper a simple first approximation for the value of the internal self-inductance of the coil is derived from the assumption that the electro-magnetic field enters the conductor like a plane electromagnetic wave, an assumption which is always justified when the current-carrying layer is thin compared with the dimensions of the conductor. In this case it follows most easily from Professor Howe's " transmission line treatment " of wave propagation that the reactive power " consumed " by the internal reactance must be equal to the real power consumed, i.e. that the internal reactance ωL_i must equal the loss resistance of the coil R_i, or $L_i \approx L/Q$ where L = total inductance of coil and where " Q " refers to the copper losses only.

As the skin thickness and therefore the losses vary as the square root of the resistivity of the conductor material, it follows that the temperature coefficient of the internal inductance equals 1/2 of the temperature coefficient of the resistivity (i.e. in the case of copper conductors it will be 2100×10^{-6}). If the variation of the internal inductance were the only change to be reckoned with, the coil as a whole would then possess a temperature coefficient of self inductance equal to $2100 \times 10^{-6}/Q$. This result is valid for all kinds of conductor cross sections and includes the effect of copper shielding cans. It is easily generalised to take account of different conducting materials in the field of the coil.

In Section 2 of the paper it is shown by means of an elementary approximation that for the case of a circular conductor the result derived in Section 1 includes the influence of the field penetration on the external field of the coil.

In Section 3 the case of additional geometrical changes of the coil dimensions is dealt with, including the case where the diameter of the coil wire expands at a rate different from that of the overall coil dimensions.

Appendix I derives a simple formula for the copper losses and the Q value of an inductance coil. An example shows quite clearly that the opinion of previous investigators as to the negligible influence of the proximity effect on the internal inductance requires revision.

For the sake of completeness Appendix II derives some skin effect formulae from transmission line considerations, including that for H. A. Wheeler's equivalent magnetic skin thickness.

1. Simple Approximation of the Internal Inductance and its Variation with Temperature.

It is a well known fact that the inductance of an air-cored coil changes with temperature as a rule much more than one would expect from the thermal changes of the coil dimensions. The discrepancy may be of the order of several hundred per cent. Professor J. Groszkowski (of Warsaw) was the first to point to the real reason for these unexpected results, namely to the change in the resistivity of the coil conductor and of other conductors situated in the field of the coil.[1] These conductors can be considered as the closed " secondaries " of a transformer, which by their reaction on the " primary " diminish the inductance seen from the input terminals. Increasing the resistance of those secondaries will decrease the eddy currents in them and thus decrease their subtractive influence on the inductance of the coil.

A slightly different point of view was put forward in an Editorial appearing conjointly with Groskowski's letter. If the resistivity of the conductors were zero, the electromagnetic field would be confined entirely to the space outside the conductors. The actual finite resistivity allows the field to penetrate into the conductors and the magnetic energy thus added appears as an increment of the inductance of the coil, this increment being quite appropriately called the " internal inductance." Variations in resistivity result in a varying depth of penetration and thus in a variation of the value of this internal inductance.

Referring to a previous publication of his,[2] the Editor pointed out that in cases where the conducting skin is thin compared with the diameter of the wire the variation of this effect with resistivity can be estimated by simple transmission line formulae ; however, as the value of this internal inductance was not known, the matter had to be left to further investigation.

There the matter rested for some time. As the calculation of the value of the internal inductance is in general rather involved, subsequent investigators based their reasoning mainly on the consideration of highly idealised cases, e.g. the straight wire and the single turn coil.[3]

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

It will be seen from the following, especially from an example given in the appendix, that these idealisations are carried too far to afford quantitative guidance. The present author's interest in this matter arose quite recently when he realised that Professor Howe's editorial of 1935 needed only a slight addition in order to give a satisfactory approximation for the practically very important case of a thin conducting skin, moreover that this approximation would be of an exceedingly simple form and yet cover at the same time the case of conductors of arbitrary cross section and the effect of eddy currents in the shielding can or other metallic conductors in the field of the coil.

In his I.E.E. paper of 1916 Professor Howe introduced the artifice of inserting thin sheets of infinitely good conducting material into the conductors in a direction normal to that of the current flow. On account of this particular orientation these strips will not alter the flow pattern of the current. It is then easily seen that the problem of the penetration of the electromagnetic field into the conductor becomes a " transmission line " problem.[4] The field penetrates by using these sheets of infinitely good conducting material (which turn out to be plane sheets) as go and return path of a transmission line. As each of these fictitious line conductors is used as go path for one line and as return path for the neighbouring line, the currents therein cancel and the actual current in the conductor is the leakage current of these transmission lines. If the geometry of the case is such that the electromagnetic wave penetrating into the conductor can be considered as a plane wave—and this is always the case if the current carrying layer is thin enough, as we can then limit ourselves to a consideration of a correspondingly small area of the wave front—these fictitious lines have constant width, and therefore constant characteristic impedance. Furthermore, the phase angle of this characteristic impedance will always be 45 degrees lagging—independent of the resistivity of the conductor and of the frequency —at least for all practical values of these data.[5]

Now these fictitious transmission lines are supplied with energy from the external field of the coil. Wherever the electromagnetic field of the coil " plays " against a conductor, electromagnetic energy is being carried away by these transmission lines. If we see—on account of the magnetic energy stored in the space external to the conductors—from the input terminals of the coil an inductance L_0, then the additional power consumed by these lines will cause us to see an additional resistance R_i, and the wattless (lagging) power consumed by these lines will cause us to see an additional inductance L_i. L_0 will remain the same if we assume that this withdrawal of energy from the field of the coil will not affect the magnetic field outside the conductors. This is justifiable as a first approximation, and, as will be shown in the following section, it will even lead to a correct result for the case of a conductor of circular cross section if the conducting skin is (infinitesimally) thin.

The magnetic field responsible for L_0 acts in this interpretation as a kind of supply medium for the energy consumed by these lines, and, as all these consumers have a phase angle of 45 degrees lagging, we can replace them as regards their effect on the input of the coil by a single consumer of the same phase angle, i.e. the resistance R_i and the inductance L_i just mentioned obey the relation

$$R_i = \omega L_i \quad \ldots \quad (1.1)$$

Now, R_i can be estimated if we know the Q of the coil. We have

$$\frac{1}{Q_{\text{Total}}} = \frac{1}{Q_{\text{Copper Loss}}} + \frac{1}{Q_{\text{Capac. Loss}}} + \ldots \quad (1.2)$$

and as a rule, the first of the right-hand terms far exceeds the others. Thus neglecting the latter for the time being (or assuming that Q in the following formulae means only the " ohmic " part of the total " Q ") we get

$$R_i = \frac{\omega L}{Q} = \omega L_i \quad \ldots \quad (1.3)$$

or

$$L_i = \frac{L}{Q} \quad \ldots \quad (1.4)$$

As (1.1), (1.3) and (1.4) are valid for all values of resistivity, the variation of L_i with temperature is the same as that of R_i, and the same as that of Z_0, the characteristic impedance of those transmission lines. This means that L_i increases with the square root of the resistivity (*see* Appendix II), i.e. that

$$\frac{1}{Z_0}\cdot\frac{dZ_0}{dT} = \frac{1}{R_i}\frac{dR_i}{dT} = \frac{1}{L_i}\frac{dL_i}{dT} = \frac{\alpha}{2} \quad \ldots \quad (1.5)$$

where

$$\alpha = \frac{1}{\rho}\frac{d\rho}{dT} \quad \ldots \quad (1.6)$$

has for copper the value 4200×10^{-6}.

Therefore we get a temperature coefficient of inductance due to the temperature variation of resistivity

$$\tau = \frac{1}{L}\frac{dL_i}{dT} = \frac{L_i}{L}\frac{1}{L_i}\frac{dL_i}{dT} = \frac{\alpha}{2Q}\left(= \frac{2100 \times 10^{-6}}{Q}\right) \quad \ldots \quad (1.7)$$

If the coil can is copper lined the losses due to the eddy currents in this lining need not be distinguished from the rest of the copper losses. There is, however, no great difficulty in carrying the analysis a little further and separating these contributions. We have

$$\tau = \frac{1}{L}\frac{dL_i}{dT} = \frac{1}{L}\left[\frac{dL_{i1}}{dT} + \frac{dL_{i2}}{dT}\right] \quad .. \quad (1.8)$$

where L_{i1} denotes the internal inductance of the coil proper and L_{i2} the internal inductance of the can. With the same assumptions as before we have

$$L_{i1} = \frac{L_i}{Q_1} \quad \text{and} \quad L_{i2} = \frac{L_i}{Q_2} \quad .. \quad (1.9)$$

where Q_1 and Q_2 refer to the contribution made by the coil proper and by the can to the total "ohmic" Q. From (1.8) and (1.9) it follows then

$$\tau = \tfrac{1}{2}\left[\frac{\alpha_1}{Q_1} + \frac{\alpha_2}{Q_2}\right] \quad .. \quad (1.10)$$

where α_1 and α_2 refer to the temperature coefficients of the resistivities of coil and can respectively. As a rule the temperature coefficient of the can is sufficiently close to that of copper to make such a detailed analysis superfluous (e.g. for aluminium we get a value of 0.0046 instead of 0.0042)*.

2. Proof that in the case of a round wire the result of Section 1 includes the reaction of the internal field on the external field.

It will be useful to introduce here a general theorem which connects the input impedance of a system with the mean energy stored and dissipated in this system.

Using complex notation and denoting with $\check{I}$ the complex conjugate of $\hat{I}$, it says that

$$\frac{\hat{E}\check{I}}{2} = \Sigma W_{\text{mean}} + 2j\omega\,(\Sigma T_{\text{mean}} - \Sigma V_{\text{mean}}) \quad (2.1)$$

where ΣW_{mean} denotes the sum total of the time averages of all energy dissipations occurring in the system.

ΣT_{mean} denotes the sum total of all the time averages of magnetic energies stored in the system.

ΣV_{mean} denotes the sum total of all the time averages of electro-static energies stored in the system†.

If we divide the last equation by $\hat{I}\check{I} = |\hat{I}|^2$ we get for the input impedance

$$Z_i = \frac{\hat{E}}{\hat{I}} = \frac{1}{|\hat{I}|^2}[2\Sigma W_{\text{mean}} + 4j\omega(\Sigma T_{\text{mean}} - \Sigma V_{\text{mean}})]$$
$$= 2\Sigma W_1 + 4j\omega(\Sigma T_1 - \Sigma V_1) \quad .. \quad (2.2)$$

where the indices $_1$ denote that the magnitudes concerned are calculated under the assumption that the input current of the system had an amplitude of 1 ampere.

The last equation expresses in mathematical form the basic idea which we used in Section 1. There it allowed us to conclude from the fact that the phase angle of the fictitious transmission lines was 45 degrees, that in the space occupied by each transmission line we had $W_1 = T_1$, and conversely if we add all the contributions W_1 and T_1 that the phase angle of the whole internal reactance of the coil is 45 degrees.

Here we shall use it in a different manner, namely, for resolving the internal impedance of the coil into two components. The magnetic field surrounding each element of the coil wire consists of two components; the one (the H_0 component) is due to the current flowing in this element, the other (the H_1 component) is due to the current flowing in all the other elements. Each of these fields penetrates into the interior of the conductor and causes thereby energy dissipation and storage of energy and we shall see presently that these effects can be calculated independently of each other. Each of the dissipation and storage effects leads then according to the preceding formula to a corresponding contribution to the input impedance of the coil. For quite obvious reasons we shall call the contributions caused by the H_0 field the "skin-effect components," and the contributions caused by the H_1 field, the "proximity effect components."

In the case of a round wire the H_0 field possesses radial symmetry. The H_1 field can be assumed to a first approximation to be homogeneous in the absence of the wire element under consideration; it is also usual to assume that the introduction of the wire element into this field will react on this field in the same way as if we had placed a cylinder of equal diameter and of infinite length into a homogeneous field of infinite extension.

The fact that the "skin effect resistance" and the "proximity effect resistance" can be calculated independently of each other is well known.

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* Assuming the conducting skin of the can to be non-magnetic; otherwise we would have to include in the analysis the change of Z_0 due to the variation of μ with temperature.

† The theorem says nothing more than that the real and reactive power metered at the input terminals of the system must be equal to the power consumption of the individual components.

A proof of the theorem based directly on the general equations of an electrical network can be found in Guillemin, Communication Networks, Vol. II, p. 226. The first publication of the theorem is apparently due to Slepian (*Proc. Am. I.E.E.*, Vol. 38 [1919], p. 1061). However, a quite analogous formulation concerning the energy flux calculated according to Poyntings Theorem seems to have been formulated previously by M. Abraham and F. Emde (*see* Abraham-Föppl, "Theorie der Elektrizität", 6th ed., p. 313).

It rests simply on the following considerations. The total instantaneous energy dissipation in a unit length of wire is given by

$$W = \rho \int i^2 \, df \qquad \ldots \quad \ldots \quad \ldots \quad (2.3)$$

where

ρ = resistivity of the wire material,

df = element of cross sectional area,

i = current density on this element.

Now

$$i = i_0 + i_1$$

where i_0 and i_1 refer to the instantaneous current densities caused by the fields H_0 and H_1 (these values vary, of course, over the cross section of the wire). Therefore

$$W = \rho \int i_0^2 df + \rho \int i_1^2 df + 2\rho \int i_0 \,.\, i_1 \,.\, df \,\ldots \quad (2.5)$$

The last term disappears however from the result as for reasons of symmetry every element of the cross section where i_0 and i_1 have the same direction has a counterpart in which they have the opposite direction. (The current distribution i_0 has radial symmetry, the current distribution i_1 is skew-symmetrical with respect to a plane through the axis of the wire parallel to the direction of the H_1 field).

The same line of reasoning can be applied to the magnetic energy stored by these two fields. This energy is given at every instance by

$$T = \frac{1}{8\pi} \int |\overline{H}|^2 \, df \qquad \ldots \quad \ldots \quad \ldots \quad (2.6)$$

where

$$\overline{H} = \overline{H}_0 + \overline{H}_1 \qquad \ldots \quad \ldots \quad \ldots \quad (2.7)$$

denotes the sum of the two space vectors $\overline{H}_0$ and $\overline{H}_1$ pertaining to the corresponding type of field, and where now the integration has to be carried out over the whole cross section of space (inside and outside the wire).

Now

$$|\overline{H}|^2 = |\overline{H}_0|^2 + |\overline{H}_1|^2 - 2|\overline{H}_0| \,.\, |\overline{H}_1| \cos\alpha \,\ldots \quad (2.8)$$

where α denotes the angle formed between $\overline{H}_0$ and $\overline{H}_1$, and, as there is always a difference of π between the angles pertaining to two diametrically opposite elements, the mutual product disappears again from the integration.

The reason why we want such a separation of W and T into separate contributions W_0 and W_1 and T_0 and T_1 is, that each of these contributions may be affected in a different way when variations of temperature alter the penetration of the field. As regards the field energy stored inside the conductor both contributions behave in the same way. Within the assumptions made, both types of field penetrate into the conductor as "plane waves," and the developments of the preceding section need not be amplified. However, this penetration process reacts obviously in quite a different way on the external field (the field responsible for L_0). The penetration of the H_0 field into the conductor does not alter the H_0 values outside the conductor; these remain unchanged at the value $2I/r$ where $I = \int i_0 df$ is the total current in the wire element and r the radial distance from its axis. On the other hand, the penetration will certainly alter the individual H_1 values in the outer space, as this penetration of the field into the conductor amounts in effect to a reduction in size of the obstacle which the conductor presents to the flow of the magnetic flux.

H. A. Wheeler gave for the case of a thin skin which we here consider only a very simple approximation for this reduction. If the boundary of the conductor recedes everywhere by a distance $t_m = t/2$, where t is the equivalent thickness of the conducting skin, and is then replaced by an ideally conducting boundary, then it is easily shown that the energy which can be stored in the additional space available to the magnetic field equals the energy stored before in the non-ideal conductor.[6]

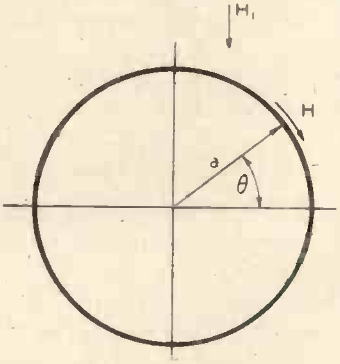

Fig. 1.

Thus, as regards the changes in "internal" magnetic energy this recession of the boundary is exactly capable of simulating the penetration of the field. We shall use it, therefore, now to estimate the influence of this penetration on the external field.*

We know from hydrodynamic theory (from the equivalent problem of a cylinder inserted across a homogeneous flow) that the field strength tangential to the boundary of the cylinder is given by

$$H = 2H_{10} \,.\, \cos\Theta \qquad \ldots \quad \ldots \quad (2.9)$$

where H_{10} denotes the field strength of the undisturbed field and Θ the angle shown in Fig. 1. If the boundary recedes by a distance da, the

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* The exact solution of this problem will be given in a further article (accepted for publication in the *Philosophical Magazine*). The result which is here obtained from elementary considerations coincides with the exact solution.

annular space between the old and the new boundary will be filled by the magnetic field. As the squared mean value of the field strength in this space is $H_m^2 = 2H_{10}^2$ and as there is no radial component, the increment of magnetic energy (per unit) length of the conductor) is

$$dT = \frac{1}{8\pi} H_m^2 . dV = \frac{1}{8\pi} . 2H_{10}^2 . 2a\pi da = \tfrac{1}{2} H_{10}^2 . a . da \quad .. \quad .. \quad (2.10)$$

From the same hydrodynamic analogy (to be discussed presently) we know that placing the wire in the field caused originally a decrease in energy equal to

$$\Delta T = \frac{1}{8\pi} . H_{10}^2 . 2a^2\pi = \tfrac{1}{4} H_{10}^2 . a^2 \quad .. \quad (2.11)$$

Differentiating the last expression gives us the increment pertaining to a change $- da$ of the wire radius

$$dT = \tfrac{1}{2} H_{10}^2 . a . da \quad .. \quad .. \quad (2.12)$$

which coincides with the value just calculated above, in which we did not take into account the changes caused in the external field (i.e., the changes caused in the external field by such an infinitesimal penetration just cancel).

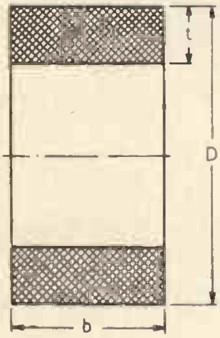

Fig. 2.

Eqn. 2.11 can be derived from a well-known result of hydrodynamic theory as follows. We know that a cylinder of infinite length when moving normal to its axis experiences on immersion in a liquid an apparent increase in mass which just equals the mass of the liquid contained in the volume of the cylinder. Let us now take a very large mass of liquid—or, to be precise, a very large slab of liquid of unit thickness and of total mass M enclosed in a rigid cylindrical shell, and let us impart to this shell an impulse P_1 which gives it a velocity v normal to its axis. Then let us repeat this experiment, however, this time with the cylindrical obstacle inserted into the liquid (with its axis parallel to that of the outer shell). To establish the same velocity v we need now a slightly larger impulse $P_2 = P_1 + \Delta P$, where

$$\Delta P = V . 2a^2\pi . \gamma \quad .. \quad .. \quad (2.13)$$

(γ = density of the liquid)

This follows immediately from the fact that we could have established the same state of the system by the following operations :

(1) Impart the velocity $- v$ to the cylindrical obstacle ; the impulse required for this is exactly equal to $- \Delta P$ if the material of the cylinder has the same density as the surrounding liquid. The outer shell acquires as a consequence of this impulse the velocity $- \Delta v = - \frac{\Delta P}{M}$.

(2) Impart the velocity $+ v$ to the outer shell (and thereby the velocity zero to the inner cylinder). The impulse required for this is

$$(v + \Delta v) \; . \; M = P_1 + \Delta P \quad .. \quad (2.14)$$

Judged by the increased impulse required to impart to it the same velocity $+ v$, the apparent mass of the outer shell has therefore increased by

$$\Delta M = 2a^2\pi\gamma \quad .. \quad .. \quad .. \quad (2.15)$$

and the kinetic energy to be supplied to the outer shell has increased by

$$\Delta T = \tfrac{1}{2}\Delta M v^2 = a^2\pi\gamma . v^2 \quad .. \quad .. \quad (2.16)$$

i.e. by an amount which equals that of a volume of liquid twice as large as that of the obstacle.

In terms of the impulse imparted to the outer shell, the kinetic energy supplied is given by

$$T = \tfrac{1}{2}\frac{P^2}{M} \quad .. \quad .. \quad .. \quad .. \quad (2.17)$$

and from this last equation it follows that keeping the imparted impulse the same in the two experiments (instead of the velocity v) the energy acquired by the outer shell will have changed by an amount

$$\Delta T^1 = - \tfrac{1}{2}\frac{P^2}{M}\Delta M = - \tfrac{1}{2}\Delta M . v^2 \quad .. \quad .. \quad (2.18)$$

which is just equal in size, but opposite in sign, to the increase calculated before.

This last result is the one which is here of interest, for in our analogous magnetic problem we have, say, the interior of a very large coil filled with a homogeneous magnetic flux, and then we introduce the cylindrical obstacle. The magnetic

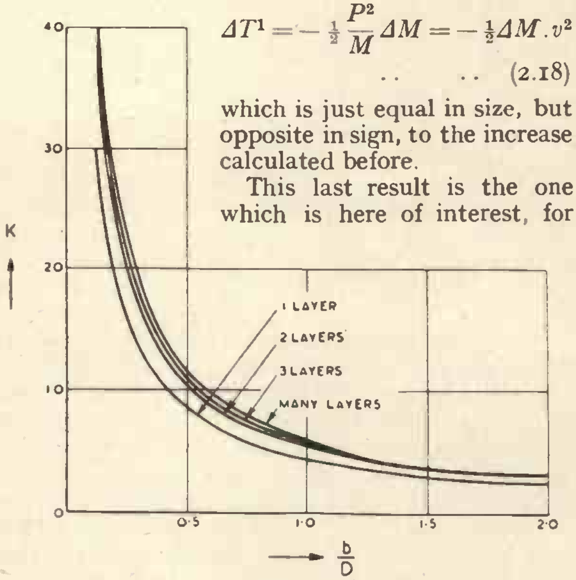

Fig. 3.

energy of the coil with constant exciting current has then been diminished by an amount equal to twice that contained in the volume of the obstacle.

3. The Change of Self-Inductance with Thermal Expansion.

If the coil wire has zero resistivity, so that the entire magnetic energy is confined to the space outside the conductor the self-inductance of the coil is simply proportional to the dimensions of the coil (if the coil dimensions increase uniformly by a factor λ the field strength in similarly situated elements of the coil space decreases by a factor λ, the volume of each element increases by a factor λ^3).

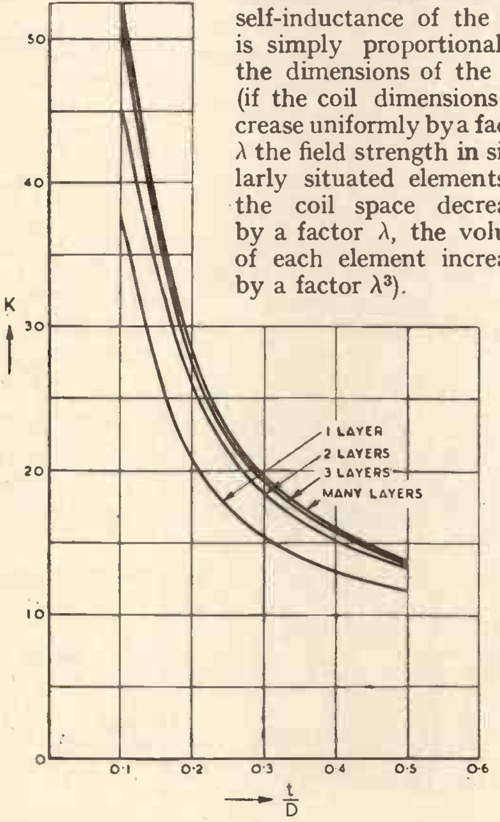

Fig. 4.

It is worth while noting that the internal inductance does not follow the same law. Actually, for our assumption of a thin skin it is easily shown that such an increase in dimensions leaves the internal inductance unchanged. The energy taken up by the skin is proportional to its area and proportional to the square of the strength of the magnetic field bounding at the skin. Now, the area of the skin increases by λ^2, and this just cancels the effect of the decrease of the magnetic field strength by the factor λ.

If β denotes the linear expansion coefficient of the coil we have therefore

$$\frac{1}{L_0}\frac{dL_0}{dT} = \beta \qquad \ldots \quad \ldots \quad \ldots \quad (3.1)$$

and

$$\frac{1}{L}\frac{dL}{dT} = \frac{1}{L_0\left[1+\frac{1}{Q}\right]}\frac{dL_0}{dT} \approx \beta\left[1-\frac{1}{Q}\right] \qquad (3.2)$$

Q is usually so large that the expression in the bracket can be taken as unity.

The preceding expression refers to the infrequent case in which all parts of the coil have the same coefficient of thermal expansion. In practice another case is frequently met with, in which the shape of the coil (coil former + winding anchored to this former) follows one law of geometrical expansion (say, thermal expansion coefficient β_1), and the diameter of the coil wire follows a different law of thermal expansion (thermal expansion coefficient β_2)*.

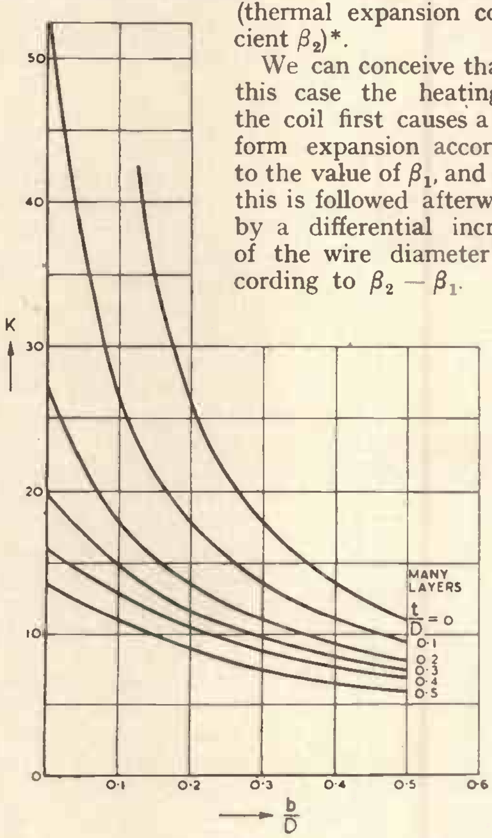

Fig. 5.

We can conceive that in this case the heating of the coil first causes a uniform expansion according to the value of β_1, and that this is followed afterwards by a differential increase of the wire diameter according to $\beta_2 - \beta_1$. This change of wire diameter has then to be added to the change in effective wire diameter caused by

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* This coefficient of thermal expansion will not usually be the coefficient of free expansion but will be modified according to Poisson's Modulus by the stress caused in the wire when the coil former has a different coefficient of thermal expansion. The correction is not difficult to calculate if one makes the often permissible assumption that the longitudinal expansion of the wire is equal to that of the coil former.

the penetration of the magnetic field which we discussed in the previous section.

The change in the effective radius of the wire caused by this penetration is

$$da = \tfrac{1}{2}t = \tfrac{1}{2}\sqrt{\frac{\rho}{\pi f \mu_0}} \quad \ldots \quad \ldots \quad (3{\cdot}3)$$

so that its variation $\delta_1(da)$ with temperature follows the law

$$\frac{\delta_1(da)}{da} = \tfrac{1}{2}\frac{\delta\rho}{\rho} = \tfrac{1}{2}\,\alpha\delta T \quad \ldots \quad \ldots \quad (3{\cdot}4)$$

where α denotes the coefficient of thermal variation of resistivity with temperature.

The purely geometrical shift of the wire boundary is given by

$$\delta_2(da) = a(\beta_2 - \beta_1)\delta T \quad \ldots \quad \ldots \quad (3{\cdot}5)$$

[in opposition to $\delta_1(da)$]

and therefore the total variation of the effective wire radius is given by

$$\frac{\delta(da)}{da} = \frac{\delta_1(da) - \delta_2(da)}{da} = \left[\frac{\alpha}{2} - \frac{a}{da}(\beta_2 - \beta_1)\right]\delta T \quad \ldots \quad \ldots \quad (3.6)$$

As the internal inductance is directly proportional to *da* the last equation can be interpreted as giving the temperature coefficient of internal inductance as modified by the differential expansion of the wire.

The ratio of this modified temperature coefficient to that calculated on the basis of eqn. (1.7) is then

$$\frac{\tau_{\text{mod}}}{\tau} = 1 - \frac{d}{t} \,.\, 2 \,.\, \frac{\beta_2 - \beta_1}{\alpha} \quad \ldots \quad \ldots \quad (3{\cdot}7)$$

APPENDIX I

The "Q" of Coils with round wire and a thin conducting skin

For the case of a thin skin the copper losses and with these the "Q" value of a coil can be very simply calculated as follows.

We know from Section 2 that the mean squared value of the H_1 type of field taken around the circumference of the conductor is $H_{10}\sqrt{2}$ so that for a case in which $H_0 = H_{10}$, the proximity losses are just twice as big as the skin effect losses.

Now, for a whole coil the value of H_{10} varies along the coil wire. The mean squared value H_{1m} of all the values H_{10} taken along the wire can be calculated from

$$H_{1m} = \frac{KN}{D} \,.\, I \quad \ldots \quad \ldots \quad \ldots \quad (4.1)$$

where I is the current through the coil,
N the number of turns of the coil,
D its outside diameter, and
K a constant, depending on the coil dimensions, which was tabulated by Butterworth.[7] We reproduce here the same information in graphical form from a paper by Douma [8] on the internal inductance of coils which will be critically reviewed in a further article.* (Figs. 2–6.)

As $H_0 = \dfrac{4I}{d}$ ($d = 2a$ = wire diameter) (4.2)

we have

$$\frac{H_{1m}}{H_0} = \frac{KN}{D} \cdot \frac{d}{4} \quad (4{\cdot}3)$$

and therefore a ratio of proximity losses to skin effect losses which equals

$$2\left(\frac{H_{1m}}{H_0}\right)^2 = \tfrac{1}{2}\left(\frac{KNd}{2D}\right)^2 \quad \ldots \quad \ldots \quad (4{\cdot}4)$$

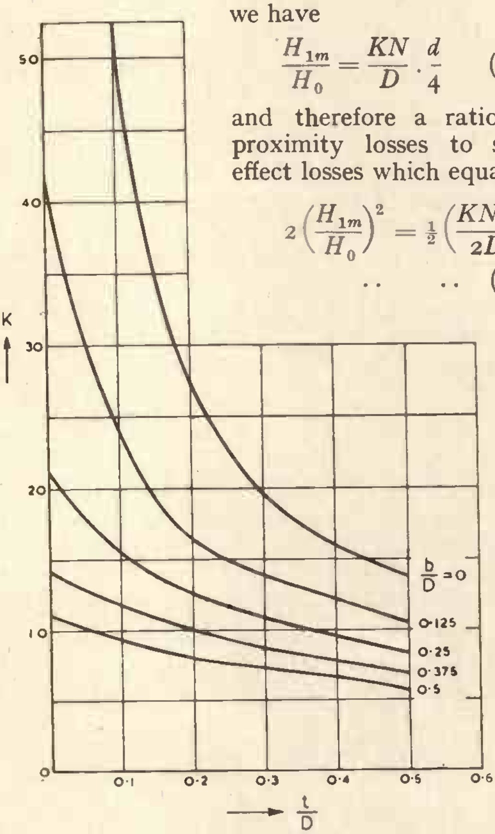

Fig. 6.

We need therefore only calculate the ordinary skin effect resistance of the coil wire, say, according to the formula

$$R = \frac{\rho_s \,.\, l}{2a\pi} = \frac{\rho_s D\pi N}{2a\pi} = \rho_s \,.\, \frac{D}{d} \,.\, N \quad \ldots \quad (4{\cdot}5)$$

where $\rho_s = \rho/t$ = surface resistivity of the coil wire, and multiply this value by the factor

$$\eta = 1 + \tfrac{1}{2}\left(\frac{KNd}{2D}\right)^2 \quad \ldots \quad \ldots \quad (4{\cdot}6)$$

in order to arrive at the total resistance.

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* *Cf.* footnote on page 362.

To calculate Q the total inductance of the coil has also to be known. It can be calculated from

$$L = L_I \, . \, N^2 D \quad \ldots \quad \ldots \quad \ldots \quad (4.7)$$
$$(L \text{ and } D \text{ in cm})$$

where L_I is a constant, also given in Butterworth's article, and presented in graph form by Douma (*see* Figs. 7–8).

The last formula in conjunction with the preceding one gives

$$Q = \frac{\omega L}{R} = \frac{\omega L_I N^2 D \, . \, d}{\rho_s \, . \, DN \, . \, \eta} = \frac{\omega L_I N d}{\rho_s \, . \, \eta} \quad \ldots \quad (4.8)$$

As an example we shall apply it to a coil which has been the subject of investigation by H. A. Thomas[9].

The data were: $N = 8$, $D = 8.4$ cm., $d = 0.64$ cm with a turn spacing of 0.84 cm. This gives an overall length b of the coil of 6.7 cm, and from $b/D = 0.8$ (Fig. 3) $K = 6$. Further, as $d/D = 1/13$ we have $\eta = 2.7$.

This is of special interest because it shows that the proximity effect, which Thomas thought to be negligible is actually 1.7 times as large as the skin effect. With $L_I = 7$ (Fig. 7) and $\rho_s = 0.47 \times 10^{-3} \, \Omega$ (for a frequency of 3.3 Mc/s) we get

$$Q = \frac{2\pi \times 3.3 \times 10^6 \times 7 \times 10^{-9} \times 8 \times 0.64}{0.47 \times 10^{-3} \times 2.7} = 586$$

According to this value of Q the contribution of the internal inductance of the temperature coefficient of inductance would be 3.5×10^{-6} parts per degree C. If we add to this the contribution of the external inductance, which is equal to the coefficient of linear thermal expansion (16×10^{-6} parts per degree C.) we arrive at a figure of 19.5×10^{-6} parts per degree C. for the temperature coefficient of the coil inductance. This value differs considerably from that found by Thomas (7×10^{-6}), presumably on account of the ill-defined geometrical expansion of such a coil (a point on which Thomas himself carried out an interesting investigation in an earlier paper[10]).

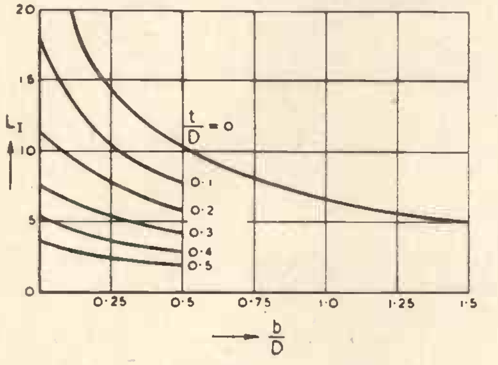

Fig. 7.

The general conclusion which Thomas reached from his measurements with this particular coil (namely, that the temperature coefficient varies little with frequency) is, however, supported by our calculations. As ρ_s is proportional to the square root of the frequency, eqn. (4.8) shows us that the temperature coefficient of internal inductance decreases with the square root of frequency, and thus find easily the following values for the temperature coefficient of this coil:

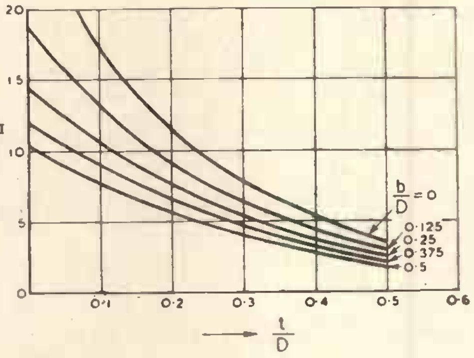

Fig. 8.

Frequency in Mc/s	:	3.3	11.5	13.3	18
Temp.-coeff. calcul.	:	19.5	18.0	17.7	17.5

These values show indeed that the temperature coefficient varies little with frequency.

Data on two coils which were wound under tension on ceramic formers and had, therefore, a well-defined geometrical expansion, were available. These data are of special interest as they were at first thought to contradict the theory as here developed: the coil with the higher value of Q showed a larger temp. coefficient of inductance.

Closer examination revealed, however, that the wire diameter of one of these coils was so small that the assumptions made in the present elementary treatment are no longer justified and that the more exact treatment, to be given elsewhere, will have to be applied. If this is done the measured and the calculated result agree as excellently as in the case of the other one of these coils, the data of which were as follows:

69 turns of 28 S.W.G. copper wire ($d = 0.376$ mm) wound on a former of 2.68 cm diameter over a length of 4.2 cm. At 1.4 Mc/s this coil showed a Q of 160.

At this frequency the equivalent skin thickness for copper equals 0.052 mm, and the application of formula (1.7) is therefore just permissible. We would thus expect a temperature coefficient due to the variation of internal inductance equal to $0.0021/160 = 13 \times 10^{-6}$. Adding to this the coefficient of linear expansion of the former (8×10^{-6}) we arrive at a temperature coefficient of 21×10^{-6} parts per degree C, to which 1–2 parts would have to be added to allow for the change in the self-capacitance of the coil, while ½ part would have to be subtracted if the correction according to eqn. (3.7) is applied. The measured value was $20 \pm 1 \times 10^{-6}$ parts per degree C.

APPENDIX II

Skin Effect Formulae

(a) *The characteristic impedance of a line with flat strip conductors*

$$Z_0 = \sqrt{Z_1 Z_2} \qquad \ldots \quad \ldots \quad \ldots \quad (5.1)$$

where

Z_1 = series impedance per unit length of line
Z_2 = shunt impedance per unit length of line

For a line of 1 cm width and 1 cm distance between the conductors we have

$$Z_1 = j\omega\mu_0 \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5.2)$$

where $\mu_0 = 1.25 \times 10^{-9}$ Henry/cm

$$Z_2 = \rho \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5.3)$$

(neglecting electric displacement currents in the metallic conductor).

Thus

$$Z_0 = \sqrt{j\omega\mu_0\rho} \qquad \ldots \quad \ldots \quad \ldots \quad (5.4)$$

If ρ varies we have

$$\frac{\delta Z_0}{Z_0} = \delta(\log Z_0) = \tfrac{1}{2}\frac{\delta\rho}{\rho} \qquad \ldots \quad \ldots \quad (5.5)$$

(b) *Thickness of equivalent conducting skin*

If a current of $\hat{I}$ amperes per cm width passes along the surface of the conductor, the input current to such a fictitious transmission line as discussed under (a) is $\hat{I}$ amperes. (This current has leaked across the neighbouring line and was carried back ro the surface of the conductor, i.e. the beginning of the next line, by the infinitely well conducting strip separating that line from the line under consideration.) The power dissipated in this line is then given by the real part of $|\hat{I}|^2 Z_0$.

If we imagine a surface layer of the conductor to carry a uniformly distributed current of equal magnitude, it would be necessary to give to this layer a thickness t so as to make

$$\text{real part of } |\hat{I}|^2 Z_0 = |\hat{I}|^2 \cdot \frac{\sqrt{\omega\mu_0\rho}}{\sqrt{2}} = |\hat{I}|^2 \cdot \frac{\rho}{t} \qquad (5.6)$$

or

$$t = \sqrt{\frac{\rho}{\pi f \mu_0}} \qquad \ldots \quad \ldots \quad \ldots \quad (5.7)$$

This, incidentally, equals the depth at which the amplitude of the eddy currents is attenuated by 1 neper.

(c) *Thickness of equivalent magnetic skin*

If the conductor surface is assumed to be of zero resistivity and receded from its actual position by the distance t_m, then we have in effect replaced the infinitely long fictitious transmission lines extending into the actual conductor by ideal loss-less lines which are short-circuited at their ends.

In order to make these loss-less and the leaky lines equivalent as regards to their magnetic energy content, we have to make the reactive components of their input impedances equal. In the case of the very short ideal lines we have

$$Z_i = j\omega\mu_0 \cdot t_m \qquad \ldots \quad \ldots \quad \ldots \quad (5.8)$$

Hence we have

$$j\omega\mu_0 t_m = \frac{1}{\sqrt{2}} j\sqrt{\omega\mu_0\rho} \qquad \ldots \quad \ldots \quad (5.9)$$

or

$$t_m = \sqrt{\frac{\rho}{2\omega\mu_0}} = \frac{t}{2}$$

REFERENCES

[1] Letter, *Wireless Engineer*, Dec. 1935.

[2] G. W. O. Howe, " The Application of Transmission Line Formulae to Skin Effect Problems." *Journ. I.E.E.*, 1916.

[3] *See*, for instance, H. A. Thomas, " The Dependence on Frequency of the Temperature Coefficient of Inductance Coils." *Journ. I.E.E.*, Vol. 84, 1939, p. 104.

[4] A more detailed account of Prof. Howe's treatment can be found in an article by R. F. Proctor : " High Frequency Resistance of Plated Conductors," *Wireless Engineer*, Feb. 1943.

[5] See Appendix II.

[6] *Proc. I.R.E.*, Vol. 30 (1942), p. 412. *See* also Appendix II of this paper.

[7] S. Butterworth, " The Effective Resistance of Induction Coils at Radio Frequency ". *Wireless Engineer*, Vol. 3, (1926), p. 417.

[8] *Philips Transmitting News*, Vol. 5 (1938), No. 1 and 2.

[9] *Journ. I.E.E.*, Vol. 84 (1939), p. 104.

[10] *Journ. I.E.E.*, Vol. 77 (1935), p. 702.

Operating Conditions of ACTIVE ELECTRICAL TRANSDUCERS*

Analysis and Design by Means of a Voltage Ratio, and the Application to Thermionic Valve Circuits

By B. M. Hadfield, B.Sc. (Hons.), M.I.E.E.

(Post Office Research Station)

SUMMARY.—The volt-ampere output, volt-ampere efficiency, and voltage transfer ratio of a circuit comprised by a source of energy and load impedance, are derived in a general manner from, and in terms of, the voltage/current characteristics of the source, both when the circuit operation is such that no limits of voltage or current are attained and when they are always just attained.

The method of attack differs from previous methods in that instead of expression and statement in terms of an impedance ratio between load and source, a voltage ratio is used. The ratio is, generally speaking, that between the load and source voltages, and it is shown that use of this method gives the simplest form of statement of the maxima conditions, that design procedure is simplified (since the ratio determines the efficiency of the circuit), and that it enables the required circuit values to be calculated rapidly and in a logical order.

In the case of a source which modulates a direct current supply between certain voltage and current limits (e.g. a thermionic valve), it is shown that design for maximum volt-ampere efficiency for a given steady dissipation is the most profitable approach, and that the ultimate in this direction can be stated easily for the guidance of the designer.

An outline of the method as applied to the design of thermionic valve circuits, including triode and pentode/tetrode types, is given, and some conclusions drawn as to the respective scope of design for each type. A simple and flexible method of stating the overall gain by this method is proposed, which enables the design of amplifying stages to be performed explicitly in terms of the required circuit voltages and currents.

CONTENTS

Introduction

THIS paper is concerned with the analysis and design of electrical circuits comprising a source of energy and a load impedance, in which it is desired to know the optimum conditions for transfer of voltage or current or both to the load. The type of source considered in some detail is one in which a direct current supply is controlled by a "modulating" device, such as a thermionic valve; but the method of attack can be applied to any source provided its internal voltage/current characteristics are determined.

In order to demonstrate the general application of the proposed method of attack, it will be postulated that the circuit voltage and current obey one law for all magnitudes up to certain values and another law for higher values. It will be assumed that the first law is suitable for the purposes of the circuit, but that the second is not; for example, the first law may have a linear or quasi-linear form (as in a thermionic valve over its normal operating range), whilst the second may have the undesirable form of the change in current being almost independent of the change in voltage

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(as in a thermionic valve outside its normal operating range). The analysis and design of the circuit may thus be attempted from two points of view :—(1) that the magnitudes of voltage and current never attain their limiting values, or (2) that they may always just attain these values. In order to apply the first method in practice, the designer must know these limits, and, in taking care that they will never be attained, his field of action is unduly restricted ; whereas if he adopts the second method he is certain that his field of action is as wide as possible, while retaining the normal characteristics of the circuit. It is the method of attack used for analysis and design with either of these operating methods, which forms the subject of this paper.

The usual method of attack endeavours to express the desired conditions of the circuit by means of a ratio between the load and source impedances, and is satisfactory when these quantities are independent of the circuit voltage and current ; that is, when the impedance-voltage and current are related by a linear law. When the impedances are not independent, however, the method becomes ponderous, even when applied to the first case of non-attainment of the limiting values, and can break down completely for the second case when these limits are always just attained. This happens because the method of attack is not based on the true mode of operation of the circuit, which is concerned solely with the values of the voltage and current and not with their quotient. As an example of such breakdown, the case of the pentode or tetrode valve may be cited. An elementary method of attack states that the condition of maximum output for a linear circuit is that the load impedance shall equal the source impedance. A casual inspection of the recommended load impedance for pentode or tetrode valves shows that they bear no such relation, or indeed any relation, to the normal anode impedance. The reason for this lies mainly in the restricted anode voltage range which may be used, if the substantially linear action of the valve and circuit is to be retained. The upper anode voltage limit is determined by reduction of the anode current to zero, and the lower by the markedly non-linear anode voltage/current characteristic at low anode voltages (i.e. at high anode currents). The quoted value of load impedance is designed primarily just to ensure operation within this range of anode voltages. It is clear that since the reasons for adopting this value of load impedance are not concerned with the normal source impedance, but with the permissible circuit voltages and currents for retention of the substantially linear operating range, then a statement of the circuit conditions by means of these latter quantities is desirable, both from the point of view of simplicity and so as to give the most useful information to the designer.

In general, therefore, and particularly under the condition of operation at the permissible limits of voltage and current, it is abortive to analyse and design circuits comprising an energy source and a load impedance on the basis of impedances. It is the purpose of this paper to demonstrate that a method based on voltage and current is equally applicable to any method of operating the circuit, and provides more factual information.

1. The Proposed Method of Attack

Bearing in mind that the usual impedance ratio method is liable to break down when the circuit operation is taken with the limiting values of voltage and current, it seems clear that the alternative is to express the behaviour of the circuit by means of a ratio between the load voltage (or current) and some constant voltage (or current), preferably that from which the load output is derived. A voltage ratio is adopted, and it may be defined in general terms, as that between the load and source voltages.

The interpretation of the words " load and source voltages " must be taken with respect to the type of source and load, and the state of the circuit voltages and currents with time. For instance, it will be assumed throughout that the circuit has been in operation for such a time that all transient effects have disappeared, that is, the circuit is in a steady state of operation. Again, during the period of steady state operation, the circuit voltages and currents may be steady, or varying cyclically with time (e.g. alternating). If the circuit operation is presumed to be such that the limiting values are never attained, then the ratio of load and source voltages may be taken at any convenient instant of time. If the presumption is that the limiting values are always just attained for design purposes, then the ratio must be taken at the particular instant of time when this state of affairs holds. In general, since there are only two directions of voltage or current which can just encounter these limits, that is, either positive or negative, then an economic design will endeavour to permit the attainment of both of these limits. Although the limits in either direction may not be caused primarily by the same quantity (i.e. voltage or current), yet the corresponding total range of load voltage is taken as the numerator of the ratio. Clearly this total range will correspond to the peak-to-peak voltage in the case of alternating quantities, and to the total available direct current output in the case of steady quantities.

As regards the source voltage which forms the denominator of the ratio, this must be that voltage or e.m.f. in the source from which the load voltage is directly derived, and it should have a steady value independent of the circuit configuration. In the case of generators, for instance, the internal e.m.f. is used, whilst in the case of "modulators" such as thermionic valves the direct current voltage drop on the valve is used.

The value of this ratio for the desired output conditions in the load will then define the behaviour of the circuit for the above instant of time, and no account need be taken of the waveform with time in the fundamental analysis and design.

The remaining feature of the present method is to refer all the values of voltage and current to the known characteristics of the source, since it is the deficiencies of the latter which necessitate the design of the circuit so that it may be used to the full. This procedure enables analysis of the circuit in terms of these deficiencies, without an explicit knowledge of the load characteristic, which can be postulated after the best use of the source for the purpose in mind has been determined.

1.1. *A simple illustration of the Method*

The case when the circuit operation is such that the voltages and currents never attain their limiting values is the simplest, because this permits of the magnitudes being taken at any convenient instant of time. If the source be a conventional generator (such as a dymano or an alternator), then if V and E be the load and source (internal) voltages at this instant, V/E is the desired ratio, which will be denoted by p. The voltage transfer ratio is therefore p, and, since the load current is common to all parts of the circuit under consideration, then p is also the volt-ampere transfer ratio, or efficiency. If i be the load current at this instant, then the volt-ampere output is $p.E.i$. Now let the relationship between the current i and the internal voltage drop in the source be found, for instance, let $i = f(v)$, where v represents the internal voltage drop. But v is also represented by $(1\text{-}p)E$, so that $i = f[(1\text{-}p)E]$. Hence the volt-ampere output in terms of the generator characteristics may be denoted by $p.E.f.[(1\text{-}p)E]$.

Hence maxima of voltage or volt-ampere efficiency in the load will be obtained by high values of p, whereas maximum output is obtained for a specific value of p; all three can only attain maxima simultaneously for certain forms of the function. For instance, if the function be assumed to be $E.Q.\,(1\text{-}p)^m$, where Q is a constant, then, assuming E to be independent of p, maximum output is obtained for $p = \frac{1}{1+m}$, by differentiation. Hence for such a circuit and where m is positive, maximum output and efficiency will only obtain simultaneously when m is vanishingly small, i.e. as the generator tends to have a constant current characteristic. For the simple case when m is 1, that is when the impedance of the generator is constant, maximum output is obtained when $p = 0.5$, and the corresponding efficiency is 50%. From this may be deduced the well known fact that if the load impedance be also constant, then since the circuit is now linear, the value of the load impedance must equal that of the source, for maximum output.

It is worth remark, however, that in neither of the above forms of the generator, or indeed in any other form, is it necessary to know the characteristics of the load in order to demonstrate the conditions under which the circuit must function. The above well-known deduction, for instance, is not the only way of satisfying the specific p value of 0.5; the load can have a non-linear voltage/current characteristic and still satsify this p value, even at all instants of time. Having determined the required p value, the means of satisfying it remain a free choice on the part of the user. It is considered that this facility forms one of the outstanding merits of the present method of attack.

2. Application of the Method to Operation of the Circuit at the Limiting Values of Voltage and Current

As indicated previously, it is a purpose of this paper to demonstrate the use of the present method of attack in determining the most profitable and simple methods of design. The specific circuit of the thermionic valve will now be studied in as general a manner as possible; the applications to practical designs of such circuits can, however, only be indicated in this paper.

The source of a thermionic valve circuit, is comprised by the valve and the direct current supply, and the internal characteristics of the valve are readily obtainable in the form of a family of anode voltage/anode current curves for given grid voltages. When the circuit is completed via the load, at a given grid voltage, a steady voltage is developed across the valve. This voltage may be varied in magnitude and sign by an appropriate, but generally smaller, variation in the grid voltage. These voltage variations about the steady value constitute the output voltage, since they appear (with reversed sign) across the load impedance. In the general case, there will also be a steady current flowing round the circuit in the absence of any grid voltage variation, which produces a steady energy dissipation within the valve. This dissipation is distinct from that within the valve when a useful output is present in the load, but it forms the source of such output. It is clear then, that the useful output, whether of voltage, current, or volt-amperes, should be referred to the steady voltage, current, and volt-amperes from which they are derived, if the transfer properties of the circuit are to be assessed.

The value of p is therefore the ratio between the useful change in the steady voltage to the steady voltage of the valve, whilst the volt-ampere transfer ratio (or efficiency) is that between the useful output and the steady valve dissipation.

Since the operation of the circuit is to be considered under the condition that the voltages and currents always just attain their limiting values in either direction, it will suffice if these peak values only are taken, for it will be assumed (as before) that the operation at values less than the limiting values is satisfactory, or can be made so, for all configurations of the circuit. No account will be taken, therefore, of the waveform with time which may be used to cause the output to vary between the permissible limits, since an optimum design for these limits is independent of waveform. For instance, the output volt-amperes will be taken as proportional to the product of the total changes in load voltage and current between the limits imposed by the valve ; if the practical functioning of the circuit depends on the rate at which the total changes are made (e.g. frequency), this will not alter the optimum output conditions for the *valve*, but will merely necessitate a certain type of load impedance to satisfy these conditions at the desired frequency.

With these provisos, and assuming all transient effects have disappeared, the following section will deal with this problem in as general a manner as possible ; the objective being to determine the best method of design, for given purposes, without restrictions as to the type of valve and load. For instance, it will not yet be assumed that the source possesses uni-directional current properties, or that the load possesses any conventional voltage/current characteristic, except that of sustaining a voltage and current in either direction which just attains the generalised boundary limits of the source for all configurations of the circuit.

2.1. *The Specific Operating Conditions*

It will be assumed that the circuit resistance to the battery is always positive, and that the impedances of both load and source are positive. Hence when the circuit current increases, due for instance, to an increase of grid voltage in this case, the load voltage increases and the valve voltage decreases by equal amounts, and vice versa, since their sum must always be equal to the battery voltage.

In Fig. 1, let v, i, represent the co-ordinate axes of voltage applied to, and current passed by, the valve, when tested between its output terminals (i.e. anode and cathode). Let $i = f_1(v)$ and $i = f_2(v)$ represent two portions of curves obtained by joining all points in the family of voltage/current characteristics of the valve, whose simultaneous values are the maximum permissible ; the area within these boundaries contains all permissible values for normal operation. Let V be the steady voltage sustained by the valve, and I the steady current, so that O is the " operating point " of the valve. Let A and B represent typical simultaneous values of voltage and current in either direction from the operating point, produced by the load when the circuit is operating at the limits of voltage and current, V_a, I_a, and V_b, I_b. Let the ratio of the voltage excursions $CR : RB$ be N, and of the current excursions $AS : SC$ be M; N and M will be prescribed by the proposed use of the circuit, and may be regarded as constants for the present. Let the negative voltage excursion CR be $p.V$.

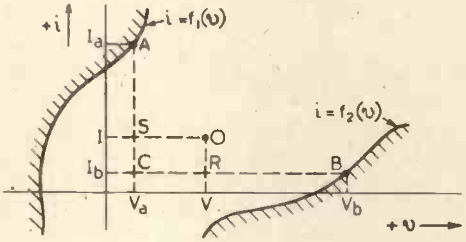

Fig. 1.

Then, since only the total changes in output voltage and current need be considered, and putting k as a constant appropriate to the specific waveform with time,

$$\text{Output volt-amperes} = k(I_a - I_b)\,(V_b - V_a) \qquad \ldots \quad \ldots \quad (1)$$

$$\text{Volt-ampere transfer ratio} = \frac{k(I_a - I_b)\,(V_b - V_a)}{V.I} \qquad \ldots \quad \ldots \quad (2)$$

$$\text{Voltage transfer ratio} = \frac{V_b - V_a}{V} \qquad \ldots \quad \ldots \quad (3)$$

Using the following relations,

$$V_a = (1 - p)V\,; \qquad V_b = (1 + p/N)V\,;$$

$$V_b - V_a = p.V(N + 1)/N\,;$$

and $$I = I_b + (I_a - I_b)/(M + 1)$$
$$= (M.I_b + I_a)/(M + 1),$$ results in,

$$\text{Output volt-amperes} = p.V(I_a - I_b)\,(N + 1)\,.\,k/N \qquad \ldots \quad \ldots \quad (4)$$

Volt-ampere transfer ratio, or efficiency

$$= p\left(\frac{I_a - I_b}{I_a + M \, . \, I_b}\right) . \, k \, \frac{(N + 1)\,(M + 1)}{N} \quad . \quad (5)$$

Voltage transfer ratio $= p\,(N + 1)/N$ .. (6)

2.2. *Consideration of the Maximum Values*

Since the circuit resistances and impedances are positive, then the output and efficiency are positive, and vary between limits of zero value as either $(V_b - V_a)$ or $(I_a - I_b)$ tend to zero. In the following analysis of the maxima requirements of the three quantities, in terms of the p value, it will be assumed that these quantities have only one maximum over their range of positive values; that is, that the solution of the zero equated differential coefficient has only one significant value.

2.21. *Maximum Volt-Ampere Output for a given V and N*

Differentiating (4) with respect to p,

$$d(4)/dp = k[V(N + 1)/N]\,[I_a - I_b + p(d(I_a)/dp - d(I_b)/dp)],$$

and the output is a maximum, taking the above assumption into account,

when $p = (I_a - I_b)/[d(I_b)/dp - d(I_a)/dp]$.

But $d(I_b)/dp = G_b \, . \, d(V_b)/dp = G_b \, . \, V/N$,

where $G_b =$ slope of $f_2\,(v)$ at B,

and $d(I_a)/dp = G_a \, . \, d(V_a)/dp = G_a \, . \, (-V)$,

where $G_a =$ *slope of* $f_1\,(v)$ at A.

Therefore the required value of

$$p = (I_a - I_b)/[V(G_a + G_b/N)] \quad .. \quad (7)$$

This can be expressed alternatively in terms of the slope of the straight line joining A and B, since $p \, . \, V = (V_b - V_a)N/(N + 1)$, as,

$$\text{Slope of line } AB = (I_a - I_b)/(V_b - V_a) = (N \, . \, G_a + G_b)/(N + 1) \quad .. \quad (8)$$

2.22. *Maximum Volt-Ampere Efficiency for given V, M and N*

Differentiating (5) with respect to p,

$$d(5)/dp = k\,(N + 1)\,(M + 1)/N \left[\begin{array}{l}(I_a - I_b)/(I_a + M \, . \, I_b) \\ \quad + p\big(d[\,(I_a - I_b)/(I_a + M \, . \, I_b)]/dp\big)\end{array}\right]$$

The efficiency is a maximum, taking the above assumption into account,

when $$p = -\left(\frac{I_a - I_b}{I_a + M \, . \, I_b}\right)\left(\frac{(I_a + M \, . \, I_b)^2}{(I_a + M \, . \, I_b)\,(G_a + G_b/N)\,(-V) - (I_a - I_b)\,(G_a - G_b \, . \, M/N)\,(-V)}\right)$$

i.e. when $p = [(I_a - I_b)\,(I_a + M . I_b)]/[V(M + 1)(G_a \, . \, I_b + G_b \, . \, I_a/N)]$ .. .. (9)

Again this may be expressed alternatively as follows,

Slope of line $AB = [\,(N \, . \, G_a \, . \, I_b + G_b \, . \, I_a)\,(M + 1)\,]/[(I_a + M \, . \, I_b)\,(N + 1)\,]$ .. .. .. (10)

2.23. *Maximum Voltage Transfer Ratio for a given N*

From (6) the only limit is that imposed by the maximum value of p, as restricted by the boundary functions.

2.3. *Comparison between Maximum Volt-Ampere Output and Maximum Volt-Ampere Efficiency*

From a comparison of (7) with (9), or of (8) with (10), the respective conditions can only be the same (for functions having a single maximum) when I_b is equal in magnitude and sign to I_a; that is, when both output and efficiency are zero. Therefore the following may be stated:—

At a given steady valve voltage, the requirements for maximum output are incompatible with those for maximum efficiency, and vice versa, (for the same ratios of voltage and current excursions which always just attain their limiting values, and for functions having a single maximum).

2.4. *Choice of Volt-Ampere Design Conditions, for Single Maximum Functions*

For a given steady valve voltage, the maximum efficiency design must deliver less output than the maximum output design, since they are mutually incompatible. But since the former has the higher efficiency, then its steady volt-ampere dissipation must be less than the latter.

Assuming that the higher steady dissipation of the maximum output design at the given steady voltage is permissible, then it is probable that this dissipation could be used to better advantage at some other steady voltage. For, if the dissipation be now considered constant, then the differential coefficient of efficiency with respect to steady voltage must be either positive, negative, or zero, at any given steady voltage. When it is positive, greater efficiency can be obtained at higher voltages; when it is negative, greater efficiency can be obtained at lower voltages; when it is zero, greater efficiency can be obtained at higher or lower voltages, provided (a) that the coefficient is not zero at all voltages, in which case no improvement can be obtained, or (b) that the slope of the coefficient about the zero value is not negative, in which case the maximum efficiency has been attained.

Thus if the design be based on the postulate of maximum output for the given steady dissipation (i.e. maximum efficiency for the given dissipation), it cannot be worse than one based on the use of a given steady voltage. In most cases it will be much better, and will thus attain the desirable characteristics of greatest output and efficiency. In view of the general method of derivation, in which the only analytical restriction consists in considering single maximum functions, this conclusion is most important, since it indicates the more profitable design approach.

For a positive differential coefficient, the only limit to the increase of output and efficiency at the given steady dissipation, is the attainment of the maximum permissible valve voltage; for a negative differential coefficient, the only limit is the attainment of the maximum permissible valve current. Since in any particular case, these limits will be known together with the permissible dissipation, then the maximum output and efficiency can be stated rigidly, and the voltage and current conditions then obtaining will form a useful guide to the designer as being the ultimate possible.

As an example of such statement, suppose the volt-ampere efficiency of the circuit has a positive differential coefficient with respect to the steady voltage over the acceptable range of steady voltages, that the permissible steady dissipation is D, and that the voltage excursion V_b forms the only limit to raising V; these postulates being generally those applying to conventional thermionic valves. Then if V_b can assume a maximum value $\overline{V}_b$, I_b is known from $I_b = f_2(\overline{V}_b)$. From $\overline{V}_b = (1 + p/N)V$, V is known in terms of p, for a given N; whilst from $I_a = f_1[(1-p)V] = (M+1)\ D/V - M.I_b$, another expression for V in terms of p is known, for a given M. Hence p and V can be found, together with I and I_a, and the ultimate output and efficiency can be calculated.

2.5. *The Voltage Transfer Ratio (and Gain) of the Valve Circuit*

The voltage transfer ratio is of importance in thermionic valve circuits, where the variations of V are produced primarily by potential variations at the control grid, since it governs the voltage gain of the whole circuit; in fact it may be of greater importance where maximum gain is required, as in amplifying stages, although its magnitude is always required to be known.

Since it is proportional only to p, it may be determined readily for the above volt-ampere conditions, and it only remains to link it up with the control grid variations to find the overall gain. Now the boundary limits $f_1(v)$ and $f_2(v)$ are generally set by, or at least correspond to, certain known grid voltage limits (for example, the former by the maximum positive, and the latter by the maximum negative, grid potential). Thus the gain of the whole circuit may be stated in terms of p, by using the total grid voltage range (corresponding to the total output voltage range) as the denominator of the voltage transfer expression. The result, which may be called the "limiting gain," will be proportional to p, and, using the same procedure as before, the limits of p set by the maximum permissible valve voltage or current may be found. Hence the limits of gain could be calculated in a similar manner to the limits of volt-ampere output and efficiency.

The limiting gain value may well be different from a value calculated from some differential function of the valve, but this only infers that the overall circuit is not linear at large output excursions, and this factor must always be taken into account in the proposed use of the circuit. The difference cannot be large for circuits intended for use under quasi-linear operation, and becomes negligibly small if means are provided to ameliorate the gain/amplitude non-linearity. On the other hand, the mode of derivation of the limiting gain value is of greater use to the designer concerned with specifying the absolute circuit voltages and currents, since it is based on these quantities.

2.6. *The General Case when I_b/I_a is Much Less Than Unity*

This assumption forms a likely practical case, since in the general interests of output and efficiency it is desirable that there shall be a large difference between I_a and I_b, and the cases where I_b can assume significant negative values are few, with normal valves. Equations (4) and (5) then become,

$$\text{Output volt-amperes} = p\,.\,V.\,I_a(N+1)\ k/N \qquad (11)$$

$$\text{Volt-ampere efficiency} = p(M+1)\ (N+1)\ k/N \qquad (12)$$

there being no change in the voltage transfer ratio expression. From these it will be seen that there is still a definite p value for maximum output at a given V, but no such value for maximum efficiency, so that maximum efficiency and voltage transfer ratio are now synonymous.

Regarding the volt-ampere design from the more profitable viewpoint of a given dissipation, instead of a given voltage, it will be seen that the differential coefficient of efficiency with V resolves itself into dp/dV. It can be seen from Fig. 1, that if I_b/I_a is negligible then, for a given dissipation, the point B travels along the voltage axis with changes in V, and that dp/dV is always positive if the slope of $f_1(v)$ is positive, and is still positive within limits even if the slope is negative.

Hence the best design for this case will involve the use of the highest permissible voltages, that is, the highest permissible p value. The recommended evaluation of this value, as outlined in section 2.4, will enable any design to be completed rapidly and successfully, by assuming a p value not exceeding the maximum, using this value in the efficiency formula (12) to find the output and working back *via* the fundamental voltage and current expressions to the required voltages, currents and load characteristic.

2.61. *The p Values for a typical $f_1(v)$ Expression (with $I_b/I_a \ll 1$)*

As an illustration of the method, and to form a bridge between the general and specific treatments, let $f_1(v) = U(v/q + a)^m$, where U, a, m, and q are positive constants; m and q being numbers, and a the zero current intercept voltage of $f_1(v)$, and considering the expression only over the range of positive values for $(v/q + a)$.

Then, by differentiation of (11) and equation to zero, maximum output for a given V and N is obtained when,

$$p \,.\, V = I_a/G_a = \frac{U(V_a/q + a)^m}{\dfrac{m \,.\, U}{q}(V_a/q + a)^{m-1}}$$

$$= \frac{q}{m}\left(\frac{V_a}{q} + a\right) = \frac{q}{m}\left(\frac{(1-p)V}{q} + a\right)$$

$$\text{Hence} \quad p = \frac{1 + a \,.\, q/V}{1 + m} \quad \ldots \quad \ldots \quad \ldots \quad (13)$$

The simplicity of this expression should be compared with that for the slope of the line AB, which is as follows :—

$$\text{Slope } AB = \frac{N}{N+1} \,.\, \frac{m \,.\, U}{q}\left[(1-p)V/q + a\right]^{m-1} \quad \ldots \quad \ldots \quad (14)$$

This slope expression is useless without a knowledge of p, unless m is 1, that is, unless $f_1(v)$ is a straight line; even so it involves knowledge of U and N (i.e. the conditions of use). Nevertheless this condition of operation is frequently quoted in this form, that is, in terms of the "optimum load resistance" (it is clear that the slope of AB is intimately related to the effective resistance of the load). This forms an excellent example of the limited and confusing statement of the optimum conditions, when attempted by the impedance ratio method. For even if quoted in the form $\dfrac{N}{N+1} \,.\, G_a$, this is of no use to the designer if G_a is not a constant, since he does know where to take the point A, whilst the $\dfrac{N}{N+1}$ factor leads to a variety of load admittances, ranging from zero to unity times G_a, according to the desired use of the circuit.

Since the slope of $f_1(v)$ is always positive, then maximum efficiency and output will be obtained with the maximum p value, as limited by the maximum permissible voltage. A general relationship for p in terms of V can be employed usefully for this case, as follows :—

$$V = D/I = D(M + 1)/I_a \quad \ldots \quad (\text{for } I_b/I_a \text{ negligible}).$$

$$\text{Therefore } V = D(M+1)/\left(U[(1-p)V/q + a]^m\right) \quad \ldots \quad \ldots \quad (15)$$

and, for a given dissipation, V has its practical minimum when p is 0, which value may-be termed V_0.

$$\text{Hence } \frac{V}{V_0} = \left(\frac{1 + aq/V_0}{1 - p + aq/V}\right)^{\frac{m}{m+1}} \quad \ldots \quad \ldots \quad (16)$$

$$\text{where } V_0^{m+1} = \frac{D(M+1)}{U}\left(\frac{q}{1 + aq/V_0}\right)^m \quad \ldots \quad (17)$$

A similar expression can be found for V_b, since this is $(1 + p/N)V$.

In many practical cases a is small, or aq is small, and a simple function of p is left, which may be plotted as a general graph for the variation of p with V/V_0. Thus if V_0 be calculated for all sources obeying this boundary law, using the permissible dissipation, then by taking the ratio of the quoted maximum voltage to V_0 for a specific sample, the maximum p value may be ascertained at a glance, and hence the maximum efficiency and output.

3. An Outline of the Application to Thermionic Valve Circuit Design

It will be obvious that the previous sections have been tending towards the use of the present method for this purpose, and the generality of statement has been purposely retained to ensure that the simplicity of the method of attack is appreciated, without controversy as to the following practical means of application. This section is an endeavour, within the scope of the present paper, to help the user of this method to apply it in practice, and certain statements, based on the author's experience, will have to be accepted without rigid proof.

In this case the $i = f_1(v)$ boundary is comprised generally by the locus of permissible maximum anode currents and minimum anode voltages, for a given maximum control grid voltage.

For a triode, the locus is simply the anode current/anode voltage characteristic at this grid voltage, and is of the form taken in section 2.61, where i is the anode current, v is the anode voltage, U is K_a/μ^m, a is $\mu.E_g$, and q is unity ; K_a and μ being constants depending on the design of the valve (where μ is the grid/anode amplification factor), and E_g the given grid voltage.

For a pentode or tetrode, the anode current is a similar function of the screen voltage E_s, that is, $i = \frac{K_a}{\mu^m}(E_s + \mu.E_g)^m$, where μ is now the grid/screen amplification factor, and holds for all values of anode voltage in excess of a certain minimum (i.e. for anode voltages above the "knee" value). This minimum is found to be related to the screen voltage, and can be put as $q.E_s$, where q is less than 1. Hence the $i = f_1(v)$ boundary is comprised by the locus of the minimum permissible anode voltage (i.e. $v = q.E_s$), and the maximum anode current produced by the screen voltage, at the given maximum grid voltage. Thus the form of section 2.61 also applies to the pentode or tetrode, if q is taken as less than 1. From inspection of the anode characteristics of commercial valves, the value of q is rarely greater than 0.2, so that this may be assumed as a conservative figure.

The value of the exponent m is the same in both cases, and is commonly accepted as 1.5. Although this value does vary with valve type, so far as can be checked experimentally, it does represent a convenient average figure, and *provided* the "constants" K_a and μ are found experimentally on the assumption that $m = 1.5$, the errors in calculation are much less, by experience, than those due to the commercial variations in these "constants" with different specimens of the same type.

As regards the $f_2(v)$ boundary, this cannot have negative values for triode, pentode or tetrode. A value of zero is fundamentally correct, but a constant, small, ratio of I_b/I_a may be allowed to meet objections that the differential action of the valve is intolerably poor at around zero current. The conditions are then similar to those taken in section 2.61, the p values not being altered materially, although the output will be reduced by the factor $(1 - I_b/I_a)$, and the efficiency by $\left(\frac{1 - I_b/I_a}{1 + M.I_b/I_a}\right)$.

As regards maximum output for a given steady voltage, it will be noticed from (13) that the required p value is always $\frac{1}{1 + m}$, provided aq be much less than V. This is always true if a be zero for either type of valve (i.e. when the maximum control grid voltage is zero), and is generally true of the pentode or tetrode for small values of a, such as those due to the flow of grid current at a small grid voltage, because q is much less than 1. (The effect of allowing a small constant ratio I_b/I_a is to divide m in this expression by $1 - I_b/I_a$). In general, therefore, the p value is the same for both types of valve for this condition of operation, which means that the minimum anode voltage is always the same fraction of the steady voltage (i.e. $V_a = \frac{m}{m + 1} . V$), independent of the voltage and current excursion ratios or of the load characteristic in general. This is a much more convenient form to memorise, than the usual statement, which incidentally only applies to a triode valve, and to the case when m is 1 and both excursions are equal, that the load resistance must be equal to the internal resistance if directly connected to the anode and twice the internal resistance if connected via a choke or transformer. It is now possible to deduce the relative outputs of the two types of valve, under this condition of design, i.e. for a constant steady voltage. The peak current I_a, and hence the output, will be many times greater for the pentode or tetrode than for the triode, other things being equal, since q for the former is less than for the latter, whilst the v is the same (i.e. $v = V_a = \frac{m}{m + 1} . V$), in the $f_1(v)$ expression. In fact if a be 0, and q be taken as 0.2 for the pentode or tetrode as compared with 1 for the triode, the ratio of outputs will be as 11.2 : 1 for $m = 1.5$, or as 5 : 1 for $m = 1.0$. The anode circuit efficiencies will, however, be the same, for p is the same for both.

As regards a design for maximum efficiency, since this consists in using a p value greater than the above, within the limit given by the electrode breakdown voltage, this matter is entirely in the hands of the valve designer. However, it can be seen from (17) that V_0 will be much smaller for the pentode or tetrode than for the triode, for the same D, M, and U (in fact 0.38 times if $q = 0.2$ for the pentode, $m = 1.5$, and aq/V_0 is negligible), so that p can be much higher for the former with the same maximum permissible electrode voltage. Consequently it will be possible to design for, and obtain, higher efficiencies more readily with the pentode or tetrode, than with the triode.

Having thus stipulated the p value from these considerations, the design can proceed as follows. The efficiency will now be known, so that the steady dissipation is known from the required output (the current and voltage excursion ratios will be known for the required use). For the maximum output design at a given steady voltage,

V will be given, I is then known, and, since p is known $\left(\text{i.e. } p = \dfrac{1 + aq/V}{1 + m}\right)$, the maximum and minimum voltages and currents are known. For the maximum efficiency design (for a given dissipation) p will be assumed at some higher value not exceeding the maximum for the dissipation and the permissible electrode voltages (this should have been already tabulated for all valves, using the methods outlined in section 2.4), V will follow from the general graph for equation (16), and the remaining procedure is as before. The load resistance, if such be the desired form, follows in either case from $p.V(1 + 1/N)$ divided by $I_a(1 - I_b/I_a)$, where M and N are now equal.

As regards the voltage gain of the circuit, this can be expressed very simply in terms of p as follows. It is the total output voltage range, $V_b - V_a$, divided by the total grid voltage range producing the limits V_a and V_b. For convenience, let the maximum positive grid voltage be s times that negative voltage which produces zero anode current (where s, of course, will be stipulated by other considerations), then the total grid voltage range is $(1 + s)$ times the negative voltage producing zero anode current. This negative voltage is V_b/μ or E_s/μ for triode and pentode respectively (where μ is the grid/anode or grid/screen amplification factor respectively). The total grid voltage range is therefore $(1 + s)V_b/\mu$ or $(1 + s)E_s/\mu$ respectively, and, by assumption, produces $V_b - V_a$. Therefore, using the relationships between V_a, V_b, and V noted in section 2.1, the gain is given by,

$$\text{Triode gain} = \frac{\mu \,.\, p(N + 1)}{(1 + s)(N + p)} \quad \ldots \quad (18)$$

$$\text{Pentode gain} = \frac{\mu \,.\, p(N + 1)}{(1 + s)N} \,.\, \frac{V}{E_s} \quad \ldots \quad (19)$$

Other forms of these expressions may be obtained incorporating the valve constants, but these are sufficient for the present purpose.

It will be noticed that the gain of a triode is limited, because p cannot be greater than 1, but that the gain of a pentode is theoretically unlimited, since it increases as the ratio V/E_s increases. In general it will be seen that the gain increases with p, so that if the limits of p are tabulated, the permissible scope of design will be indicated. These limits are due to the same causes as for the volt-ampere designs, that is, permissible electrode voltages and dissipation. Again the method of attack enables a design to be postulated readily in terms of the required circuit voltages and currents. The value of gain determined by this method will be lower than that obtained conventionally by using the mutual conductance, but it can be shown that the error is only 6 per cent. under the usual grid bias conditions (i.e. by comparison with the gain calculated from the normal value of mutual conductance). The error tends to zero as the gain/amplitude characteristic of the circuit is made more nearly linear, for instance, when using a triode with a high anode impedance, or by means of negative feedback.

Conclusions

It should be clear from the above that the general and specific design of circuits comprising a source of energy and a load, whether the operation be such as never to attain, or just to attain the circuit voltage and current limits, and whether the design be for volt-ampere output, or efficiency, or for voltage transfer ratio, is expressed most directly and usefully by means of a ratio between the load and source voltages. It is most direct, because the required conditions cannot be stated generally without use of such a ratio, and most useful for design purposes, because the circuit conditions can be stated in terms of the required practical values of voltage and current. Furthermore, as the volt-ampere efficiency and voltage transfer are intimately related to this ratio, and maxima of these quantities should be the ultimate aim of the designer, expression by means of this ratio makes for a rapid and successful design procedure.

Indexes to Abstracts and References

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THERMAL CONDUCTION WITH RADIO HEATING*

By H. Herne

SUMMARY.—A review of the literature on problems of thermal conduction which are raised when bodies are heated by dielectric hysteresis effects is given briefly. The general equation of heat conduction is given and its solution for the one-dimensional case is obtained by a simple and direct method and by a more powerful method involving the use of Duhamel's theorem. Extensions of this latter method are indicated and a practical problem is evaluated numerically.

CONTENTS

Introduction

DURING the last two or three years the method of heating large sections of poor thermal conductors by dielectric hysteresis has been developed extensively[1]. In this system the material to be heated is placed between two conducting electrodes across which a high voltage, high frequency field is maintained by a powerful radio-frequency generator; all materials absorb some of the stored energy on each field reversal and convert it to heat, the quantity of heat generated being proportional to the square of the electric field strength, to the frequency, to the dielectric constant and to the loss tangent of the material being heated. The outstanding advantage of this method of heating is that the heat is generated at every point of the material simultaneously. No longer is it necessary to allow a time interval for the heat to be conducted; it can now be generated where it is wanted. Consequently the obvious applications of the technique are to those bodies which are so large and are so poor conductors of heat that it was previously uneconomical or impossible to heat them uniformly in a permissible time. So far, the two major uses are in the heating and curing of large blocks of thermo-setting plastics and in the heating of large composite sections of wood to accelerate the hardening of the glue in the joints. As a rough guide, the method is of value when the moulding is thicker than about one inch and when the composite wood board is thicker than about two inches.

The whole problem of developing the technique then becomes one of obtaining a uniform temperature rise in all the material at once. This problem separates itself into two parts: firstly the body must be studied to determine the general time-temperature relationships for various rates of generation and loss of heat: and secondly the electrodes must be so shaped as to produce that electric field intensity at every point which will then give a uniform temperature rise. The following is intended as a contribution to the first half of this problem.

Review of Previous Work

Any review of work on the theory of heat conduction must begin with a mention of Fourier who not only laid the foundations of the theory but also built most of the superstructure. For our purpose his work is adequately summarised in a book "Conduction of Heat"[2] by H. S. Carslaw. In this book the generation of heat in a body is considered only for a filament passing an electric current (p. 84); this case is somewhat similar to our problem but with a wire we assume that the cross-section is an isothermal surface and that radiation is important. With radio heating these conditions often do not fit the problem; frequently the radiation is negligible and a cross-section is not an isothermal.

The first specific figures and graphs given for temperature distributions in radio heating are by J. P. Taylor in an article "Heating Wood with Radio-Frequency Power"[3]. These results seem to be experimental ones obtained in the R.C.A. laboratories by Brown, Bierwirth and Hoyler. Dr. G. H. Brown has since published a paper "Heat Conduction Problems in Presses Used for Gluing of Wood"[4] which is by far the most valuable contribution to the subject. He derives

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* MS. accepted by the Editor, June, 1943.

the standard form of Fourier's equation of heat conduction and applies it to presses with one or two heated platens; then he gives the modifie equation when there is dielectric hysteresis generating heat uniformly and he solves it for one dimension by analogy with a transmission line and some arduous operational calculus. From this solution he deduces various graphs of temperature distributions in one dimension, and other allied relationships.

Equation of Heat Conduction with Dielectric Hysteresis Heating

To obtain the general equation of heat conduction we start from an assumption, based on a large number of experimental results, that the heat passing through a surface equals $-K \operatorname{grad} \theta$ per unit area per unit time, where K is a physical constant of the material called the "thermal conductivity", and θ is the temperature.

If, then, we consider a small volume v of the material we have that the heat conducted out of this volume per unit time is the surface integral of $-K \operatorname{grad} \theta$ over the whole surface of v; but by Green's—or, more properly, Gauss's—theorem this surface integral equals the volume integral of div $(-K \operatorname{grad} \theta)$ taken throughout the volume v. Then the heat conducted away from the volume v per unit time is the volume integral through v of $-K\nabla^2\theta$, where ∇^2 is the usual Laplacian operator "div.grad". Also the heat absorbed by the volume v in raising its temperature is $cs\frac{\partial\theta}{\partial t}v$ per unit time, where c is the density of the material and s its specific heat. If, in addition, we are supplying a quantity of heat H per unit volume per unit time the equation for the conservation of energy becomes

$$cs\frac{\partial\theta}{\partial t}v - K\nabla^2\theta v = Hv$$

i.e. $$\frac{\partial\theta}{\partial t} = k\nabla^2\theta + \frac{H}{cs} \qquad \ldots \quad \ldots \quad \ldots \quad (1)$$

where k is written for $\frac{K}{cs}$ and is called the "thermal diffusivity". If H is zero this equation becomes the familiar Fourier equation

$$\frac{\partial\theta}{\partial t} = \mathrm{k}\nabla^2\theta \qquad \ldots \quad \ldots \quad \ldots \quad (2)$$

A more detailed and rigorous derivation of equation (2) is given in reference[2], whilst equation (1) is derived in more detail in reference[4]; but as both these equations are quite familiar we shall start from the differential equation (1) and make various simplifying assumptions. Firstly, all the physical properties of the material are assumed to be independent of both position and temperature so that we are considering only homogeneous materials for which K, c, s and k are constants. Secondly, we shall consider only the case when H is a constant; in practice this is approximately true although since the dielectric constant and loss tangent of the material are not independent of temperature it is not strictly so. For example, with wood H usually increases with temperature at a constant applied voltage; but if the generator is being operated all the time at maximum output as is often the case the simplification of assuming H a constant is justified. Thus in equation (1) H, K, c, s and k are all numerical constants.

Solution of the Fundamental Equation for the One-Dimensional Case

In the above notation the fundamental equation (1)

$$\frac{\partial\theta}{\partial t} = k\nabla^2\theta + \frac{H}{cs}$$

becomes, for one dimension,

$$\frac{\partial\theta}{\partial t} = k\frac{\partial^2\theta}{\partial x^2} + \frac{H}{cs} \qquad \ldots \quad \ldots \quad \ldots \quad (3)$$

Suppose we have a very large sheet of material of thickness d between platens maintained at zero temperature. This latter assumption is legitimate since one may apply the superposition theorem to solutions of the temperature distribution; therefore, one may measure temperature from any arbitrary zero and finally raise the temperature of the whole arrangement by any uniform amount to coincide with the conditions of a practical problem. θ is rather a measure of temperature difference than of absolute temperature. Then, measuring x perpendicular to the platens, we have the boundary conditions

$\theta = 0$ at $x = 0$ and $x = d$ for all values of t

$\theta = 0$ at $t = 0$ for all values of x.

To solve equation (3) for these conditions we split it up by assuming

$$\theta = U + V \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

where U is a function independent of time, i.e. is the equilibrium distribution after an infinitely long time, and V is a function of both time and position. Then we have

$$0 = k\frac{d^2U}{dx^2} + \frac{H}{cs} \qquad \ldots \quad \ldots \quad \ldots \quad (5)$$

and the boundary conditions

$U = 0$ at $x = 0$ and $x = d$.

Remembering that $k = K/cs$, equation (5) gives us

$$U = \frac{H}{2K}(dx - x^2) \qquad \ldots \quad \ldots \quad \ldots \quad (6)$$

As is conventional in these problems we analyse U into a Fourier sine series in the interval $x = 0$ to $x = d$, so that

$$U = \sum_{n=1}^{\infty} b_n \sin\frac{n\pi x}{d}$$

Then the coefficient b_n is given by

$$b_n = \frac{2}{d}\int_0^d U \sin\frac{n\pi x}{d}\,dx$$

$$= \frac{H}{dK}\int_0^d (dx - x^2)\sin\frac{n\pi x}{d}\,dx$$

i.e. $$b_n = \frac{2Hd^2}{\pi^3 K}\cdot\frac{1 - \cos n\pi}{n^3}$$

Then

$$U = \frac{H}{2K}(dx - x^2)$$

$$= \frac{2Hd^2}{\pi^3 K}\sum_{n=1}^{\infty}\frac{1 - \cos n\pi}{n^3}\sin\frac{n\pi x}{d} \quad \ldots \quad (7)$$

From equations (3) and (4) we have

$$\frac{\partial U}{\partial t} + \frac{\partial V}{\partial t} = k\frac{\partial^2 U}{\partial x^2} + k\frac{\partial^2 V}{\partial x^2} + \frac{H}{cs}$$

With equation (5) this becomes

$$\frac{\partial V}{\partial t} = k\frac{\partial^2 V}{\partial x^2}$$

and the boundary conditions for V are obviously

$V = 0$ at $x = 0$ and $x = d$ for all values of t

$V = -U$ at $t = 0$ for all values of x.

This is a conventional problem dealt with in detail in reference [2].

By separation of the variables we have the general solution,

$$V = e^{-m^2kt}(A\cos mx + B\sin mx)$$

where m is a parameter. On substituting the boundary conditions this becomes

$$V = -\frac{2Hd^2}{\pi^3 K}\sum_{n=1}^{\infty}\frac{1 - \cos n\pi}{n^3}\sin\frac{n\pi x}{d}\,e^{-\frac{kn^2\pi^2 t}{d^2}} \qquad \ldots \quad \ldots \quad (8)$$

and it is now obvious why U was analysed into a sine series.

Then equations (4), (7) and (8) give

$$\theta = \frac{H}{2K}(dx - x^2) - \frac{2Hd^2}{\pi^3 K}\sum_{n=1}^{\infty}\frac{1 - \cos n\pi}{n^3}\sin\frac{n\pi x}{d}\,e^{-\frac{kn^2\pi^2 t}{d^2}} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

or $$\theta = \frac{2Hd^2}{\pi^3 K}\sum_{n=1}^{\infty}\frac{1 - \cos n\pi}{n^3}\sin\frac{n\pi x}{d}\left(1 - e^{-\frac{kn^2\pi^2 t}{d^2}}\right) \qquad \ldots \quad \ldots \quad (10)$$

The expressions for θ given by equations (9) and (10) are identical but the series of equation (9) is more rapidly convergent and lends itself more readily to computation; however, each term must be evaluated more accurately for this series than for that of equation (10), so that if one is limited by availability of numerical tables it is safer to compute more terms of the latter series.

The result given by equation (10) is the same as equation (48) of reference [4] (p. 543). Since the successive sections of reference [4] deal with the application of this equation to a number of problems it is unnecessary to repeat that work here. In reading reference [4] it is helpful to remember that the equilibrium temperature distribution is

$$\theta_e = \underset{t\to\infty}{Lt}\ \frac{2Hd^2}{\pi^3 K}\sum_{n=1}^{\infty}\frac{1 - \cos n\pi}{n^3}\sin\frac{n\pi x}{d}\left(1 - e^{-\frac{kn^2\pi^2 t}{d^2}}\right)$$

i.e. $$\theta_e = \frac{H}{2K}(dx - x^2)$$

An Alternative Method of Solving the Fundamental Equation using Duhamel's Theorem

There is an alternative physical approach to the problem of radio heating which depends on the superposition theorem. Briefly, this theorem states that if one time-space-temperature relationship is the result of one set of boundary conditions and a second time-space-temperature relationship is the result of a second set of boundary conditions, then the result of both sets of boundary conditions acting simultaneously is the sum of the two time-space-temperature relationships. To apply this idea to radio heating we consider two sets of boundary conditions; firstly, the material is originally at zero temperature and the platens are maintained at a variable temperature of $-\dfrac{Ht}{cs}$; and secondly, both material and platens are uniformly heated at a rate of H/cs degrees per unit time. Then the combined boundary conditions are that the platens are at $-\dfrac{Ht}{cs} + \dfrac{Ht}{cs}$, i.e. at zero temperature at any time, whilst the material is given a uniform heat input of $cs\,.\dfrac{H}{cs}$, i.e. of H per unit time. The first of the above problems is of a standard form, whilst the second is trivial.

To evaluate a problem in heat conduction when the boundary conditions are a function of time we need to use a result due to Duhamel[2]. Suppose that the body is originally at zero temperature and that the boundary condition is $\theta_b = f(x, y, z, t)$. If the solution of the Fourier equation for the boundary condition $\theta_b = f(x, y, z, T)$ where T is a constant is

$$\theta'_T = F(x, y, z, T, t)$$

then Duhamel's theorem states that the required temperature distribution with variable boundary conditions is

$$\theta = \int^t \frac{\partial}{\partial t} F(x, y, z, T, t\text{-}T)\, dT \quad \ldots \quad (11)$$

We can apply this method to the above problem. Firstly, consider the case when the material is originally at zero temperature and the platens are at a uniform constant temperature $-\frac{HT}{cs}$. The solution of this problem is a standard result[2], and is

$$\theta = -\frac{HT}{cs}\left(1 - \frac{2}{\pi}\sum_{n=1}^{\infty}\frac{1-\cos n\pi}{n}\sin\frac{n\pi x}{d}\, e^{-\frac{kn^2\pi^2 t}{d^2}}\right)$$

Then, by Duhamel's theorem, the temperature distribution with platens at a variable temperature $-\frac{Ht}{cs}$ is

$$\theta = \int_0^t \frac{\partial}{\partial t}\left\{-\frac{HT}{cs}\left(1 - \frac{2}{\pi}\sum_{n=1}^{\infty}\frac{1-\cos n\pi}{n}\sin\frac{n\pi x}{d}\, e^{-\frac{kn^2\pi^2(t-T)}{d^2}}\right)\right\} dT$$

$$= -\frac{2H}{\pi cs}\sum_{n=1}^{\infty}\frac{1-\cos n\pi}{n}\sin\frac{n\pi x}{d}\, e^{-\frac{kn^2\pi^2 t}{d^2}}\int_0 \frac{kn^2\pi^2 T}{d^2}\, e^{\frac{kn^2\pi^2 T}{d^2}}\, dT$$

$$= -\frac{2H}{\pi cs}\sum_{n=1}^{\infty}\frac{1-\cos n\pi}{n}\sin\frac{n\pi x}{d}\left\{t - \frac{d^2}{kn^2\pi^2}\left(1 - e^{-\frac{kn^2\pi^2 t}{d^2}}\right)\right\}$$

$$= -\frac{Ht}{cs}\,\frac{2}{\pi}\sum_{n=1}^{\infty}\frac{1-\cos n\pi}{n}\sin\frac{n\pi x}{d} + \frac{2Hd^2}{\pi^3 csk}\sum_{n=1}^{\infty}\frac{1-\cos n\pi}{n^3}\sin\frac{n\pi x}{d}\left(1 - e^{-\frac{kn^2\pi^2 t}{d^2}}\right)$$

i.e.

$$\theta = -\frac{Ht}{cs} + \frac{2Hd^2}{\pi^3 K}\sum_{n=1}^{\infty}\frac{1-\cos n\pi}{n^3}\sin\frac{n\pi x}{d}\left(1 - e^{-\frac{kn^2\pi^2 t}{d^2}}\right) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (12)$$

If now the platens and material are all given a steady temperature rise of $\frac{H}{cs}$ degrees per unit time, the value of the temperature everywhere due to this condition is

$$\theta = \frac{Ht}{cs} \quad \ldots \quad \ldots \quad \ldots \quad (13)$$

Superposing the results given by equations (12) and (13) we have for a material with a steady heat input of H per unit volume per unit time and bounded by platens at temperature zero,

$$\theta = \frac{2Hd^2}{\pi^3 K}\sum_{n=1}^{\infty}\frac{1-\cos n\pi}{n^3}\sin\frac{n\pi x}{d}\left(1 - e^{-\frac{kn^2\pi^2 t}{d^2}}\right) \quad \ldots \quad \ldots \quad \ldots \quad (14)$$

Obviously, equations (10) and (14) are identical.

Numerical Solution of a Typical Problem

The following problem is typical of what can be attacked theoretically by equation (14).

A pack of fourteen sheets of wood making a total thickness of 16 cm. are heated uniformly by radio-frequency currents. The temperature at the outermost glue line as a percentage of the temperature of the centre of the pack is required as a function of time when the pack is pressed between cold platens.

The values for the physical properties of the wood are taken to be

$K = 3{\cdot}45.10^{-4}$ c.g.s. units,
$c = 0{\cdot}520$ gm./c.c.,
$s = 0{\cdot}397$,

and thus $k = 1{\cdot}61.10^{-3}$ c.g.s. units.

For the centre of the pack, in the above notation, $x = d/2$, whilst for the outermost glue joint $x = d/14$. If the temperature of the outermost glue joint is P % of the temperature of the centre of the pack, from equation (14) we have

$$P = 100\,\frac{\dfrac{2Hd^2}{\pi^3 K}\displaystyle\sum_{n=1}^{\infty}\frac{1-\cos n\pi}{n^3}\sin\frac{n\pi}{14}\left(1 - e^{-\frac{kn^2\pi^2 t}{d^2}}\right)}{\dfrac{2Hd^2}{\pi^3 K}\displaystyle\sum_{n=1}^{\infty}\frac{1-\cos n\pi}{n^3}\sin\frac{n\pi}{2}\left(1 - e^{-\frac{kn^2\pi^2 t}{d^2}}\right)}$$

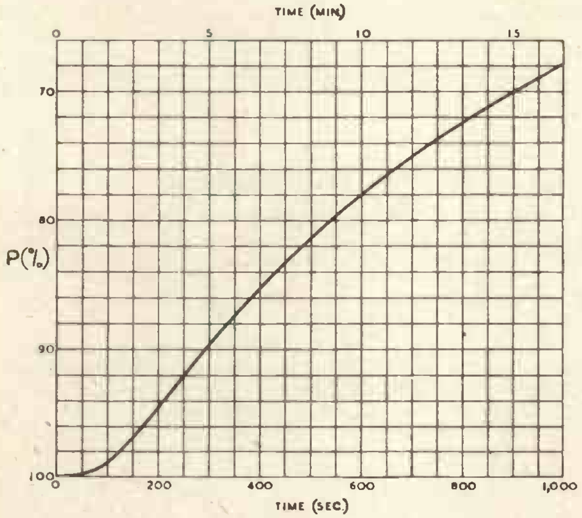
or from equation (9)

$$P = 100\,\frac{\dfrac{H}{2K}\left(\dfrac{d^2}{14} - \dfrac{d^2}{14^2}\right) - \dfrac{2Hd^2}{\pi^3 K}\displaystyle\sum_{n=1}^{\infty}\frac{1-\cos n\pi}{n^3}\sin\frac{n\pi}{14}\,e^{-\frac{kn^2\pi^2 t}{d^2}}}{\dfrac{H}{2K}\left(\dfrac{d^2}{2} - \dfrac{d^2}{2^2}\right) - \dfrac{2Hd^2}{\pi^3 K}\displaystyle\sum_{n=1}^{\infty}\frac{1-\cos n\pi}{n^3}\sin\frac{n\pi}{2}\,e^{-\frac{kn^2\pi^2 t}{d^2}}}$$

i.e.

$$P = 100\,\frac{\dfrac{13\pi^3}{784} - \displaystyle\sum_{n=1}^{\infty}\frac{1-\cos n\pi}{n^3}\sin\frac{n\pi}{14}\,e^{-0.000062n^2t}}{\dfrac{\pi^3}{16} - \displaystyle\sum_{n=1}^{\infty}\frac{1-\cos n\pi}{n^3}\sin\frac{n\pi}{2}\,e^{-0.000062n^2t}} \quad \ldots \quad (15)$$

The two series in equation (15) have been evaluated numerically to seven figures on a " Brunsviga " machine for various values of t, and the resultant values of P as a function of t are given in the table below and the graph.



From this curve one can find the minimum power—that is, the maximum time—when a certain percentage drop is permissible. For example, if the temperature of the outermost glue joint must be not less than 90 per cent. that at the centre, the maximum heating time is just under five minutes, and the power input to produce the required temperature in this time can simply be calculated. It must be remembered that " temperature " in this context is more accurately " temperature rise above the original, ambient temperature."

Suggested Extension of the Duhamel's Theorem Method of Solution

The method using Duhamel's theorem, outlined above for the one-dimensional case, may be extended to other problems quite simply. In general we must consider two sets of boundary conditions, the first when the body is originally at zero temperature and the boundary is at a variable temperature $-\dfrac{Ht}{cs}$, and the second when both the body and the boundary are given a steady temperature rise of H/cs degrees per unit time. The combination of these two conditions gives that of the boundary always at zero temperature and a steady heat input to the body of H per unit volume per unit time.

The solution of the Fourier equation of heat conduction—equation (2) above—is assumed to be of the form $\theta = f(t).F(p)$ where $f(t)$ is a function of time only and $F(p)$ is a function of position only. Then equation (2) becomes

$$\frac{d.f(t)}{dt}F(p) = kf(t)\,\nabla^2 F(p)$$

or

$$\frac{\dfrac{d.f(t)}{dt}}{kf(t)} = \frac{\nabla^2 F(p)}{F(p)} \quad \ldots \quad \ldots \quad \ldots \quad (16)$$

The right-hand side of equation (16) is independent of t, so that both sides must be equal to a constant,

Time, t (sec.)	50	100	150	200	250	300	350	400	450	500
P %	99.92	98.89	96.87	94.48	92.00	89.60	87.32	85.18	83.18	81.31

Time, t (sec.)	550	600	650	700	750	800	850	900	950	1000
P %	79.56	77.93	76.40	74.96	73.60	72.32	71.10	69.96	68.86	67.83

say m : thus

$$\frac{d\,.f(t)}{dt} = kmf(t) \quad \ldots \quad (17)$$

and $$\nabla^2 F(p) = mF(p) \quad \ldots \quad (18)$$

The solution of (17) is $f(t) = e^{kmt}$, and we assume that equation (18) can be solved to give $F(p) = \phi(p,m)$. Then the solution of equation (2) becomes the sum of any number of terms like $e^{kmt}\phi(p, m)$.

Suppose that $\theta = \sum\limits_m e^{kmt}\phi(p, m)$ satisfies the condition of unit temperature originally everywhere in the body and zero temperature permanently on the boundary; then

$$\begin{aligned}\sum_m \phi(p, m) &= 1 \text{ for all values of } p \text{ in the body}\\ &= 0 \text{ for the boundary} \quad \ldots \quad (19)\end{aligned}$$

Then, for the body originally at zero temperature and the boundary permanently at unit temperature,

$$\theta = 1 - \sum_m e^{kmt}\phi(p, m).$$

So for the body originally at zero temperature and the boundary at the variable temperature $-\dfrac{Ht}{cs}$ we have, by Duhamel's theorem,

$$\begin{aligned}\theta &= \int_0^t \frac{\partial}{\partial t}\left\{-\frac{HT}{cs}\left(1 - \sum_m e^{km(t-T)}\phi(p, m)\right)\right\}dT\\ &= \frac{H}{cs}\sum_m \phi(p, m)\, e^{kmt}\int_0^t kmT\, e^{-kmT}\, dT\\ &= -\frac{Ht}{cs}\sum_m \phi(p, m) - \frac{H}{csk}\sum_m \phi(p, m)\,\frac{1 - e^{kmt}}{m}\end{aligned}$$

Then, from equation (19)

$$\theta = -\frac{Ht}{cs} - \frac{H}{K}\sum_m \phi(p, m)\,\frac{1 - e^{kmt}}{m} \quad \ldots \quad (20)$$

If we now superpose on equation (20) the trivial case of

$$\theta = \frac{Ht}{cs}$$

due to the second set of boundary conditions, we have for the final temperature distribution

$$\underline{\underline{\theta = -\frac{H}{K}\sum_m \phi(p, m)\,\frac{1 - e^{kmt}}{m}}} \quad \ldots \quad (21)$$

This last equation gives us the desired result and the general rule :—

" If the solution of Fourier's equation of heat conduction for any body with the body originally at unit temperature and the boundary permanently at zero temperature is $\theta = \sum\limits_m \phi(p, m)\, e^{kmt}$ then the temperature distribution in the body for the boundary permanently at zero temperature, the body originally at zero temperature and a steady heat input of H per unit volume per unit time is

$$\theta = -\frac{H}{K}\sum_m \phi(p, m)\,\frac{1 - e^{kmt}}{m}\text{''}$$

Solutions of the standard problems in heat conduction are given in reference [2] for many cases; another useful source of information is the bibliography at the end of " Heat Transmission " by W. H. McAdams (McGraw–Hill, 2nd Edition, 1942), pages 419–448.

REFERENCES

[1] See Bibliography at end of "Welding of Thermoplastic Materials by means of Radio Frequency Currents", H. P. Zade, *Plastics* (March 1944), Vol. VIII, No. 82, p. 100.

[2] "Conduction of Heat", H. S. Carslaw (McMillan, 1921).

[3] "Heating Wood with Radio Frequency Power", J. P. Taylor, *Trans. Am. Soc. Mech. Eng.* (April 1943), Vol. 65, No. 3, p. 201.

[4] "Heat Conduction Problems in Presses Used for Gluing of Wood", G. H. Brown, *Proc. I.R.E.*, (October 1943), Vol. 31, No. 10, p. 537.

I.E.E. "Radio Section"

IT is learned from the Secretary of the Institution of Electrical Engineers that on the recommendation of the Wireless Section Committee the Council has decided to change the name of the Section to " Radio Section " and to modify the rule which deals with the scope of the Section to read as follows :—

" The Section shall include within its scope all matters relating to the study, design, manufacture or operation of apparatus for communication by wave radiation, for high-frequency and electronic engineering, or for the electrical recording or electrical reproduction of sound."

The following have been elected to fill the vacancies occurring on the Section Committee on September 30th : Chairman, H. L. Kirke (B.B.C. Research Divn.) ; Vice-Chairman, C. E. Strong (Standard Telephones and Cables) ; Ordinary Members, Dr. J. Greig (Northampton Polytechnic), Dr. S. E. A. Landale (Admiralty Signal Establishment), E. M. Lee (Belling & Lee), S. B. Smith (Marconi's W.T. Co.) and K. J. R. Wilkinson (B.T.-H. Research Section).

I.E.E. Council

THE result of the ballot for the vacancies occurring on the Council of the Institution of Electrical Engineers on September 30th is announced by the Secretary. The following have been elected : President, Sir Harry Railing ; Vice-President, W. J. H. Wood ; Hon. Treasurer, E. S. Byng ; Ordinary Members, H. Bishop (B.B.C.), W. N. C. Clinch, F. C. Winfield and Dr. R. W. Sillars.

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

560 335.—Loudspeaker of the public-address type in which a common horn or resonator box is energised by a group of reproducer units, each connected to a separate sound-expanding passage.

G. R. Fountain; G. C. Wheeler; and H. J. Houlgate. Application date 17th November, 1942.

560 702.—Push-pull "compressor" stage, particularly for making sound records, in which negative reaction is utilised to eliminate spurious variations in gain.

Marconi's W.T. Co. (assignees of K. Singer). Convention date (U.S.A.) 13th October, 1941.

RECEIVING CIRCUITS AND APPARATUS

(See also under Television)

560 285.—Switch device for controlling the intermittent feed of the paper strip in a tape or similar telegraphic receiver.

H. E. Brain and The Automatic Telegraph and Radio Transceiver Co. Application date 26th August, 1942.

560 337.—Resilient holder for a valve or photo-electric cell of the uncapped type.

Cinema-Television and G. S. Elphick. Application date 17th November, 1942.

560 412.—Dish-shaped holder with resilient fingers for securing a thermionic valve in position over an apertured support.

Carr Fastener Co. and G. Wagstaff. Application date 14th October, 1942.

560 471.—Quick-tuning device, wherein the control spindle is traversed bodily to one of several predetermined tuning points, and is then rotated to secure an accurate setting.

Philips Lamps and C. L. Richards. Application date 1st October, 1942.

TELEVISION CIRCUITS AND APPARATUS

For Transmission and Reception

560 457.—Television transmitter tube with means for linearising the scanning motion imparted electrostatically to an electron stream which is also subject to the control of a longitudinal magnetic field.

H. G. Lubszynski and H. Miller. Application date 25th July, 1942.

560 496.—Cathode-ray tube with internal and external optical elements for projecting a televised picture without spherical aberration.

Cinema-Television (communicated by C. S. Szegho). Application date 1st, September, 1942.

TRANSMITTING CIRCUITS AND APPARATUS

(See also under Television)

560 554.—Transformer particularly adapted to handle high-power pulses in mobile radio transmitting sets.

A. W. Martin and E. K. Cole. Application date 28th January, 1943.

560 556.—Radio transmitter in which the modulator serves as a dynamic absorbing unit for maintaining a constant load during keying.

Amalgamated Wireless (Australasia). Convention date (Australia) 17th February, 1942.

SIGNALLING SYSTEMS OF DISTINCTIVE TYPE

560 671.—Signalling system in which the advantages that are normal to the use of a double or reversed current impulse are secured from a single current.

B. M. Hadfield. Application date 4th September, 1942.

560 923.—Secret signalling system in which the significant signal is applied to the rotary winding of a generator which also supplies polyphase currents to mask the signal from an eavesdropper not supplied with a synchronised motor.

P. P. Eckersley. Application date 29th October, 1940.

CONSTRUCTION OF ELECTRONIC-DISCHARGE DEVICES

560 453.—Electron optical system for a beam deflection amplifier in which a series of parallel elements with flared ends are used to minimise aberration.

Western Electric Co. Inc. Convention date (U.S.A.) 31st May, 1941.

560 490.—Electron discharge tube wherein the cathode stream is first concentrated into a beam and is then deflected so as to fall on to one or other of several separate anodes.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date 6th February, 1942.

560 574.—Construction of discharge tube for generating a beam or column of positive ions.

The British Thomson-Houston Co. Convention date (U.S.A.) 1st August, 1941.

SUBSIDIARY APPARATUS AND MATERIALS

560 260.—Device for measuring mechanical strains by observing the resultant changes in electrical resistance.

F. Aughtie; F. R. Thurston; and E. P. Coleman. Application date 8th October, 1942.

560 307.—Stroboscopic glow-lamp or frequency-measuring device comprising a fluorescent electric-discharge tube having a cathode of low current-capacity.

The British Thomson-Houston Co. and H. R. Ruff. Application date 9th November, 1942.

560 372.—Variable condenser of the kind in which the dielectric is in the form of a tube along which one of the electrodes is moved longitudinally by screw control.

The Mullard Radio Valve Co.; C. W. Vinall; W. C. Barry; and C. E. Maitland. Application date 2nd December, 1942.

560 501.—Metal rectifier in which the area of the sensitive surfaces is graded in order to ensure stability in performance and a high reverse impedance.

Standard Telephones and Cables and A. M. Searle. Application date 2nd October, 1942.

Abstracts and References

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For the information of new readers it is pointed out that the length of an abstract is not necessarily an indication of the importance attached to the work concerned. An important paper in English, in a journal likely to be readily accessible, may be dealt with by a square-bracketed addition to the title, while a paper of similar importance in German or Russian may be given a long abstract. In addition to these factors of difficulty of language and accessibility, the nature of the work has, of course, a great influence on the useful length of its abstract.

PROPAGATION OF WAVES

2476. EXCITATION OF ELECTROMAGNETIC WAVES IN WAVE-GUIDES AND CAVITIES.—J. Miles. (*Phys. Review*, 1st/15th Feb. 1944, Vol. 65, No. 3/4, p. 153: abstract only.)

"The impedance of thin transverse wires in rectangular wave-guides and cavities has been evaluated by application of the vector potential. Both the resistive and reactive components have been obtained, and one is thus enabled to place a driving or receiving element so as to match a given source or load for the maximum power transfer."

2477. REPRESENTATION OF IMPEDANCE FUNCTIONS IN TERMS OF RESONANT FREQUENCIES [in connection with Transmission-Line Sections & Cavity Resonators].—Schelkunoff. (*See* 2498.)

2478. TRANSMISSION-LINE THEORY IN TERMS OF PROPAGATION CHARACTERISTICS AND REFLECTION COEFFICIENTS.—Colebrook. (*See* 2499.)

2479. AN IMPROVED TRANSMISSION-LINE CALCULATOR [fundamentally a Special Kind of Impedance Coordinate System, Mechanically Arranged with respect to a Set of Movable Scales to portray the Relationship of Impedance at Any Point along a Uniform Open-Wire or Coaxial Transmission Line to the Impedance at Any Other Point and to Several Other Electrical Parameters].—P. M. Smith. (*Electronics*, Jan. 1944, Vol. 17, No. 1, pp. 130–133 and 318..325.)

2480. CHARACTERISTIC IMPEDANCE OF TRANSMISSION LINES: A NOTE ON CERTAIN PARTICULAR CASES.—Eaglesfield. (*See* 2501.)

2481. LOSS-LESS TRANSMISSION LINES: ANALYSIS BY MEANS OF TWO SIMPLE DIAGRAMS.—Bloch. (*See* 2502.)

2482. INTERCOUPLED TRANSMISSION LINES AT RADIO FREQUENCIES.—M. Fuchs. (*Elec. Communication*, No. 4, Vol. 21, 1944, pp. 248–256.)

"When one pair of lines is placed in proximity to another pair, interactions take place that are best explained by setting up transmission-line equations which take this intercoupling into account. The purpose of the present paper is to formulate a system of equations applicable to the problems of intercoupling encountered by radio engineers."

2483. ERRATUM: TRANSMISSION-LINE THEORY AND ITS APPLICATION.—R. King. (*Journ. Applied Physics*, March 1944, Vol. 15, No. 3, p. 292.) *See* 732 of March.

2484. TRANSMISSION-LINE ANALOGIES OF PLANE ELECTROMAGNETIC-WAVE REFLECTIONS.—A. Bronwell. (*Proc. I.R.E.*, April 1944, Vol. 32, No. 4, pp. 233–241.)

"The similarity between the equations for unguided plane electromagnetic-wave propagation and those of propagation along conventional transmission lines is illustrated. It is shown that the conventional transmission-line equations expressed in terms of receiving-end voltage and current may be used to express the field-intensity components of uniform plane waves in any medium. Normal-incidence reflection of plane waves at surfaces of discontinuity are shown to be analogous to transmission-line reflections at impedance discontinuities. The transmission-line equations are then modified to apply to oblique-incidence reflection."

2485. HISTORICAL NOTES ON THE DETERMINATION OF DISTANCE BY TIMED RADIO WAVES.—C. D. Tuska. (*Journ. Franklin Inst.*, Jan. & Feb. 1944, Vol. 237, Nos. 1 & 2, pp. 1–20 & 83–102.)

(i) The Kennelly-Heaviside layer: measurements of Appleton & Barnett: measurements of Breit &

Tuve: observations of Smith-Rose & Barfield: of Hollingworth: further measurements of Appleton & Barnett: experiments and observations of Heising: apparatus for timing radio-wave propagation (Löwy's patent, for distance-determination of a reflecting object): transmitter-modulating device (Tuve & Dahl): New-York/San-Francisco tests (Peterson): Bentley's aeroplane-altitude-indicating system: Rieber's method and apparatus for distance-determination to discontinuity in the wave-propagating medium: layer-height measuring method of Mirick & Hentschel: layer studies of Hafstad & Tuve: layer-echo system (Goubau).

(ii) Patent applications filed in 1930 (altimeter, distance-measurement: Espenschied, Hart, Wolf, Turner): Schafer & Goodall's "simultaneous" measurement of layer-height, and their dual indicating c.r. tube: automatic recorder of Gilliland & Kenrick: continuous recorders of Mimno & Wang and of Kenrick & Pickard: multi-frequency automatic recorder of ionosphere heights (Gilliland): direct-reading layer-height c.r. tube apparatus (Kirby, Berkner, Gilliland, & Norton): Bontch-Bruewitch's measurements in polar regions: apparatus used by Verman, Char, & Mohammed, by Berkner & Wells, and others.

Developments in 1935 to 1943 (account largely based on U.S. patents): (a) phase-measuring devices:—Hollmann's distance-measuring system using modulated u.h.f: Heising's u.s.w. altimeter: Alexanderson, Patterson, & Nickle's two-carrier system: Crosby's distance-measuring system with frequency-modulated wave: Budenbom's measurement of distances within less than a wavelength of the transmitter ("induction-field" method): (b) pulse echo measuring instruments:—Smith's distance-measuring apparatus: Hunter's "radio contourmeter": Lyman, Moseley, & Hunter's altimeters: (c) frequency-modulating-type altimeters:—Newhouse (with amplitude-limiting), Lane, Higgins; Sanders, Wolff; Guanella (several species); Alford; Chaffee; Varela (with amplifier including attenuator which is inoperative in absence of l.f. signals).

(d) Miscellaneous devices (1935/43):—Rice's use of Doppler principle for measuring the velocity of an aeroplane, which transmits and receives back its own signals: Gunn's use of same principle to determine velocity and also (by using pulses) distance, with a relay station on the ground: Hershberger's system for locating a reflecting object with respect to a pair of radiation patterns, and for measuring the distance from the transmission point to the object: Budenbom's beat-frequency altimeter, with ground relay station and aircraft receiver which separates the lower frequency components (indicating altitude) from the higher (indicating distance). "In the war period the notes are necessarily incomplete because of the scarcity of publications. . . ."

2486. On the Observational Evidence for Changes in Ionisation of the Upper Atmosphere attributable to the Moon.—H. T. Stetson. (*Terr. Mag. & Atmos. Elec.*, March 1944, Vol. 49, No. 1, pp. 9–24.)

An analysis of some 18 000 hours of field-intensity measurements extending over a period of eight years is presented to show such evidence as may have indicated an effect of the moon upon the transmission and reception of radio waves at broadcast frequencies between the vicinity of Chicago & that of Boston. The results strongly indicate an effect that depends upon the age of the moon and lend support to the belief that changes in ionisation in the upper atmosphere take place with the changing phases of the moon. For quite different researches also supporting the moon's claim to influence terrestrial happenings *see* Burr, 2462 of July.

2487. Preliminary Summary, Auroral Observations, Meanook, Canada, December 1, 1932, to June 30, 1933.—E. H. Vestine. (*Terr. Mag. & Atmos. Elec.*, March 1944, Vol. 49, No. 1, pp. 25–36.)

2488. Solar Flares and Magnetic Storms [1859/1942 Data & Deductions: the Processes of a Great Magnetic Storm: the Problem of the Smaller Storms, continuing throughout Solar Minimum].—H. W. Newton. (*Nature*, 29th April 1944, Vol. 153, No. 3887, p. 532: summary, from *Mon. Not. Roy. Astron. Soc.*, 1943.) For previous work *see* 3502 of 1942.

2489. A Theoretical Note on the Magnetic Field of a Circular Sunspot.—S. Chapman. (*Terr. Mag. & Atmos. Elec.*, March 1944, Vol. 49, No. 1, pp. 37–42.)

A pair of associated sunspots of opposite magnetic polarities is interpreted as marking the ends of an electromagnet connecting the two spots beneath the sun's surface, and having the form of half an anchor ring.

2490. Exploration of Cosmic Rays [Electronic Devices used in Study of Soft, Medium, and Penetrating Radiations and of Sunspot Radio Disturbances].—H. T. Stetson. (*Electronic Industries*, Jan. 1944, Vol. 3, No. 1, pp. 94–96 and 244..252.)

2491. Absorption in the Atmosphere and Decay of Cosmic Rays.—A. Duperier. (*Nature*, 29th April 1944, Vol. 153, No. 3887, pp. 529–530.)

Summary of a provisional analysis of the data dealt with in 2279 of 1942 [*see* 1374 of 1943 for a later letter, and *cf.* 2127 of July]. The high value of − 0.87 is obtained for the correlation coefficient between the hourly numbers of cosmic particles and the corresponding barograph readings. The separation of the effects of absorption and decay (which, on the hypothesis of the instability of the hard component, together determine the barometric coefficient) has been accomplished by establishing that the variation of the number N of cosmic particles at ground-level is a function first of the variation of the air mass and secondly of the change in height of the pressure-level at which mesons are generated. Various quantitative results are obtained.

2492. A New Cosmic-Ray Recorder and the Air-Absorption and Decay of Particles [Photographic Recorder registering Cosmic-Ray Threefold Coincidences without Any Screen].—A. Duperier. (*Terr. Mag. & Atmos. Elec.*, March 1944, Vol. 49, No. 1, pp. 1–7.)

2493. CASCADE SHOWERS AND NUCLEAR DISINTEGRATIONS AT 10 000 FEET.—W. E. Hazen. (*Phys. Review*, 1st/15th Feb. 1944, Vol. 65, No. 3/4, pp. 67–75.)

A large cloud chamber containing eight lead plates was operated without counter control at 10 000 feet. In 8500 photographs, 1090 cascade showers & 58 nuclear disintegrations were observed. Approximately one-third of the observed nuclear disintegrations contained particles that penetrated at least 0.7 cm of lead, and four contained particles that penetrated at least 2.8 cm of lead. The initiating particles were neutrons & protons, and most of the disintegration particles were protons or mesotrons.

2494. FURTHER STUDIES ON THE LEAST PENETRATING COMPONENT OF THE INCOMING COSMIC RAYS.—R. A. Millikan, H. V. Neher, & W. H. Pickering. (*Phys. Review*, 1st/15th Feb. 1944, Vol. 65, No. 3/4, p. 152: abstract only.)

2495. THE AVERAGE SPECIFIC IONISATION OF THE MESOTRONS 100 FEET UNDERGROUND [Cloud-Chamber Photographs under 100 Feet of Rock].—W. E. Hazen. (*Phys. Review*, 1st/15th Feb. 1944, Vol. 65, No. 3/4, p. 152: abstract only.)

2496. ON THE VISIBILITY OF DISTANT OBJECTS THROUGH MIST [Calculations for Mist consisting of Water Drops whose Radius is Greater than Twice the Wavelength of the Light: Good Agreement with Experimental Results].—J. Bricard. (*Comptes Rendus* [Paris], 3rd/31st May 1943, Vol. 216, No. 18/22, pp. 644–646.)

PROPERTIES OF CIRCUITS

2497. EXCITATION OF ELECTROMAGNETIC WAVES IN WAVE-GUIDES AND CAVITIES.—Miles. (*See* 2476.)

2498. REPRESENTATION OF IMPEDANCE FUNCTIONS IN TERMS OF RESONANT FREQUENCIES.—S. A. Schelkunoff. (*Proc. I.R.E.*, Feb. 1944, Vol. 32, No. 2, pp. 83–90.)

Author's summary:—"The conventional extension of Foster's reactance theorem to electric circuits with an infinite number of degrees of freedom (sections of transmission lines and cavity resonators) leads to series which converge so slowly that often seemingly natural approximations make the series actually divergent. There exist, however, modified expansions which are suitable for numerical calculations and which admit of an attractive physical interpretation. Similar expansions can also be obtained for the transfer impedance. The method of approach is function-theoretic and is based on the assumption that the driving-point impedance and the transfer impedance are analytic functions of the oscillation constant. When these functions are single-valued, they may be represented as certain series of partial fractions or series of functions analogous to partial fractions. In the case of pure reactances each term of these series corresponds to a resonant circuit coupled to the input element or a resonant transducer. The results are approximately true for slightly dissipative systems."

2499. TRANSMISSION-LINE THEORY IN TERMS OF PROPAGATION CHARACTERISTICS AND REFLECTION COEFFICIENTS [instead of Usual Impedances & Hyperbolic Functions: Advantages in respect of Simplification of Formulae & Clearness of Physical Significance].—F. M. Colebrook. (*Wireless Engineer*, April 1944, Vol. 21, No. 247, pp. 167–174.)

It is pointed out, incidentally, that the reflection coefficient of a line termination may in some cases slightly exceed unity in magnitude ("a point of academic rather than of practical interest"). "Certain limitations of the conception of impedance at very high frequencies, particularly in relation to methods of measurement, are emphasised. It is suggested, in fact, that at very high frequencies the only property of a termination which can be determined with certainty is its reflection coefficient when associated with a particular line."

2500. AN IMPROVED TRANSMISSION-LINE CALCULATOR.—Smith. (*See* 2479.)

2501. CHARACTERISTIC IMPEDANCE OF TRANSMISSION LINES: A NOTE ON CERTAIN PARTICULAR CASES [where One Conductor is a Thin Strip and the Other a Hollow Square symmetrically surrounding the Strip, or an Infinite Plane parallel to the Strip: Measurements: the "Equal Perimeter" Rule, and Empirical Formulae].—C. C. Eaglesfield. (*Wireless Engineer*, May 1944, Vol. 21, No. 248, pp. 222–226.) For a letter from C. F. Brockelsby correcting the interpretation of a capacitance formula *see* June issue, No. 249, p. 279.

2502. LOSS-LESS TRANSMISSION LINES: ANALYSIS BY MEANS OF TWO SIMPLE DIAGRAMS ["Clock" Diagram and "Crank" Diagram (Howe, 1884 of 1943), and Their Uses: Relations between the Two Diagrams: the "Cartesian" Chart of Willis Jackson & Huxley (1871 of June)].—A. Bloch. (*Wireless Engineer*, April 1944, Vol. 21, No. 247, pp. 161–166.)

2503. PARALLEL TRANSMISSION LINES [Relation between Their Mutual Inductance and Mutual Capacitances].—A. Bloch. (*Wireless Engineer*, June 1944, Vol. 21, No. 249, pp. 280–281.) "The purpose of this short note is to show in an elementary manner that not only self inductances but also mutual inductances can be deduced from electrostatic considerations."

2504. INTERCOUPLED TRANSMISSION LINES AT RADIO FREQUENCIES.—Fuchs. (*See* 2482).

2505. ERRATUM: TRANSMISSION-LINE THEORY AND ITS APPLICATION.—R. King. (*Journ. Applied Phys.*, March 1944, Vol. 15, No. 3, p. 292.) *See* 732 of March.

2506. IMPEDANCE TRANSFORMATION: PART I [General] AND PART II [Graphical Methods of U.H.F. Transmission Line Analysis].—P. J. Selgin. (*Communications*, Feb. 1944, Vol. 24, No. 2, pp. 50–56 and 104: March 1944, No. 3, pp. 40–44 and 87.)

2507. REMARKS ON MY PAPER "ELECTRICALLY 'SMOOTH' CONSTRUCTIONAL ELEMENTS OF CONCENTRIC LINES AT HIGH FREQUENCIES" [28 of January].—H. Meinke: Weissfloch. (*Hochf:tech. u. Elek:akus.*, Oct. 1943, Vol. 62, No. 4, p. 123.) Continuing the Meinke–Weissfloch argument as to who invented what, mentioned in the abstract cited above.

2508. ARRANGEMENT FOR SUPPRESSING THE HIGH-FREQUENCY CURRENT APPEARING ON THE OUTER SIDE OF THE SHEATH OF A CONCENTRIC U.H.F. LINE AT A JUNCTION POINT. —F. Tischer. (*Hochf:tech. u. Elek:akus.*, Oct. 1943, Vol. 62, No. 4, p. 127, Fig. 13.)

A Telefunken patent, D.R.P.733 697, applied for 29/8/39. The line sheath *L* is surrounded at the point of discontinuity by a toroidal coil tuned by the condenser *C* to resonance so as to act as a rejector circuit.

2509. ULTRA-HIGH-FREQUENCY EQUIPMENT [Characteristics of Cavities Horns, & Sources of 3000 Mc/s Waves].—R. E. Soria. (*Radio News* [Chicago], April 1944, Vol. 31, No. 4, Supp. pp. 3–8 and 40.)

2510. THE ELECTRICAL OSCILLATIONS OF A PROLATE SPHEROID: PAPER II.—L. Page. (*Phys. Review*, 1st/15th Feb. 1944, Vol. 65, No. 3/4, pp. 98–110.)

The vector wave equation in prolate spheroidal coordinates is set up, the variables are separated, and the characteristic values (eigenvalues) and characteristic functions (eigenfunctions) of the resulting ordinary differential equations are obtained in series which converge rapidly in the neighbourhood of resonance for spheroids of eccentricity near to unity. *See* also 2511, below.

2511. THE ELECTRICAL OSCILLATIONS OF A PROLATE SPHEROID: PAPER III [The Antenna Problem].—L. Page. (*Phys. Review*, 1st/15th Feb. 1944, Vol. 65, No. 3/4, pp. 111–117.) The straight-wire antenna is approximated by a perfectly conducting prolate spheroid of eccentricity very close to unity.

2512. HIGH-FREQUENCY CABLE WITH VARYING CHARACTERISTIC IMPEDANCE [by Use of Spiral Inner Conductor of Varying Pitch, giving a Characteristic Impedance altering Exponentially: for Matching Purposes: Differences between This and Previous "Exponential" Cables (*e.g.* Bell System): Data].—E. Keutner. (*Zeitschr. f. Fernmeldetech.*, 15th Jan. 1944, Vol. 25, No. 1, pp. 17–18: summary, from *Europ. Fernsprechd.*, 1943.) *See* also end of 2513, below (Kaden).

2513. THE DESIGN CALCULATIONS FOR COAXIAL CABLE WITH SPIRALLY-WOUND CONDUCTORS. —H. Kaden. (*T.F.T.*, Sept. 1943, Vol. 32, No. 9, pp. 195–202.)

Author's summary:—"In coaxial submarine cables with spiral-band outer conductor enclosed in a lead sheathing, additional losses are produced by the eddy currents induced in the lead sheath by the axial field. Formulae, valid at all frequencies, are derived for these losses. In the region of skin effect, that is at high frequencies, the lead sheath acts as a short-circuited turn for the axial field; in this case the losses increase with the square root of the frequency. In the region of low frequencies, where no skin effect is yet present, all the actions of the axial field can be determined from the equivalent-circuit diagram of a transformer in which the lead sheath forms the secondary loading resistance and the external conductor the primary series resistance.

"In matching and transit-time [delaying] cables, on the other hand, the inner conductor is spiralled while the outer conductor takes the form of a homogeneous tube. Characteristic impedance, transit time, and attenuation are calculated and shown in curves. If the characteristic impedance or the transit time is given, there is a specially favourable ratio of diameters and a specially favourable angle of slope for the inner-conductor spiral, for which the attenuation for a given cable-diameter will be a minimum. In contrast to the cable with homogeneous conductors, for which the optimum ratio of diameters r_a/r_i is 3.6, the value for the matching cable is 2.7 and for the transit-time cable 1.8. The optimum turns-density [and consequently the optimum angle of pitch for the spiral] of the inner conductor is then, by eqn. 55, proportional to the characteristic impedance and to the transit time. The design calculations of such cables thus becomes very simple.". Recently Keutner (2512, above) has described an "exponential" cable in which the turns-density of the inner conductor increases steadily. Such a cable has the advantage over cables with constant turns-density that the matching between two resistances is possible not merely for one single frequency but for an infinite frequency-band stretching upwards from a lower limit, like that of a high-pass filter. The formulae derived in the present paper can be used as a basis for the calculation of such exponential cables.

2514. TRANSIENT RESPONSE IN FREQUENCY MODULATION.—D. A. Bell. (*Phil. Mag.*, March 1944, Vol. 35, No. 242, pp. 143–158.)

Author's summary:—"Square-wave modulation is assumed to be applied both to an amplitude-modulated and a frequency-modulated system, in each of which the band-width is limited by a single resonant circuit tuned to the carrier frequency, and the responses are computed. It is found that F.M. gives a better transient response than A.M. The response of a single tuned circuit to sinusoidal frequency modulation, of such high frequency of modulation that the side-bands fall on the skirt of the circuit resonance characteristic, is also examined and it is shown that severe harmonic distortion is introduced."

2515. "ELECTRIC CIRCUITS" [Book Review].—E.E. Staff of M.I.T. (*Proc. I.R.E.*, March 1944, Vol. 32, No. 3, p. 184.)

2516. "COMMUNICATION CIRCUITS" [Book Reviews].—L. A. Ware & N. R. Reed. (*Proc. I.R.E.*, Jan. & April 1944, Vol. 32, Nos. 1 & 4, pp. 56 & 244.) For another review *see* 2659 of 1943.

2517. "GRAPHICAL CONSTRUCTIONS FOR VACUUM-TUBE CIRCUITS" [Book Review].—A. Preisman. (*Proc. I.R.E.*, March 1944, Vol. 32, No. 3, p. 183.)

2518. Vacuum-Tube Networks.—Llewellyn & Peterson. (*See* 2578.)

2519. Signs of Voltages and Currents in Vacuum-Tube Circuits.—H. Stockman. (*Communications*, Feb. 1944, Vol. 24, No. 2, pp. 32–38 and 104.)

2520. Linearity Circuits.—Clarke. (*See* 2677.)

2521. Using Series Tubes as Control Impedances [Linearity Characteristics of Series-Operated Direct-Coupled Valves, and Factors influencing Gain and Performance].—W. Moulic. (*Electronic Industries*, Jan. 1944, Vol. 3, No. 1, pp. 88–90 and 194, 196.)

2522. Negative Capacitance.—C. Brunetti & L. Greenough. (*Communications*, March 1944, Vol. 24, No. 3, pp. 28–31.)

When the output of an ordinary two-stage amplifier is coupled back to the input through a condenser, it is possible by proper adjustment of the amplification to secure an input impedance that behaves as a negative capacitance. A negative capacitance is a reactive circuit element whose reactance varies inversely as the frequency but is positive in sign. At any given frequency a negative capacitance will present the same type of reactance as an inductance.

2523. Modulated Carrier for D.C. Amplifiers [Thyratron for Generation of Oscillations for Amplification of D.C. and Low-Frequency Potentials].—S. L. Javna. (*Electronic Industries*, Jan. 1944, Vol. 3, No. 1, pp. 102, 103, and 194.)

2524. "Performance Factor" [Arbeitsvermögen] of Some Common Resistance-Amplifier Stages.—R. Wunderlich. (*E.T.Z.*, 13th Jan. 1944, Vol. 65, No. 1/2, p. 18.)

Short summary of the paper referred to in 1880 of June. "In a resistance-amplifier stage with internal and external resistances R_i and R_a the d.c. amplification is known to be $v_o = S \,.\, R_aR_i/(R_a+R_i)$. Taking account of the fact that the d.c. amplification of any resistance stage, with or without linear negative feedback, can be brought into this form (provided that, where necessary, R_a and R_i are made to represent not the actual existing resistance but rather certain resistance values dependent on the degree of negative feedback), and representing by f_{max} an arbitrarily determined maximum frequency which marks the upper limit of the working range, $0 < f \leq f_{max}$, of the amplifier, then naturally the product $Sf_{max} \,.\, R_aR_i/(R_a+R_i)$ must be the same for all types of resistance amplifier. On the other hand, the working range is obviously reduced by the presence of negative feedback, since the d.c. amplification decreases with increasing negative feedback (a linear negative feedback is assumed throughout: for example, in a current-type feedback, equality of the time constants of the cathode and anode circuits is postulated). In the present paper the product v_of_{max} is termed the 'performance factor', and the above identities and relations are derived in full and elucidated by diagrams and formulae. In particular the pure 'cathode amplifier' is dealt with: as might be expected, this provides no discrepancies".

2525. The Cathode-Coupled Double-Triode Stage [and Its Many Useful Properties].—E. Williams. (*Electronic Eng:g*, May 1944, Vol. 16, No. 195, pp. 509–511.)

In 1941, Miller described a highly sensitive and stable d.c. amplifier, incorporating a precision voltage stabiliser (2314 of 1942). In both the amplifier and stabiliser there appeared a type of amplifier stage using a double-triode valve. The properties of this stage are here given further description. The stage may be used as a d.c. amplifier, and also has an appreciable gain at supersonic frequencies. It may be used as a comparator with an input voltage on each grid. A further valuable property of this stage is its ability to give automatic compensation for variations of cathode temperature—a very valuable property in a d.c. amplifier. Finally in a d.c. amplifier several (but not an unlimited number) of such stages may be connected in cascade without the use of coupling batteries and without the necessity for an unduly large h.t. supply voltage.

2526. Theory and Design of [Untuned-Primary] Radio-Frequency Transformers.—J. B. Rudd. (*A.W.A. Tech. Review*, No. 4, Vol. 6, 1944, pp. 193–256.)

Introduction: scope of paper: notation: general analysis of transformer: two-point matching—secondary capacitance tuned for maximum response: operating characteristics with variable capacitance or frequency: effect of shunt capacitance in the primary mesh: effect of dissipation in primary and secondary inductances: worked examples illustrating the design procedure.

2527. High Selectivity [at Audio & Intermediate Frequencies]—E. L. Thomas. (*Wireless World*, June 1944, Vol. 50, No. 6, pp. 175–178.)

2528. High-Q Audio Reactor [Analysis of Effect of Magnetic Core and Demonstration of Commercial Practice of Inductance Manufacture].—C. A. Campbell. (*Communications*, March 1944, Vol. 24, No. 3, pp. 33–38 and 87..91.)

2529. Frequency-Compensating Attenuators.—Light. (*See* 2612.)

2530. Attenuator Design [for Unequal Steps of Attenuation, useful in Checking the Frequency Response of Amplifier or Receiver: Generalisation of the Sequential Method of Calculation, lending itself to Tabulation].—R. F. Blackwell & T. A. Straughan. (*Wireless Engineer*, March 1944, Vol. 21, No. 246, pp. 122–123.) From the Murphy laboratories.

2531. Circuit Design of Mixers and Fader Controls: Part II.—P. B. Wright. (*Communications*, Dec. 1943, Vol. 23, No. 12, pp. 44–56 and 96..100.) For Part I *see* 1624 of May.

2532. Audio-Frequency Mixers.—Cooper. (*See* 2614.)

2533. Symmetry and Symmetry Measurement in Telephone Engineering [with Particular Reference to Crosstalk on Lines and Cables: Introduction of the Quantity "Operative

Symmetry Transmission Equivalent" analogous to "Crosstalk Transmission Equivalent:" Measuring Apparatus: etc.].—C. Moerder. (*T.F.T.*, Sept. & Oct. 1943, Vol. 32, Nos. 9 & 10, pp. 185–195 & 203–211.)

2534. On a Solution of the Telegraphists' Equation.—H. Parodi. (*Comptes Rendus* [Paris], 3rd/31st May 1943, Vol. 216, No. 18/22, pp. 606–608.)

2535. Pulse Generation [Short Survey].—J. M. A. Lenihan. (*Electronic Eng:g*, March 1944, Vol. 16, No. 193, pp. 408–411.)

2536. The Multivibrator: Applied Theory and Design: Part I.—E. R. Shenk. (*Electronics*, Jan. 1944, Vol. 17, No. 1, pp. 136–141 and 332..337.)

This first part of a three-part paper from the R.C.A. Laboratories is devoted largely to the multivibrator operating at its natural frequency. The wave shape of the synchronising voltage and its point of application to the multivibrator are considered. The analysis of the multivibrator is developed on the basis of simple capacitor–resistor time constants. An equation relating the natural frequency of the multivibrator to the characteristics of the valves and circuit components is derived and discussed.

2537. Analysis of a Multivibrator.—S. C. Snowdon. (*Phys. Review*, 1st/15th Feb. 1944, Vol. 65, No. 3/4, p. 151: abstract only.)

2538. New Electronic-Key Circuits [Two Adaptations of Multivibrator Principle].—W. L. Gardner & C. H. Page. (*QST*, March 1944, Vol. 28, No. 3, pp. 15–17.)

2539. Low-Frequency Quartz-Crystal Cuts having Low Temperature Coefficients [*MT* & *NT* Cuts].—Mason & Sykes. (*See* 2651.)

2540. A Low-Pass Quartz Filter with Complex Points of Infinitely High Attenuation.—W. Herzog. (*T.F.T.*, Sept. 1943, Vol. 32, No. 9, pp. 181–185.)

For previous work *see* 1538/1540 of May. "A low-pass circuit with oscillating quartz crystals was first given by Mason (U.S.A. Pat. 1921 035). As a differential bridge the arrangement had the appearance shown in Fig. 1, in which each bridge-arm contains a quartz. This circuit, however, is only realisable in a few cases. Mason himself points out that the parallel capacitance C_0, as calculated for a desired filter performance, is often smaller than the self-capacitance of the quartz itself. This difficulty can be overcome by the device of paralleling a suitable inductance, as described in a previous paper (1540 of May). What is far more serious, however, is a disadvantage not to be removed by any of the usual means, namely the great inequality of the [required] inductances of the quartzes in the different bridge-arms, which exceeds the inductance variation possible for quartz. The necessary inductance ratios (which will be discussed in detail in section 3) can to some extent be obtained by the use of asymmetrical transformers, but this plan always leads to difficulties in loss-compensation and prevents a practical reproduction of the theoretical relations from being attained. The present paper show how, by the introduction of complex points of infinity on the attenuation characteristic, a desired inductance ratio may be obtained, in particular an inductance equality of the quartzes in the various bridge-arms. In this way a complete realisation of the theoretical attenuation curve is made possible."

As an example, a low-pass filter on these lines is calculated for a cut-off frequency $f_2 = 534.850$ kc/s, to have a steep slope for a pass-band of at least 15 kc/s. The series-resonance frequencies of the quartzes work out at 532.490 and 525.050 kc/s; Telefunken Type QEE 4 quartzes (Bechmann, 3332 of 1942) were used, which at those frequencies show inductance values $L_3 = 8.23$ H and $L_2 = 7.65$ H. Fig. 5 shows the excellent agreement between the calculated and measured attenuation characteristics.

2541. "Wave Filters" [Book Review].—L. C. Jackson. (*Wireless Engineer*, March 1944, Vol. 21, No. 246, p. 123.) For another review *see* 2156 of July.

2542. Image-Representations of Linear Complex Functions by the Use of Their "Fixed Points," with Two Examples of Application taken from the Theory of Four-Terminal Networks.—H. Schulz. (*T.F.T.*, Oct. & Nov. 1943, Vol. 32, Nos. 10 & 11, pp. 218–222 & 231–234.)

A chapter taken from a not yet completed book for communication engineers. The linear function may have either of two forms: (1) $w = g(z) = az + b$, or (1a) $w = l(z) = (az + b)/(cz + d)$, where c is not zero. The "fixed points" mentioned in the title are those in which z and w, the original and the image, coincide: there are only two of these possible, for linear functions, and in case (1) one of the two is always at infinity, while in case (1a) both are finite. The two examples of the use of the method both deal with the image-representation of the plane of the terminating resistance of the quadripole on that of its input resistance: in the first, the quadripole is symmetrical and the solution already found by Feldtkeller in his book (2085 of 1943), while in the second the problem is solved for an asymmetrical network.

2543. An Investigation, with the aid of Equivalent Electrical Circuits, of the Dynamics of Regulating Mechanisms.—E. I. Fondaminski. (*Automatics & Telemechanics* [in Russian], No. 4/5, 1941, pp. 35–54.)

The use of equivalent electrical circuits for studying mechanical oscillatory systems is discussed, and such methods are then applied to a detailed investigation of the operation of governors of engines. Various conditions are dealt with, including the regulation of two engines working in parallel, and it is claimed that a number of new results have been obtained.

TRANSMISSION

2544. Generation of High-Power Oscillations with a Magnetron in the Centimetric Band.—N. F. Alekseev & D. D. Malairov. (*Proc. I.R.E.*, March 1944, Vol. 32, No. 3, pp. 136–139.) Translation of the Russian paper dealt with in 2639 of 1942.

2545. Experimental 225.6 Mc/s A.M. Relay Transmitter [Output Power 10 Watts: Controlled by 4.7 Mc/s Crystal].—W. L. Widlar. (*Communications*, Jan. 1944, Vol. 24, No. 1, pp. 22–24.)

2546. A Note on [Unwanted] Frequency Modulation, with Particular Reference to Standard-Signal Generators.—Colebrook. (*See* 2637.)

2547. A Note on Frequency-Modulation Terminology.—H. Stockman & G. Hok. (*Proc. I.R.E.*, March 1944, Vol. 32, No. 3, pp. 181–183.)

Tentative definitions are put forward in an attempt to clarify the terminology used to describe frequency modulation. Only two fundamental, independent types of modulated waves are possible: amplitude-modulated and frequency-modulated. Three definitions are introduced to specify transmissions of frequency-modulated waves:—(1) Flat frequency modulation, FFM (frequency deviation proportional to signal amplitude and independent of signal frequency); (2) flat phase modulation, FPM (amplitude of phase deviation is proportional to amplitude and independent of frequency of modulating wave; and (3) standard frequency modulation, SFM (amplitude of frequency deviation proportional to signal but varies with signal frequency according to standard accentuation curve).

RECEPTION

2548. Transient Response in Frequency Modulation.—Bell. (*See* 2514.)

2549. F.M. Distortion in Mountainous Terrain [Some Observations of Multi-Path Reception of F.M. Signals].—A. D. Mayo & C. W. Sumner. (*QST*, March 1944, Vol. 28, No. 3, pp. 34–36.)

2550. Combination A.M./F.M. Detector [Versatile Limiter–Detector responding to either F.M. or A.M. Signals for Receiving, Transmitting, or Control Purposes: One Tube, a Duplex Diode Triode, provides Functions of A.M. Detector, F.M. Detector, Limiter, & Discriminator, and also provides Automatic Volume Control].—F. C. Everett. (*Communications*, Feb. 1944, Vol. 24, No. 2, pp. 25–27 and 94, 95.)

2551. Adjustable I.F. Selectivity [Advantages of Variable I.F. Band-Width of Receiver: Result Obtained by Simple Method of Transformer Design].—S. Lobel. (*QST*, March 1944, Vol. 28, No. 3, pp. 49–50 and 92.)

2552. High Selectivity [at Audio & Intermediate Frequencies].—E. L. Thomas. (*Wireless World*, June 1944, Vol. 50, No. 6, pp. 175–178.)

2553. Tracking in Superheterodyne Receivers: Part I.—S. W. Amos. (*Electronic Eng:g*, March 1944, Vol. 16, No. 193, pp. 412–413 and 422, 423.)

2554. Appliances and Radio Interference.—"Supervisor." (*Electrician*, 2nd June 1944, Vol. 132, No. 3444, pp. 475–476.)

The need is stressed for careful consideration of interference problems after the war. Emphasis is placed on the bad features of the single-phase series-wound motor widely used in domestic appliances. It is suggested that the use of three-phase motors would reduce interference to radio reception and, in addition, would lead to cheaper appliances. *Cf.* 2187 of July.

2555. Regulations for the Interference-Suppression of Apparatus and Equipments of the Armed Forces: *also* Component Elements for Interference Suppression: *and* The Interference-Suppression of Apparatus and Equipments of the Armed Forces: *finally* High-Frequency Chokes for Interference-Suppression.—E. Henning: W. Mennerich: K. Volk & R. Zechnall: W. Patzschke. (*E.T.Z.*, 13th Jan. 1944, Vol. 65, No. 1/2, pp. 5–6: pp. 6–9: pp. 9–15: pp. 15–18.)

(i) General introduction to Regulations V.D.E. 0878. (ii) Recent designs, of smaller size and increased efficiency, of condensers, chokes, and resistances: filters, and their potential distribution for three wave-bands. (iii) Supplement to V.D.E.0878, giving practical examples of screening and filtering, with illustrations, for electric motors, aeroplane-engine ignition systems, lighting dynamos with built-in Tirrill regulators, etc: trolley-mounted measuring equipment: radiation diagrams: dependence of interfering range on length of radiator (Fig. 20, for 10 m wave). (iv) Especially the properties and advantages of the latest closed-iron-core coils using compressed-powder materials (D.I.N. E 41261/62) and sealed in insulating aggregates: the effect of adding quartz powder in reducing temperature-rise: etc.

2556. The "Etherscope" [Experimental Device enables Signals from All Stations in Given Wave-Band to be Viewed Simultaneously on Cathode-Ray Tube].—D. G. Hull. (*Electronic Eng:g*, May 1944, Vol. 16, No. 195, pp. 497–499.)

"To see at a glance how many stations there are on a given band, their relative strength, whether c.w. or modulated, when any of them close down, and when any new ones become active". On inactive bands, the instrument may be used with a receiver as an automatic "search" set, the few stations appearing on the screen being "rubbed out" by wave traps. Not to be confused with the "Panoramic Spectroscope".

2557. Radio-Telegraph Signals [High-Speed Recording Systems].—R. B. Armstrong & J. A. Smale. (*Electrician*, 26th May 1944, Vol. 132, No. 3443, p. 453: summary of I.E.E. paper.) *See* also "High-Speed Radio Recording: Overcoming Distortional Effects", *Elec. Review*, 19th May 1944, Vol. 134, No. 3469, p. 707.

AERIALS AND AERIAL SYSTEMS

2558. Antennae for Ultra-High Frequencies.—L. Brillouin. (*Elec. Communication*, No. 4, Vol. 21, 1944, pp. 257–281.)

This paper presents a general study of ultra-high frequency antenna problems and a comparison of the theories developed by different authors. An account is given of the results achieved, together with a discussion of the weak points of the different theoretical methods and an attempt to draw some general conclusions.

The later sections of the paper are to be published in the next issue of the journal.

2559. The Electrical Oscillations of a Prolate Spheroid: Papers II and III [with Application to Aerials].—Page. (*See* 2510 & 2511.)

2560. Radio-Frequency Feeders [Analysis of the Function and Operation of Transmission Lines at High Frequencies with Matching Networks].—R. A. Whiteman. (*Radio News* [Chicago], April 1944, Vol. 31, No. 4, Supp. pp. 22–25 and 41.)

2561. High-Frequency Cable with Varying Characteristic Impedance [" Exponential Cable "], *and* The Design Calculations for Coaxial Cable with Spirally-Wound Conductors.—Keutner: Kaden. (*See* 2512/3.)

2562. The Application of Helmholtz's Theorems to Aerial Characteristics [Editorial prompted by Burgess's Paper, 2563, below: the Principle of Superposition & the Reciprocal Theorem].—G. W. O. H. (*Wireless Engineer*, April 1944, Vol. 21, No. 247, pp. 153–154.)

2563. Aerial Characteristics: Relation between Transmission and Reception.—R. E. Burgess. (*Wireless Engineer*, April 1944, Vol. 21, No. 247, pp. 154–160.)

" It has often been suggested in investigations of aerials that the impedance, effective height, and polar diagram may not be the same for reception as for transmission. This present paper is the outcome of an attempt to resolve the problem by reference to the fundamental principles which apply to all linear systems, of which an aerial is one.

" The first section of the paper is concerned with demonstrating the identity of the impedance and effective height of an aerial for any condition of excitation. An investigation of the arguments which led some writers to suggest that the identity may not hold has resulted in a critical examination of the methods of calculation of aerial impedance which is presented in the second section [field-equations method, Poynting-vector and induced-e.m.f. methods, transmission-line method]. The third section briefly discusses the simplifying assumptions usually made in these methods of calculation ". The errors in the papers where differences between the transmitting and receiving impedances have apparently been found are indicated: *e.g.* Niessen & de Vries. Schelkunoff's " Radiation Paradox " is also explained.

2564. Reactance and Effective Height of Screened Loop Aerials.—R. E. Burgess. (*Wireless Engineer*, May 1944, Vol. 21, No. 248, pp. 210–221.)

It was pointed out in an earlier paper (117 of 1940) that the theory there developed represented only a first approximation, and that it could be extended by taking into account the distributed self and mutual capacitances along the lines of the classical transmission-line theory. " The present paper gives the formal analysis of this extension, and is analogous to the analysis by Colebrook of the unscreened loop (4345 of 1938 [and 1455 of 1939]) ". Balanced and unbalanced loops are considered, current and potential distributions in transmitting and receiving conditions are compared, and experimental results given: general reasons for any discrepancy between theory and experiment are mentioned.

2565. Arrangement for the Avoidance of Subsidiary Radiation in Aerial Combinations with Sharp Directivity.—C. Lorenz Company. (*Hochf:tech. u. Elek: akus.*, Oct. 1943, Vol. 62, No. 4, p. 127, Fig. 12.) Swiss Patent 220 880, priority of 12/10/39.

2566. Phase Monitor [gives Absolute Value of Phase of Radiated Field: Accuracy believed to be of Order 2°].—V. J. Andrew. (*Communications*, Jan. 1944, Vol. 24, No. 1, p. 32.)

2567. A Chart for Rhombic Antenna Design.—W. G. Baker. (*A.W.A. Tech. Review*, No. 4, Vol. 6, 1944, pp. 177–192.) Author's summary:—" A chart has been prepared for the design of rhombic antennae to solve simply such problems as the following: the best proportions, the angle of maximum radiation at any wavelength, and the wavelength of maximum radiation at any angle of elevation. The results apply only in the vertical plane containing the principal diagonal."

2568. A Dummy Dipole Network.—H. Salinger. (*Proc. I.R.E.*, Feb. 1944, Vol. 32, No. 2, pp. 115–116.)

Author's summary:—" Design data are presented for a network which closely simulates the impedance of a dipole antenna in the range from one half to twice its series-resonance frequency."

2569. Explanatory Remarks on the V.D.E. Provisions concerning Aerial Installations, V.D.E. 0855, 0856, and 0857 [with Special Reference to Community Aerials].—F. Eppen. (*E.T.Z.*, 27th Jan. 1944, Vol. 65, No. 3/4, pp. 43–44: to be concluded.)

2570. Universal Abacs [Nomograms] for the Mechanical Calculation of Overhead Lines.—R. Dupenloup. (*Génie Civil*, 1st Jan. 1944, Vol. 121, No. 1, p. 11: summary, from *Rev. Gén. de l'Élec.*, Aug. 1943.) *Cf.* K. Kohler, *Zeitschr. f. Fernmeldetech.*, 15th Jan. 1944, Vol. 25, No. 1, pp. 9–12.

VALVES AND THERMIONICS

2571. Practical Results from Theoretical Studies of Magnetrons.—L. Brillouin. (*Proc. I.R.E.*, April 1944, Vol. 32, No. 4, pp. 216–230.)

The space charge in magnetrons is found to have a profound effect upon performance, even though the critical motions of the electrons may be correctly determined by disregarding it. The inclusion of space charge gives a simple picture based on a rotating cloud of space charge. Possible vibration modes for this space-charge cloud are discussed, and their relation to the impedance seen from an external circuit is correlated with the possibility of oscillation-production. The description of the results is visualised by comparison with well-known problems of electrotechnics, such as alternators or cyclotrons.

2572. Magnetron Oscillator for Instruction and Research in Microwave Techniques.—J. T. Tykociner & L. R. Bloom. (*Univ. of Illinois Bull.*, 18th Jan. 1944, Vol. 41, No. 22, 30 pp.)

A magnetron oscillator for wavelengths from 6 to 17 centimetres (5000 down to 1700 Mc/s) is described, for use either in the laboratory or for instruction. It consists of a split-anode magnetron inserted between the pole-pieces of a magnet whose housing serves to couple the oscillating system to transmission systems of various types. For the longer wavelengths a permanent magnet is used, and a more powerful electromagnet for the shorter wavelengths.

2573. Arrangement for the Amplification and Subsequent Rectification of Ultra-High-Frequency Oscillations using a Cascade Electron-Multiplier [Diode in Same Bulb as Multiplier, Ancillary Circuits enclosed in the Screening Cap covering Those Parts of the Multiplier which carry the Stronger H.F. Currents].—W. Flechsig. (*Hochf:tech. u. Elek:akus.*, Oct. 1943, Vol. 62, No. 4, p. 127, Fig. 10.) A Fernseh Company patent, D.R.P.733 426, applied for 29/3/39.

2574. Comparative Investigations on the Influence of the Form of the Grid Bars on the Functioning and Efficiency of Emissive-Grid-Type Electron-Multipliers [" Prallgittervervielfachern "].—W. Reichel. (*E.T.Z.*, 13th Jan. 1944, Vol. 65, No. 1/2, p. 20 : summary, from *Physik. Zeitschr.*, Vol. 44, 1943, p. 279 onwards, a 17-page paper with many diagrams.)

" Electrodes of the ' prallgitter '-type multiplier take the form of gapped surfaces such as gauzes or grids. Special magnetic fields for guiding the electrons are not necessary. The present paper gives information as to the optimum design of the electrodes (shading factor, mesh, network construction, spacing and relative positioning of the grids). The multipliers are divided into two groups. In the first, the field between the successive stages is homogeneous. The range w of the secondary electrons (SE) is large compared with the width of the grid bars and their spacing. The relations between the form of the grid, the primary-electron shading factor b (ratio of the sum of all the impact-receiving surfaces to the total surface of the electrode), the useful secondary electrons (NSE), the primary electrons P, and the secondary-emission factor η are shown in Table 1."

This table gives four examples with $b = 0.5$ (flat strips in one plane, with spacings equal to their widths ; square-sectioned bars ; flat strips in Venetian-blind arrangement ; and circular-sectioned bars ; all with the primary electrons incident normally to the total surface) and four with $b = 1$ (square-sectioned bars, with electrons incident at an angle ; flat strips on edge, parallel to each other, electrons incident at 45° ; the same, with electrons incident at 60° ; and the Venetian-blind strips, with oblique incidence so that the electrons strike the strip-surfaces normally). For all these arrangements except the last, the total output $NSE + PE$ (with $\eta = 10$) is given as ranging from $2P$ to $3.7P$, whereas for the last it is given as $6.1P$.

" In the second of the two groups the range of the secondary electrons is about equal to the width of the bars. The electric fields have an inhomogeneous course. In order to avoid having the useful secondary electrons pass through the gaps of the next grid without striking, the accelerating field between the grids must be reduced or the spacing between the grids increased as compared with the bar dimensions."

2575. Power Loss in Deflecting Condensers [Short Derivation of Formula previously obtained by Recknagel and Hollmann & Thoma].—D. Gabor. (*Wireless Engineer*, March 1944, Vol. 21, No. 246, pp. 115–116.) For a vigorous correspondence (Owen Harries, Rodda, Benham, and the author) *see* issues for April, May, and June.

2576. Deflected Electron Beams.—J. H. Owen Harries. (*Wireless Engineer*, June 1944, Vol. 21, No. 249, pp. 267–277.)

Modulation by acceleration or deceleration of the electrons in an electron-beam valve in a direction transverse to the initial direction of the electrons is examined mathematically. Equations are obtained which give the trajectories of the electrons and the relative phase and amplitude of the deflection with respect to the deflecting voltages. The power required is determined and it is shown that the input impedance of the valve can be high.

2577. On the Currents carried by Electrons of Uniform Initial Velocity.—G. Jaffé. (*Phys. Review*, 1st/15th Feb. 1944, Vol. 65, No. 3/4, pp. 91–98.)

" The following problem is treated. Electrons enter the space between two infinite parallel planes with uniform velocity at right angles to the planes. The current is studied for all possible values (positive and negative) of the potential difference between the planes. The complete solution can be obtained when the number of electrons entering the discharge space is equal to or smaller than a given number N_0 per cm^2 per second and is for each potential as high as the potential permits."

2578. Vacuum-Tube Networks.—F. B. Llewellyn & L. C. Peterson. (*Proc. I.R.E.*, March 1944, Vol. 32, No. 3, pp. 144–166.)

Authors' summary :—" The performance characteristics of vacuum-tube amplifiers are analysed by combining the fundamental relations governing the motions of electrons within the vacuum tube with the methods of circuit-network theory. The result is an equivalent network based upon the electron-discharge stream rather than upon the external terminals of the tube. It is connected to the external terminals through simple impedance elements and allows the amplifier performance to be calculated in a comparatively straightforward manner even in the case of multi-element tubes and when the electron transit time is not restricted to a small portion of the cycle. The phase delay in the transmission which results from electron transit time is calculated together with the input loading. This calculated loading must be increased to include the effects of Maxwellian distribution of electrons, which may be disregarded for a first approximation in many other applications. The analysis methods are applicable to velocity-variation devices as well as to density-variation or space-charge control, and methods of handling such problems are briefly indicated."

2579. THE RECLAMATION OF THE MOTIONAL ENERGY OF THE ELECTRONS IN AMPLIFIER VALVES.—G. Pasqualigo. (*Radio e Televisione*, Vol. 7, 1942, p. 1 onwards: a 14-page paper summarised by Strutt in *E.T.Z.*, 27th Jan. 1944, Vol. 65, No. 3/4, p. 41.)

" The writer starts with the fact that in thermionic valves used as Class A or B amplifiers the highest efficiency amounts to 50% or 78%; that is, that in the anode circuit these fractions of the d.c. power supplied are converted into a.c. power. The remaining 50% or 22% is lost, and produces an unwanted heating of the valve anode, the electrons impinging with great force on this electrode. If this lost power could be reduced it would be possible to apply a considerably higher d.c. power and thus to obtain a correspondingly greater a.c. output. The power dissipation in question is in no way unavoidable thermodynamically, like, for example, the losses appearing in the conversion of heat, according to the Second Law. It is rather a question of motional energy given to the electrons in the accelerating field and then transformed into heat by the impact of these electrons on the anode.

" One may attempt to reclaim this motional energy by putting a brake on the electrons either at the end of their path (analogy with the water turbine) or along the last section of their path (mill-wheel analogy). Such a braking action must have no prejudicial effect on the output circuit of the amplifier. Pasqualigo proposes to obtain the desired result by the use of an anode in the form of a grid, behind which (seen in the direction of the electron flow) a sequence of other grid-type electrodes is arranged, each with a potential lower than that of the preceding one, the last of all being practically at cathode potential. These potentials can be derived, for instance, from a suitable battery of accumulators. As the electrons pass through this series of grids, they become gradually slowed-down. As a consequence, a current will flow in the leads of the battery in such a direction as to charge the latter. The external circuit is connected to the first grid-type anode, which obtains its anode voltage from a further d.c. source.

" It is evident that the anode circuit remains unaffected by the use of the subsidiary grids and their associated battery. The efficiency of the arrangement will approach 100% the more closely, the more grids are employed and the better it can be contrived to avoid loss due to electron-bombardment at these grids. This basic plan may be applied to triodes as well as pentodes. With the help of curve-families, the output and efficiency calculations are carried out for certain typical circuits, and it is shown to what degree these quantities can be pushed up in such a manner in actual practice.

" With the second of the two methods mentioned (mill-wheel analogy), a valve, either triode, tetrode, or pentode, with a very high amplification coefficient has its anode side connected in series with triodes whose cathodes are all connected to the first-named anode, while each of their own anodes is given a somewhat higher potential than the next triode-anode. The grid alternating voltages of these triodes vary in synchrony with the alternating voltage of the first-named valve, and the grid control is so ordered that the anode of this valve is at any moment connected to that battery-tapping which has the lowest possible potential with respect to its cathode. This arrangement also, like the first, provides the theoretical possiblity of increasing the efficiency."

2580. THE DEPENDENCE OF INTERELECTRODE CAPACITANCE ON SHIELDING.—L. T. Pockman. (*Proc. I.R.E.*, Feb. 1944, Vol. 32, No. 2, pp. 91–98.)

Author's summary:—" Although it has been known for many years that the interelectrode capacitances of a vacuum tube with a glass envelope depend on the shielding of the tube, no quantitative information on the extent and character of this dependence has been published. In the present work the general theory is developed with the help of Maxell's coefficients of capacity and induction. A simple mathematical transformation shows why these coefficients may be used for practical measurements in which all potentials are measured with regard to the earth rather than infinity. The relation between the Maxwell coefficients and the interelectrode and electrode-to-earth capacitances is also developed. The effect of changes in shielding is not necessarily small. The experiments reported show that C_{pf} for the particular triode studied can be made to vary from 0.16 micromicrofarad to 0.41 micromicrofarad by changes in the geometry of the external environment. Furthermore, ungrounding the shield with which C_{pf} was 0.16 micromicrofarad made the 'effective' C_{pf} 1.40 micromicrofarad."

2581. " MODERN MULTIGRID ELECTRON TUBES " [Book Review].—M. J. O. Strutt. (*Proc. I.R.E.*, March 1944, Vol. 32, No. 3, p. 183.)

2582. VARIABLE-MU OR VARIABLE-μ? [Editorial on the Present Confusion: Essential Characteristic of Such Valves is Variable Mutual Conductances, and " Variable-Mu " must represent Abbreviation of This: Variation of μ is only Incidental].—G. W. O. H. (*Wireless Engineer*, May 1944, Vol. 21, No. 248, pp. 205–206.) For a postscript *see* June issue, No. 249, p. 255.

2583. THE SAGA OF THE VACUUM TUBE: PART II [describing a Number of Unusual Early Valves].—G. F. J. Tyne. (*Radio News* [Chicago], April 1944, Vol. 31, No. 4, pp. 54–56 and 92..98: to be contd.) For Part I *see* 1217 of April.

2584. PREVENTION OF CAPILLARY DISTURBANCES IN ELECTROLYTIC FIELD-PLOTTING TROUGHS AND IN MCLEOD GAUGES.—O. Klemperer. (*Journ. of Scient. Instr.*, May 1944, Vol. 21, No. 5, p. 88.)

2585. SPECTROGRAPHIC ANALYSIS IN THE MANUFACTURE OF RADIO TUBES.—S. L. Parsons. (*Proc. I.R.E.*, March 1944, Vol. 32, No. 3, pp. 130–135.)

2586. THE PROCESSING OF GLASS IN THE LAMP AND RADIO-VALVE INDUSTRIES.—R. L. Breadner & C. H. Simms. (*G.E.C. Journal*, Aug. 1943, Vol. 12, No. 4, pp. 192–208)

DIRECTIONAL WIRELESS

2587. AUTOMATIC DIRECTION-FINDING ARRANGEMENT.—K. Jirfa. (*Hochf:tech. u. Elek:akus.*, Oct. 1943, Vol. 62, No. 4, p. 128.)

A Telefunken patent, D.R.P.733 522, applied for 28/7/39. "In the output circuit an alternating voltage is generated (for example by the combination of a frame voltage and an auxiliary-aerial voltage, and the periodic reversal of polarity of one of these) which is dependent as to phase on the sense of the bearing and as to amplitude on the deviation of the directive system from the bearing-direction. This alternating voltage is made to adjust the directive system to the bearing direction by means of a rotating-field motor with short-circuited armature. One motor winding is fed with a fixed-phase, constant-amplitude auxiliary alternating voltage, the other with an alternating voltage (of the same frequency) varying with the phase and amplitude of the receiver output-voltage. This second voltage is derived from a rotary transformer whose primary is fed with the fixed-phase auxiliary voltage [*see* above] and whose rotor is in electromechanical equilibrium and is mechanically controlled by the output voltage from the receiver, for example by a dynamometer or Ferraris system."

2588. A TELEFUNKEN DIRECTION-FINDING RECEIVER PATENT.—K. Fränz. (*Hochf:tech. u. Elek:akus.*, Oct. 1943, Vol. 62, No. 4, pp. 127–128.)

D.R.P.733 427, applied for 26/7/39. "In order to be able to tell, in a d.f. receiver in which the bearing of a station is indicated by a pointer on a fixed scale, whether the station is still transmitting, the scale is made visible (*e.g.* illuminated) only so long as energy is being received from that station."

2589. VISUAL DIRECTION FINDERS: PART III.—D. S. Bond. (*Electronics*, Jan. 1944, Vol. 17, No. 1, pp. 144–148 and 202..208.)

Description and circuit of the Bendix Model MN-31 automatic direction finder for aircraft which automatically provides a direct indication of the bearing of the radio station tuned in by the pilot. A self-synchronous repeater system is used for the bearing indicator. The system is of the self-orienting loop type like the RCA–Sperry Mark I system. For Parts I and II *see* 1606 of May.

2590. "RADIO DIRECTION FINDERS" [Book Preview].—D. S. Bond. (*Proc. I.R.E.*, April 1944, Vol. 32, No. 4, p. 243.) This is the book referred to in 1606 of May: *see* also 2589, above.

2591. THE RADIO-RANGE GONIOMETER [Exposition of Principles, Design, and Modern Applications].—W. W. Macalpine. (*Communications*, Dec. 1943, Vol. 23, No. 12, pp. 36–42 and 95, 96.)

2592. DESIGN AND OPERATION OF RADIO-RANGE BEACONS: PARTS I AND II.—W. G. McConnell. (*Communications*, Feb. & March 1944, Vol. 24, Nos. 2 & 3, pp. 40–48, 104 & 54–58, 74.)

2593. AUTOMATIC RADIO COMPASS [Operation, Design, and Basic Principles].—M. F. Eddy. (*Radio News* [Chicago], April 1944, Vol. 31, No. 4, pp. 27–28 and 86, 88.)

2594. ABSOLUTE ALTIMETERS [Technical History of Absolute-Altimeter Developments].—P. C. Sandretto. (*Proc. I.R.E.*, March 1944, Vol. 32, No. 3, pp. 167–175.)

2595. HISTORICAL NOTES ON THE DETERMINATION OF DISTANCE BY TIMED RADIO WAVES [with 81 Literature & Patent References].—Tuska. (*See* 2485.)

2596. CIRCUIT ARRANGEMENTS FOR THE SUPPRESSION OF INTERFERING VOLTAGES IN A PROCESS FOR DETERMINING THE DISTANCE OF REFLECTING SURFACES WITH THE HELP OF ELECTRIC WAVES.—E. Alsleben. (*Hochf:tech. u. Elek:akus.*, Oct. 1943, Vol. 62, No. 4, p. 128, Fig. 15.)

A Siemens & Halske patent, D.R.P.733 781, applied for 29/3/40. "If the transmitted frequency is altered periodically, in order to obtain a measure of the distance of the reflecting surface from the transmitter in the difference frequency produced by superposing the direct and reflected radiation, an amplitude variation occurs in the transmitter oscillations, and this produces an interfering frequency. For short distances, for which the reflected oscillation has a large amplitude, the difference frequency falls in the neighbourhood of the interfering frequency, so that in filtering out the latter the difference frequency is also suppressed, or at any rate so much weakened that as a result of the always-present harmonics no reliable indication can be obtained.

"To prevent this from happening, two stages of the receiver amplifier, 2 and 3, are coupled by a voltage-divider composed of the resistance 4 and the series-resonance circuit 7, tuned to the interfering frequency: this circuit 7 is bridged by a voltage-dependent resistance, in the form of two rectifiers 5, 6 connected in parallel with opposed pass-directions, so that the filtering action of the series-resonance circuit is cut out on the appearance of large difference voltages".

2597. METHOD OF DRIVING OR FLYING IN A PRESCRIBED DIRECTION TO A PRESCRIBED DISTANCE [a D.V.L. Patent].—P. von Handel. (*Hochf:tech. u. Elek:akus.*, Oct. 1943, Vol. 62, No. 4, p. 128, Fig. 14.)

D.R.P.733 780, applied for 28/3/35. The controlling car or aeroplane has a non-directive transmitter whose signals are received by the controlled craft on a non-directional aerial, to which a rigidly built-in, non-rotatable directive aerial is connected for short periods by an automatic switching device. The steady-current deflection of the receiver's indicating instrument is a measure of the distance of the controlled craft from the controlling station. If the controlled craft deviates from the prescribed direction, the indicating instrument will show "twitches" which either increase or decrease the steady-current deflection and thus show on which side the deviation is.

2598. GYRO FLUX GATE COMPASS [Stabilised Earth-Inductor Element gives Greater Accuracy and Eliminates Magnetic Disturbances].—Bendix Aviation. (*Electronic Industries*, Dec. 1943, Vol. 2, No. 12, pp. 94, 95 and 172..174.) *See* also 1607 of May.

ACOUSTICS AND AUDIO-FREQUENCIES

2599. MICROPHONES AND RECEIVERS.—L. C. Pocock. (*Elec. Communication*, No. 4, Vol. 21, 1944, pp. 218–231.)

The paper includes amongst its aims the collection of the data necessary to answer as fully as possible the question of how many volts various microphones will deliver to amplifier and radio equipment. The corresponding question of the power required at the reproducing end is also dealt with. As regards future developments, it is concluded that the frequency range of high-quality reproduction will be extended to the limits that the congestion of wavelengths will allow. It is considered that stereophonic transmission over two channels limited to 5 kc/s is preferable to single-channel reproduction up to 15 kc/s, so that development of stereophonic reproduction must ultimately be expected as giving a better performance for a given wavelength occupancy.

2600. POLYDIRECTIONAL MICROPHONE.—H. F. Olson. (*Proc. I.R.E.*, Feb. 1944, Vol. 32, No. 2, pp. 77–82.)

Author's summary:—"This paper describes a polydirectional microphone consisting of a single ribbon, the back of which is coupled to a damped folded pipe and an inertance in the form of an aperture. A single infinity of directional characteristics, ranging from bidirectional through all variations of unidirectional to nondirectional, may be obtained by simply varying the size of the aperture."

2601. NOISE-ATTENUATING LIP MICROPHONE [Differential Microphone gives Highest Signal-to-Noise Ratio by Acoustic Cancellation of Background Sound Waves].—(*Electronic Industries*, Dec. 1943, Vol. 2, No. 12, pp. 84, 85.) *See* also 1617 of May.

2602. "WAVE FILTERS" [Book Review].—L. C. Jackson. (*Wireless Engineer*, March 1944, Vol. 21, No. 246, p. 123.) For another review *see* 2223 of July.

2603. TELEPHONE SETS FOR NOISY LOCATIONS [New Set in Two Forms, one Non-Amplifying & the other Amplifying: for Locations where the Anti-Side-Tone Set alone is Not Adequate].—J. W. Foley. (*Bell Lab. Record*, April 1944, Vol. 22, No. 8, pp. 371–373.)

2604. PUBLIC ADDRESS SYSTEMS.—H. Brennan: A. Cross. (*Journ. of British I.R.E.*, No. 7, Vol. 3, 1943/4, pp. 289–309: pp. 309–316.)

The object of both papers is to promote discussion on various aspects of public address systems, and it is felt that the best way of achieving this purpose is to review present day knowledge of the subject, starting with the elementary principles of electro-acoustics directly relating to difficulties met with in practice, and leading on to suggestions and observations in connection with practical applications of main and auxiliary equipment, according to circumstances. The various aspects dealt with include loudness and the gain control, reverberation, interference, peak power and amplifier, microphones, loudspeakers, lay-out and operation of complete installations, description of recent work, and future development of high-fidelity systems. Discussions follow on pp. 316–320.

2605. LOUDSPEAKER RESPONSE MEASUREMENTS [Response Curves related to the Acoustic Environment of the Loudspeaker].—(*Radio News* [Chicago], April 1944, Vol. 31, No. 4, pp. 35–37 and 106..110.)

2606. APPARATUS FOR THE AUTOMATIC RECORDING OF THE ELECTROACOUSTICAL CHARACTERISTICS OF EMITTING, TRANSMITTING, OR RECEIVING SYSTEMS [in a Continuous Trace, Time adjustable between 1 Second & 3 Minutes].—P. Chavasse. (*Génie Civil*, 15th Dec. 1943, Vol. 120, No. 24, p. 286: short summary, from *Comptes Rendus* [Paris], 31st May 1943, pp. 722–723.)

2607. NOTES ON RADIATION IMPEDANCE.—B. B. Bauer. (*Journ. Acous. Soc. Am.*, April 1944, Vol. 15, No. 4, pp. 223–224.)

"Experimental work in electrical circuit analysis of acoustical meshes involving radiation impedance is generally complicated by the fact that radiation resistance and inertance terms in the usual series $R + jX$ form vary with frequency. This objection can be overcome through the use of the equivalent parallel mesh which has approximately constant circuit parameters". The appropriate series/parallel transformation is described. The concept of radiation impedance as consisting of two fixed circuit elements connected in parallel holds strictly in the case of a pulsating sphere only, but the analogy can be extended to (*e.g.*) a circular piston in an infinite baffle. The magnitude of the errors involved is discussed.

2608. THE DIFFICULTIES FOR WORKERS IN ACOUSTICS DUE TO LACK OF NAMES FOR COMMONLY USED UNITS OF IMPEDANCE—ACOUSTICAL, WAVE, AND MECHANICAL: A TENTATIVE LIST OF NAMES.—V. Salmon. (*Journ. Acous. Soc. Am.*, April 1944, Vol. 15, No. 4, p. 225.)

2609. B.B.C. MOBILE RECORDING EQUIPMENT: TECHNICAL DETAILS OF SOME OF THE MACHINES NOW IN USE.—(*Wireless World*, May 1944, Vol. 50, No. 5, pp. 133–135.)

2610. SOUND RECORDING.—G. F. Dutton & others. (*Elec. Review*, 3rd March 1944, Vol. 134, No. 3458, p. 311.) *See* also 1970 of June.

2611. ENGINEERING DETAILS OF MAGNETIC-WIRE RECORDER.—D. W. Pugsley. (*Electronic Industries*, Jan. 1944, Vol. 3, No. 1, pp. 116–118 and 206..212.)

2612. FREQUENCY-COMPENSATING ATTENUATORS [Nature & Extent of Subjective Distortion caused by Reproduction of Radio Programme at a Loudness Level Different from Original: Means of Compensating for This Effect].—G. S. Light. (*Electronic Eng:g*, May 1944, Vol. 16, No. 195, pp. 520–521.)

2613. CIRCUIT DESIGN OF MIXERS AND FADER CONTROLS: PART II.—P. B. Wright. (*Communications*, Dec. 1943, Vol. 23, No. 12, pp. 44–56 and 96..100.) For Part I *see* 1624 of May.

2614. Audio-Frequency Mixers.—M. F. Cooper. (*Wireless Engineer*, March 1944, Vol. 21, No. 246, pp. 117–121.)

"The design of a.f. mixing units, although straightforward, is not quite the simple problem sometimes imagined, and rarely seems to be understood by manufacturers of such components as constant-impedance faders, if one may judge by the circuit diagrams some publish." The writer sets out six requirements for a satisfactory mixer unit, and then deals in turn with parallel, series, and series–parallel mixers, mixer insertion loss, and the choice of a mixer circuit. The following design rules are derived : when the impedance of the input circuit is required to be higher than that of the output circuit, a parallel mixer should be used ; a series mixer should be used in the converse case ; if both circuits are required to be about equal in impedance, a series–parallel mixer is indicated. The impedance of the input circuits bears a fixed relation to that of the output circuit, according to the number of input circuits decided on : it by no means follows that this relation will be a convenient one unless a further impedance-matching network or transformer is used. Finally, a mixer with four input circuits for certain given requirements is calculated, including a taper network for adjusting the impedauce of the output circuit.

2615. High-Q Audio Reactor.—Campbell. (*See* 2528.)

2616. Acoustical Design and Treatment for Speech Broadcast Studios.—E. J. Content & L. Green. (*Proc. I.R.E.*, Feb. 1944, Vol. 32, No. 2, pp. 72–77.)

2617. "Fundamentals of Telephony" [Book Review].—A. L. Albert. (*Proc. I.R.E.*, April 1944, Vol. 32, No. 4, pp. 244–245.)

2618. Telephone Repeaters [Thermionic Valve Type for Submarine Cables].—R. J. Halsey. (*Elec. Review*, 19th May 1944, Vol. 134, No. 3469, pp. 712–713.) Summary of I.E.E. paper & Discussion : *see* also 2812, below.

2619. On the Quality of Telephonic Transmission [Address to Berne Conference on Communications Technique].—H. Keller. (*Bull. Assoc. Suisse des Élec.*, 3rd Nov. 1943, Vol. 34, No. 22, pp. 666–671 : in German,)

2620. Statistical Trends among Hearing-Aid Users : a Study of 10 000 Case Records.—E. Strommen. (*Journ. Acous. Soc. Am.*, April 1944, Vol. 15, No. 4, pp. 211–222.) From the Acousticon Laboratories.

2621. The Ear and Hearing, a Base of Communications Technique.—W. Furrer. (*Bull. Assoc. Suisse des Élec.*, 3rd Nov. 1943, Vol. 34, No. 22, pp. 659–666 : in German.)

Construction and functioning of the ear : its properties for individual stationary sounds : for several stationary sounds heard simultaneously (masking effect, etc.) : for non-stationary sounds : etc. Address to Berne Conference on Communications Technique.

2622. "Hearing" [Book Review].—S. S. Stevens & H. Davis. (*Radio News* [Chicago], April 1944, Vol. 31, No. 4, Supp. p. 42.)

2623. "The Physics of Music" [Book Reviews].—A. Wood. (*Nature*, 25th March 1944, Vol. 153, No. 3882, pp. 357–358 : *Wireless World*, May 1944, Vol. 50, No. 5, p. 136.)

2624. A Keyboard Instrument in Just Intonation [Construction & Test of Organ suggested in 1065 of 1940].—C. Williamson. (*Journ. Acous. Soc. Am.*, Jan. 1944, Vol. 15, No. 3, pp. 173–175.)

2625. Correspondence on "A Simple Method of Measuring the Wavelength of Sound in Free Air" [507 of February].—J. S. Forrest : Knowles. (*Journ. of Scient. Instr.*, Feb. 1944, Vol. 21, No. 2, p. 33.)

2626. Relation between Area and Velocity for Isothermal Gas Flow [and Some Comparisons between Isothermal, Adiabatic, & Incompressible Flow : the Acoustic Velocities, etc.].—R. C. Binder. (*Journ. Franklin Inst.*, Jan. 1944, Vol. 237, No. 1, pp. 43–47.)

2627. Simple Sensitive Flames [Experimental Results tending to support Burniston Brown's Theory (rejected by Andrade) that the Sensitive Frequencies express a Property of the Particular Gas].—G. A. Sutherland. (*Nature*, 25th March 1944, Vol. 153, No. 3882, pp. 376–377.) For Andrade's reply *see* issue for 22nd April, No. 3886, p. 498.

2628. "Ultrasonics" [Book Review].—L. Bergmann. (*Radio News* [Chicago], April 1944, Vol. 31, No. 4, Supp. p. 42.) Translated from the German.

PHOTOTELEGRAPHY AND TELEVISION

2629. Television without Scanning [Principles of Operation of Craig System, which Transmits All Picture Elements Simultaneously but requires Scanning at Receiver].—P. H. Craig. (*Electronic Industries*, Jan. 1944, Vol. 3, No. 1, pp. 122 and 222..230.)

2630. Television Survey.—R. W. Hallows. (*Wireless World*, June 1944, Vol. 50, No. 6, pp. 166–169.)

The immediate pre-war history of television broadcasting is reviewed and some shortcomings of the service are indicated. The need is stressed for a better welding of sound and vision broadcasts and a more careful study of the suitability of the subject material used in television broadcasts. Legislation will be necessary to check interference from vehicle ignition systems, which can mar otherwise high-fidelity v.h.f. reception.

2631. Television Broadcast Coverage.—A. B. DuMont & T. T. Goldsmith. (*Proc. I.R.E.*, April 1944, Vol. 32, No. 4, pp. 192–205.)

An extensive field survey has been made of the three television transmitters in the New York City area. The paper deals extensively with the multipath problem in television broadcasting which causes multiple patterns in the received picture. Extensive use is made of photographs and diagrams illustrating the appearance of these patterns and explaining the causes of these various types of "ghosts."

The findings of the survey lead to the conclusion that the lower-frequency channels provide the least multi-path interference in metropolitan territory.

2632. Electron Bombardment in Television Tubes [Detailed Analysis of Actions occurring in an Iconoscope when an Elemental Area of the Mosaic is Bombarded by the Scanning Electron Beam under Conditions varying from Dark to Light: "Sticking Effect," Important in Projection Iconoscopes, is Explained].—I. G. Maloff. (*Electronics*, Jan. 1944, Vol. 17, No. 1, pp. 108–111 and 327..331.)

2633. High-Frequency Cable with Varying Characteristic Impedance [" Exponential Cable "], *and* The Design Calculations for Coaxial Cable with Spirally-Wound Conductors.—Keutner: Kaden. (*See* 2512/3.)

2634. Standards on Facsimile [Temporary Test Standards].—(*I.R.E. Publication*, 1943.)

MEASUREMENTS AND STANDARDS

2635. A Method of measuring Complex Admittances in the Decimetric-Wave Region.—K. S. Knol & M. J. O. Strutt. (*Zeitschr. f. Fernmeldetech.*, 15th Jan. 1944, Vol. 25, No. 1, pp. 18–19.)

This is a summary of the *Physica* paper referred to in 2174 of 1943. The method is an improvement and extension of the Lecher-wire procedure used by Rude (? no reference is given) and Roosenstein (*see*, for example, 1934 Abstracts, p. 104). Thus it was found essential, if movements in the neighbourhood were not to produce variable readings, to enclose the two-wire line entirely in metal: further, its ends were provided with short-circuiting plates to prevent radiation: these plates connected (for h.f.) the Lecher system to the screening. Since measuring diodes were to be moved along the Lecher wires, and this was preferably to be accomplished without moving supply lines, the lines were formed of component parts which were connected (for h.f.) to each other. At a distance $\lambda/4$ from one end-short-circuit, a coupling loop was inserted with a resistance in series which was equal to the characteristic impedance of the Lecher pair, while at the same distance from the other end the admittance to be measured was connected between the wires of the pair. Between these, the coupling loop and the unknown admittance, the measuring diode was slid to and fro. This arrangement had the advantage that the operator was not restricted to one definite distance between coupling loop and unknown admittance, while the potential difference between the wires was dependent only on the distance of the particular point from the unknown admittance: the diode admittance was negligible in comparison with the characteristic impedance of the Lecher pair. These properties enabled the method to be used over wide wave-ranges.

The general expression for the reflection coefficient of a wave entering a resistance connected between two lines shows that the absolute value and the phase angle can be determined from it. If, then, a point is considered where the potential is a minimum, the course of the potential along the line in the neighbourhood of the minimum can readily be represented as a function of the absolute value of the reflection coefficient, which itself may be found from the measured course of the potential. Moreover, the position of the minimum gives the magnitude of the phase angle. "For the mathematical determination of these values it is necessary to develop fairly complicated and extensive formulae, but these can be avoided if graphical methods are employed. These lead to a diagram of locus curves composed of three groups of circles. For working out the results, the characteristic impedance of the Lecher line must be determined accurately, since the absolute value of the resistance under measurement is found in relation to this. The problem, none too simple mathematically, is carried through in detail. Finally, a discussion is given of the measuring errors which may be produced by the various wave trains on the three-line system."

2636. Frequency Measuring and Calibrating Installations for Decimetric Waves.—L. Rohde & H. M. Schmidt. (*T.F.T.*, Oct. 1943, Vol. 32, No. 10, pp. 211–218.)

For the testing and final adjustment of decimetric-wave transmitters and receivers, the adjustment of filters, the checking of the frequency-constancy of oscillators, and particularly the calibration, on series-production lines, of transmitters and receivers in the frequency range 50–1500 Mc/s. For such purposes the requirements include high accuracy of frequency measurement (uncertainty less than 5×10^{-5}), direct reading of frequency differences, the possibility of ink-writer recording of the measured frequencies, and the possibility of using the apparatus to calibrate frequency-scales without having to adjust it for each separate calibration point. It was decided that these requirements could best be satisfied by the use of harmonic frequency spectra such as had already been employed in the calibrating apparatus for lower frequencies developed in the Rohde & Schwarz laboratories (*see* Rohde's book, ref. "1.")

Authors' summary:—"A frequency-measuring installation for decimetric waves is described. The measuring principle depends on the use of harmonic standard-frequency spectra, which with the fundamental frequencies of 100 and 10 Mc/s can be derived up to 1500 Mc/s, and with the fundamental frequency of 1 Mc/s up to 1000 Mc/s. The 10 and 1000 Mc/s frequencies are obtained by multiplication of a 1 Mc/s fundamental frequency generated in a quartz-controlled oscillator with a precision within 1×10^{-6} [*see* later]. The unknown frequencies are determined by superposing the harmonic of the standard-frequency spectrum which is closest to them. The resulting difference frequency is measured with a direct-reading frequency meter with a range extending to 500 kc/s [on the condenser-charging principle: Oehrl, 2262 of July]. Higher frequencies than this can be made to indicate on this frequency-indicator after the formation of difference frequencies with any frequency up to 100 Mc/s in two modulators embodied in the instrument itself [*see* p. 214, r-h column: two mixing stages M_1, M_2 (Fig. 8) are used in cascade, the suitable auxiliary frequency being derived from an external generator].

"Thanks to the use of frequency spectra, with their individual components all present at the same time, the installation can be employed very conveniently for the series calibration of transmitters and receivers. As another application, the adjustment of decimetric-wave filters is described [Figs. 12–14 and adjacent text]. The ability to record the measured frequencies on an ink-writer allows constancy measurements on all kinds of transmitters to be carried out [p. 217, r-h column]. As an example, the checking of a 1 Mc/s quartz-controlled transmitter against a quartz clock is described, the frequencies employed being 100 Mc/s, obtained by multiplication of the frequencies under comparison. These recordings give the variation, with temperature and mains voltage, of the standard frequency in the control field of the measuring installation."

The 1 Mc/s quartz-controlled generator has its crystal in a thermostat whose temperature is regulated by a gas triode, itself controlled by a bolometer arrangement. This has the advantage, over contact-thermometer devices, of insensitivity to vibration and change of position, as well as absence of interference-producing sparking and trouble from the burning of contacts. Many other constructional details are given in the paper.

2637. A NOTE ON [Unwanted] FREQUENCY MODULATION, WITH PARTICULAR REFERENCE TO STANDARD-SIGNAL GENERATORS.—F. M. Colebrook. (*Wireless Engineer*, March 1944, Vol. 21, No. 246, pp. 112–115.)

" It is well known that the amplitude modulation of valve oscillators is liable to give rise to some degree of frequency modulation. The object of the present note is to call attention to some of the consequences of this frequency modulation, particularly in the case of short-wave standard-signal generators, where the 'index' of the frequency modulation may be very large," so that the f.m. may dominate the spectrum to such an extent that the a.m. has practically no significance except as the cause of the f.m. It is shown that f.m. of large index spreads the total original energy over a wide band practically equal to twice the frequency excursion, with a tendency to an increase of energy density towards the outer extremes. This is in marked contrast to the spectrum arising from pure a.m., and would produce a correspondingly marked difference in the response of a receiver, particularly one of narrow band-width.

Qualitative confirmation of the main conclusions is given by tests with two commercial makes of u.s.w. signal generators. The familiar technique of master-oscillator and amplifier, a possible means of eliminating the unwanted f.m., presents difficulties at u.h.f., especially where a wide range of frequencies is desired. An alternative, which has not so far been fully exploited, is to replace the conventional modulating mechanism by some form of a.f. on-and-off switching, giving in effect 100% square-wave modulation. For some remarks by K. R. Sturley, agreeing with much of the paper (he found, in early experiments with f.m. receivers, than an a.m. signal generator served as a useful producer of f.m. signals) but criticising the writer's " undue stress " on the difference between the sine and cosine forms of the modulation, *see* June issue, No. 249, pp. 278–279.

2638. SIMPLE MODULATION MEASUREMENTS [Change of R.M.S. Value as an Indication of Modulation Depth].—G. S. Light. (*Wireless World*, June 1944, Vol. 50, No. 6, p. 174.)

2639. ON THE HEATING OF A [Non-Magnetic or Ferromagnetic] SPHERE BY FOUCAULT CURRENTS, *and* ON THE HEATING BY FOUCAULT CURRENTS OF A SPHERE AND AN ELLIPSOID OF REVOLUTION, ELONGATED OR FLATTENED.—M. Jouguet. (*Comptes Rendus* [Paris], 3rd/31st May 1943, Vol. 216, No. 18/22, pp. 635–636: pp. 725–726.) *Cf.* the work of Divilkovsky & Fillipov (3082 of 1943 and back references).

2640. AN IMPROVED TRANSMISSION-LINE CALCULATOR.—Smith. (*See* 2479.)

2641. SQUARE-WAVE MEASUREMENTS [Convenient Method for measuring Inductance and Stray Capacitance of Coils with Square-Wave Generator and Oscillograph].—(*Electronic Industries*, Jan. 1944, Vol. 3, No. 1, p. 107 and 218..220.)

2642. CAPACITY METER [.001 to 100 mmfds, for Inter-Electrode Capacitances].—(*Radio News* [Chicago], April 1944, Vol. 31, No. 4, Vol. 31, No. 4, Supp. pp. 38, 43.) A product of the Technical Apparatus Company of Boston.

2643. LETTER ON " TEMPERATURE COEFFICIENT OF CAPACITANCE " [Schick, 2263 of July].—T. J. Rehfisch: Schick. (*Wireless Engineer*, April 1944, Vol. 21, No. 247, pp. 175–176.)

" The author's most striking contribution to the subject is summarised in his Fig. 3, showing a temperature/time curve relating to a typical test. This is completed within fifteen minutes," the conventional method taking hours. More details of his results would be appreciated. He falls into the not uncommon error of assuming that the t.c. of a beat oscillation is independent of the t.c. of the beating frequencies, if each beating frequency has the same t.c: " this is true for zero beat only. . . ." Finally, " the circuit arrangement for measuring minute capacitance changes need hardly be more complicated than that of a well-shielded r.f. bridge," and a suitable procedure is described.

2644. SYMMETRY AND SYMMETRY MEASUREMENT IN TELEPHONE ENGINEERING.—Moerder. (*See* 2533.)

2645. PHASE MONITOR [for Radiated Fields].—Andrew. (*See* 2566.)

2646. ATTENUATOR DESIGN [for Unequal Steps of Attenuation].—Blackwell & Straughan. (*See* 2530.)

2647. STANDARD-FREQUENCY BROADCAST SERVICE OF NATIONAL BUREAU OF STANDARDS.—(*Proc. I.R.E.*, March 1944, Vol. 32, No. 3, pp. 175–176.)

The services, which are continuous at all times day and night, include: (1) standard radio frequencies, (2) standard time intervals accurately synchronised with basic time signals, (3) standard audio frequencies, and (4) standard musical pitch, 440 cycles per second, corresponding to A above middle C. *Cf.* 2241 of July.

2648. SOME PROPERTIES OF NON-OXIDISABLE INVAR.—Volet & Bonhoure. (*See* 2739.)

2649. ANALYSIS OF A MULTIVIBRATOR.—S. C. Snowdon. (*Phys. Review*, 1st/15th Feb. 1944, Vol. 65, No. 3/4, p. 151: abstract only.)

2650. THE MULTIVIBRATOR: APPLIED THEORY AND DESIGN—PART I.—Shenk. (*See* 2536.)

2651. LOW-FREQUENCY QUARTZ-CRYSTAL CUTS HAVING LOW TEMPERATURE COEFFICIENTS [Describing Two New Cuts, *MT* and *NT*, yielding Crystals suitable for Use in Filters and Oscillators in the Frequency Range from 4 to 100 kc/s.].—W. P. Mason & R. A. Sykes. (*Proc. I.R.E.*, April 1944, Vol. 32, No. 4, pp. 208–215.)

2652. QUARTZ CRYSTALS—DEVELOPMENT AND APPLICATION.—S. A. Bokovoy. (*Elec. Communication*, No. 4, Vol. 21, 1944, pp. 233–246.)

2653. PROCESSING QUARTZ [with Data on Moh Hardnesses, Relative Lapping Speeds, etc.].—W. L. Bond. (*Bell Lab. Record*, April 1944, Vol. 22, No. 8, pp. 359–361.)

2654. QUARTZ CRYSTAL FINISHING.—L. A. Elbl. (*Electronics*, Jan. 1944, Vol. 17, No. 1, pp. 122–125 and 288..290.)

2655. THE USE OF QUARTZ ORIENTATION DEVICES AND SAWING EQUIPMENT.—S. X. Shore. (*Communications*, Dec. 1943, Vol. 23, No. 12, pp. 24–31 and 91.)

2656. QUARTZ LAPPING AND FINISHING [How Sawed Wafers are Etched, Laid Out, Diced, Angles Double Checked, Lapped, Channel Checked, and Hand Finished].—S. X. Shore. (*Communications*, Jan. 1944, Vol. 24, No. 1, pp. 46–47 and 50, 52, 79.)

2657. QUARTZ TESTING [Analysis of Reject Reasons and Salvage Possibilities].—S. X. Shore. (*Communications*, Feb. 1944, Vol. 24, No. 2, pp. 58–66 and 96, 98.)

2658. QUARTZ ORIENTATION [Production Methods of Locating *X*, *Y*, and *Z* Areas with Conoscope and X-Ray Measurements].—R. Setty. (*Electronic Industries*, Dec. 1943, Vol. 2, No. 12, pp. 102, 103, and 176.)

2659. HISTORIC FIRSTS: THE CRYSTAL CLOCK.—W. A. Marrison. (*Bell Lab. Record*, March 1944, Vol. 22, No. 7, p. 335.)

2660. HANDY CALCULATOR FOR TIME CONVERSIONS.—I. E. Slutzky. (*QST*, Feb. 1944, Vol. 28, No. 2, pp. 58–59.)

2661. SPECIFIC RESISTANCE, VOLUME RESISTIVITY, AND MASS RESISTIVITY [and the Need for Clarification: the Term "Volume Resistivity" is an Unfortunate One and the British Standards Institution's Decision to give it Precedence over "Specific Resistance" is to be Regretted: etc.].—G. W. O. H. (*Wireless Engineer*, May 1944, Vol. 21, No. 248, pp. 206–207.)

2662. "DAS KALANTAROFF-GIORGISCHE MASSSYSTEM MIT DIMENSIONELLER KOHÄRENZ, FÜR MECHANIK, ELEKTROMAGNETIK, UND WÄRMELEHRE" [Book Review].—E. Bodea. (*Elektrot. u. Masch:bau*, 10th Dec. 1943, Vol. 61, No. 49/50, pp. 615–616.) A long review by Kneissler-Maixdorf.

2663. ELECTRICAL MEASUREMENTS [Fundamental Laws and Relations between Quantities: Design and Construction in U.S.A. of New Standard Inductances on Pyrex Glass Formers: etc.].—L. Hartshorn. (*Electrician*, 26th May 1944, Vol. 132, No. 3443, p. 455: summary of I.E.E. paper.)

2664. PENTODE–DIODE VALVE VOLTMETER.—T. A. Ledward. (*Wireless World*, June 1944, Vol. 50, No. 6, pp. 162–165.)

The instrument described is a voltmeter designed primarily for the measurement of small audio-frequency voltages but offering facilities for the measurement of a wide range of a.c. and d.c. voltages. The fundamental theory is given, showing that the basic circuit is a bridge with the measuring valve in one arm and a valve rectifier and d.c. meter as detector. The instrument has been designed so that a milliammeter with a linear scale reading 0–1 mA gives a direct reading of input voltage. Voltages can be measured from below 0.1 volt up to 1000 volts, though the upper ranges are suitable only for d.c. and low-frequency a.c. measurements.

2665. A NEW TYPE OF ELECTRON-OPTICAL VOLTMETER.—L. Jacob. (*BEAMA Journ.*, May 1944, Vol. 51, No. 83, pp. 167–171: reprint of I.E.E. paper). A summary was dealt with in 2281 of July.

2666. THE NEW "CORRECT VOLTAGE" METER [Sollspannungsmesser]. — W. Oesinghaus. (*E.T.Z.*, 27th Jan. 1944, Vol. 65, No. 3/4, pp. 33–34.)

Many electrical machines and appliances will only function properly if the voltage supplied is constant or at least departs only slightly from its nominal value. For monitoring purposes in such cases the ordinary service meters are too insensitive or inaccurate, while precision-type meters are unsuitable for constant service use. What is required is a meter in which the sensitiveness and accuracy is concentrated in a narrow zone around the particular nominal voltage. Previous methods of suppressing or compressing the lower part of the scale have, however, simply given an increase in the accuracy with which the reading can be taken, without increasing in any way the absolute accuracy (a previous paper, 2000 of June, is referred to here).

The new voltmeter here described uses a simplified version of the incandescent-lamp bridge (in which incandescent lamps working at about 8–15% of their nominal voltage act as voltage-dependent resistances: such bridges show high absolute accuracy, have behaved well in service, but are too elaborate and expensive). In its simplest form (Figs. 1–3) the voltmeter consists of a moving-coil meter with one small incandescent lamp across it and a comparatively high resistance in series with the combination. If the meter has a classified accuracy within 1.5%, the values in the desired range (*e.g.* between 8 & 10 volts) can be read with an absolute accuracy within 0.5%. Still better results are obtained by replacing the linear-characteristic m.c. instrument by a rectifier-type meter with its non-linear characteristic in the lower part of the scale. The resulting combination (Figs. 4–6) has many advantages; among other things, a diameter of 130 mm gives a higher accuracy of reading than that provided by a 300 mm-diameter meter of the ordinary type.

2667. Universal Measuring Instrument: II.—G. A. Hay. (*Wireless World*, June 1944, Vol. 50, No. 6, pp. 170–172.) For Part I *see* 2280 of July.

2668. A High-Sensitivity Magnetic Null-Current Amplifier for Measuring and Control Technique.—W. Geyger. (*E.T.Z.*, 27th Jan. 1944, Vol. 65, No. 3/4, pp. 39–40.) A long summary, with diagram, of the paper referred to in 1664 of May.

2669. A High-Sensitivity String Galvanometer [Sensitivity 10^{-9} Ampere per Scale Division: Period of Less than One Tenth Second].—A. Lockenvitz. (*Phys. Review*, 1st/15th Feb. 1944, Vol. 65, No. 3/4, p. 153: abstract only.)

SUBSIDIARY APPARATUS AND MATERIALS

2670. On the Currents carried by Electrons of Uniform Initial Velocity.—Jaffé. (*See* 2577.)

2671. Power Loss in Deflecting Condensers [Short Derivation of Formula previously obtained by Recknagel and Hollmann & Thoma].—Gabor. (*See* 2575.)

2672. Electron Optics [Fundamental Mathematical Relations of Electron Optics applied to Electron Focusing].—Fidelman. (*Radio News* [Chicago], April 1944, Vol. 31, No. 4, Supp. pp. 16–19 and 44.)

2673. "Electron Optics" [Book Review].—Hatschek. (*Proc. I.R.E.*, April 1944, Vol. 32, No. 4, p. 244.) Translated from the German.

2674. A Note on [Optical] Ray Tracing by Machine.—Ellis: Comrie. (*Journ. Opt. Soc. Am.*, Dec. 1943, Vol. 33, No. 12, pp. 665–666.) Supplementing Comrie's paper, 3555 of 1940.

2675. A Note on Mr. W. Nethercot's Paper on "Recording of High-Speed Transients" [2290 of July].—Moss. (*Electronic Eng:g*, March 1944, Vol. 16, No. 193, p. 411.)

"The net conclusions from these remarks are that (i) the commercially available tubes when operated at about 6–10 kv can, as Mr. Nethercot has shown, cover a wide range of work in single-stroke transients, although the photographic requirements are quite severe; and (ii) that sealed-off tubes can be designed which will compete in all senses with the continuously pumped type, and at a fraction of the cost."

2676. Circuit for Generating Circular Traces of Different Frequencies on an Oscillograph. — Hershberger. (*Proc. I.R.E.*, April 1944, Vol. 32, No. 4, pp. 205–208.)

Author's summary:—"A circuit is described which enables two circular timing traces to be placed on a cathode-ray oscillograph. Switching from one trace to the other is effected at a super-flicker rate, so they are viewed 'simultaneously.' The circle frequencies normally are in the ratio of five or ten to one; thus when the same transient is viewed on both scales, the slow sweep gives a general picture of the phenomenon being studied and the fast sweep allows a more detailed examination of a chosen portion of the transient. The analysis of the circuit yields the information needed for elemental design."

2677. Linearity Circuits. — Clarke. (*Wireless Engineer*, June 1944, Vol. 21, No. 249, pp. 256–266.)

Circuits devised to modify in the direction of linearity the exponential variation of the voltage obtained from the simplest time-base circuit are generally known as "linearity circuits." The paper discusses the theory of their operation and investigates their limitations. Certain actual or possible circuits are found to be incapable of producing perfect correction though satisfactory for many practical purposes. An enquiry is made into the types of circuit which would be capable of producing perfectly linear voltages. The discussion is confined to voltage time bases.

2678. A New Circuit for the Production of Time-Proportional [Linear] Deflections in Cathode-Ray Oscillographs.—Berger. (*Bull. Assoc. Suisse des Élec.*, 26th Jan. 1944, Vol. 35, No. 2, pp. 33–40: in German.)

The ordinary spark-gap time-base circuits, giving a logarithmic scale, are practicable for recording times up to about 1 ms, though even here the scale is rather seriously compressed at the end of the stroke. For still longer times they are definitely unsuitable, and a linear base becomes necessary. These may be divided into two classes: in the first, the recording medium is moved mechanically (rotating drum, moving film), while in the second the ray is deflected as linearly as possible by electric or magnetic fields. "All the methods known to-day in the second class are approximate methods. Not one of them attains even roughly the accuracy of the first class": the writer mentions a few types, such as valve circuits for producing a constant charging current (Gábor relays, pentodes, etc.), methods using an addition or superposition of component sinusoidal or exponential curves, and so on. On the other hand, the more accurately linear methods involving rotating drums or moving films have very decided disadvantages of their own, so that the writer's new arrangement, giving an electrical time base as accurately linear even as that afforded by the rotating drum, and suitable both for singly-occurring and recurrent phenomena, would appear to fill an important gap in c.r.o. technique. By combining it and a logarithmic circuit into a single time-base unit, a "Universal" equipment is obtained covering a complete time scale from 1 μs to 1 s, the change from logarithmic to linear scale occurring at about 1 ms. Further, the two rays of a dual-beam oscillograph can be controlled simultaneously at different speeds

(Fig. 6): thus one ray can record the whole of a long lightning current, linearly, while the other records logarithmically the front of the surge.

The basic principle of the arrangement is the compensation of the decay in the charging current of the time-base condenser C in the simple exponential circuit of Fig. 3 by the provision of an auxiliary branch circuit, so that the arrangement of Fig. 4 is obtained in which the total charging current i is split into two parts, i_1 and i_2, of which i_1 flows in the branch R_1 C_1 and i_2 in the auxiliary branch R_2 C_2. To keep i_1 (charging the time-base condenser C_1) constant, i_2 must decrease more rapidly than i_1 on closing the "switch" S: this means that the voltage at C_2 must increase more rapidly than that at C_1, or the time constant $T_2 = C_2 R_2$ must be smaller than $T_1 = R_1 C_1$. The fully developed circuit arrangement for recurrent phenomena is seen in Fig. 5, with its discharge ("kipp") gap F_e and its slave gap F_m, while Fig. 6 shows the more complicated circuit for non-recurrent phenomena, with its provision for ray locking and release, involving a double (three-electrode) gap to take the place of F_e, and an additional "blocking" gap F_b.

On pp. 36–39 the accuracy of the linear deflection is calculated from theory, assuming the time-base voltage to be that of the ray of the oscillograph (a plan which has more than one advantage), and the optimum circuit constants are found. Experiments confirm the theoretical results (pp. 39–40). Finally, the calibration of the time axis and the applications of the new equipment are discussed.

2679. "Time Bases" [Book Review].—Puckle. (*Proc. I.R.E.*, April 1944, Vol. 32, No. 4, pp. 243–244.) For a previous review *see* 3521 of 1943.

2680. The Electron Microscope. — Wilson. (*Electronic Eng:g*, March 1944, Vol. 16, No. 193, pp. 414–420.)

2681. The New Microscopes: a Discussion [the Electron Microscope: Resolution & Magnification of the Ordinary Microscope: Reduction in Theoretical Limit of Resolution Demonstrated (Work of Lucas, Graton & Dane, Barnard, & others): the Universal Microscope (Rife)].—Seidel & Winter. (*Journ. Franklin Inst.*, Feb. 1944, Vol. 237, No. 2, pp. 103–130.)

2682. Phosphors for Electron Tubes [Résumé of the Theory of Fluorescence and Its Application to Phosphor Chemicals in Electron Tubes].—Leverenz. (*Radio News* [Chicago], April 1944, Vol. 31, No. 4, Supp. pp. 9–12 and 36.)

2683. Silver-Powder Substance makes Conductive Coating [New Composition for Use as Conducting Coating: does Not require Heat Treatment].—du Pont de Nemours. (*Sci. News Letter*, 18th March 1944, p. 184: *Science*, 24th March 1944, Supp. p. 10.)

2684. A Pirani Vacuum Gauge [for Much Lower Pressures than Usual: Its Usefulness: Point of Inflection found to occur in Calibration Curves for Tungsten Filaments].—Mukerji. (*Sci. & Culture* [Calcutta], Jan. 1944, Vol. 9, No. 7, pp. 303–304.)

2685. Prevention of Capillary Disturbances in Electrolytic Field-Plotting Troughs and in McLeod Gauges.—Klemperer. (*Journ. of Scient. Instr.*, May 1944, Vol. 21, No. 5, p. 88.)

2686. Problems in Vacuum Engineering from the Field of Rectifier Technique [Vacuum Production: Taps & Valves: Flow Resistance in Tubes: Vacuum Measurement: Materials (especially the Question of the Vacuum-Tightness of Iron)].—Schulze. (*Electrot. u. Masch:bau*, 10th Dec. 1943, Vol. 61, No. 49/50, pp. 593–601.)

2687. H.F. Oscillations from Thyratrons.—Kersta. (*Electronic Eng:g*, Feb. 1944, Vol. 16, No. 192, p. 380: summary of Kersta's paper, 539 of February.)

2688. The Construction and Mode of Action of Cathodes for Current Converters [particularly the Oxide and Mercury-Pool Types].—Mierdel. (*Elektrot. u. Masch:bau*, 21st Jan. 1944, Vol. 62, No. 3/4, pp. 25–30.) A V.D.E. lecture.

2689. Power Rectifiers: Operating Temperature—Why it is Important, How the Heating Losses are Dissipated and Heat Added when Necessary, and Temperature Regulated [including the Use of Sodium Chromate as Corrosion Inhibitor].—Remscheid. (*Gen. Elec. Review*, March 1944, Vol. 47, No. 3, pp. 25–28.)

2690. Selenium Rectifiers for Tin Plating [providing Currents up to 60 000 Amperes].—(*Electronics*, Oct. 1943, Vol. 16, No. 10, pp. 176 and 178.)

2691. Practical Applications of Selenium Rectifiers.—Reinken. (*Electronic Industries*, Jan. 1944, Vol. 3, No. 1, pp. 110, 111 and 212..218.)

2692. A Voltage Regulator for High Voltages.—Pickering & Snowdon. (*Phys. Review*, 1st/15th Feb. 1944, Vol. 65, No. 3/4, p. 151: abstract only.) Circuit using a radio-frequency signal modulated by the variations in output voltage to transmit these variations across the potential difference to a tube in series with the high-potential bus.

2693. Voltage Stabiliser [Electronic Regulator to Stabilise a Three-Phase 4 kVA 50 c/s Alternator].—Patchett. (*Elec. Review*, 28th April 1944, Vol. 134, No. 3466, pp. 602–604.)

2694. The Cascade Generator as a Stabilised Voltage Source.—Greinacher. (*Sci. Abstracts*, Sec. B, Feb. 1944, Vol. 47, No. 554, p. 35.)

2695. Investigation [Theoretical & Experimental] of the Charging Process in Cascade [Greinacher] Generators for the Production of High-Tension Direct Current from Alternating Current. — Jaggi. (*Bull. Assoc. Suisse des Élec.*, 14th July 1943, Vol. 34, No. 14, pp. 386–399: in German.)

2696. A High-Voltage Apparatus for Atomic Disintegration Experiments. — Craggs. (*Met.-Vick. Gazette*, April 1944, Vol. 20, No. 344, pp. 289–295.)

2697. Generators with Permanent-Magnet Poles.—Walter. (*Elektrot. u. Masch:bau*, 29th Oct. 1943, Vol. 61, No. 43/44, pp. 517–525.) Again coming into the picture because of recent progress in permanent-magnet construction.

2698. The Alternating-Current Unipolar Machine, *and* Theory of the Unipolar Machine. — Strobl: Kneissler - Maixdorf. (*Elektrot. u. Masch:bau*, 1st Oct. 1943, Vol. 61, No. 39/40, pp. 472–479: pp. 479–486.) For an argument on a paper by Zorn on unipolar machines, *see* pp. 491–492.

2699. Three-Horse-Power Electric Motor weighing Seven Pounds and fitting into Palm of Hand.—General Electric. (*Science*, 18th Feb. 1944, Vol. 99, No. 2564, Supp. p. 12.) Speed 120 000 r.p.m. *See* also *Gen. Elec. Review*, April 1944, p. 61.

2700. Polarographic Studies of Storage-Battery Acid [for Measurement of Iron, Antimony, & Lead Content].—Walker. (*Bell Lab. Record*, April 1944, Vol. 22, No. 8, pp. 349–354.)

2701. Detection of as Little as One Millionth of a Gram of Sulphur [as Sulphides on Surfaces] by Microchemical Analysis. —Mattson. (*Bell Lab. Record*, April 1944, Vol. 22, No. 8, p. 373: paragraph & photograph only.)

2702. Tests of Thermoplastics for Electrical Applications.—Cliver. (*Electronic Eng:g*, Feb. 1944, Vol. 16, No. 192, p. 392: summary, from *Elec. World*, 16th Oct. 1943.) A.S.T.M. methods and equipment, and additional non-standardised tests.

2703. Some Mechanical Properties of Plastics and Metals under Sustained Vibrations. —Lazan. (*Sci. Abstracts*, Sec. A, Jan. 1944, Vol. 47, No. 553, p. 22.)

2704. High-Frequency Heating for Plastics.—(*Sci. Abstracts*, Sec. B, Feb. 1944, Vol. 47, No. 554, p. 37.)

2705. High-Frequency Heating [Applications to Plastics Industry: for Drying Materials, for Partial Pre-Heating, and for Complete Heating and Curing].—Jarvis. (*Elec. Review*, 26th May 1944, Vol. 134, No. 3470, pp. 728–731.)

2706. Heatronic Moulding [and Its Advantages (for Phenolic Materials) over Standard Infra-Red Pre-Heating].—(*Sci. Abstracts*, Sec. B, Feb. 1944, Vol. 47, No. 554, p. 37.) *Cf.* Taylor, 907 of March.

2707. The Drying of Condensing Synthetic-Resin Varnishes by Irradiation.—Saatmann. (*E.T.Z.*, 16th Dec. 1943, Vol. 64, No. 49/50, p. 661.) Summary of the pamphlet dealt with in 2034 of June.

2708. Sources of Plastics [Great Britain's Situation: Many Raw Materials, upon which Plastics Industry Depends, Can be Produced in Great Britain].—(*Elec. Review*, 2nd June 1944, Vol. 134, No. 3471, p. 788.)

2709. Plastics in the Building Trade [Electrical, Plumbing, Heating and Lighting Applications].—(*Elec. Review*, 26th May 1944, Vol. 134, No. 3470, p. 732.)

2710. Cord Sets [Plugs of Old & New Designs: Anchoring the Cord: Heat-Resistant Connectors: New Moulding Compounds: etc.]. —Strubel. (*Gen. Elec. Review*, March 1944, Vol. 47, No. 3, pp. 47–49.)

2711. Substitutes for Silk Insulation of Fine Wires.—Brookes. (*Engineering*, 14th April 1944, Vol. 157, No. 4083, pp. 281–283.) Concluded from p. 264 of previous issue.

2712. Lassolastic, Lassovic, and Lassoband Identification Tapes.—(*Electrician*, 7th May 1943, Vol. 130, No. 3388, pp. 463–464.)

2713. Insulation Tracking [Methods of Testing Insulating Materials for Their Resistance to Carbonisation].—McNeill & Rubinstein. (*Elec. Review*, 31st March 1944, Vol. 134, No. 3462, pp. 444–446.)

2714. Discharges in Dielectrics [Methods of Detection (High-Frequency, Oscillograph-Bridge, Power-Factor, Visual, Aural)].—Austen & Hackett. (*Elec. Review*, 3rd March 1944, Vol. 134, No. 3458, p. 306: summary of I.E.E. paper.)

2715. Synthetic Rubbers in the Wire and Cable Industry [One of 13 Papers read at A.S.T.M. Spring Meeting on Applications of Synthetic Rubbers].—Schatzel. (*Am. Soc. Test. Materials Bull.*, March 1944, No. 127, pp. 6–12.)

2716. Properties of Paracon [Synthetic Rubber]. —Biggs. (*Bell Lab. Record*, March 1944, Vol. 22, No. 7, pp. 317–319.) *See* also 2226 of 1943.

2717. "Encyclopedia of Substitutes and Synthetics" [Book Review]. —Schoengold (Edited by). (*Journ. Franklin Inst.*, Jan. 1944, Vol. 237, No. 1, p. 76.)

2718. Method of Sealing Electrodes into a [Superheated] Steam Chamber [Use of Bakelite-Bonded Asbestos (Easily Machined)].—Munday. (*Journ. of Scient. Instr.*, April 1944, Vol. 21, No. 4, p. 67.)

2719. The Processing of Glass in the Lamp and Radio-Valve Industries.—Breadner & Simms. (*G.E.C. Journal*, Aug. 1943, Vol. 12, No. 4, pp. 192–208.)

2720. The Comparative Strengths of Ceramic and Other Insulating Materials [Tables showing Mechanical Characteristics: Ceramics have Certain Advantages over Organic Materials].—Rosenthal. (*Electronic Eng:g*, May 1944, Vol. 16, No. 195, pp. 505–507.)

2721. Variable Condenser with Ceramic Material as Dielectric.—Gutzmann. (*Hochf: tech. u. Elek:akus.*, Oct. 1943, Vol. 62, No. 4, p. 127.) A C. Lorenz patent, D.R.P.733 084. No information is given, so that the principle may be old or perhaps a new one such as is envisaged by Meyerson (1745 of May).

2722. Paper Capacitors under Direct Voltages. —Brotherton. (*Proc. I.R.E.*, March 1944, Vol. 32, No. 3, pp. 139–143.)

Author's summary :—" This article discusses and illustrates the influence of voltage, temperature, and materials on the life of paper capacitors under direct voltages. The life decreases as the applied voltage and ambient temperature increase. Operating voltages which are safe at room temperatures may produce rapid dielectric failure at high temperatures unless the most suitable materials and best manufacturing processes are employed. It is essential that temperature as well as voltage be taken into account in the design, manufacture and use of paper capacitors if trouble-free service is to be insured. Paper capacitors should be rated for a maximum direct operating voltage at a maximum ambient temperature. An accelerated life test on representative samples is the best criterion of the life performance that may be expected of a manufactured lot of capacitors in service.

" This article also describes some types of asphalt-sealed and hermetically sealed paper capacitors designed for direct-current operation in different types of service."

2723. Letter on " Temperature Coefficient of Capacitance."—Rehfisch : Schick. (*See* 2643.)

2724. Aluminium Electrolytic Condensers [Equivalent Circuit : Characteristics as Functions of Temperature & Frequency : Corrosion : etc.].—Robinson & Burnham. (*Sci. Abstracts*, Sec. B, Feb. 1944, Vol. 47, No. 554, pp. 34–35.)

2725. Calculation of Electric Arcs from the Elenbaas–Heller Differential Equation [and the Two Possible Discharge Forms, one with Rising & the other with Descending Characteristic]. — Weizel & Schmitz. (*Physik. Zeitschr.*, 1st Nov. 1943, Vol. 44, No. 18, pp. 383–391.)

2726. The Decay of Carrier Density and Electron Temperature in Low-Pressure Discharges in the Process of Extinction.—Mierdel. (*Zeitschr. f. Phys.*, 24th Aug. 1943, Vol. 121, No. 9/10, pp. 574–585.) From the Siemens–Schuckert Works.

2727. Sparking Potentials in Air in a Plane Parallel Gap at and below Atmospheric Pressure.—Fisher. (*Phys. Review*, 1st/15th Feb. 1944, Vol. 65, No. 3/4, p. 153 : abstract only.)

2728. The Residual Corona Current and Its Extinction [on Very High Voltage Lines]. —Senn. (*Arch. f. Elektrot.*, 31st Aug. 1943, Vol. 37, No. 8, pp. 361–379.) Continued in No. 9 and concluded in No. 10 (31st Oct. 1943, pp. 478–504).

2729. New Investigations on the Alternating-Current Corona on Line Wires [of 25 mm Diameter & More].—Läpple. (*E.T.Z.*, 27th Jan. 1944, Vol. 65, No. 3/4, pp. 25–31.)

2730. " Zinc-Knet " Alloys of High Strength against Prolonged Stress [New Zn–Fe Alloys for Electrical Lines].—Reinbach. (*Zeitschr. V.D.I.*, 25th Dec. 1943, Vol. 87, No. 51/52, p. 817 : summary only.) With many advantages over the Zn–Al 1 alloy.

2731. Nickel-Plated Steel Wire replaces Solid Nickel [for Supports for Tungsten Lamp-Filaments].—Conolly & Rimbach. (*Sci. News Letter*, 29th Jan. 1944, Vol. 45, No. 5, p. 73.)

2732. Wrapped and Spliced Joints for Steel Overhead Lines [largely replacing Copper, by Order of Inspector General for Water & Energy].—Almers & Walther. (*E.T.Z.*, 13th Jan. 1944, Vol. 65, No. 1/2, p. 19 : summary only.)

2733. Small Welding Tools [giving Welded Joints instead of Soldered, for Fine Wires & Thin Sheet : Some Recent Appliances & Methods].—Kleemann. (*Zeitschr. f. Fernmeldetech.*, 15th Jan. 1944, Vol. 25, No. 1, pp. 12–16.) *Cf.* the A.E.G. " small tongs," 2339 of July.

2734. The " Alutherm " Welding Process for the Joining of Aluminium and Aluminium-Alloy Conductors [in the Field, using the " Alutherm " Heating Cartridge]. —Schiltknecht. (*Bull. Assoc. Suisse des Élec.*, 26th Jan. 1944, Vol. 35, No. 2, pp. 41–47 : in French.)

2735. Some 1943 Products [Meters, Plugs & Sockets, Attenuators & Tapped Resistors, Electrochemical Etching Apparatus, " Pyrobit " Soldering Irons, " Fuzit " Jointer, Rotary Switches].—(*Electronic Eng:g*, Jan. 1944, Vol. 16, No. 191, pp. 342–344.)

2736. Electro-Thermal Zinc.—Arend. (*Electrician*, 14th April 1944, Vol. 132, No. 3437, pp. 317–319.)

2737. Electrolytic Processes for the Production of Very Pure Metals [Copper, Zinc, Aluminium, etc.] from the Ore and the Crude Metal [and the Changed Properties of the Metals thus obtained].—Hänsel. (*E.T.Z.*, 4th Nov. 1943, Vol. 64, No. 43/44, pp. 579–584.) *See* also a paper by G. C. Mitter on " Electro-Chemical Industries," *Sci. & Culture* [Calcutta], March 1944, Vol. 9, No. 9, pp. 383–388.

2738. " Cerrobend " [Modification of Wood's Metal, melting at 70° C] for the Bending of Copper Tubing.—Cerro de Pasco Copper. (*Journ. Applied Phys.*, Feb. 1944, Vol. 15, No. 2, p. 202.) The molten alloy expands on solidification and fills all the small imperfections in the tubing.

2739. Some Properties of Non-Oxidisable Invar [Investigation of Hasumoto's Iron–Cobalt–Chromium Alloys yields a Special Invar with Lower Expansion than Guillaume's Steel–Nickel Invar, and Practically Non-Oxidisable: Its Behaviour when drawn into Wire: etc.].—Volet & Bonhoure. (*Génie Civil*, 15th Dec. 1943, Vol. 120, No. 24, p. 286: summary, from *Comptes Rendus* [Paris], 31st May 1943, pp. 734–735.)

2740. Laws governing the Growth of Films on Metals.—Evans. (*Sci. Abstracts*, Sec. B, Dec. 1943, Vol. 46, No. 552, p. 205.)

2741. Bonding and Structural Variations of Commercial Electroplatings 2–55 × 10^{-6} Inch Thick [and the X-Ray Diffraction Technique developed for the Investigations].—Clark & others. (*Journ. Applied Phys.*, Feb. 1944, Vol. 15, No. 2, pp. 193–200.)

2742. Metals and Finishes [Properties of Electro-Deposited Metals, Dipped Metals, Phosphate Films, Oxide Films, Lacquers, etc., for the Radio Industry].—Sutherland & others. (*Elec. Review*, 28th April 1944, Vol. 134, No. 3466, p. 598: summary of I.E.E. opening paper and Discussion.) *See* also *Electrician*, 28th April 1944, Vol. 132, No. 3439, p. 370, and *cf.* 2050/2 of June.

2743. Chromium Development [New Process of Plating].—Warner Laboratories. (*Radio News* [Chicago], April 1944, Vol. 31, No. 4, Supp. p. 32.) Using the new "Skalite" chromium salt.

2744. Designing Stabilised Permanent Magnets.—Underhill. (*Electronics*, Jan. 1944, Vol. 17, No. 1, pp. 118–121 and 310..316.)

2745. New Magnetic Alloys [of the Alnico and Comol Series, for Electrical Instruments].—Wilson & Whittenton. (*Radio News* [Chicago], April 1944, Vol. 31, No. 4, Supp. pp. 32, 45: summary of A.I.E.E. paper.)

2746. The Design of Stampings for Low-Frequency Transformers.—Mawson. (*Electronic Eng:g*, May 1944, Vol. 16, No. 195, pp. 514–516.)

Author's summary:—"After obtaining an expression by which the relative merits of stampings may be compared, this formula is used in the following ways: (a) to determine the optimum core area and position of the core, (b) to determine the optimum stamping when one dimension is fixed, and (c) to determine the optimum shape of the stamping for a given area. A second formula is used to determine the shape of the stamping giving the maximum inductance for a given wire size."

2747. Wound-Core Transformer Design [Improved Magnetic Circuits based on the Grain-Oriented High-Silicon Steel, Hipersil].—Lee. (*Electronic Industries*, Jan. 1944, Vol. 3, No. 1, pp. 114, 115 and 220..222.)

2748. Influence of Thermal and Mechanical Treatments on the Poisson Coefficient of Metals and Alloys [including the Reversible Anomaly of the Poisson Coefficient, linked with the Magnetic Transformation of the Ferro-Nickels: the Poisson Coefficient as a Sensitive Detector of Anisotropy of Mechanical Origin: etc.].—Chevenard & Crussard. (*Génie Civil*, 15th Dec. 1943, Vol. 120, No. 24, p. 285: from *Comptes Rendus* [Paris], 3rd/31st May 1943, Vol. 216, pp. 685–687.) Further development of the work described in *Comptes Rendus*, 1942, Vol. 215, p. 58.

STATIONS, DESIGN AND OPERATION

2749. Superiority of Stereophonic Transmission over Single-Channel, for a Given Wavelength-Occupancy.—Pocock. (In paper dealt with in 2599, above.)

2750. Studies on the Technique of Ultra-Short Waves in the 1 m Wave-Band [Zurich Dissertation, 1942, on Tests from the Jungfraujoch (3550 m), on Simultaneous Speech & Telegraphy from a 5–7 Watt Push-Pull Transmitter (Fig. 2) with Inductively Coupled Amplifier, using Three "Pot Oscillators" (Cavity Resonators of Special Design & Merits): Good Reception as far as Basle (117 km) without Directive Aerials].—Schüpbach. (*Hochf:tech. u. Elek:akus.*, Oct. 1943, Vol. 62, No. 4, pp. 124–125: summary only.)

2751. Experimental Micro-Wave System Projected [Note on A.T. & T. Plan for "Trial of New Type of Inter-City Communications Facility"].—A.T. & T. (*Bell Lab. Record*, April 1944, Vol. 22, No. 8, p. 380.)

2752. Frequency-Modulated Studio-to-Transmitter Links.—David. (*Communications*, Dec. 1943, Vol. 23, No. 12, pp. 15–19.)

2753. Phase-Modulated Communication System for Chicago Surface Lines [Radio Communication System used in Chicago to provide City-Wide Coverage for Emergency Operation now has Background of more than a Year of Successful Operation].—Dudley. (*Electronics*, Jan. 1944, Vol. 17, No. 1, pp. 102–106 and 238..249.) *Cf.* Phillips, 1358 of April.

2754. A Walking WERS Station [Self-Contained 112 Mc/s Transmitter-Receiver].—French. (*QST*, March 1944, Vol. 28, No. 3, pp. 11–14.)

2755. A 2½ Metre Transceiver for WERS [Constructional Details].—Bowman. (*Radio News* [Chicago], April 1944, Vol. 31, No. 4, pp. 38–39 and 72, 74.)

2756. Army Mobile Wireless Stations [Designed for Duplex Working, Handling 30 000 Words a Day in Both Directions].—(*Engineering*, 24th March 1944, Vol. 157, No. 4080, pp. 227–228.)

2757. R.A.F. Communications.—Morris. (*Communications*, March 1944, Vol. 24, No. 3, pp. 25–26 and 75.)

2758. Signal Corps Long-Wave Radio System [Six Arctic-Area Stations].—Davies. (*Electronic Industries*, Dec. 1943, Vol. 2, No. 12, pp. 76, 77 and 228..230.)

2759. Policing the Ether [U.S. Monitoring Service for Interception of Illicit Transmissions].—(*Wireless World*, June 1944, Vol. 50, No. 6, p. 165.)

2760. Radio in Sweden [Note on the Establishing of Two Short-Wave Transmitters each of 100 kW].—(*Electrician*, 9th June 1944, Vol. 132, No. 3445, p. 494.)

2761. Marine Console Radio Unit [Three Transmitters and Three Receivers as well as Auto Alarm provided in New Victory Ship Job].—McDonald & Hopkins. (*Electronic Industries*, Jan. 1944, Vol. 3, No. 1, pp. 108, 109 and 262.)

2762. An Electronic Train-Telephone System [Belvidere–Delaware Branch of Pennsylvania Railroad].—(*Science*, 25th Feb. 1944, Vol. 99, No. 2565, Supp. p. 10: *Sci. News Letter*, 4th March 1944, p. 150.)

GENERAL PHYSICAL ARTICLES

2763. Influence of Newton's Work on Scientific Thought.—Teich. (*Nature*, 8th Jan. 1944, Vol. 153, No. 3871, pp. 42–45.)

2764. Non-Linear Optics and Electrodynamics [Note on Dublin Institute for Advanced Studies' Investigations on Consequences of replacing Maxwell's Equations by Those of Born & Infeld: the Mutual Influence of Light Waves: etc.].—Schrödinger & others. (*Nature*, 29th April 1944, Vol. 153, No. 3887, p. 532.) "There are grave difficulties to be overcome, which, it is suggested, may be resolved by using the theory of radiation damping due to Heitler & Peng" [3166 of 1941 and 233 of 1943].

2765. A Problem of Two Electrons and Newton's Third Law [Editorial on a Recently Propounded Problem which appeared to Cast Doubts on the Validity of the Law].—G. W. O. H. (*Wireless Engineer*, March 1944, Vol. 21, No. 246, pp. 105–107.)

2766. On a New Type of Electron [" Relativity suggests the Existence of a New Particle which differs from the Dirac Electron while having the Same Mass, the Same Charge, & in a Certain Sense the Same Spin "].—Proca. (*Portugaliae Physica* [Lisbon], No. 2, Vol. 1, 1944, pp. 59–65: in French.) "A fourth element, corresponding precisely to a new property, seems necessary to define completely a relativistic electron. . . ."

2767. An Approximate Method of Calculating Diamagnetic Susceptibility [*e.g.* of a Hydrogen Atom].—Koppe. (*E.T.Z.*, 27th Jan. 1944, Vol. 65, No. 3/4, p. 41: summary, from *Zeitschr. f. Phys.*, Vol. 121, 1943, p. 614–628.) Avoiding the difficulties of the usual quantum-mechanical method.

MISCELLANEOUS

2768. Mathematical Methods applicable to Linear Phenomena.—Whitehead. (*Journ. of Scient. Instr.*, May 1944, Vol. 21, No. 5, pp. 73–79.)

"In applied science mathematics is usually felt to be either a tool or a means of formulating physical ideas in a quantitative, symbolic, and presumably logical manner. Both these aspects are comprised within what the author believes to be the better view, namely, mathematics as a way of expressing a physical argument. . . . It is usually possible to find a kind of mathematics which expresses within the mathematical canon the type of argument which has been successfully used in a qualitative or non-mathematical way about a set of phenomena. Such a choice properly made, the major steps in the mathematical analysis are physically significant, the mathematical tool is simpler and more flexible, while the symbolic formulations are easier to generalise. It is proposed to illustrate this in a particular field, linear phenomena, with reference to particular mathematical methods, namely, topology, matrices, and integral forms."

Linear phenomena are described as those where the action is proportional to the force, the reactions and interactions obey a similar law, and all the quantities are superposable. The illustrations are mainly taken from electrical circuits.

2769. Fourier Analysis by Geometrical Methods.—Williams, (*Wireless Engineer*, March 1944, Vol. 21, No. 246, pp. 108–111.)

"The use of pulse transmissions has, amongst other things, greatly increased the number of occasions on which an engineer is interested in a Fourier analysis. . . . It will be noticed that the method outlined is merely the converse of the process of synthesising a complex wave-form—an idea with which we are all familiar. Yet the possibilities in an analytical process are not generally realised by engineers when faced with a Fourier analysis. . . ."

2770. On a Solution of the Telegraphists' Equation.—Parodi. (*Comptes Rendus* [Paris], 3rd/31st May 1943, Vol. 216, No. 18/22, pp. 606–608.)

2771. On the Limiting Forms of Statistical Distributions [Method of Specifying the (β_1, β_2) Combination corresponding to the Transition from Skew Normal Distribution to the Normal Form].—Bose & Rao. (*Sci. & Culture* [Calcutta], March 1944, Vol. 9, No. 9, pp. 402–403.)

2772. The Slide Rule: a Method of obtaining Increased Accuracy in Reading and Setting [" Vernier "-Principle Method giving Results under Certain Conditions which would otherwise be Unattainable].—Hay. (*Wireless Engineer*, March 1944, Vol. 21, No. 246, pp. 124–125.)

2773. " Über Wesen, Sinn und Zweck [Nature, Meaning & Purpose] der Laplace-Transformation " [Book Review].—Schulz. (*Hochf:tech. u. Elek:akus.*, Oct. 1943, Vol. 62, No. 4, p. 128.)

"An introduction for communication engineers" is the sub-title. For a recent English-language book on different lines *see* Widder, 3148 of 1942.

2774. " Mathematical Essentials to Electricity and Radio " [Book Review].—Cooke & Orleans. (*Proc I.R.E.*, Jan. 1944, Vol. 32, No. 1, p. 56.) For another review *see* 1734 of May.

2775. " Quarterly of Applied Mathematics " [Critical Survey of the Desirable & the Apparent Actual Scope of the New Quarterly (2878 of 1943 & 958 of March)].—Brown University. (*Science*, 28th Jan. 1944, Vol. 99, No. 2561, pp. 81–82.) The reviewer concludes: " If wisely conducted, it will achieve a notable place among the other American publications in this field ".

2776. " Reference Data for Radio Engineers " [Book Review].—Federal Telephone & Radio. (*Proc. I.R.E.*, Jan. 1944, Vol. 32; No. 1, p. 55.) For other reviews *see* 1741 of May.

2777. " Glossary of Terms used in Telecommunication " [Book Review].—British Standards Institution. (*Wireless Engineer*, May 1944, Vol. 21, No. 248, p. 209.) Reviewed by G. W. O. H: *see* also 2661, above. For another review *see* 2092 of June.

2778. " Electrical Engineering, Basic Analysis " [Book Review].—Strong. (*Journ. Franklin Inst.*, Jan. 1944, Vol. 237, No. 1, p. 79.)

2779. " Electronic Physics " [Book Review].—Hector, Lein, & Scouten. (*Proc. I.R.E.*, Jan. 1944, Vol. 32, No. 1, p. 56.)

2780. " The Physics and Technique of Ultra-Short Waves " [Book Review].—Hollmann. (*Proc. I.R.E.*, Jan. 1944, Vol. 32, No. 1, p. 55.) Photographic reproduction of book published in Germany in 1936 (784 of 1937).

2781. " Practical Radio Communication " [Book Review].—Nilson & Hornung. (*Proc. I.R.E.*, Jan. 1944, Vol. 32, No. 1, p. 54–55.) For another review *see* 2397 of July.

2782. " Short-Wave Wireless Communication " [Book Review].—Ladner & Stoner. (*Proc. I.R.E.*, March 1944, Vol. 32, No. 3, p. 183.)

2783. " Basic Radio Principles " [Book Review].—Suffern. (*Proc. I.R.E.*, Feb. 1944, Vol. 32, No. 2, p. 120.)

2784. " Radio Materiel Guide " [Book Review].—Almstead & Tuthill. (*Proc. I.R.E.*, March 1944, Vol. 32, No. 3, p. 184.)

2785. " Meet Dr. Franklin " [Book Review].—(*Journ. Franklin Inst.*, Feb. 1944, Vol. 237, No. 2, pp. 173–175.)

2786. State Scientific Research in Great Britain [Note on Issue of White Paper " Scientific Research and Development " (Command 6514)].—(*Nature*, 22nd April 1944, Vol. 153, No. 3886, p. 490.) For an account of the debate on Gibson's motion in the House of Commons *see* issue for 29th April, No. 3887, p. 519.

2787. Institution of Electrical Engineers Wireless Section Silver Jubilee [Addresses by Col. Sir A. Stanley Angwin, Dr. W. H. Eccles, Professor G. W. O. Howe, Admiral Sir Charles E. Kennedy Purvis, Mr. H. Bishop, and Dr. R. L. Smith-Rose].—(*Elec. Review*, 12th May 1944, Vol. 84, No. 3468, pp. 661–664.)

2788. Institute of Radio Engineers [Constitution of, as Amended up to Oct. 1943].—(*I.R.E. Publication*, 1943.)

2789. Radio Progress during 1943 [Transmitters and Antennas: Frequency Modulation: Electronics: Television: Facsimile: Piezoelectricity].—I.R.E. Committee. (*Proc. I.R.E.*, March 1944, Vol. 32, No. 3, pp. 125–130.)

2790. A Report on the I.R.E. Winter Technical Meeting [Main Points of Papers dealing with Orthicon Cameras, Quantum Theory, Piston Attenuator, Transmission Lines, Oscillators, and Transients].—Winner. (*Communications*, Feb. 1944, Vol. 24, No. 2, pp. 28–31 and 100..102.)

2791. Electrical Research [Summary of Annual Report of E.R.A: Intrinsic Electric Strength: Effect of Corona on Dielectrics: Rheological Properties of Dielectrics: Mechanism of Electric Spark].—(*BEAMA Journ.*, April 1944, Vol. 51, No. 82, pp. 117–123.) For previous summaries *see* 1749 of May.

2792. Radio Development in Australia [Paper read before British Institution of Radio Engineers]. — Fisk. (*Journ. of British I.R.E.*, No. 7, Vol. 3, 1943/4, pp. 277–288.)

2793. Imperial College of Science and the Massachusetts Institute of Technology.—Southwell. (*Science*, 3rd March 1944, Vol. 99, No. 2566, p. 175: extract from letter in *The Times* [1002 of March].)

"The Massachusetts Institute of Technology has accepted proposals made by the Imperial College of Science & Technology to its president Dr. K. T. Compton, during his visit to this country last summer, and the two institutions are planning to maintain, after the war, a regular interchange both of staff and of post-graduate students."

2794. University Development in Great Britain [Leading Article on Various Reports, Pamphlets, & Articles].—(*Nature*, 22nd April 1944, Vol. 153, No. 3886, pp. 471–475.)

2795. Creative Radio-Research Workers—Their Opportunities and Obligations [Shortcomings of the Pre-War Radio Industry and the Need for a Well-Balanced Research and Engineering Organisation].—Nicholas. (*Proc. I.R.E.*, April 1944, Vol. 32, No. 4, p. 187.)

2796. A Biologist looks at Radio.—Simon. (*Electronic Eng:g*, May 1944, Vol. 16, No. 195, p. 518.)

"Research work in radio seems to the author to involve relatively little that can properly be called scientific, most of it being of a technological nature. Scientific research is concerned with the fundamental problems; examples of these in radio are rather scattered—the study of thermionic emission and fluorescent screens, the piezoelectric effect in certain crystals, and the transmission of wireless waves and design of aerial systems."

2797. Research Workers: Their Education and Their Place in Industry [from Second Address on Science and Industry at Manchester Chamber of Commerce].—Fleming. (*Engineering*, 24th March 1944, Vol. 177, No. 4602, pp. 234–235.)

2798. Engineers of the Future: I—Education and Training (Fleming): II—Part-Time Education: Prospects raised by the New Bill (Dunsheath): III—Apprentice Training by the B.T.H. Scheme (Warren): IV—The Education Bill (Coode-Adams): V—Apprentices and Students: English Electric Company's Training System (Caunce): VI—Fundamentals of Training in the Brush Engineering Company's Scheme (Hoseason).—Fleming & others. (*Elec. Review*, 17th, 24th, 31st March & 7th, 14th, 21st April 1944, Vol. 134, Nos. 3460/5.)

2799. British Union Catalogue of Periodicals [Note on Project supported by Rockefeller Foundation].—Besterman & others. (*Nature*, 22nd April 1944, Vol. 153, No. 3886, p. 490.)

2800. Radio Markets after the War [Collected Excerpts from Bureau of Foreign and Domestic Commerce Publications].—(*I.R.E. Publication*, 1944.)

2801. Exported Radio Apparatus [Treatment & Tests for Service in Extreme Conditions of Temperature, Pressure, Humidity, etc.].—Coursey & others. (*Elec. Review*, 7th April 1944, Vol. 134, No. 3463, p. 494: summary of I.E.E. discussion.) *See* also 2279 of July.

2802. Electricity in Aircraft [Comparison of British, American, & German Generator Systems: Need for Standardisation].—Woodford & others. (*Elec. Review*, 3rd March 1944, Vol. 134, No. 3458, p. 294: summary of I.E.E. discussion.)

2803. Ultra-High-Frequency Equipment [Characteristics of Cavities, Horns, & Sources of 3000 Mc/s Waves].—Soria. (*Radio News* [Chicago], April 1944, Vol. 31, No. 4, Supp. pp. 3–8 and 40.)

2804. The "Etherscope" [enabling Signals from All Stations in Given Wave-Band to be Viewed Simultaneously on C.R. Tube].—Hull. (*See* 2556.)

2805. German Papers on the Interference-Suppression of Apparatus and Equipments of the Armed Forces.—Henning & others. (*See* 2555.)

2806. Weather Maps for Radio Broadcast [Developments in Complete Weather Maps for "Radio Print" Broadcast Service].—Reichelderfer. (*Radio News* [Chicago], April 1944, Vol. 31, No. 4, pp. 21–23.) At present, until facsimile-telegraph facilities are available, the maps are "canned" in a numerical code.

2807. On a Meteoric Shower mentioned in the Bible [Joshua's Miracle explained as a Prolongation of Daylight resulting from a Meteoric Shower mentioned as the Shortly-Preceding Hail of Large Stones].—Bosler. (*Comptes Rendus* [Paris], 3rd/31st May 1943, Vol. 216, No. 18/22, pp. 597–599.)

2808. Geophysical Exploration in Canada and the United States [Summary of "Fifteen Years of Geophysics, 1924–1939" (in *Geophysics*, July 1940)].—Macelwane. (*Nature*, 22nd April 1944, Vol. 153, No. 3886, pp. 503–504.)

2809. On the Applicability of Conducted High Frequencies Below Ground in Mines [Urgent Present Need for Extended Communication Facilities: Carrier-Current Systems along Existing Communication Lines rather than Power Lines, or better still over Wide-Band Cables: Suitability of Mechanical Conductors (Pipes, Wire Ropes, etc.) Not Yet Established: Compressed-Air Pipes as U.H.F. Wave-Guides: Use of Supersonic Waves: Telemetering, & the Requirements demanded of Impulse Generators, etc: Some Transmission Tests in Mines].—Burgholz. (*Electr. i. Bergbau*, Vol. 18, 1943, p. 17 onwards: short summary in *E.T.Z.*, 27th Jan. 1944, Vol. 65, No. 3/4, p. 40.)

2810. Induction Radio [Limited-Range Industrial Communications by A.M. and F.M. Carrier - Radio - Telephony]. — Halstead. (*Electronic Industries*, Dec. 1943, Vol. 2, No. 12, pp. 86–89 and 200..206.)

2811. Wired Radio [Practical Circuits for Carrier-Current Communications using Power Lines].—Turner. (*Radio News* [Chicago], April 1944, Vol. 31, No. 4, pp.29–31 and 62, 64, 135.)

2812. Submarine-Cable Telephony [Use of Submerged Repeaters].—Halsey. (*Electrician*, 19th May 1944, Vol. 132, No. 3442, p. 429: summary of I.E.E. paper.) For previous work *see* 1349 of 1943. *See* also 2618, above.

2813. The Saga of the Vacuum Tube: Part II.—Tyne. (*See* 2583.)

2814. An Interesting Patent Decision [Editorial: Marconi's W.T. Co. of America *versus* the United States: Judgment of

Supreme Court on Early Patents].—G. W. O. H. (*Wireless Engineer*, June 1944, Vol. 21, No. 249, pp. 253–255.) *See* also 1018 of March.

2815. War-Time Changes in the Patent and Registered-Design Laws.—Werren. (*Zeitschr. V.D.I.*, 11th Dec. 1943, Vol. 87, No. 49/50, pp. 781–784.)

2816. Vacuum Science Products, Ltd: Change of Name to Radio Electronics, Ltd.—(*Electronic Eng:g*, Feb. 1944, Vol. 16, No. 192, p. 391.)

2817. Radio-Frequency Heating Sets Glue in Laminated Aircraft Spars [Use of Electronic Gear Reduces Glue Setting Time from Eight Hours to Twenty Minutes].—Taylor. (*Electronics*, Jan. 1944, Vol. 17, No. 1, pp. 96–101 and 196..198.)

2818. Radio Heating Equipment [Part III: High-Powered Valves: Automatic-Control Devices].—Langton. (*Wireless World*, June 1944, Vol. 50, No. 6, pp. 179–182.) For previous parts *see* 2100 of June.

2819. Heat Treatment by Induction [Lepel Spark-Gap System, 100–300 kc/s].—(*Sci. Abstracts*, Sec. B, Feb. 1944, Vol. 47, No. 554, p. 37.) *Cf.* 369 of January.

2820. Papers on the Heating of a Sphere and of an Ellipsoid of Revolution by Foucault Currents.—Jouguet. (*See* 2639.)

2821. Papers on High-Frequency Heating for Plastics.—(*See* 2704/6.)

2822. High-Frequency Therapy: Part VII.—Therapy Machine Design and Operation.—Oliphant. (*Electronic Eng:g*, March 1944, Vol. 16, No. 193, pp. 426–430.) For previous parts *see* 1474 of April.

2823. On the Physiological Fundamental Law of the Perception of Light Stimuli.—Berek. (*Zeitschr. f. Instrum:kunde*, Vol. 63, 1943, p. 297 onwards: summary in *E.T.Z.*, 27th Jan. 1944, Vol. 65, No. 3/4, pp. 40–41.)

2824. Photoelectric Photometer for determining Carbon Disulphide in the Atmosphere.—Silverman. (*Sci. Abstracts*, Sec. A, Feb. 1944, Vol. 47, No. 554, p. 34.) *Cf.* du Pont de Nemours Company, 1832 of May.

2825. Spectrographic Analysis in the Manufacture of Radio Tubes.—Parsons. (*Proc. I.R.E.*, March 1944, Vol. 32, No. 3, pp. 130–135.)

2826. X-Ray Inspection [Discussion before the North East Coast Institution of Engineers and Shipbuilders].—(*Elec. Review*, 5th May 1944, Vol. 84, No. 3467, p. 627.)

2827. X-Rays in Electrical Engineering.—Mullins. (*Electronic Eng:g*, March 1944, Vol. 16, No. 193, pp. 405–407.)

2828. X-Ray Analysis in Industry: Conference of the X-Ray Analysis Group of the Institute of Physics.—(*Nature*, 29th April 1944, Vol. 153, No. 3887, pp. 533–535.)

2829. Action of X-Rays on the Frequency of a Bacterial Mutation.—Croland. (*Comptes Rendus* [Paris], 3rd/31st May 1943, Vol. 216, No. 18/22, pp. 616–618.)

2830. Electronics in Post-War Industry, *and* Electronic Aid for Industry.—(*Sci. Abstracts*, Sec. B, Feb. 1944, Vol. 47, No. 554, p. 39: p. 39.) From *Steel*, 1943, and *Machinist*, 1943.

2831. An Investigation, with the Aid of Equivalent Electrical Circuits, of the Dynamics of Regulating Mechanisms.—Fondaminski. (*See* 2543.)

2832. A High-Sensitivity Magnetic Null-Current Amplifier for Measuring and Control Technique.—Geyger. (*E.T.Z.*, 27th Jan. 1944, Vol. 65, No. 3/4, pp. 39–40.) A long summary, with diagram, of the paper referred to in 1817 of May.

2833. Direct-Current Amplifiers for Electrical Process-Control Equipments.—Kuntze. (*Die Chemische Technik*, Oct. 1943, Vol. 16, No. 21, pp. 213–218.)

(A) D.C. amplifiers with stabilised supply. (B) Amplifiers with null-galvanometers in compensating circuits (with photoelectric or bolometric control). (C) D.C. amplifiers with strong negative feedback. (D) Their application to *p*H measurement and to polarographic measurements and photoelectric pyrometry.

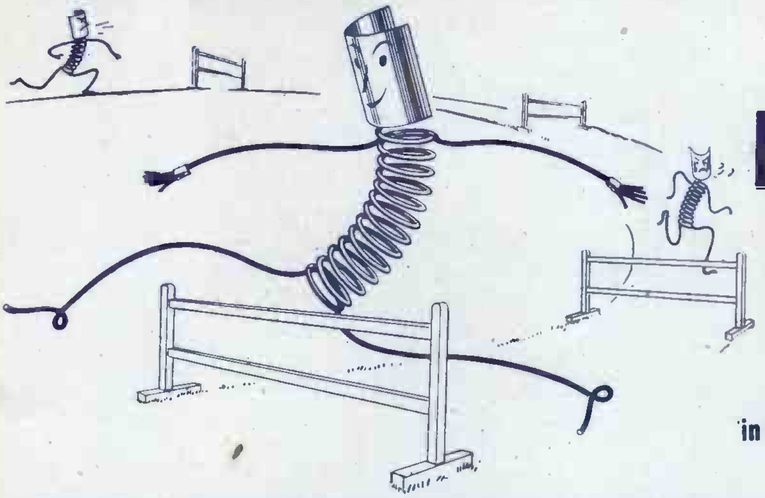
2834. A Wide-Range Sensitive Thermoregulator.—Coates. (*Journ. of Scient. Instr.*, May 1944, Vol. 21, No. 5, pp. 86–87.)

The thermoregulator is controlled by a resistance thermometer in an a.c. bridge. Its operation is based on the reversal of the phase of the out-of-balance e.m.f. of the bridge which occurs on passing from one side of balance to the other. Accurate phase adjustment is not required. The regulator can be used at any temperature for which a platinum resistance thermometer is suitable.

2835. An Automatic Vibration Analyser [for Aircraft Power Plant & Aircraft Structures: Complete Equipment].—Marble. (*Bell Lab. Record*, April 1944, Vol. 22, No. 8, pp. 376–380.)

2836. "Messung mechanischer Schwingungen: Dynamik der Schwingungsmessgeräte" [Book Review].—Klotter. (*Génie Civil*, 1st Jan. 1944, Vol. 121, No. 1, p. 12.)

2837. The "Microtimer" [Instrument for Measurement of Time-Intervals from One Millisecond to One Second].—(*Engineer*, 24th March 1944, Vol. 177, No. 4602, p. 236.)

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