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WIRELESS ENGINEER

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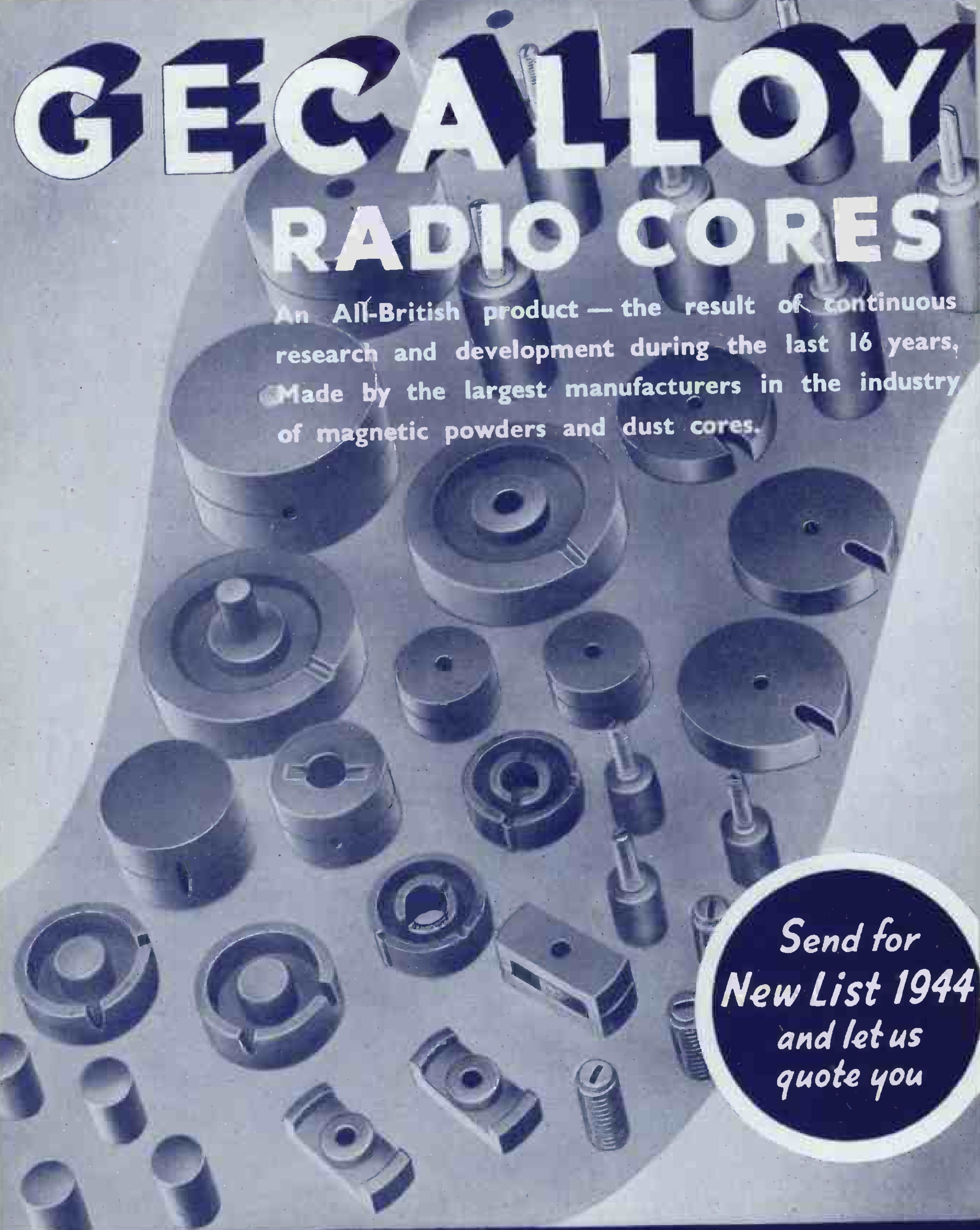
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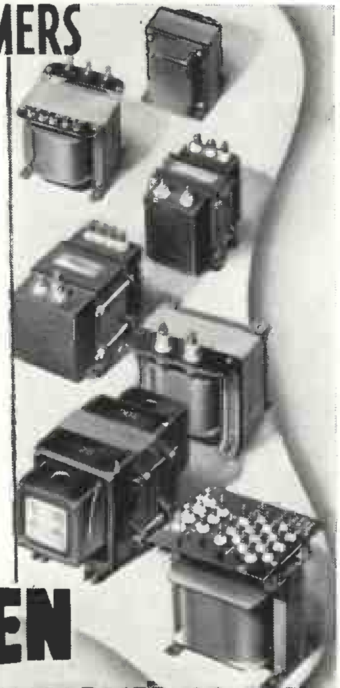

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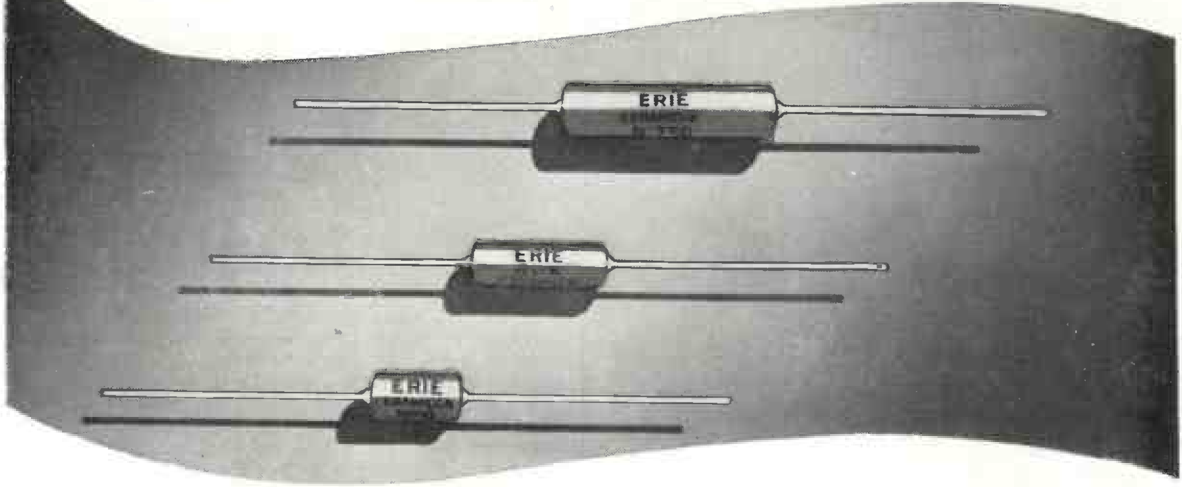

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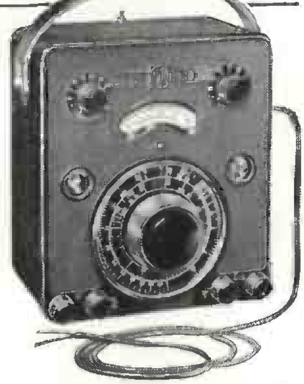

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WHY ERSIN MULTICORE

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

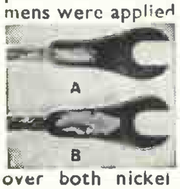
Multicore Solder wire contains 3 cores of flux to ensure flux continuity. In Multicore there is always sufficient proportion of flux to solder. If only two cores were filled with flux, satisfactory joints are obtained. In practice, the care with which Multicore Solder is made means that there are always 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 DECEMBER, 1944 No. 255

The Half-wave Dipole Aerial

IN the November Editorial we referred to a Paper by C. H. Collie* on "Electrical Resonance" and considered a quarter-wave coaxial line, from a somewhat different point of view from that adopted in the paper. We now propose to follow the same procedure in the consideration of a straight thin wire with its axis parallel to the electric field of a plane electromagnetic wave, and we shall confine our attention mainly to the case in which the length of the wire is approximately half a wavelength, that is, the simplest case of resonance.

In considering the quarter-wave coaxial line Collie assumed it to be energised by a probe near the open end, whereas we assumed the source of electromotive force to be at the short-circuited end. In the present case the location is prescribed; the excitation acts uniformly over the whole length of wire. In our April number it was shown that this is equivalent to an electromotive force $E \times l_{eff}$ acting at the mid-point, where the effective length l_{eff} is the same for reception as for transmission. As in the case of the coaxial line, Collie pictures a succession of waves travelling to and fro along the wire and being reflected at its ends, but we consider it preferable to adopt a different procedure. The cylindrical wire introduces mathematical difficulties, to overcome which we may imagine it to be replaced by a conical wire* having a mean diameter equal to that of the actual wire. It is assumed that the electric field follows circular arcs about the mid-point of the wire as shown in Fig. 1a; this is probably not very far from the actual distribution when oscillating at the resonant frequency. On this assumption the capacitance C between a cm. of wire on one half of the aerial and the corresponding cm. on the other half is constant and given by the formula

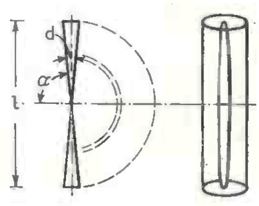


Fig. 1.

$$C = \frac{1}{4 \log_e l/2r} \times \frac{1}{9 \times 10^{11}} \ F/cm$$

where l is the length of the wire, which at resonance is approximately $\lambda/2$. Similarly

$$L = 4 \log_e l/2r \times 10^{-9} \ H/cm.$$

This follows from the formula†

$$C = \frac{1}{4 \log_e \tan\left(\frac{\alpha}{2} + \frac{\pi}{4}\right)}$$

since if ϕ is the small semi-angle $(\pi/2 - \alpha)$ at the apex of the cone,

$$\tan\left(\frac{\alpha}{2} + \frac{\pi}{4}\right) = \tan\left(\frac{\pi}{2} - \frac{\phi}{2}\right) = \cot\!\text{an}\ \phi/2 = \frac{l}{2r}$$

where r is the mean radius.

The wire is therefore equivalent to a quarter-wave line with these values of C and L per cm. of length and an electromotive force $\mathcal{E} l_{eff}$ acting at the short-circuited end.

Instead of the conical arrangement Collie assumes the wire to be a prolate spheroid (Fig. 1b), the electrostatic capacitance of which can be calculated rigidly by methods

* *Proc. Phys. Soc.*, 56, 1944, p. 255.

† Paper by R. E. Burgess, p. 154 and Editorial.

* Howe. "Inductance, Capacity and Natural Frequency of Aerials." *Yearbook of Wireless Telegraphy and Telephony*, 1917, p. 693.

† *See* July Editorial, p. 305.

described in such books as Jeans and Abraham to which Collie refers. It hardly seems a legitimate approximation to assume the whole wire to be charged to the same potential, the other electrode being a far distant sphere, and then to divide the so calculated electrostatic capacitance by the length, and employ this as the effective capacitance per unit length under the entirely different conditions of the problem.

The characteristic or surge impedance of our equivalent quarter-wave line, consisting of the two half wires in series, is

$$Z_0 = \sqrt{L/C} = 120 \log_e l/2r = 120 \log_e \lambda/2d$$

where $\lambda = 2l$ and $d = 2r$ is the mean diameter of the wire. By the method which we have criticised Collie obtains $Z_0 = 60 \log_e \lambda/d$ for each half wire. If we assume that $\lambda = 1$ metre, $l = 50$ cm., $d = 0.1$ cm., then $Z_0 = 120 \times 2.3 \times \log_{10} 500 = 745$ ohms, whereas Collie's formula gives 414 ohms for each half wire, i.e. a total of 828 ohms. We have followed Collie in taking the diameter of the prolate spheroid at the mid-point, equal to that of the cylindrical wire. Strictly speaking it should be somewhat greater so that its mean diameter approximates to that of the cylinder. It can be shown that to have the same surface area as the wire, the prolate spheroid should have a diameter of about $4d/\pi = 1.27d$. This would increase the capacitance by about 3.5 per cent. and reduce Z_0 in the same ratio, giving 800 ohms instead of 828. This is still 1.07 times the value obtained from the conical arrangement.

We can imagine someone saying that the assumption that the wire is a prolate spheroid is much nearer the facts than the assumption that it is a double cone. This argument is, however, quite illusory since the latter assumption is made solely because, with the assumed field distribution, it gives a constant capacitance per unit length; it is merely a graphical way of saying that we shall assume a constant capacitance per unit length. Collie, having determined the capacitance per unit length from the electrostatic value, assumes it to apply to the oscillating aerial, and thus virtually assumes the conical aerial, but endowed with the electrostatic capacitance.

If the frequency be increased until the wavelength, instead of being $2l$, is only $2l/3$, the distribution of charges and electric field will be approximately as shown in Fig. 2. To obtain a constant capacitance per cm. of length the aerial is assumed to be made up of a number of cones having a mean diameter equal to that of the actual cylindrical wire and therefore of the same surface area. In calculating the capacitance the term $\log_e l/d$ in the denominator now becomes $\log_e l/3d$, which in the example means that $\log_e 500 = 2.699$ becomes $\log_e 500/3 = 2.222$, and the capacitance per cm. is 1.21 times its fundamental value. Z_0 for a single wire will now be reduced to 307 ohms and for a two wire line to 614 ohms. This further departure from

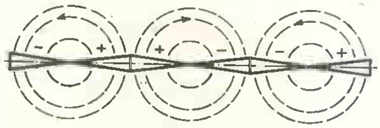


Fig. 2.

the value calculated by Collie is to be expected, since the path of the electric field is more circumscribed and therefore further removed from the assumption that it goes off to infinity.

The radiation resistance of a half-wave aerial at its fundamental frequency can be shown to be 73 ohms. This is the resistance which, inserted at the middle, would dissipate the same amount of power. If I is the r.m.s. current at the middle, the radiated power is therefore $I^2 \times 73$ watts. If the incident field has an r.m.s. value of $\mathcal{E}$ volts/cm., the power supplied to the aerial from the field will be $\mathcal{E} \times \frac{2I}{\pi} \times l$ watts, assuming the current to be sinusoidally distributed. Neglecting losses due to resistance

$$73\, I^2 = \frac{2}{\pi} \mathcal{E} I l = \frac{2}{\pi} \mathcal{E} I \frac{\lambda}{2}$$

$$\therefore \quad I = \frac{\mathcal{E} \lambda}{73\pi} \text{ amperes.}$$

As Collie points out, the same damping would be obtained if, instead of 73 ohms concentrated at the centre, twice this resistance were uniformly distributed over the whole wire, giving it a resistance of $146/l = 292/\lambda$ ohms per cm. Each cm. of length of the equivalent quarter-wave line has 2 cm. of wire, and therefore a resistance of $584/\lambda$ ohms. This gives for the attenuation coefficient of the quarter wave line

$$\alpha = \frac{R}{2}\sqrt{\frac{C}{L}} = \frac{R}{2Z_0} = \frac{292}{\lambda Z_0} \text{ per cm.}$$

Putting $Z_0 = 120 \log_e \lambda/2d$

$$\alpha = \frac{2.43}{\lambda \log_e \lambda/2d} = \frac{1.057}{\lambda \log_{10} \lambda/2d}$$

whereas Collie obtains $\frac{1.057}{\lambda \log_{10} \lambda/d}$

For the example taken above $\alpha = 3.92 \times 10^{-3}$ per cm., whereas Collie's formula gives 3.5×10^{-3} per cm.

This difference is due to the fact that we regard the two halves of the wire as the go and return wires of a quarter-wave line with an electric field distribution as shown in Fig. 1a, whereas Collie regards the whole wire as one conductor of a transmission line of which the other conductor is an infinitely distant sphere. We have shown it as a surrounding cylinder. An interesting magnitude is the Q value of such a dipole. From the fact that in an oscillatory circuit this is equal to $\omega L/R$, and that, to produce a phase shift of 45° $\left(\omega L - \frac{1}{\omega C}\right)$ must be equal to R, it is easy to see that this is obtained by varying the frequency by an amount δf where $\delta f = \frac{f_r}{2Q}$ or, in the case of the dipole, by varying the half-length by an amount δl where $\delta l = \frac{l_r}{2Q}$, f_r and l_r being the resonant values. Putting $l_r = \lambda/4$ we have $Q = \frac{\lambda}{8\delta l}$. From Fig. 2 of the November Editorial it can be seen that the phase angle will be 45° when the horizontal $\beta\delta l$ is equal to the vertical $\alpha\lambda/4$, that is, when $\frac{\lambda}{\delta l} = \frac{4\beta}{\alpha}$. Substituting this in the formula for Q we obtain $Q = \beta/2\alpha = 2\pi/2\alpha\lambda = \pi/\alpha\lambda$. In our example $\lambda = 100$ cm. and we have seen that $\alpha = 3.92 \times 10^{-3}$ per cm., hence $Q = 8$. It is interesting to note that the Q value of a tuned dipole is equal to π divided by the attenuation coefficient per wavelength.

Collie discusses the correction due to the fact that the current is not zero at the end of the wire since some has to turn the corner in order to charge the end surface, assuming the end to be flat. We may regard the line as being terminated by the capacitance between these end surfaces.

The formula $V_1 = V_2 \cosh Pl + I_2 Z_0 \sinh Pl$ becomes $V_1 = V_2 (\cos \beta l - \omega C Z_0 \sin \beta l)$ if one neglects the line losses and assumes the load to be a condenser of capacitance C. For resonance $V_1 = 0$ and therefore $\cot \beta l = \omega C Z_0$.

If $C = 0$, i.e. if the line is open circuited, $\beta l = \pi/2$ and $l = \lambda/4$, but if C has a small value, then $\cot\left(\frac{\pi}{2} - \beta.\delta l\right) = \tan \beta.\delta l = \omega C Z_0$. Hence $\tan \frac{2\pi.\delta l}{\lambda} = \omega C Z_0$; this should enable one to calculate the amount δl by which the resonant quarter-wave line is shortened due to the end capacitance C. Unfortunately the proper value of C to employ is a matter of great doubt. Collie suggests as an approximation the electrostatic capacitance of the end surfaces of the wire, either assumed to be hemispheres or discs in free space. This use of the electrostatic value would appear to give too large a value for C. The other extreme is to calculate the value, assuming the electric field to follow circular arcs as in Fig. 1, between cylindrical extensions of the actual wire equal in area to the end surfaces. Collie's method gives an addition to the length of 1.4 per cent., whereas the latter method gives only about 0.2 per cent.; the actual value will lie between them if, indeed, one is justified in regarding this correction apart from the general end correction which is certainly much larger. Quite apart from the flat ends of the wire, it is obviously an over-simplification to assume that the electric field leaving the wire near the ends will follow circular paths as we have pictured in Fig. 1, but a more detailed analysis of the problem is beyond the scope of the present note.

G. W. O. H.

An "Unterminated" Line

In looking through a recently published book we came across references to an "unterminated" line, and we naturally assumed that this was another way of saying an infinitely long line for only by being infinitely long—or completing a circle—could a line avoid having a terminus. To our surprise, however, we found that the reference was to an open-circuited or open-ended line, the idea presumably being that no "termination" had been applied to such a line. This has undoubtedly resulted from the use of the word "termination" not for the end of the line but for the thing stuck on the end. As a matter of fact, a line terminated by infinite impedance, that is, open-circuited, is, if anything, more effectively terminated than one terminated by zero impedance, that is, short-circuited. We were relieved to find no trace of this misleading usage in the recently published British Standards Glossary of Terms used in Telecommunications, but it would appear to be current in some circles.

G. W. O. H.

Fresnel's Reflection Formulae and PARALLEL TRANSMISSION LINES*

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

(Research Laboratories of The General Electric Company, Limited, England)

SUMMARY.—It is shown, how Professor Howe's "transmission line treatment" of a plane electro-magnetic wave can be applied to the case of a wave obliquely incident on a second medium.

PROFESSOR HOWE showed some time ago† that the propagation of a plane electro-magnetic wave can be treated as the propagation of waves which travel along fictitious parallel transmission lines—these lines consisting of fictitious strips of infinitely good conducting material which are inserted normal to the direction of the electric field.

One of the immediate consequences which follows from this treatment is the formula for the reflection loss suffered by such a wave when it enters a material of different dielectric constant, and when its direction of propagation is normal to the boundary of this material. The case corresponds then to the case of a wave travelling along a transmission line to which is joined another line of different characteristic impedance.

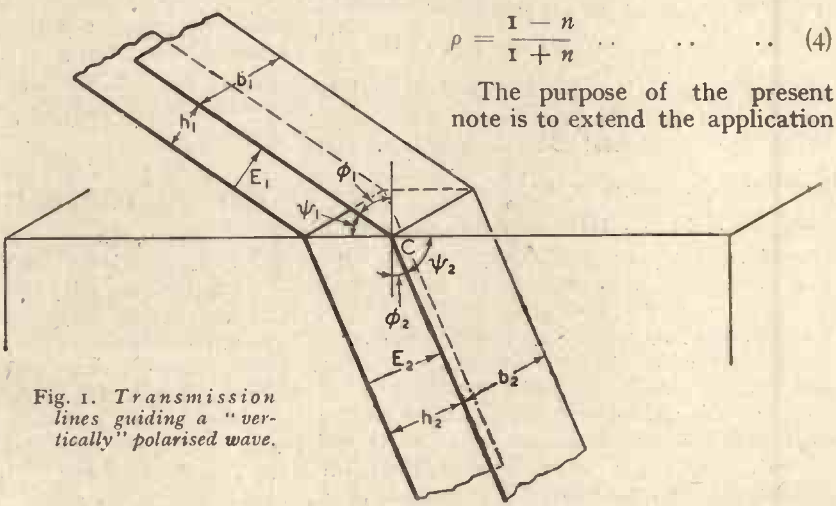


Fig. 1. *Transmission lines guiding a "vertically" polarised wave.*

We know that in such a case a reflected wave appears, the field strength of which is related to that of the incident wave as

$$\rho = \frac{Z_2 - Z_1}{Z_2 + Z_1} = \frac{1 - \dfrac{Z_1}{Z_2}}{1 + \dfrac{Z_1}{Z_2}} \quad \ldots \quad \ldots \quad (1)$$

As the characteristic impedance of such a line is given by

$$Z = \sqrt{\frac{L}{C}} \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

where L and C refer to the inductance and capacitance of the line per unit length, we have (denoting the dielectric constants by ϵ_1 and ϵ_2).

$$\frac{Z_1}{Z_2} = \sqrt{\frac{\epsilon_2}{\epsilon_1}} = n, \text{ say} \quad \ldots \quad \ldots \quad (3)$$

and, hence

$$\rho = \frac{1 - n}{1 + n} \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

The purpose of the present note is to extend the application of this treatment to the case of a wave of oblique incidence and to derive in this way Fresnel's general reflection formulae (for the case of reflection on a non-conducting material). In the case of a wave of oblique incidence the reflected wave does not travel back along the same path as the incident wave and, if we introduce the fictitious strips it seems as if we would interfere altogether either with the propagation of the incident or the reflected wave. However, if we look more closely we see that both these waves are propagated through the space in front of

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

† *Journal I.E.E.*, Vol. 54, p. 473. 1916.

the separating boundary as if this space were completely empty. We need not fear, therefore, that the introduction of these fictitious strips—as a means of calculation—contradicts the mechanism of propagation of either of these waves.* For reasons of symmetry the characteristic impedance of the transmission lines for the reflected wave is the same as that for the incident wave. Hence the fact that the reflected wave returns by a path different from that of the incident wave does not alter the "reflection balance" and the validity of eqn. (4). (The "task" of the reflected wave is to bring about equality of the line current arriving at the interface of the two media with the line currents leaving, and the magnitude of the line currents leaving is determined by the line voltage at the interface and by the line impedances offered—in a forward and backward direction—to this voltage.)

The arrangement of these transmission lines differs according to the two cases :

(*a*) Electric field vector in the plane of incidence (corresponding to the case of vertical polarisation in the case of a radio wave incident on the ground).

(*b*) Electric field vector normal to the plane of incidence (corresponding to the case of horizontal polarisation).

The two cases are illustrated in Figs. 1 and 2. We notice that in the first case the width b of the transmission line is the same in the two media, while in the second case the distance h of the strips remains constant. The changeover from the line with characteristic impedance Z_1 to the line with characteristic impedance Z_2 does not take place discontinuously as in the case of normal incidence. However, as we are not limited as to the choice of the dimensions b or h, we can always achieve, by selecting them sufficiently small that the dimensions of this ill-defined zone (marked $ABCD$ in Fig. 3) become negligibly small compared with one wavelength of the wave propagated, i.e., we can approach the discontinuous change as closely as we wish.

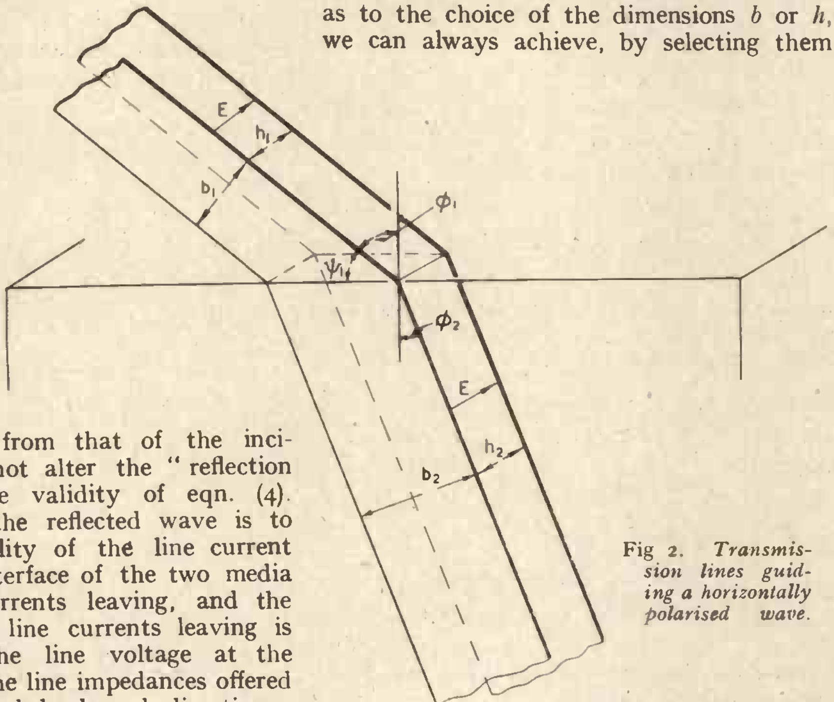


Fig 2. *Transmission lines guiding a horizontally polarised wave.*

The characteristic impedance of such a strip line is in each case inversely proportional to its width (for two equal lines laid side by side carry twice the current with the same applied voltage), and directly proportional to their height h (for two such lines, laid "on top" of each other require evidently twice the voltage for the same current flowing in each strip). If the dielectric constant also changes—as it does here—the square root of these constants also enter—as we have seen above in equations (2) and (3).

From Fig. 1 it follows then that

$$\frac{Z_1}{Z_2} = \frac{h_1}{h_2}\sqrt{\frac{\epsilon_2}{\epsilon_1}} = \frac{\cos \phi_1}{\cos \phi_2} n \quad \ldots \quad \ldots \quad (5)$$

* The reader who is familiar with the theory of functions of a complex variable will remember the concept of a complex plane which is thought to consist of several layers (Riemann's Surface.) Sommerfeld introduced in an analogous fashion the concept of a multiple space (*Cf.* Jeans, "Electricity and Magnetism," 5th edit., p. 334). The present case is an elementary application of this concept ; the two spaces filled by the incident and the reflected wave are joined together at the boundary of the two media.

and therefore

$$\rho_v = \frac{1 - \dfrac{\cos\phi_1}{\cos\phi_2}\cdot n}{1 + \dfrac{\cos\phi_1}{\cos\phi_2}\cdot n} = \frac{\cos\phi_2 - n\cos\phi_1}{\cos\phi_2 + n\cos\phi_1} \quad \ldots \quad \ldots \quad (6)$$

Taking into account the law of refraction

$$\sin\phi_1 = n\sin\phi_2 \quad \ldots \quad \ldots \quad (7)$$

or $\cos\psi_1 = n\cos\psi_2$

this can be rewritten as

$$\rho_v = \frac{\sin\psi_2 - n\sin\psi_1}{\sin\psi_2 + n\sin\psi_1} = \frac{\sqrt{n^2 - \cos^2\psi_1} - n^2\sin\psi_1}{\sqrt{n^2 - \cos^2\psi_1} + n^2\sin\psi_1} \quad \ldots \quad \ldots \quad (8)$$

which is Fresnel's reflection formula for the case of a vertically polarised wave.

From Fig. 2 it follows that

$$\frac{Z_1}{Z_2} = \frac{b_2}{b_1}\sqrt{\frac{\epsilon_2}{\epsilon_1}} = \frac{\cos\phi_2}{\cos\phi_1}\cdot n \quad \ldots \quad \ldots \quad (9)$$

and hence

$$\rho_h = \frac{\cos\phi_1 - n\cos\phi_2}{\cos\phi_1 + n\cos\phi_2}$$

$$= \frac{\sin\psi_1 - \sqrt{n^2 - \cos^2\psi_1}}{\sin\psi_1 + \sqrt{n^2 - \cos^2\psi_1}} \quad \ldots \quad \ldots \quad (10)$$

Fresnel's reflection formula for a wave of horizontal polarisation.

Formulae (8) and (10) can be applied to the case where the wave enters a semi-conducting medium if we ascribe to this medium a complex—instead of a real—dielectric constant; the physical interpretation of this result is however too complicated to be dealt over on this occasion.

The law of refraction (equation 7) which has been used in this derivation can also be derived from the well-known formula for the velocity of waves travelling along transmission lines:

$$v = \frac{1}{\sqrt{L\,.\,C}} \quad \ldots \quad \ldots \quad \ldots \quad (11)$$

where L and C have the same meaning as in equation (2).

From this last equation follows that the wave velocity in the two media are related as $v_2/v_1 = \sqrt{\epsilon_1/\epsilon_2} = \frac{1}{n}$ for obviously we may compare two transmission lines of equal cross section, i.e. of equal L.

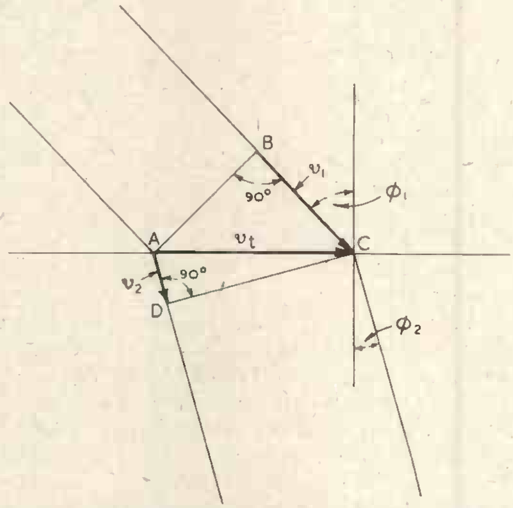


Fig. 3. *Relation between wave velocity and the phase velocity V_t along the boundary of the two media.*

The incoming wave lays down on the boundary of the two media a certain phase pattern, which sweeps across this boundary with a velocity equal to $v_t = v_1/\sin\phi_1$. (*See* Fig. 3). This phase pattern is responsible for the wave travelling into the second medium. Evidently the relationship between v_t and the wave velocity in the second medium is $v_t = v_2/\sin\phi_2$ (we need only think the second wave to be travelling in the opposite direction). Hence we have

$$\frac{\sin\phi_1}{\sin\phi_2} = \frac{v_1}{v_2} = \sqrt{\frac{\epsilon_2}{\epsilon_1}} = n \quad \ldots \quad \ldots \quad (12)$$

Notes on ELECTRO-MECHANICAL EQUIVALENCE*

By H. Jefferson, B.A., A.Inst.P.

ELECTRIC circuit theory is only a restricted form of dynamics. Its practical importance lies in the fact that the design of quite elaborate systems has been reduced to routine operations. Complex systems comprising a number of meshes, in which attention is restricted to only two meshes, have become the subject of special study, and there is a background of basic rigorous theorems to the methods of network synthesis of various degrees of accuracy. For most purposes the designer can consult tables in the standard textbooks, in which he will find formulae for the elements of all types of filter. The use of filters built up from constant-k and M-derived sections can be avoided by more refined design techniques, more particularly those of Cauer, Bode and Darlington. Although details of these methods are readily accessible, it is rare to find a network designed by any but the simplest formulae. The behaviour of networks designed by any of these methods when subjected to impulses and other transient disturbances can be studied by known methods which are tedious in computation rather than difficult in application.

In comparison, the solution of problems in mechanical systems is very clumsy. Each problem must be treated as a fresh one and the basic equations for each element written down. From this assembly of Newton's laws and Hooke's law the required solution can be painfully extracted. The solution is cluttered up with unwanted information about conditions in intermediate meshes.

It is well known that the methods evolved for electric circuit design can be used for mechanical circuit design, when we are considering mechanical systems subjected to alternating or impulsive forces. Indeed, hydraulic systems also can be converted into analogous electric networks. Many mechanical engineers, however, are reduced to computation from first principles, or to "cut-and-try" methods, because they have found no sufficiently clear account of the operation of expressing mechanical systems in terms of electrical networks. A number of papers treat this equivalence problem, but commonly these confine themselves to some special aspect, and do not cover the whole field. Some textbooks, also, have chapters on this subject, but these textbooks do not seem to reach the hands of those who meet with difficulty.

It is the purpose of these notes to develop the bases of equivalent systems and to maintain through this development the complete duality which exists. This duality is obscured by many of the writers: it arises because there is no fundamental reason why the equivalent of force should be voltage rather than current, or the equivalent of velocity current rather than voltage. As long as a mechanical system alone is under consideration, the choice is a free one. When the circuit contains both electrical and mechanical elements, coupled together by means of an electro-mechanical transducer, it is commonly convenient to choose the mechanical-electrical transformation to suit the transducer. If, for example, the transducer is a device in which a current at the terminals produces a proportional force, it is simple to adopt throughout that convention which makes current and force equivalent. When this is done, the transducer takes the circuit form of a normal transformer. If at one end of the mechanical system the transducer gives a force proportional to current and at the other end there is a transducer in which force produces a voltage, we avoid any discontinuity in the analysis by choosing whichever equivalent system we please, and then allowing the transducer equivalents to straighten things out. We shall find that one transducer will have an equivalent which can be described as that of an inverting transformer which has a ratio of $1 : \sqrt{-n^2}$. The use of this rather artificial device leads to a straightforward analysis procedure.

To determine the equivalents of various elementary mechanical systems, we shall write down the equations of motion for the mechanical system and compare these equations with the equations governing the behaviour of basic electric networks. We shall treat mechanical systems in terms of

* MS. accepted by the Editor, October 1944.

linear motion, and will assume also that the equations with which we are concerned are all linear.

Any four-terminal network will have the form of Fig. 1. Two terminals, the input terminals, have applied to them a voltage V_1, and a current I_1 flows in at 1_1 and out again at 1_2. At the output terminals there exists a voltage V_2, and a current I_2 flows out at 2_1 and returns at 2_2. The voltages and currents satisfy the general circuit equations

$$V_1 = A_{11}V_2 + A_{12}I_2 \quad \ldots \quad \ldots \quad (1)$$

$$L_1 = A_{21}V_2 + A_{22}I_2 \quad \ldots \quad \ldots \quad (2)$$

The four quantities A_{11}, A_{12}, A_{21}, A_{22} are characteristic of the network, and satisfy also, if the network is passive and contains no energy sources,

$$A_{11}A_{22} - A_{12}A_{21} = 1 \quad \ldots \quad \ldots \quad 3$$

For reasons made clear in the Appendix, we shall refer to the four quantities A_{11}, A_{12}, A_{21}, A_{22}, considered collectively as the characteristics of the network, as (A).

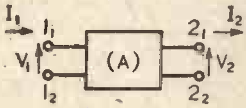


Fig. 1.

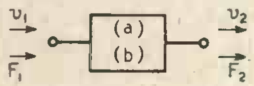


Fig. 2.

To represent a mechanical equivalent of this general four-terminal network we shall take Fig. 2. Here the input pair of terminals is replaced by an input rod, to which a force F_1 is applied, and which moves with a velocity v_1. An output rod, moving with velocity v_2 and producing a force F_2, replaces the output pair of terminals. It is possible to add to this diagram the second terminal of the pair, by including the reference frame, which corresponds to the earth of an unbalanced electrical system. It does not seem really necessary, however, although this may be borne in mind should a problem arise where this point may serve to clarify the issue.

We shall write the equations relating the input and output of the mechanical system in either of two ways:

$$v_1 = a_{11}v_2 + a_{12}F_2 \quad \ldots \quad \ldots \quad (4)$$

$$F_1 = a_{21}v_2 + a_{22}F_2 \quad \ldots \quad \ldots \quad (5)$$

or

$$F_1 = b_{11}F_2 + b_{12}v_2 \quad \ldots \quad \ldots \quad (6)$$

$$v_1 = b_{21}F_2 + b_{22}v_2 \quad \ldots \quad \ldots \quad (7)$$

In the same way as above, we shall refer to these sets of four coefficients which characterise the network as (a) and (b).

The basis of our method of deriving equivalents is this: having written down equations (4) and (5), we replace v_1, v_2, F_1, F_2 by V_1, V_2, I_1, I_2 respectively. This casts (4), (5) into the form of (1), (2) but with a_{11}, a_{12}, a_{21}, a_{22} written in place of A_{11}, A_{12}, A_{21}, A_{22}. We then say that the electrical network which satisfies these equations is the a-equivalent of the mechanical system. We then obtain the b-equivalent by replacing F and v in equations (6) and (7) by V and I and comparing this result with equations (1) and (2). An example will make this perfectly clear.

Let us consider the equations of motion of a mass, Fig. 3. We shall assume here, and throughout these notes, that we are concerned with simple harmonic forces and velocities, so that we may write

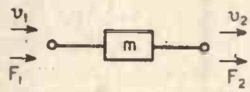


Fig. 3.

$$F = F_0 \exp j\omega t\,; \quad v = v_0 \exp j\omega t \qquad (8)$$

where $j = \sqrt{-1}$, ω is the angular frequency $= 2\pi f$, where f is the frequency in cycles per second. We shall write $\lambda = j\omega$ in much that follows.

$$\text{From (8)} \; dF/dt = \lambda F\,; \quad dv/dt = \lambda v \qquad (9)$$

Our mass must obviously move as a whole, and consequently

$$v_1 = v_2 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (10)$$

By Newton's Third Law, the motion must satisfy

$$F_1 - F_2 = m\, dv/dt \quad \ldots \quad \ldots \quad (11)$$

where F_2 is the force passed on to a succeeding element, which must produce a corresponding reaction of $-F_2$. This convention is very important; F_1 is the force applied *to* the input rod, F_2 is the force applied *by* the output rod. Rewriting these equations in the form of (4) and (5)

$$v_1 = v_2 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (10)$$

$$F_1 = \lambda m\, v_2 + F_2 \quad \ldots \quad \ldots \quad \ldots \quad (11)$$

Consequently we have for a mass

$$a_{11} = 1\,; \; a_{12} = 0\,; \; a_{21} = \lambda m\,; \; a_{22} = 1 \quad \ldots \quad \ldots \quad (12)$$

and

$$b_{11} = 1\,; \; b_{12} = \lambda m\,; \; b_{21} = 0\,; \; b_{22} = 1 \quad \ldots \quad \ldots \quad (13)$$

Let us now assume that velocity can be replaced by voltage and force by current. We have

$$V_1 = V_2 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (14)$$

$$I_1 = \lambda m\, V_2 + I_2 \quad \ldots \quad \ldots \quad \ldots \quad (15)$$

This pair of equations is satisfied by a network of the form of Fig. 4, in which the shunt admittance Y is of value λm, that is, by a shunt condenser. If we consider the b-equivalent we shall find that the resulting network equations can be satisfied by a series impedance as shown in Fig. 5, where the value of Z is λm, that is we have an inductance of size m. We shall say that the

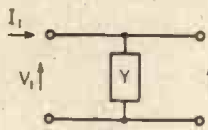


Fig. 4.

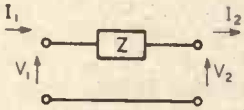


Fig. 5.

a-equivalent of a mass is a condenser, and the b-equivalent is an inductance. It is of interest to notice the energy stored in this mass and its equivalents. The mass itself, at any instant, is moving with velocity v, and has in consequence kinetic energy of $\frac{1}{2} mv^2$. In its a-equivalent the instantaneous voltage across the condenser is V, and the energy stored, $\frac{1}{2} CV^2$, is equal to $\frac{1}{2} mV^2$. In the b-equivalent the instantaneous current in the inductance is I, and the energy stored is $\frac{1}{2} mI^2$, the inductance being m. These forms are those which are derived directly by saying that the a-equivalent of a mass is a shunt capacitance, and of velocity, voltage ; and that the b-equivalent of mass is a series inductance and of velocity, current. In a-equivalent the conservation of momentum appears as conservation of charge, for the momentum of a mass is $mv = CV$, the charge on the condenser.

We can show, by similar reasoning, that if the mechanical network comprises an elastic rod of modulus K represented sym-

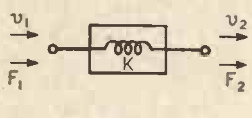


Fig. 6.

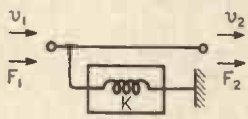


Fig. 7.

bolically in Fig. 6, the a-equivalent is a series inductance, K, and the b-equivalent a shunt capacitance, K. If there is a stiff rod which has a restoring spring of modulus K, represented in Fig. 7, the a-equivalent is a shunt inductance $1/K$ and the b-equivalent a series capacitance $1/K$. These results are derived in the Appendix.

Friction appears in mechanical systems in two different ways. Most common is its appearance as a bearing friction, as shown in Fig. 8. This is found to have an a-equivalent of a shunt resistance. Sometimes friction appears in the form of a dash-pot or slipping clutch. This is often made more complicated by non-linearities introduced by friction, but so long as the system is linear it can be replaced by an a-equivalent of a series resistance and a b-equivalent of a shunt resistance.

If the list of electrical equivalents discussed briefly above is examined it will be seen that the complete set of single element networks is present with the exception of the series capacitance in the a-equivalents and shunt inductance in the b-equivalents. This form is not, so far as the writer is aware, treated elsewhere. It will be considered below as a special case of the lever.

Fixed and free shafts are sometimes encountered. Their equivalences are easily determined as limiting cases of the simple elements. The fixed shaft is one connected to an infinite mass. In a-equivalent this involves an infinite shunt capacitance, that is, a short-circuit. This result can be derived by straightforward physical reasoning. A free shaft is one which includes a section of infinitely soft spring, and thus has as a-equivalent an open circuit and as b-equivalent a short-circuit.

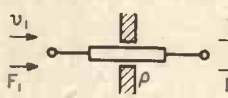


Fig. 8.

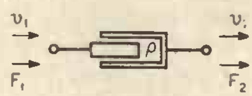


Fig. 9.

If we look back we see that we have derived a dual system of equivalents for the simpler mechanical elements, in which the a-series represents masses by capacitances and springs by inductances and the b-series represents masses by inductances and springs by capacitances. Any element which appears as a series element in one equivalent system appears as a shunt element in the other. Extending the idea to rotating systems, we can replace mass in the above discussion by moment of inertia, force by torque, velocity by angular velocity and linear elasticity by twist per unit torque. This is a substitution which does not need to be laboured further.

The lever is a network element of some importance, which in the rotational system appears as a gear pair. Its simplest form is that shown in Fig. 10, from which we can write down immediately

$$v_1 = (l_1/l_2)\, v_2 = nv_2 \quad \ldots \quad \ldots \quad (16)$$
$$F_1 = (l_2/l_1)\, F_2 = (1/n)F_2 \quad \ldots \quad \ldots \quad (17)$$

An electric circuit having equations

$$V_1 = nV_2 \quad \ldots \quad (18)$$

$$I_1 = (1/n)\, I_2 \quad \ldots \quad (19)$$

is the ideal transformer of ratio 1 : n. This, then, is the a-equivalent. The b-equivalent is clearly an ideal transformer of ratio n : 1.

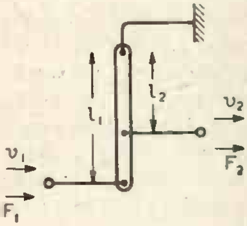


Fig. 10.

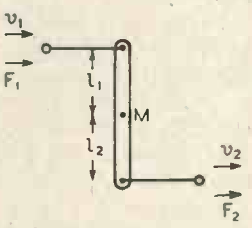


Fig. 11.

A much more interesting form of the lever is that shown in Fig. 11. This is an infinitely stiff rod, which is not fixed but free, and has a mass M. The derivation in the Appendix shows that this arrangement is equivalent to an imperfect transformer, having finite inductance windings and some leakage inductance. This equivalent is the b-equivalent: the a-equivalent is a π network of capacitances, a form sometimes used as a transformer of limited range in band-pass filter networks. There are some special cases of interest. If input and output rods are attached to the same point the system behaves like a mass, scaled down in value in the ratio $1/[1 + (l^2/h^2)]$ where h is the radius of gyration. Another very interesting form is obtained when all the mass is concentrated at the centre of gravity and $l_1 = l_2$. This, apart from a minus sign, is found to provide the missing simple equivalents. The a-equivalent is a series capacitance, the b-equivalent a shunt inductance. The minus sign is disposed of by introducing a 1 : -1 ideal transformer, and we have the system of Fig. 12, which we required to complete the set of simple circuit elements. This result means that if we wish to obtain a mechanical equivalent to any electrical system we can now perform the transformation. Without this equivalent it was impossible to construct mechanical systems equivalent to certain types of high- and band-pass filters known in electric circuit theory. This element is of use if it is desired to take an alternating drive into a unit without preventing movement of the unit. We can block out the d.c. term in mechanical problems.

Further aspects of these basic elements are touched on in the Appendix.

A derived element is the mechanical form of the transmission line. A rod having mass m per unit length and elasticity K per unit length is clearly equivalent to a transmission line: in the a-equivalent the capacitance per unit length is m and the inductance K; in the b-equivalent although we still have a transmission line, the capacitance per unit length is K and the inductance m. This equivalent is of use in the rigid analysis of systems having imperfectly stiff rods, and springs having finite mass. The velocity of propagation of waves in such a line is

$$v_0 = (1/mK)^{\frac{1}{2}} \quad \ldots \quad (20)$$

and the characteristic impedance is

$$Z_0\,(a) = (K/m)^{\frac{1}{2}} : Z_0\,(b) = (m/K)^{\frac{1}{2}} \quad (21)$$

This completes the survey of mechanical elements which can be represented by electrical elements which obey similar equations. With the assistance of Table I, any mechanical system subjected to alternating forces can be replaced by either of its two analogues, by an element-by-element substitution, remembering that once the decision as to a- or b-equivalents is made, it must be adhered to throughout. Comparison of the resulting networks with the standard forms given in textbooks on filter theory will enable the behaviour to be predicted, or the elements to be chosen to provide a desired performance.

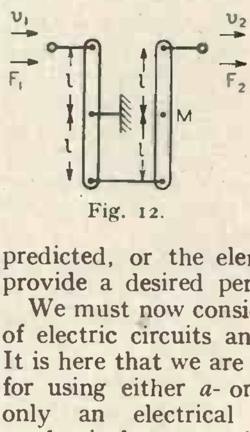
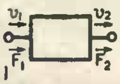
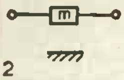
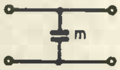
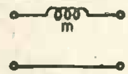


Fig. 12.

We must now consider the interconnection of electric circuits and mechanical systems. It is here that we are provided with a reason for using either a- or b-equivalents. When only an electrical system, or only a mechanical system is concerned, self-consistency is easily guaranteed. As soon as a mixed system must be considered, special care is needed to ensure that there is no failure of consistency between these two divisions of the circuit. This becomes particularly difficult when there are two transducers of different kinds in the circuit, and although it is easy to cope analytically with this form of problem, it presents difficulties in physical interpretation. We can only say in such cases, with Laplace, "Go on, conviction will come to you later."

(*Continued on p.* 568.)

TABLE I

 1	$\begin{pmatrix} v_1\\ F_1\end{pmatrix}=\begin{pmatrix}a_{11} & a_{12}\\ a_{21} & a_{22}\end{pmatrix}\begin{pmatrix}v_2\\ F_2\end{pmatrix}$		$\begin{pmatrix} F_1\\ v_1\end{pmatrix}=\begin{pmatrix}b_{11} & b_{12}\\ b_{21} & b_{22}\end{pmatrix}\begin{pmatrix}F_2\\ v_2\end{pmatrix}$	
 2	$\begin{pmatrix}1 & 0\\ \lambda m & 1\end{pmatrix}$		$\begin{pmatrix}1 & \lambda m\\ 0 & 1\end{pmatrix}$	
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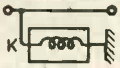
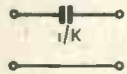
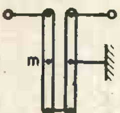
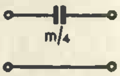
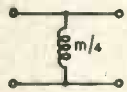
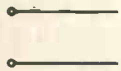
 4	$\begin{pmatrix}1 & 0\\ K/\lambda & 1\end{pmatrix}$		$\begin{pmatrix}1 & K/\lambda\\ 0 & 1\end{pmatrix}$	
 5	$\begin{pmatrix}1 & 4/\lambda m\\ 0 & 1\end{pmatrix}$		$\begin{pmatrix}1 & 0\\ 4/\lambda m & 1\end{pmatrix}$	
 6	$\begin{pmatrix}1 & 0\\ \infty & 1\end{pmatrix}$		$\begin{pmatrix}1 & \infty\\ 0 & 1\end{pmatrix}$	
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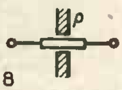
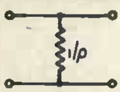
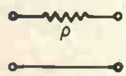
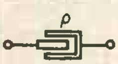
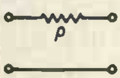
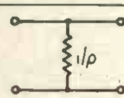
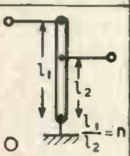
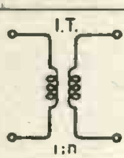
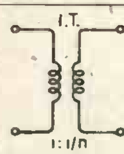
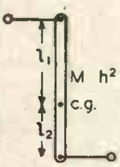
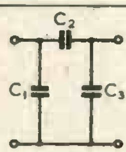
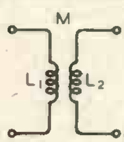
 8	$\begin{pmatrix}1 & 0\\ \rho & 1\end{pmatrix}$		$\begin{pmatrix}1 & \rho\\ 0 & 1\end{pmatrix}$	
 9	$\begin{pmatrix}1 & \rho\\ 0 & 1\end{pmatrix}$		$\begin{pmatrix}1 & 0\\ \rho & 1\end{pmatrix}$	
 10	$\begin{pmatrix}n & 0\\ 0 & 1/n\end{pmatrix}$		$\begin{pmatrix}1/n & 0\\ 0 & n\end{pmatrix}$	
 11	$\begin{pmatrix}\frac{h^2+l_1^2}{h^2-l_1l_2} & \frac{1}{\lambda M}\frac{(l_1+l_2)^2}{h^2-l_1l_2}\\ \lambda M\frac{h^2}{h^2-l_1l_2} & \frac{h^2+l_2^2}{h^2-l_1l_2}\end{pmatrix}$	 $C_1 = Ml_2/(l_1+l_2)$ $C_2 = M(h^2-l_1l_2)/(l_1+l_2)^2$ $C_3 = Ml_1/(l_1+l_2)$	$\begin{pmatrix}\frac{h^2+l_2^2}{h^2-l_1l_2} & \lambda M\frac{h^2}{h^2-l_1l_2}\\ \frac{1}{\lambda M}\frac{(l_1+l_2)^2}{h^2-l_1l_2} & \frac{h^2+l_1^2}{h^2-l_1l_2}\end{pmatrix}$	 $L_1 = n^2L_2$ $M^2 = K^2L_1L_2$ $n^2 = (h^2+l_2^2)/(h^2+l_1^2)$ $K^2 = (h^2-l_1l_2)^2/(h^2+l_1^2)(h^2+l_2^2)$ $L_1 = M(h^2+l_2^2)/(l_1+l_2)^2$

C

The general form of electro-mechanical transducer is shown in Fig. 13. This is a reversible linear system, having two terminals and an output (or input) rod. When a voltage is applied across the terminals, a current flows and the rod moves. The system satisfies equations of the form

$$V_1 = p_{11}\, v_2 + p_{12}\, F_2 \quad \ldots \quad (22)$$

$$I_1 = p_{21}\, v_2 + p_{22}\, F_2 \quad \ldots \quad (23)$$

or, written the other way round

$$V_1 = q_{11}\, F_2 + q_{12}\, v_2 \quad \ldots \quad (24)$$

$$I_1 = q_{21}\, F_2 + q_{22}\, v_2 \quad \ldots \quad (25)$$

It will be remembered that to obtain the a-equivalent we wrote V_2 in place of v_2 and I_2 in place of F_2, and then sought an electrical network satisfying the resulting pair of equations. We shall do this again here, using the equations in p to give us the a-transformation and the equations in q to give the b-transformation. The procedure will be clarified by an example. One common driver circuit is the electro-magnetic driver, of which the moving-coil loudspeaker is a typical example. This is a system in which a current flowing in a conductor in a magnetic field causes an interaction force on the conductor. The "type" equation is, in fact: $I_1 = p_{22} F_2 \quad \ldots \quad (26)$

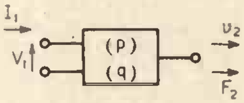


Fig. 13.

where p_{22} is a constant. The energy going into the system is $V_1 I_1$ and if we consider an idealised system, this energy must come out as mechanical work, at a rate $F_2 v_2$. A second equation follows:

$$V_1 = p_{11}\, v_2 = (1/p_{22})\, v_2 \quad \ldots \quad (27)$$

This circuit, when we make the $v_2 - V_2$, $F_2 - I_2$ substitution, is seen to have as a-equivalent an ideal transformer of ratio $p_{22} : 1$. Its b-equivalent is a circuit which has the general circuit equations.

$$V_1 = q_{22}\, I_2 \quad \ldots \quad (28)$$

$$I_1 = q_{11}\, V_2 \quad \ldots \quad (29)$$

This pair of equations can be said to be the equations of an inverting transformer, that is a transformer which gives a secondary current proportional to the primary voltage, and a secondary voltage proportional to the primary voltage. So long as we stick to the algebra, this need not embarrass us. It is, however, to avoid this device that in systems having electro-magnetic drives we use whenever possible the a-equivalent system. It may be noted here that if across an "inverting transformer" we connect an inductance, the impedance presented at the primary is capacitive. The "inverting transformer" is in fact a device for converting between a- and b-equivalents.

The other form of transducer commonly used is that typified by the electro-static loudspeaker, the piezo-electric crystal and the condenser microphone. Here voltage and force are related and the "type" equation is

$$V_1 = q_{11}\, F_2 \quad \ldots \quad (30)$$

and as before $I_1 = q_{22}\, v_2 = (1/q_{11})\, v_2 \quad (31)$

Clearly the b-equivalent is an ideal transformer, the a-equivalent being an "inverting transformer."

Any practical transducer will include certain elements we have omitted here. Resistive losses, stray capacitances and inductances, all must be included in the circuit equivalent. Where the losses are electrical, they will normally appear on one side of the transformer; where they are mechanical they will appear on the other. After conversion into the same units circuit methods for simplifying the network can be adopted.

This account of electro-mechanical equivalence is, it is hoped, sufficiently complete and concise to be of assistance both to those who wish to make use of the simple methods of filter design to solve their mechanical problems, and to those who seek a unified account in order to obtain a rational approach to problems of mixed transducers. It is hoped that the result, believed to be new, in Fig. 12, will be of use to those who find a need for constant-k band-pass filters or high-pass filters.

Many of the results quoted above are derived in the Appendix. This has been kept short, as it is thought that most readers would be content with the statement of results provided in Table I.

APPENDIX

A Summary of the Analysis

This appendix constitutes an analytical version of the material in the main body of the notes. The method used is to consider the general circuit matrix for the various elements.

Equations (1) and (2) of the notes can be written in an abbreviated form as

$$\begin{pmatrix} V_1 \\ I_1 \end{pmatrix} = (A) \begin{pmatrix} V_2 \\ I_2 \end{pmatrix} \quad \ldots \quad (A.1)$$

with the condition $|A| = 1 \quad \ldots \quad$ (A.2)

The matrix (A) thus defines three independent parameters, which in turn define the network. These parameters are related to other properties of the network, and, in particular, the open-circuit impedance at the input end is

$$Z_{oc,1} = A_{11}/A_{21} \quad \ldots \quad (A.3)$$

the short-circuit impedance at the same end is

$$Z_{sc,1} = A_{12}/A_{22} \quad \ldots \quad (A.4)$$

and for a symmetrical network, in which $A_{11} = A_{22}$, the characteristic impedance is

$$Z_o = (A_{12}/A_{21})^{\frac{1}{2}}$$

The particular importance of the general circuit matrix is seen when two networks are connected in tandem. Then for the first

$$\begin{pmatrix} V_1 \\ I_1 \end{pmatrix} = (A_1) \begin{pmatrix} V_2 \\ I_2 \end{pmatrix} \text{ and for the second}$$

$$\begin{pmatrix} V_2 \\ I_2 \end{pmatrix} = (A_2) \begin{pmatrix} V_3 \\ I_3 \end{pmatrix} \quad \ldots \quad (A.5)$$

clearly then $$\begin{pmatrix} V_1 \\ I_1 \end{pmatrix} = (A_1)(A_2) \begin{pmatrix} V_3 \\ I_3 \end{pmatrix} \quad \ldots \quad (A.6)$$

The general circuit matrix of two four-terminal networks connected in tandem is thus the product of the individual general circuit matrices. This property is particularly useful in enabling a rapid calculation of the transfer coefficients of a network to be made, as many networks can be considered as tandem connections of simple elements. The advantage of this method is that it imposes a simple routine of multiplication and addition which can be carried out very quickly. Errors are less likely to creep in than with less automatic methods and a final check can be made by seeing whether the determinant of the whole general circuit matrix is identically unity. Tables of general circuit matrices for various simple elements together with the various transformations for series and parallel connection are useful aids.

The general circuit matrices for the simple elements are :

For a series impedance, Fig. 5,

$$V_1 = V_2 + ZI_2 \quad \ldots \quad (A.7)$$

$$I_1 = I_2 \quad \ldots \quad (A.8)$$

giving $$(A) = \begin{pmatrix} 1 & Z \\ 0 & 1 \end{pmatrix} \quad \ldots \quad (A.9)$$

If Z consists of an inductance, resistance and condenser in series

$$(A) = \begin{pmatrix} 1 & \lambda L + R + 1/\lambda C \\ 0 & 1 \end{pmatrix} \quad \ldots \quad (A.10)$$

This form includes the three separate forms of inductance, resistance and condenser alone.

For a shunt admittance Y, Fig. 4, it is easy to see that

$$(A) = \begin{pmatrix} 1 & 0 \\ Y & 1 \end{pmatrix} \quad \ldots \quad (A.11)$$

or, if Y consists of inductance, resistance ($G = 1/R$) and condenser in parallel

$$(A) = \begin{pmatrix} 1 & 0 \\ 1/\lambda L + G + \lambda C & 1 \end{pmatrix} \quad \ldots \quad (A.12)$$

As we have seen, in equations (14) and (15), the mass of Fig. 3 has

$$(a) = \begin{pmatrix} 1 & 0 \\ \lambda m & 1 \end{pmatrix}; \quad (b) = \begin{pmatrix} 1 & \lambda m \\ 0 & 1 \end{pmatrix} \quad \ldots \quad (A.13)$$

and the equivalents are obvious on comparison with (A.10) and (A.12). For the spring of Fig. 6 we must have

$$F_1 = F_2 \quad \ldots \quad (A.14)$$

$$v_1 = v_2 - dl/dt \quad \ldots \quad (A.15)$$

By Hookes' Law $dl/dt = -K\,dF/dt = -\lambda KF$ $\quad \ldots \quad$ (A.16)

giving $$(a) = \begin{pmatrix} 1 & \lambda K \\ 0 & 1 \end{pmatrix}; \quad (b) \begin{pmatrix} 1 & 0 \\ \lambda K & 1 \end{pmatrix} \quad \ldots \quad (A.17)$$

When the spring appears, as in Fig. 7, as a restoring spring the equations of motion are

$$v_1 = v_2 \quad \ldots \quad (A.18)$$

$$F_1 = K\int v\,dt + F_2 \quad \ldots \quad (A.19)$$

or $$F_1 = (K/\lambda)\,v_2 + F_2 \quad \ldots \quad (A.20)$$

These equations lead to

$$(a) = \begin{pmatrix} 1 & 0 \\ K/\lambda & 1 \end{pmatrix}; \quad (b) = \begin{pmatrix} 1 & K/\lambda \\ 0 & 1 \end{pmatrix} \quad (A.21)$$

These results were quoted as equivalents in the body of the text. The derivation of the friction forms is implicit in the above.

We now consider in some detail the free lever shown in Fig. 11. This is a heavy stiff bar, with the input force applied normal to the bar at one end and the load attached to the other end. If Mh^2 is the moment of inertia, v_0 the velocity of the centre of gravity, θ the angle between the bar and an arbitrary direction fixed in space and l_1 and l_2 the distances of the " terminals " from the centre of gravity, the equations of motion are :

$$F_1 - F_2 = \lambda M v_0 \quad \ldots \quad (A.22)$$

$$F_1 l_1 + F_2 l_2 = \lambda M h^2 \dot{\theta} \quad \ldots \quad (A.23)$$

$$v_0 - v_2 = l_2 \dot{\theta} \quad \ldots \quad (A.24)$$

$$v_1 - v_0 = l_1 \dot{\theta} \quad \ldots \quad (A.25)$$

$$(a) = \begin{pmatrix} \dfrac{h^2 + l_1^2}{h^2 - l_1 l_2} & \dfrac{1}{\lambda M}\dfrac{(l_1 + l_2)^2}{h^2 - l_1 l_2} \\ \dfrac{\lambda M h^2}{h^2 - l_1 l_2} & \dfrac{h^2 + h_2^2}{h^2 - l_1 l_2} \end{pmatrix} \quad (A.26)$$

$$(b) = \begin{pmatrix} \dfrac{h^2 + l_2^2}{h^2 - l_1 l_2} & \dfrac{\lambda m\, h^2}{h^2 - l_1 l_2} \\ \dfrac{1}{\lambda M}\dfrac{(l_1 + l_2)^2}{h^2 - l_1 l_2} & \dfrac{h^2 + l_1^2}{h^2 - l_1 l_2} \end{pmatrix} \quad (A.27)$$

The imperfect transformer, having finite winding inductances L_1 and L_2, with mutual inductance of M, where $L_1 = n^2 L_2$ and $M^2 = k^2 L_1 L_2$, has a general circuit matrix :

$$(A) = \begin{pmatrix} n/k & \lambda L_1 (1 - k^2)/nk \\ n/\lambda L_1 k & 1/nk \end{pmatrix} \quad \ldots \quad (A.28)$$

The π network of capacitances in Fig. 13 has a general circuit matrix

$$(A) = \begin{pmatrix} 1 + \dfrac{C_3}{C_2} & \dfrac{1}{\lambda C_2} \\ \lambda[C_1 + \dfrac{C_1 C_3}{C_2} + C_3] & 1 + \dfrac{C_1}{C_2} \end{pmatrix} (A.29)$$

Clearly (A.27) and (A.28) are the same form, as are (A.26) and (A.29). Thus the a-equivalent of the free lever is a π network of capacitances with

$$\left.\begin{aligned} C_1 &= M\, l_2/(l_1 + l_2) \\ C_2 &= M\,(h^2 - l_1 l_2)/(l_1 + l_2)^2 \\ C_3 &= M\, l_1/(l_1 + l_2) \end{aligned}\right\} \quad \ldots \quad (A.30)$$

and the b-equivalent is an imperfect transformer with

$$\left.\begin{aligned} L_1 &= M(h^2 + l_2^2)/(l_1 + l_2)^2 \\ n^2 &= (h^2 + l_2^2)/(h^2 + l_1^2) \\ k^2 &= (h^2 - l_1 l_2)^2/(h^2 + l_1^2)(h^2 + l_2^2) \end{aligned}\right\} \quad \text{(A.31)}$$

A feature of interest is seen immediately: if $h^2 - l_1 l_2 = 0$, $C_2 = 0$ in one equivalent and $k^2 = 0$ in the other. This is well known as the equation defining the centre of percussion. It appears here as a complete isolation of input from output. The other interesting form is obtained if $h = 0$ and $l_1 = l_2$. Then

$$(a) = \begin{pmatrix} -1 & -4/\lambda M \\ 0 & -1 \end{pmatrix} = \begin{pmatrix} -1 & 0 \\ 0 & -1 \end{pmatrix}\begin{pmatrix} 1 & 4/\lambda M \\ 0 & 1 \end{pmatrix} \quad \text{(A.32)}$$

and $$(b) = \begin{pmatrix} -1 & 0 \\ 0 & -1 \end{pmatrix}\begin{pmatrix} 1 & 0 \\ 4/\lambda M & 1 \end{pmatrix} \quad \text{(A.33)}$$

The a-equivalent in equation (A.32) is that of an ideal transformer of ratio 1 : − 1 followed by a series capacitance. The b-equivalent is an ideal transformer followed by a shunt inductance.

A useful device will be illustrated by an example. If we have a stiff light lever, supported by a springy fulcrum, we need not write down the basic equations and solve them. We can proceed as follows. If we compare (A.21) with (A.13) we see that the substitution of a spring for a mass was effected by writing K/λ in place of λm. If in (A.26) and (A.27) we write $M = K/\lambda^2$ and $h^2 = 0$, we get the desired result,

$$(a) = \begin{pmatrix} -\dfrac{l_1}{l_2} & -\dfrac{\lambda}{K}\,\dfrac{(l_1 + l_2)^2}{l_1 l_2} \\ 0 & -\dfrac{l_2}{l_1} \end{pmatrix} \quad \text{(A.34)}$$

$$(b) = \begin{pmatrix} -\dfrac{l_2}{l_1} & 0 \\ -\dfrac{\lambda}{K}\,\dfrac{(l_1 + l_2)^2}{l_1 l_2} & -\dfrac{l_1}{l_2} \end{pmatrix} \quad \text{(A.35)}$$

This method can be used for more complex frequency transformations.

We shall now consider some more general aspects of the a- and b-equivalents. It is obvious that (a) and (b) are related. In fact $a_{11} = b_{22}$; $a_{12} = b_{21}$; $a_{21} = b_{12}$; $a_{22} = b_{11}$. This can be expressed by writing

$$\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} . (a) . \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} = (b)$$

and $$\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} . (b) . \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} = (a) \quad \text{(A.36)}$$

These multiplying coefficients appear in considerations of transducers. We note that

$$\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}\begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \quad \text{(A.37)}$$

Alternatively we can write

$$\begin{pmatrix} 0 & j \\ j & 0 \end{pmatrix} (a) \begin{pmatrix} 0 & -j \\ -j & 0 \end{pmatrix} = (b) \quad \text{(A.38)}$$

$$\begin{pmatrix} 0 & j \\ j & 0 \end{pmatrix} (b) \begin{pmatrix} 0 & -j \\ -j & 0 \end{pmatrix} = (a)$$

and writing $\begin{pmatrix} 0 & j \\ j & 0 \end{pmatrix} = (J)$; $\begin{pmatrix} 0 & -j \\ -j & 0 \end{pmatrix} = (-J)$ .. .. (A.39)

we have $(J) . (-J) = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$

and the very simple form

$$(J)\,(a)\,(-J) = (b)\,; \quad (J)\,(b)\,(-J) = (a) \quad \text{(A.40)}$$

If we now look at equations (22 — 25), we can see that we must have

$$(p)\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} = (q)\,; \quad (q)\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} = (p) \quad \text{(A.41)}$$

or in a symmetrical form $(q)\,(J) = (J)(p)$ (A.42)

It is the unsymmetrical appearance of the matrix $\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$ which is so embarrassing; it cannot be represented by a physical network, for its determinant is equal to − 1, not 1. We therefore choose our transformation so that we do not incorporate this matrix, whenever this is possible. The effect of this matrix is seen in the following example. Consider this "inverting transformer" as we have called it, connected in tandem with a shunt condenser. The resulting general circuit matrix is

$$\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}\begin{pmatrix} 1 & 0 \\ \lambda C & 1 \end{pmatrix} = \begin{pmatrix} \lambda C & 1 \\ 1 & 0 \end{pmatrix} \quad \text{(A.43)}$$

If this is considered to be the g.c.m. of a real network, the open-circuit input impedance is λC: in the absence of the "inverting" transformer it was $1/\lambda C$.

For an introduction to the use of matrix algebra in circuit work, reference should be made to Strecker and Feldtkeller, *E.N.T.*, 1929, Vol. 6, No. 3, p. 93.

Brit. I.R.E. Council

AT the recent annual general meeting of the British Institution of Radio Engineers, the following members were elected to the General Council: P. Adorjan (Rediffusion), J. W. Ridgeway (Ediswan), H. Brennan (Universal Relay, Gateshead), Lt.-Col. F. Taylor (War Office), T. D. Humphreys (Cossor), and M. M. Levy (Standard Telephones & Cables). The following members remain on the Council for a further 12 months:—G. A. V. Sowter (T.C.M.) Chairman, Sq.-Ldr. S. R. Chapman, L. H. Bedford (Cossor), Dr. N. W. McLachlan (Philco), W. W. Smith (C.E.B.), and J. Dimmick (Norwood Technical Institute).

I.E.E. Meetings

DR. D. C. ESPLEY will open the discussion on "The Sound Channel in the Television Receiver" at the meeting of the Radio Section of the Institution of Electrical Engineers at Savoy Place, Victoria Embankment, London, W.C.2, on Tuesday, December 19th, at 5.30.

At a meeting of the Cambridge and District Radio Group at 5.30, on January 2nd, at the Technical School, Collier Road, Cambridge, D. Q. Fuller and A. V. Lord will give a paper on "High Frequency Heating in Industry."

TESTING HIGH-FREQUENCY CABLES

A Resonance Line Method for the Measurement of Characteristics in the Decimetre Wave Range

By F. Jones, B.Sc. (Hons.), A.M.I.E.E., and R. Sear, B.Sc. (Hons.), A.Inst.P.

(Concluded from page 520 of the November issue)

SUMMARY.—In the previous issue a method of resonant line testing was given, and its practical application discussed. A description of the apparatus employed included a detailed account of the measuring lines, detectors, generators and wavemeters. In this concluding instalment of the paper the problems concerned with maintaining the accuracy of the method, and extending its usefulness are treated. A method of calibrating the measuring line is given. The effect that reactive discontinuities at the centre line support, and at the cable junction, have on measurements is investigated. Attention is paid to phenomena associated with the detector, and to the special difficulties encountered in testing twin cables. The appendix is a full treatment of the theory of the method.

The symbols used were defined in the previous issue.

3. Measuring Line Calibration

THE impedance Z_f at the junction of a short circuited measuring line and open circuited cable is given by,[3.4]

$$\frac{1}{Z_f} = \frac{1}{Z_0 \tanh (A + jB)L} + \frac{1}{Z_c \coth (\alpha + j\beta)l} \quad \ldots \quad (8)$$

$$= \frac{1}{Z_0} \cdot \frac{1 + j \tanh AL \tan BL}{\tanh AL + j \tan BL} + \frac{1}{Z_c} \cdot \frac{\tanh \alpha l + j \tan \beta l}{1 + j \tanh \alpha l \tan \beta l}$$

Rationalising and equating reactance components to zero

then

$$\frac{1}{Z_0} \cdot \frac{\tan BL_1(1 - \tanh^2 AL_1)}{\tanh^2 AL_1 + \tan^2 BL_1} = \frac{1}{Z_c} \cdot \frac{\tan \beta l(1 - \tanh^2 \alpha l)}{1 + \tanh^2 \alpha l \tan^2 \beta l} \quad \ldots \quad (9)$$

Equation (9) is the condition for resonance of the combined system of the line and cable. If $\tanh^2 AL_1$ and $\tanh^2 \alpha l \ll 1$, $\tanh^2 AL_1 \ll \tan^2 BL_1$, and $\tan^2 \beta l \ll 1$, then equation (9) reduces directly to

$$Z_0 \tan BL_1 = Z_c \cot \beta l \quad \ldots \quad \ldots \quad (10)$$

If δL_1 indicates a small amount by which the line length for resonance of the combined system differs from the length at which the measuring line alone resonates, and if δl is the amount by which the cable differs from a resonant length

that is

$$\delta L_1 = L_1 - \frac{(2n' + 1)\pi}{2B} \quad \text{and} \quad \delta l = l - n\pi/\beta$$

then $$Z_0/B\delta L_1 = -Z_c/\beta\delta l \quad \ldots \quad \ldots \quad (11)$$

Since $B/\beta = v/_c$ and $v = 1/CZ_c$ equation (11) may be written as

$$Z_0 = -\delta L_1/Cc\delta l \quad \ldots \quad (12)$$

Equation (12) may be used to determine the characteristic impedance of a measuring line. A cable of good uniformity, and insulated with a material such as polythene, whose dielectric constant is known not to vary appreciably with frequency, is required. Its capacitance C per cm. is measured on a low frequency bridge. A length of the cable slightly in excess of $n\lambda_c/2$ is connected to the measuring line, and successive short lengths cut off until it is slightly less than $n\lambda_c/2$, the corresponding measuring line lengths for resonance of the combined system being observed at each stage. A plot is made of cable length against line length, and this gives a straight line over the region near $\delta L_1 = 0$. Z_0 is derived by inserting the gradient of this line for $\delta L_1/\delta l$ in equation (12).

It is advisable when thus calibrating a measuring line to repeat the determination for various values of n, to check the uniformity of the cable employed. Values of $\delta L_1/\delta l$ consistent to $\pm 1\%$ should be obtained for a satisfactory calibration.

Where several measuring lines are in use, it is convenient to calibrate one by the above method, and to use this as a standard against which other lines may be calibrated. The procedure is identical with that described, except that the standard line takes the place of the cable, successive changes in line length being read directly on the scales provided. If both lines are air-insulated,

$\beta = B$, and the gradient $\delta L_1/\delta l$ is simply the ratio of their characteristic impedances.

The value of Z_0 obtained for unbalanced measuring lines using a polythene insulated

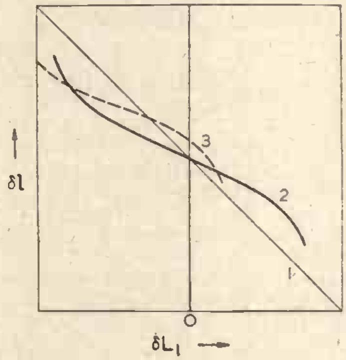


Fig. 9. *δλ against* δL_1.

cable as the standard, is found to agree to within 1% with that calculated from the well known formula for an air-insulated line.

$$Z_0 = 138 \log_{10} D/d \quad \ldots \quad \ldots \quad (13)$$

where D = inside diameter of outer conductor

d = outside diameter of inner conductor.

When an appreciable reactance exists in the junction of the two lines, or of the line and cable, a non-linear plot of δl against δL_1 is obtained in the region $\delta L_1 = 0$. Regard this reactance as composed of a distributed component terminated by a "lumped" component. Then letting the distributed portion effectively lengthen the standard line or cable by θ/β and letting the lumped portion be $1/J$, equation (10) becomes

$$Z_0 \tan(\beta\delta l + \theta) = -Z_c(\tan B\delta L_1 + JZ_0) \quad \ldots \quad \ldots \quad (14)$$

where δl and δL_1 are as previously defined.

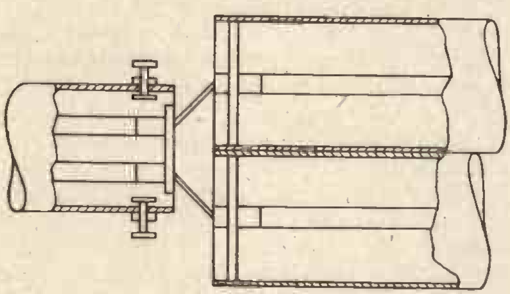


Fig. 10. *Connections for balanced line calibration.*

The effect of the distributed component θ/β is such as to put the zero from which δl is measured in error, so that θ includes all causes of zero error. Fig. 9 shows diagrammatically the effect on a plot of δl against δL_1 of measuring δl from a false zero. Curves 1 and 2 are obtained for $Z_c = Z_0$ and $Z_c < Z_0$ respectively when $\beta = B$ and $\theta = 0$. Curve 3 shows the effect on Curve 2 of a zero error θ/β in δl. If $\tan \beta\delta l$ is plotted against $\tan B\delta L_1$, conditions 1 and 2 both give straight lines, but 3 remains curved. This is also true if $\beta \neq B$.

Differentiating equation (14)

$$\frac{d(\tan \beta\delta l)}{d(\tan B\delta L_1)} = -\frac{Z_c}{Z_0}\left[\frac{(1 - \tan\theta \tan\beta\delta l)^2}{1 + \tan^2\theta}\right] \quad \ldots \quad \ldots \quad (15)$$

If the plot of $\tan \beta\delta l$ against $\tan B\delta L_1$ is non-linear, the gradient may be measured for various values of δl, and equation (15) solved for θ. Tan $(\beta\delta l + \theta)$ plotted against

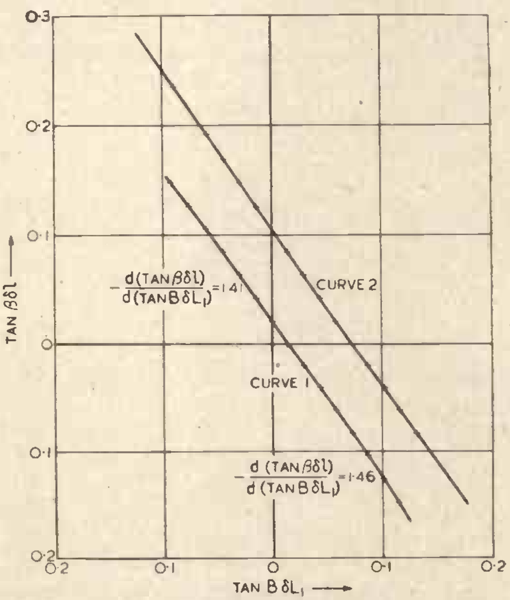


Fig. 11. *Balanced line calibration.*

$\tan B\delta L_1$, now gives a straight line of gradient $-Z_c/Z_0$.

A case in which the application of this correction has been found necessary, is in the calibration of a balanced twin line against two unbalanced lines of identical construction which have themselves been previously calibrated. This indirect procedure becomes necessary as the direct calibration of a balanced line against a twin cable may not be satisfactory owing to "velocity unbalance" effects in the cable.

The lines are arranged as shown in Fig. 10, the two unbalanced lines when connected together as shown behaving as a balanced line of characteristic impedance double that of each line. Fig. 11 shows the results that were obtained at about 200 Mc/s in such a calibration. Curve 1 is a plot of $\tan \beta\delta l$ against $\tan B\delta L_1$ where L_1 refers to the balanced line and l to the two unbalanced lines. Each unbalanced line had a characteristic impedance of 107Ω, and therefore for the two connected together $Z_c = 214\Omega$ The values of $d(\tan \beta\delta l)/d(\tan B\delta L_1)$ at $\tan\beta\delta l = +0.1$ and -0.1 were 1.41 and 1.46 respectively. Substitution of these values in equation (15) gave $\tan \theta = 0.085$ and the resulting plot, curve 2, of $\tan (\beta\delta l + \theta)$ against $\tan B\delta L_1$ gave a straight line of gradient 1.445 corresponding to $Z_0 = 148\Omega$ for the balanced line. For the same line, a value of 146Ω was obtained by calibration against a twin cable. A theoretical value of 151Ω is obtained from the approximate formula

$$Z_0 = 276 \log_{10}\left[\frac{2D\,(1 - h^2)}{d(1 + h^2)}\right] \quad \cdots \quad (16)$$

There d = outer diameter of inner conductors.

D = separation of centres of inner conductors.

D_s = inner diameter of screen.

$h = D/D_s$

The value adopted was 148Ω to $\pm 1\Omega$. The discrepancy between this value and that yielded by equation (16) is greater than can be accounted for by experimental error.

This treatment of junction effects can only be expected to apply when these are small. The balanced line calibration against two unbalanced lines was repeated at about 600 Mc/s, with a consequent increase in the curvature of the plot of $\tan\beta\delta l$ against $\tan B\delta L_1$. In that case it became necessary to stipulate a more complex circuit to simulate the junction effect, and this was unsatisfactory for a calibration. However, with more usual connections, e.g. the coaxial cable connectors described in Section 2 (i), no such curvature is obtained, even at 600 Mc/s. Nevertheless, most junctions cause some discontinuity, and at some frequency, effects similar to those described will be evidenced. The treatment given is therefore of value in extending the frequency range over which the relationship expressed by equation (12) may be applied.

It should be understood that equation (8) assumes that the measuring line is short-circuited at the detector, and ignores the effect of the thermocouple and the length of the piston beyond it. If this effect is allowed for, it is found to contribute only to J in equation (14), and therefore does not affect the results.

Equation (12) has several applications[12] in addition to the measuring line calibrations described. The most important of these is the direct measurement of the high frequency capacitance of cables. The procedure is identical with that described for a measuring line calibration. Z_0 is now known, and C is the unknown in equation (12). The method has been found particularly useful in measurements on unscreened twin cables. The capacitance of such cables depends on the proximity of local earthed objects, and should be measured under the same conditions as the resonant peak width, since it is required for the evaluation of both α and Z_c. The present method permits both the capacitance and curve width to be measured without moving the cable. The method is also useful for measurements on cables insulated with materials whose permittivity is not independent of frequency, e.g. polyvinyl chloride.

The procedure may also be adapted to the investigation of cable uniformity. Local irregularities in a cable are observed as a departure from linearity in the plot of δl against δL_1 and more gradual changes in the cable dimensions as differences in the gradients obtained for successive values of n.

Equation (12) is useful for calculating the length to be removed from a cable which is somewhat longer than a resonant length, to bring it exactly to resonance in a single cut. This is advantageous for large cables where cutting is laborious.

4. The Effect of Reactive Discontinuities on Attenuation Measurement.

In the use of equation (1), it is assumed that at no point in the combined system of the measuring line and cable is there any reactive discontinuity. In practice such a discontinuity exists at the junction of the measuring line and cable, and again at the support spacing the conductors of the measuring line. In this section a theoretical treatment of both these effects is given, together with an account of some experimental work which has been conducted to substantiate the theories developed.

(i) *Discontinuity at the junction of Measuring Line and Cable.*

Let the measuring line length for resonance be $(L_0 - a)$, where a would be zero in the absence of any discontinuity at the junction, when a resonant length l_0 of cable is connected to it. Further, let the measuring line length for resonance be L_1 when a length l of cable differing by a small amount from l_0 is connected to it.

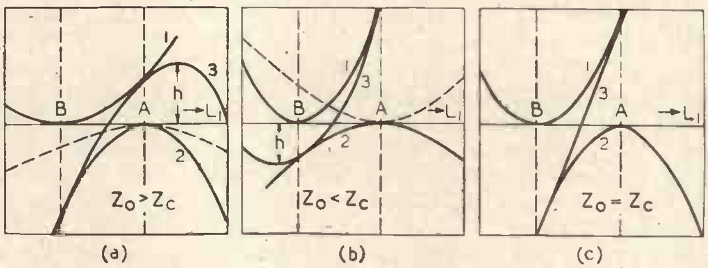


Fig. 12. *Effects of junction discontinuity.*

Then the cable attenuation is given by equation $A/29$ of the Appendix.

$$\alpha = \frac{B\Delta L Z_c \sec^2 B(L_0 - L_1)}{2lZ_0 \sec^2 \beta(l - l_0)} \quad .. \quad (17)$$

From equation (11)

$$(l - l_0) = \frac{BZ_c (L_0 - L_1 - a)}{\beta Z_0} \quad .. \quad (18)$$

and equation (17) may be written as

$$\alpha = \frac{B\Delta L Z_c}{2lZ_0}\left[\frac{\sec^2 B(L_0 - L_1)}{\sec^2\{BZ_c(L_0 - L_1 - a)/Z_0\}}\right] \quad .. \quad .. \quad (19)$$

Since ΔL_0 is the resonance curve width when the cable length is l_0 and $a = 0$

$$\alpha = \frac{B\Delta L_0 Z_c}{2l_0 Z_0} \quad .. \quad .. \quad .. \quad (20)$$

Provided l is not very different from l_0

$$\frac{\Delta L}{\Delta L_0} = \frac{\sec^2\{BZ_c(L_0 - L_1 - a)/Z_0}{\sec^2 B(L_0 - L_1)} \quad (21)$$

Provided $(L_0 - L_1) \ll \lambda_a$ and $a \ll \lambda_a$, equation (21) approximates to

$$\frac{\Delta L}{\Delta L_0} = 1 + [BZ_c(L_0 - L_1 - a)/Z_0]^2 - [B(L_1 - L_0)]^2 \quad .. \quad .. \quad (22)$$

The bracketed terms on the R.H.S. of equation (22) give the effect on ΔL as the cable length is varied, of the cable length variation and the change in line length for resonance respectively. Figs. 12(a) and 12(b) show diagrammatically the variation of $\Delta L/\Delta L_0$ with L_1 for $Z_0 > Z_c$ and $Z_0 < Z_c$ respectively. In each case curves 1 and 2 show the separate contributions of the two bracketed terms in equation (22), whilst curve 3 shows the total effect of varying the cable length. The dotted curve shows the result when $a = 0$.

In Figs. 12 (a) and 12 (b), A is the point $L_1 = L_0$, i.e. measuring line resonant, and B is the point $L_1 = L_0 - a$, i.e. cable resonant. The intersection of curve 3 on $\Delta L/\Delta L_0 = 1$ is given by

$$L_0 - L_1 = \frac{aZ_c}{Z_c \pm Z_0} \quad .. \quad .. \quad (23)$$

in both cases.

The maximum value of $\Delta L/\Delta L_0$ in curve 3 of Fig. 12 (a), and the minimum value in curve 3 of Fig. 12 (b) are given by

$$\Delta L/\Delta L_0 = 1 + h \quad .. \quad .. \quad (24)$$

where

$$h = \frac{a^2B^2Z_c^2}{Z_0^2 - Z_c^2} \quad .. \quad .. \quad (25)$$

and the position at which both these values occur is given by

$$L_0 - L_1 = \frac{aZ_c^2}{Z_c^2 - Z_0^2} \quad .. \quad .. \quad (26)$$

When $Z_c = Z_0$, equation (22) reduces to

$$\Delta L/\Delta L_0 = 1 - aB^2(2L_0 - 2L_1 - a) \quad (27)$$

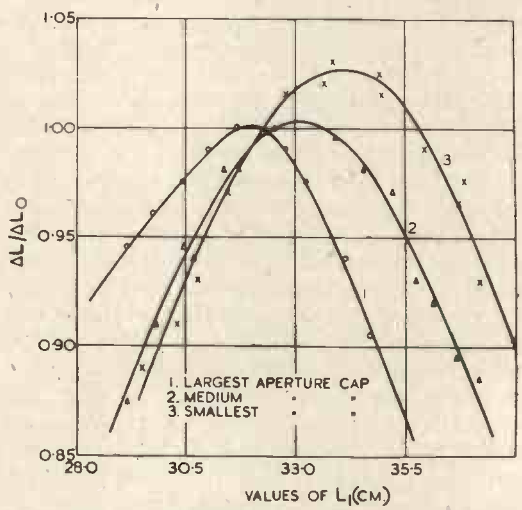


Fig. 13. *Error in curve width for $Z_0 > Z_c$.*

The variation of $\Delta L/\Delta L_0$ against L_1 is now a straight line as shown in Fig. 12 (c), with a gradient of $2aB^2$. The intersection of this line on $\Delta L/\Delta L_0 = 1$ is given by

$$L_0 - L_1 = a/2 \quad .. \quad .. \quad (28)$$

This provides a simple method of determining a, the reactive effect at a junction, since

$$a = \text{measured gradient } /2B^2 \quad .. \quad (29)$$

When $a = 0$, the horizontal line $\Delta L/\Delta L_0 = 1$ is obtained.

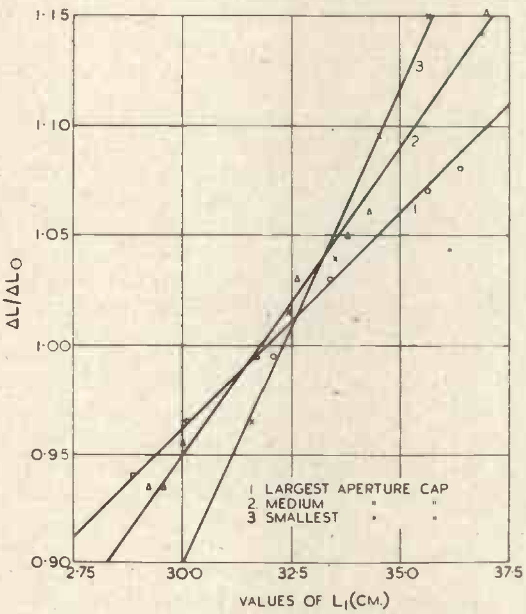


Fig. 14. *Error in curve width for $Z_0 = Z_c$.*

Fig. 13 shows the results that were obtained when a coaxial cable of characteristic impedance 71Ω was taken through its resonant length in short steps at a frequency of about 600 Mc/s. The measuring line characteristic impedance was 107Ω. Connecting caps of the type described in Section 2 were used, the three curves corresponding to caps of various size apertures. The results obtained are anticipated from equation (22), but the magnitudes do not permit of quantitative comparison.

Fig. 14 shows the results obtained using the same three connecting caps, but with a cable of 102Ω characteristic impedance. This gave a condition sufficiently near $Z_0 = Z_c$ for linear plots to be obtained in accordance with equation (27).

The junction effects deduced from the gradients of these straight lines according to equation (29) are shown in Table I.

TABLE I

Diameter of Connecting cap aperture	a cm.
2.6 cm.	0.57
1.3 ,,	0.83
0.8 ,,	1.28

A knowledge of a permits the use of equation (22) and the application of the method to the measurement of the attenuation of cables which differ from resonant lengths.

For routine purposes it is more convenient to employ the particularised equation (20). This is achieved by cutting the cable so that resonance occurs about midway between the positions for resonance obtained for the measuring line with and without the cap attached and no cable connected. In this way the conditions of equation (23) are approximately satisfied. With the worst of the three caps mentioned, an error within $\pm 1\%$ in the measurement of ΔL_0 at about 600 Mc/s is incurred in this way. This precaution only becomes necessary, even for the smallest aperture cap, above about 300 Mc/s. The accuracy of measurement of the velocity ratio is only slightly affected by the procedure.

(ii) *Discontinuity at the Measuring Line Support.*

Consider a measuring line A B as shown in Fig. 15, with the conductance G it is required to measure connected at the open end A, and a "lumped" susceptance jH connected across the conductors at a point C distant x from the detector at B.

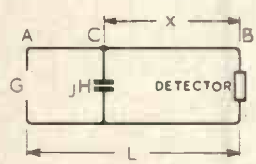


Fig. 15.

If Y is the admittance of jH in parallel with that portion of the line $(L - x)$ terminated by G then

$$YZ_0 = jHZ_0 + \tanh [P(l - x) + \tanh^{-1} GZ_0] \quad .. \quad .. \quad (30)$$

Consider the portion of the line from the detector up to but not including jH as being used to measure Y.

When the line is tuned to resonance, and by substitution of the appropriate quantities in equation (A/23) of the Appendix,

$$jHZ_0 + \tanh [P(L_1 - x) + \tanh^{-1} GZ_0] = \tanh [B\Delta L/2 + jB(L_0 - x)] \quad \ldots \quad (31)$$

Equating the imaginary parts of equation (31) to obtain the condition for resonance, and using the expansion given in equation (A/25)

$$HZ_0 + \tan B(L_1 - x) = \tan B(L_0 - x) \quad (32)$$

Equation (32) may be expanded to give

$$L_0 - L_1 = \left\{\tan^{-1}\left[\frac{HZ_0}{1 + HZ_0 \tan B(L_1 - x) + \tan^2 B(L_1 - x)}\right]\right\}/B \quad \ldots \quad \ldots \quad (33)$$

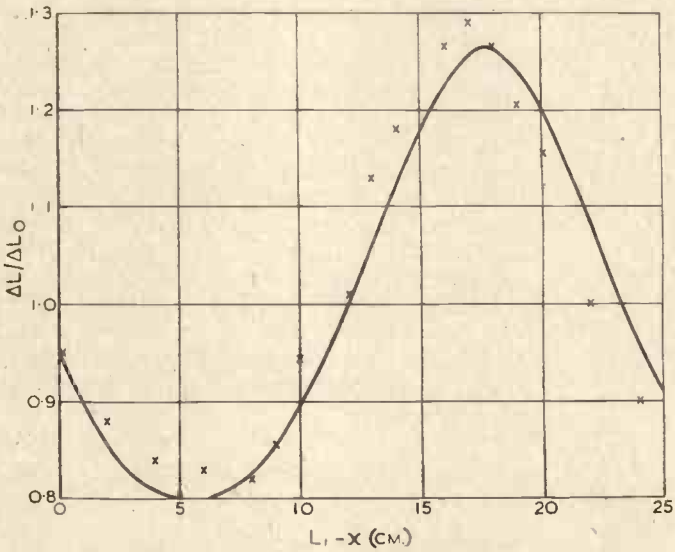


Fig. 16. *Effect of a reactance along the line.*

Equating the real parts of equation (31) and again using equation (A/25) then

$$[A(L_1 - x) + \tanh^{-1} GZ_0] \sec^2 B(L_1 - x) = B\Delta L \sec^2 B(L_0 - x)/2 \quad \ldots \quad (34)$$

When $H = 0$, $L_1 = L_0$ and $\Delta L = \Delta L_0$. Then neglecting $A\ (L_1 - x)$, equation (34) gives

$$\frac{\Delta L}{\Delta L_0} = \frac{\sec^2 B(L_1 - x)}{\sec^2 B(L_0 - x)} = \frac{1 + \tan^2 B(L_1 - x)}{1 + \tan^2 B(L_0 - x)} \quad \ldots \quad \ldots \quad (35)$$

Eliminating $\tan B\ (L_0 - x)$ between equations (32) and (35)

$$\frac{\Delta L}{\Delta L_0} = \frac{1 + \tan^2 B(L_1 - x)}{1 + [\tan B(L_1 - x) + HZ_0]^2} \quad \ldots \quad \ldots \quad (36)$$

Equations (33) and (36) express respectively the changes in line length for resonance and the resonance curve width due to the introduction of a susceptance jH at an arbitrary distance $(L_1 - x)$ from the end A of the line.

The purpose of the treatment above was primarily to investigate the errors caused by ignoring the presence of any reactance due to the insulating disc which supports the inner conductor of an unbalanced measuring line, or the twin conductors of a balanced line, symmetrically with respect to the outer conductor.

An experiment was conducted at about 600 Mc/s in which this disc was of keramot and 0.25in. thick. G was a loading conductance of a suitable value. The resonance curve width and the displacement of the piston position for resonance were observed for each setting of the disc as it was moved in successive steps down the measuring line. The values obtained are shown as the crossed points of Figs. 16 and 17.

The value of $(L_0 - L_1)$ when $L_1 = x$ was substituted in equation (33) to give HZ_0, and the latter value was then used to obtain the theoretical curves for equations (36) and (33). These are shown in Figs. 16 and 17. The agreement between these curves and the experimental points is seen to be good.

When the spacing disc is situated at the end A of the measuring line, the correction for it may be included in that due to the junction, which is treated in the first part of this section. If the disc is moved in slightly, and this is usually desirable to facilitate external connections to the line, a rapid deviation from this relatively simple correction results. In order to reduce the magnitude of these effects, it is necessary to reduce as much as possible the magnitude of the susceptance jH. This has been achieved by using polystyrene spacers, 0.125in. thick and cut away to leave only sufficient material for mechanical strength. For all positions of these discs on a measuring line, and at the frequencies considered here, it is found that $\Delta L = \Delta L_0$ to within $\pm \cdot 1\%$.

The curves of Figs. 16 and 17 are of interest. It is commonly thought that a capacitive discontinuity placed across a resonant measuring line has its maximum effect if placed at a voltage antinode. Fig. 17 shows this to be true of the effect on the line length for resonance, but Fig. 16 shows that the maximum effects on conductance occur when the loading capacitance is situated intermediately between a voltage node and an antinode. They are alternatively positive and negative in sign in successive quarter wavelengths of the line. The two positions at which zero error is incurred are at a voltage node, and again at some distance, dependent on the value of the capacitance, from the voltage antinode. The variation in the error, with an appreciable capacitance, in the neighbourhood of both these positions is extremely rapid, and very critical positioning is required for the effect to be eliminated.

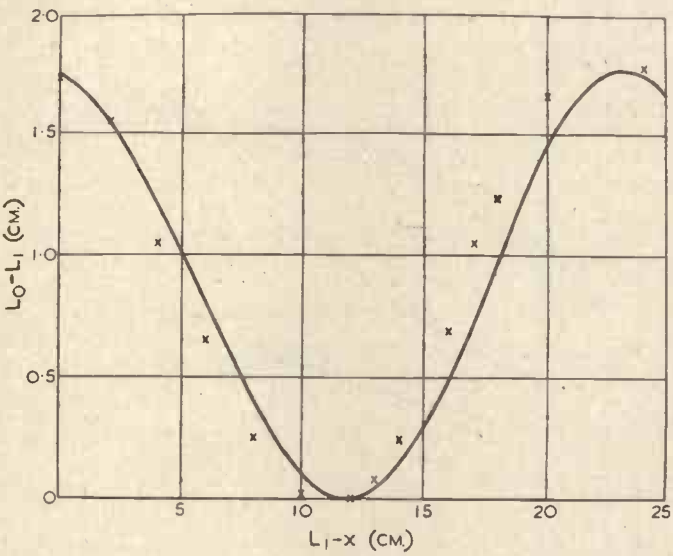


Fig. 17 (Above). *Effect of a reactance along the line.*

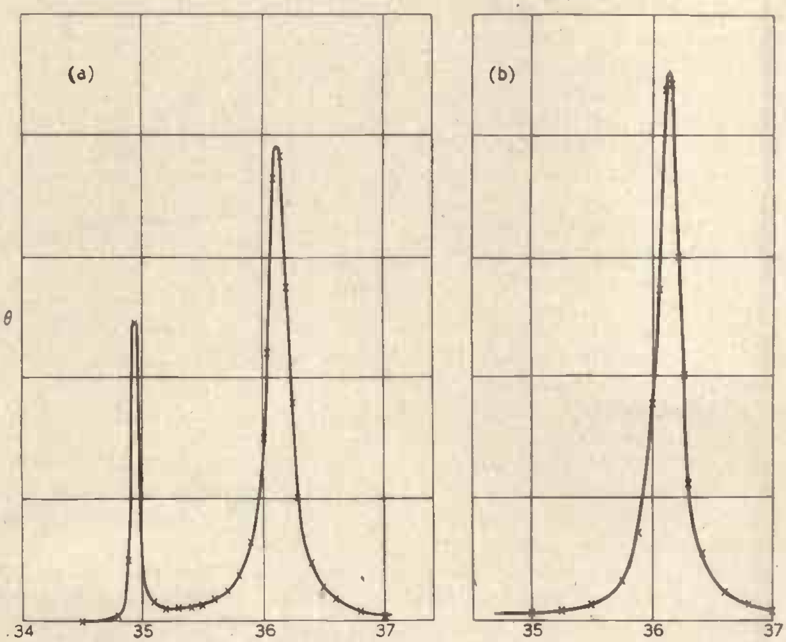


Fig. 18 (Right). *Resonance curves for the balanced line. (a) With unbalanced injection, (b) with balanced injection.*

An analogous treatment by A. L. Meyers[13] for the reactive loading of a cable, shows that the effect on the propagational characteristics of the cable depends on the position of the capacitance in a similar manner.

5. Investigation of Thermocouple Failure in Balanced Lines

In the discussion of thermocouples a form of breakdown was mentioned, which resulted in the detection of double peaks on the balanced lines when the injection was slightly unbalanced. The thermocouples were normal in other respects. The following investigation was undertaken to explain the failure.

Preliminary experiments were performed on a balanced line, using a thermocouple on which the breakdown was pronounced. A resonance curve containing the two peaks was plotted at 200 Mc/s, with the injection probes adjusted for approximately equal injection in the normal way, but without special care being taken. The experiment was repeated after carefully adjusting one probe to minimise the secondary peak. The Figs. 18 (a) and 18 (b) respectively, show the curves obtained. This was supplemented by another experiment, in which the centre conductors of the measuring line were short-circuited with a straight wire connector. In this way, resonance of the balanced mode of propagation was prevented for this line length. It was found that a resonance was still obtained in the same position at which the secondary peak had appeared. Since this could only be due to a concentric mode of resonance, as the harmonics generated by the oscillator were inappreciable, it is evident that the breakdown was due to the thermocouple becoming unduly sensitive to the concentric mode of propagation. From the first experiment it appears that this mode of propagation becomes existent when the injection system is electrically unbalanced, but that with normal thermocouples, while still existing, it is not detected.

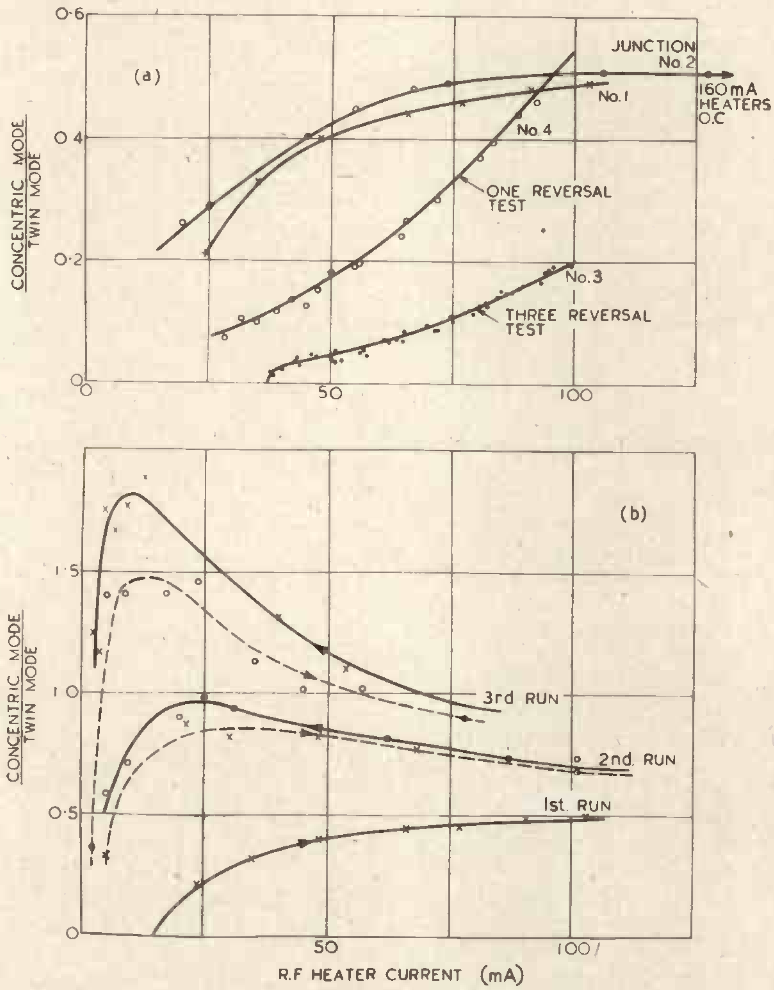


Fig. 19. (*a*) *Relative peak values; thermocouples Nos.* 1–4; (*b*) *relative peak values; thermocouple No.* 1.

To explain the failure, four new thermocouples were successively mounted in a balanced line. The relative amplitudes of the two peaks was observed in each case, as the coupling to the oscillator, and consequently the heater current, were increased. The injection was made by a single probe in order to obtain its maximum unbalance, and hence to facilitate the detection of the concentric mode of propagation. This was supplemented in every case by taking insulation resistance measurements, with apparatus capable of measuring up to 10MΩ, between the heater and couple. For two thermocouples microphotographs of the couple were taken before and after testing, and their d.c. sensitivities also measured, with a view to establishing heater-couple movement.

The thermocouples were numbered 1 to 4, and initially No. 1 was subjected to increasing current at 200 Mc/s, the ratio of the peak values of the concentric and balanced mode resonances being noted. It was then subjected to a cycle of heater current 0-100-0 mA, which was repeated at intervals. The results are contained in Fig. 19. The values of current were calculated from the d.c. rating and the galvanometer and couple resistance, assuming inappreciable skin effect of the heater wire current. No. 2 was tested to heater burn-out, this occurring at 160 mA as shown in curve 2 of Fig. 19 (a). Thermocouples Nos. 3 and 4 were then subjected to 0-100-0 mA cycles of heater current. The results are given in curves 3 and 4 of Fig. 19 (a). In both of these cases the curves were repetitive and the performance of thermocouple No. 1 was not repeated. The d.c. sensitivities after testing had decreased slightly from the initial values. For all four thermocouples the continuous check of the heater-couple insulation resistance gave values greater than 10 MΩ. The microphotographs taken indicated only that no major change in the shape of the dielectric bead had taken place. Small changes of shape were obscured by possible slight changes of the camera angle.

The shape of the curves obtained is not readily explained, due to the obscurity of the conditions of the injection and the complex nature of the effect. From Fig. 19(a) it is seen that the curves obtained differ greatly in shape. Since all the junctions were new it follows that some characteristic is capable of wide variation. The most probable variant is the heater to couple capacitance. With this assumption, a tentative deduction is that the steepness of the curves at low heater currents is related to this capacitance. The larger this capacitance, the more appreciable is the high frequency current which tends to flow through it. The heating effect in the dielectric already present from the heater wire is consequently intensified, and the tendency to melting is increased. In Fig. 19(a) the curves for Nos. 1 and 2 are similar, and also curves for Nos. 3 and 4 are similar. Those for Nos. 3 and 4 proved to be exactly repeatable on cyclic runs, while the curve for No. 1 displayed the variations of Fig. 19(b). As thermocouple No. 2 was tested to destruction, similar cycles could not be obtained. A point of significance arising from the test on No. 2 is that the dielectric bead must have melted at some heater current less than 160 mA, since the construction is only possible if the fused bead does not melt the heater wire and couple when they are mounted. The curves of Fig. 19(b) indicate that melting does actually occur, allowing heater and couple to move relatively, in this case, successively closer to each other in view of the enhanced slope at small heater currents, and the higher peak ratios. This view is supported by the observation of the thermocouples in production testing lines. In a number of cases failure has occurred through the heater and couple coming into direct contact. The thermocouples 3 and 4 provide slight corroborative evidence in that no successive breakdown occurred while a slight decrease in d.c. sensitivity was obtained. This indicates relative movement of the heater and couple, but in a direction which has decreased the capacitance. The movement must have been small as evidenced by the reversal curves, particularly for the thermocouple No. 4.

The evidence obtained indicates that the heater and couple are capable of relative movement and consequently that melting or softening of the dielectric bead occurs. Two other items of value are also obtained from the experiments. From Fig. 19(a) the selection of thermocouples for use with balanced measuring lines becomes possible as the thermocouples 3 and 4 show a resistance to breakdown on overloading. The second consideration is that balanced line thermocouples should be used with as low values of heater current as is practicable.

6. Velocity Unbalance in Twin Cables

Velocity unbalance is the term used to express the occurrence of a phase difference between the propagations along the two conductors of a twin cable. One cause of this is a difference in the effective dielectric constants of the media surrounding the conductors, giving rise to different velocities of propagation. A second cause is uneven twisting together of the cores, giving different physical lengths to the conductors. Reactive discontinuities along a cable length give rise to phase changes, and if such discontinuities are unequal for the two conductors, they constitute a third cause of velocity unbalance. Variations of dielectric constant and uneven twisting may contribute to this third cause, but reactive discontinuities are mainly due to variations in the distance of the conductors from the screen of a cable. A uniform difference in the distance of the two conductors from the screen gives rise to a capacitance unbalance, sometimes known as the coefficient of asymmetry of a twin cable, but not to velocity unbalance. In practice there is found to be little correlation between the measured values of velocity and capacitance unbalance.

The causes of velocity unbalance enumerated above may occur systematically along a length of cable and produce an additive effect, or they may occur locally and partially cancel out over a length of cable. The presence of velocity unbalance may be more easily detected in the former than in the latter case, but in either case it is to be expected that the high frequency characteristics of the cable, and the attenuation in particular, will be affected.

In the investigation of thermocouple breakdown, it was found that unequal amplitudes of injection to the two conductors of a balanced measuring line give rise to a concentric mode of propagation in addition to the normal balanced mode, and that the concentric mode is capable of detection by the thermocouple. The concentric mode of propagation is also produced if the conductors of a balanced measuring line are subjected to unequal reactive loading. With an unloaded line and a balanced injection, no concentric mode is found to be present. If the injection is now unbalanced, a concentric mode is detected, but this may be eliminated by introducing a suitable capacitance between the screen and the appropriate conductor. Alternatively, the concentric mode may be produced by introducing a capacitance between one conductor and the screen, and practically eliminated by suitably unbalancing the injection.

When a twin cable is connected to a balanced measuring line, and cut to resonance, the effect, if the cable possesses a velocity unbalance, is to produce unequal reactive loading of the conductors of the measuring line and the concentric mode of propagation appears. A combination of two resonance curves is observed, and the width of the curve corresponding to the balanced mode of propagation cannot be measured until the concentric mode has been eliminated. This can be achieved by suitably unbalancing the injection, but it is more convenient to maintain a balanced injection and to introduce a "lumped" capacitance at the open end of the measuring line which compensates for the unequal loading of the two conductors by an unbalanced cable. This balancing procedure has been previously described in detail. For the measuring line alone, the injection balance required to eliminate the concentric mode may be rather critical, depending on the sensitivity of the thermocouple to this mode, which has been shown to be variable. When a cable is connected to the line, however, it is found for normal thermocouples that the injection balance required is not critical, and provided that the two injection probes appear to be approximately equidistant from their respective conductors, an undistorted resonance curve is always obtained after the capacitance balancing procedure has been completed. It is known that this curve may be broader than would be obtained with a cable having no velocity unbalance. Although increased losses are likely in a cable possessing velocity unbalance, it is not known if this broadening of the resonance curve measures the actual increase in attenuation of the cable, as the measurements are made under artificial conditions. This is not very important in production testing, since for cables of normally good construction the attenuations as determined by the present method vary within relatively narrow limits, and in any case a twin cable of bad velocity unbalance is an unsatisfactory product.

The effect that a velocity unbalance at any one point in a cable has on its characteristics, depends on the magnitude of the unbalance occurring at that point and on the voltage and current distribution in the conductors. Therefore changes in frequency cable length or terminating impedances which affect the distribution will change the magnitude of the effects due to the velocity unbalance. This is illustrated by the results shown in Fig. 22 of an experiment to be described. It follows that unless it occurs uniformly along a cable length, it is not possible to define a quantitative measurement of velocity unbalance that has more than a very limited significance.

The balanced measuring line may be used to obtain a quantitative estimate of the velocity unbalance of a cable sample for the conditions of the test. The cable is originally slightly longer than $n\lambda_c/2$. Referring to Fig. 20, let L_a be the line length for resonance with condenser B shorted, L_b the line length for resonance with condenser A shorted, β_1 and β_2 the wavelength constants of conductors a and b respectively of the cable, L the line length for resonance with either A or B shorted before the cable is connected, and l the cable length.

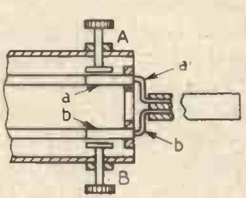


Fig. 20.

Initially the length l is such that L_a and L_b are smaller than L. If L_a is greater than L_b then condenser B is shorted, and the cable is cut until $L_a = L$. The cable conductor a is then resonant, and if l_1 is the cable length $\beta_1 = n\pi/l_1$ Condenser B is screwed back to its initial position and condenser A shorted. The cable is cut again until $L_b = L$, when the cable conductor b is resonant. If l_2 is the new cable length,

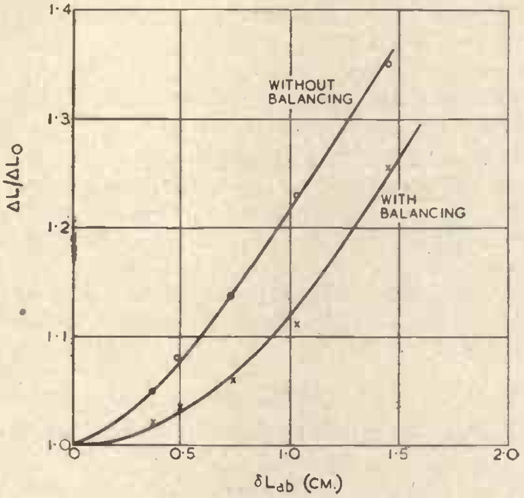


Fig. 21. *Effect of velocity unbalance.*

$\beta_2 = n\pi/l_2$. The velocity unbalance is then given by

$$V.U.B. = \frac{100(\beta_2 - \beta_1)}{(\beta_2 + \beta_1)/2} = \frac{100(l_1 - l_2)}{(l_1 + l_2)/2} \% \quad \ldots \quad (37)$$

This measurement refers to the specific conditions under which it is made, and usually has no other significance than indicating whether the cable should be classed as good or bad for velocity unbalance. If, however, the same value is obtained at various frequencies, or for different sections of the cable, the velocity unbalance may be assumed of uniform distribution, and the value obtained is applicable to any condition of use of the cable.

Some experiments have been made to show the effects of velocity unbalance at a frequency of about 600 Mc/s. For these experiments, two concentric cables were laid side by side with their returns connected together at both ends, so that they formed a screened twin cable. This cable was cut to resonance in the usual way.

Initially the cable had zero velocity unbalance, and the resonant curve width ΔL_0 was observed in this condition. Various small capacitances were introduced between the screen and one conductor near the far end of the cable, and resonant curve widths ΔL were observed both with and without the use of the measuring line condensers. Fig. 21 shows $\Delta L/\Delta L_0$ plotted against δL_{ab}, the difference between the measuring line lengths required to resonate separately the two conductors.

In another experiment, one value of the small unbalancing capacitance was chosen, and this was introduced at various points near a voltage antinode along the standing wave on the cable. Fig. 22 shows $\Delta L/\Delta L_0$ and δL_{ab} plotted against the distance of the unbalancing capacitance from a voltage antinode. The results show that the effect on attenuation measurements varies considerably with the position at which the unbalance is introduced.

The conditions of the above experiments only approximately represent those encountered in practice, as a normal twin cable was not used, and a "lumped" unbalance was introduced, instead of the random distributed unbalances that must normally occur.

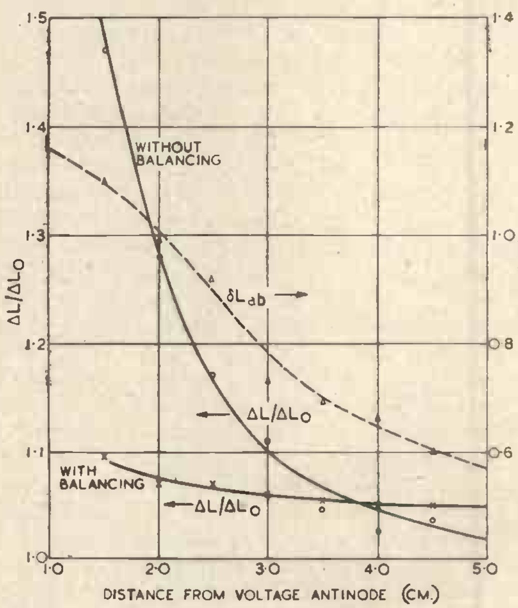


Fig. 22. *Effects of position of velocity unbalance.*

It may be said that sufficient is known about the effects of velocity unbalance in high frequency twin cables for the purposes of the routine examination of factory production, though there is scope for further work on this subject.

Conclusions

A method has been developed which is particularly suitable for the routine testing of high frequency cables in the decimetre wave range. It has been shown that speedy and accurate testing is possible provided cables are uniform. The effect of reactive discontinuities capable of producing error has been fully treated and a simple means for their correction is provided.

The treatment shows that the connecting caps for coaxial cables can cause appreciable errors, but that these may be minimised by a slight modification of the cable test length. The measuring line spacers used do not contribute appreciably to the effect. From the discussion of these spacers it is seen that the effect of a reactive discontinuity in the measuring line on conductance measurement is not a maximum when placed at a voltage antinode but at some distance therefrom. A method of calibration of the measuring lines for characteristic impedance has been described. The calibration is affected by reactive discontinuities, but these are normally negligible, and otherwise may be allowed for, provided they are small.

The necessary equipment has been developed to a stage which ensures reasonably trouble free testing. Difficulties which were encountered have been largely overcome, but further improvements could, nevertheless, be incorporated. Examples of these are mechanical improvements such as the permanent incorporation of a micrometer drive, the provision of mechanical stability of the rack and pinion, and improvement of the mechanical features of the injection. A wavemeter has been developed capable of extreme accuracy of setting, giving, with careful design, or with calibration, a comparable accuracy of measurement.

The testing of twin cables by the method is possible provided the velocity unbalance encountered is small. The presence of a velocity unbalance increases the cable attenuation in the electrical condition of test, and the increase is dependent on the position of the irregularities with respect to the standing wave distribution, but is small for small unbalances. It also gives rise to a concentric mode of propagation in addition to the balanced mode, and leads to the distortion of the resonance curve. The distortion produced requires correction with the balance condensers provided, to obtain correct conditions for measurement.

The investigation of thermocouple detectors reveals that these are capable of selection for use with balanced lines. The use of a detector in these lines which is insensitive to the concentric mode of propagation is desirable, since it would probably eliminate the need for any balancing procedure in twin cable testing. It is also shown that thermocouples should be used with working values of heater current well below the rated value.

The authors are indebted to Dr. E. W. Smith, under whose direction the work was performed, to Mr. A. L. Meyers for the contributions referred to, and to the Management of the Telegraph Construction and Maintenance Company for permission to make use of the information given in the paper.

APPENDIX

General Theory of Resonant Line Measurements

Consider a transmission line terminated by impedances Z_1 and Z_2 at its ends. The corresponding vector reflection coefficients are given by

$$\rho_1 = \frac{Z_1 - Z_0}{Z_1 + Z_0} \quad \ldots \quad \ldots \quad \ldots \quad (A/1)$$

$$\rho_2 = \frac{Z_2 - Z_0}{Z_2 + Z_0} \quad \ldots \quad \ldots \quad \ldots \quad (A/2)$$

Let a voltage E be injected into the impedance Z_1, and let V_2 be the voltage thereby developed across the impedance Z_2, then[1]

$$V_2 = E\left[e^{-PL} + \rho_2 e^{-PL} + \rho_1\rho_2 e^{-3PL} + \rho_1\rho_2{}^2 e^{-3PL} + \ldots\right]$$

$$= \frac{E(1 + \rho_2)}{e^{PL} - \rho_1\rho_2 e^{-PL}} \quad \ldots \quad \ldots \quad \ldots \quad (A/3)$$

In the case of a measuring line, the impedance Z_2 is the input impedance of the detector and short-circuiting piston. The current I_2 through the detector is proportional to V_2, and may be written

$$Kf(L) = \frac{K}{e^{PL} - \rho_1\rho_2 e^{-PL}} \quad \ldots \quad \ldots \quad (A/4)$$

where $f(L)$ has been shown[14] to be independent of the location and nature of the coupling of the source to the line, i.e. whether capacitive or inductive, and whether distributed or fed in at a point.

Let $\quad \rho_1\rho_2 = e^{-2(s + jt)} \quad \ldots \quad \ldots \quad (A/5)$

so that $\quad s = -\tfrac{1}{2}\log|\rho_1\rho_2| \quad \ldots \quad \ldots \quad (A/6)$

and $\quad t = -\tfrac{1}{2}\text{ phase } \rho_1\rho_2 \quad \ldots \quad \ldots \quad (A/7)$

then

$$f(L) = \frac{e^{s + jt}}{e^{PL+s+jt} - e^{-PL-s-jt}} = \frac{e^{s + jt}}{2\sinh(PL + s + jt)} \quad \ldots \quad \ldots \quad (A/8)$$

$$= \frac{e^{s + jt}}{2\sinh[AL + s + j(BL + t)]} \quad \ldots \quad (A/9)$$

and

$$|f(L)|^2 = \frac{e^{2s}}{4\,[\sinh^2(AL+s)+\sin^2(BL+t)]} \qquad \text{(A/10)}$$

If $A \ll B$, $|f(L)|^2_{max}$ occurs when $\sin(BL_1+t)=0$, so that

$$t = n'\pi - BL_1 \qquad \text{(A/11)}$$

Then

$$\frac{|f(L)|^2_{max}}{|f(L)|^2} = \frac{\theta_{max}}{\theta} = \frac{\sinh^2(AL+s)+\sin^2(BL+t)}{\sinh^2(AL_1+s)} \qquad \text{(A/12)}$$

where θ is the galvanometer deflection when the detector has a square law response.

In practice the line is detuned to half the maximum deflection on either side of the peak, so that $\theta_{max}/\theta = 2$.

From equation (A/11), and if $\delta L \ll L_1$, equation (A/12) approximates to

$$\sinh(AL_1+s) = \sin B\delta L/2 \qquad \text{(A/13)}$$

where $\delta L = 2(L-L_1)$ .. .. .. (A/14)

Provided that A, s and δL are small, equation (A/14) becomes

$$s = B\delta L/2 - AL_1 \qquad \text{(A/15)}$$

and using (A/6),

$$s = -\tfrac{1}{2}\log|\rho_1\rho_2| = B\delta L/2 - AL_1 \qquad \text{(A/16)}$$

When no external impedance is connected to the open end of the line, $|\rho_1| = 1$

and $s_0 = -\tfrac{1}{2}\log|\rho_2| = B\delta L_0/2 - AL_0$ .. (A/17)

To obtain the reflection coefficient for any external impedance $|\rho_2|$ is eliminated between (A/16) and (A/17). If $A(L_1-L_0)$ is negligible then

$$s - s_0 = -\tfrac{1}{2}\log|\rho_1| = B(\delta L - \delta L_0)/2 = B\Delta L/2 \qquad \text{(A/18)}$$

and $|\rho_1| = e^{-2(s-s_0)}$ .. .. .. (A/19)

Similarly from equations (A/7) and (A/11)

$$(t-t_0) = -\tfrac{1}{2}\,\text{phase}\,\rho_1 = -B(L_1-L_0) \qquad \text{(A/20)}$$

where $t_0 = -\tfrac{1}{2}\,\text{phase}\,\rho_2 = n'\pi - BL_0$;

then $\text{phase}\,\rho_1 = e^{-2j(t-t_0)}$ .. .. (A/21)

Hence $\rho_1 = e^{-2[(s-s_0)+j(t-t_0)]}$ .. (A/22)

From equations (A/1) and (A/22)

$$Z_0/Z_1 = (1-\rho_1)/(1+\rho_1) = \tanh[(s-s_0)+j(t-t_0)] \qquad \text{(A/23)}$$

The hyperbolic tangent can be expanded in Taylor's Series

$$\tanh(x+jy) = j\tan y + x\sec^2 y - jx^2\sec^2 y\tan y - \tfrac{1}{3}x^3\sec^2 y\,(3\sec^2 y - 2) + \ldots \qquad \text{(A/24)}$$

Provided $x \ll 1$, and y is not near $(2n+1)\pi/2$, equation (A/24) approximates to

$$\tanh(x+jy) = j\tan y + x\sec^2 y \qquad \text{(A/25)}$$

If G is the real part of $1/Z_1$, then provided that $(s-s_0) \ll 1$ and $(t-t_0)$ is not near $(2n+1)\pi/2$, the expansion given by equation (A/25) applied to equation (A/23) gives

$$GZ_0 = (s-s_0)\sec^2(t-t_0) \qquad \text{(A/26)}$$

and substituting for $(s-s_0)$ and $(t-t_0)$ from equations (A/18) and (A/20)

$$GZ_0 = [B\Delta L\sec^2 B(L_0-L_1)]/2 \qquad \text{(A/27)}$$

(A/27) is the general equation expressing the real part of a small admittance in terms of the width and position of the resonance curve produced on the measuring line.

The special case where it is required to measure the attenuation of a short cable length will now be considered. The input impedance Z_1 of an open circuited cable is given by [3,4]

$$1/Z_1 = Z_c\tanh(\alpha+j\beta)l$$

If αl is small and βl is not near $(2n+1)\pi/2$, then from the expansion given by equation (A/25), provided Z_c is real,

$$GZ_c = \alpha l\sec^2\beta l = \alpha l\sec^2\beta(l-l_0) \qquad \text{(A/28)}$$

Eliminating G between equations (A/27) and (A/28)

$$\alpha = \frac{B\Delta L Z_c\sec^2 B(L_0-L_1)}{2lZ_0\sec^2\beta(l-l_0)} \qquad \text{(A/29)}$$

In practice, measurements are made when both the measuring line and cable are separately resonant, i.e. when $L_1 = L_0$ and $l = l_0$ and consequently ΔL becomes ΔL_0. Equation (A/29) then reduces to

$$\alpha = \frac{B\Delta L_0 Z_c}{2l_0 Z_0} \qquad \text{(A/30)}$$

REFERENCES

[1] R. A. Chipman. *Journ. App. Phys.*, 1939, Vol. 10, p. 27.

[2] H. Bruckman, *Hochf:tech. u. Elek:akus.*, 1938, Vol. 51, p. 128.

[3] H. W. Malcolm, "Theory of the Submarine Telegraph and Telephone Cable," 1917, p. 213 (Book).

[4] A. Rosen *Journ. I.E.E.*, 1930, Vol. 68, p. 499.

[5] L. Hartshorn and W. H. Ward, *Journ. I.E.E.*, 1936, Vol. 79, p. 597.

[6] R. F. J. Jarvis and J. C. Simmonds, *P.O. Elect. Eng. Journ.*, 1943, Vol. 36, pp. 37 and 76.

[7] F. E. Planer, *Electronic Eng:g.*, 1943, Vol. 15, p. 452.

[8] L. Essen, *Journ. I.E.E.*, 1944, Vol. 91, Pt. III, p. 84.

[9] J. C. Slater, "Microwave Transmission," 1942, p. 39 (Book).

[10] F. Jones, *Journ. Sci. Insts.*, 1942, Vol. 19, p. 53.

[11] A. Hund, "High Frequency Measurements," 1933, p. 190 (Book).

[12] R. Sear, T.C.M. Co. Techn. Paper, H.F.T.2, 1941.

[13] A. L. Meyers, T.C.M. Co. Techn. Paper, H.F.T. 11, 1943.

[14] A. L. Meyers, T.C.M. Co. Techn. Paper, H.F.T. 14, 1941.

Indices

As is our custom the index to the Articles and Authors for the current volume is included in this issue.

The index to the Abstracts and References published throughout the year is in course of preparation and will, it is hoped, be available in February, priced 2s. 8d. (including postage). As supplies will be limited our Publishers ask us to stress the need for early application for copies.

CORRESPONDENCE

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

"Deflected Electron Beams"

To the Editor, "Wireless Engineer"

SIR,—Dr. Gabor shows by his letter in the October issue that he does not understand where the "slip" occurred. We cannot obtain the correct answer, which is

$$i_d = \frac{I_0 e E e^{j\omega t}}{d^2 \omega^2 m} (j\omega\tau - 1 + e^{-j\omega\tau})$$

simply by changing the middle term of Harries' equation (3.1). As may be seen from my own analysis for this over-simplified case[1], we must integrate keeping t constant in order to find the induced current corresponding to all electrons *momentarily* present in the condenser. Mr. Harries was possibly quoting some early work of Hollmann and Thoma (1937) which contained precisely the same error, namely that integration for the induced current was effected at t_0 constant.

Mr. Jenkins[2] is in order in pointing out that Ramo's analysis (1939) may be usefully invoked. While this analysis contained no new result, the generality of the work has brought it deservedly to the attention. Mr. Jenkins is wise enough to refrain from committing himself to any statement as to what formula for the inter-plate impedance Z arises from his expression for the induced current.

The formula which seems to offer most likelihood of being correct is simply

$$Z = j\omega C \quad \ldots \quad (1)$$

where C is the electrostatic capacitance between the deflector plates.

Dr. Gabor remarks [3] that there is no need for experimenting with different interpretations! Possibly it is because I have the advantage of so many years' experience in this field that my "experiments" on the subject of electron transit times may be worthy of more detailed consideration. I hope to be in a position to publish an article along these lines very shortly, but so far as the present subject is concerned readers will find that my letter in the May issue[4] amply supports equation (1) of this note.

W. E. BENHAM.

Chipperfield, Herts.

Push-Pull Amplification

To the Editor, "Wireless Engineer"

SIR,—The paper by R. L. Russell in the October issue of *Wireless Engineer* draws attention to the fact that only valves with certain shapes of characteristic, such as parabolic or hyperbolic, are suitable for distortionless Class AB push-pull amplification. I believe the general criterion is that the valve anode current should be a function of grid voltage of not higher than second degree; for perfectly matched valves this may be demonstrated as follows.

The current of one of the valves may in general be expressed in the form

$$I_1 = a(V - V_0) + b(V - V_0)^2 + c(V - V_0)^3 + d(V - V_0)^4 + \ldots \quad (1)$$

where V is the variable (signal) voltage applied to the grid, and V_0 the difference between bias and cut-off grid voltage. The second valve is driven in opposite phase, so that its current may be found by writing $-V$ for V in equation (1). The required condition for freedom from distortion is that the difference of the two anode currents should be a linear function of V, i.e. $(d/dV)\ (I_1 - I_2)$ = constant. Differentiating the two currents,

$$\left.\begin{aligned} \frac{dI_1}{dV} &= a + 2b(V - V_0) + 3c(V - V_0)^2 + 4d(V - V_0)^3 + \ldots \\ \frac{dI_2}{dV} &= -a - 2b(-V - V_0) - 3c(-V - V_0)^2 - 4d(-V - V_0)^3 - \ldots \end{aligned}\right\} \quad (2)$$

From equations (2) it may be seen that $dI_1/dV - dI_2/dV$ is equal to the constant $2a - 4bV_0$ on either of two conditions :—

(a) c, d and all coefficients of higher powers of V are zero, or

(b) V_0 is zero *and* the coefficients of all odd powers of V are zero.

Condition (b) is for bias to cut-off, which is usually impracticable for two reasons: the average slope would be low, and the appropriate anode load resistance very high, and, secondly, if one works very largely over the cut-off region, it is likely that the coefficients of the odd powers of V will be appreciable. The practical condition is, therefore, that the characteristic shall approximate to the form $I = a(V - V_0) + b(V - V_0)^2$.

The great practical advantage of Mr. Russell's hyperbolic representation is that it allows the anode current to approach zero asymptotically, instead of requiring a definite cut-off point as assumed in defining V_0 above, and this is likely to facilitate the analysis of actual valve characteristics.

London, N.21. D. A. BELL.

"Direct Reading of the Frequency of Resonant Circuits"

To the Editor, "Wireless Engineer"

SIR,—I had occasion to refer to my article in your November, 1943, issue, and to my regret discovered an error on page 531. The working in col. 1 should read as follows :—

$$f_x = f_A + \left\{\frac{80}{N - 1} \cdot \frac{df}{d\theta} \text{ at } \theta_x\right\}$$

$$= f_A + \left\{\frac{80}{N - 1}\left(\frac{df}{d\theta} \text{ at } \theta_A + \frac{80}{N - 1} \cdot \frac{d^2f}{d\theta^2}\right)\right\}$$

The correct frequency at X is, however,

$$f_x = f_A + \left\{\frac{80}{N - 1}\left(\frac{df}{d\theta} \text{ at } \theta_A + \frac{40}{N - 1} \cdot \frac{d^2f}{d\theta^2}\right)\right\}$$

The error is not very serious, because I have arrived at the correct answer in expression (21) which follows, and therefore none of the conclusions which follow is affected.

Reigate, Surrey. W. H. F. GRIFFITHS.

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[1] Benham, *Wireless Engineer*, Dec., 1939, p. 559.
[2] Jenkins, *Wireless Engineer*, Aug., 1944, p. 358.
[3] Gabor, *Wireless Engineer*, June, 1944, p. 279.
[4] Benham, *Wireless Engineer*, May, 1944, p. 208.

BOOK REVIEW

Radio Terminology

By B. F. Weller. Pp. VIII + 358, with 113 Figs. Chapman and Hall, 11, Henrietta Street, London. W.C.2. Price 21s.

The aim of this book is stated to be the provision of something intermediate between elementary manuals and full-size standard text-books. With the great increase in the number of those compelled, with very little scientific foundation, to take an interest in this subject there is naturally a large demand for text-books dealing with the subject in an elementary way and a corresponding temptation to write such books. It is a pity that the author succumbed to the temptation, for he has evidently not sufficient grasp of fundamental principles to undertake such a task. Already on page 3 we read "Kirchhoff's Second Law is for series circuits and may be stated: In any closed circuit, the sum of the potential differences in the circuit, reckoned negative, is equal and opposite to the applied electromotive force, reckoned positive. Or, in symbols, if there is an applied E.M.F. E_1 and a current flows through resistance R_1, R_2, $R_3 \ldots R_n$: $IR_1 + IR_2 + IR_3 \ldots + IR_n = -E$."

It should be noted that it is the same current in all the resistances and that it flows in the opposite direction to the E.M.F. This is, of course, a travesty of Kirchhoff's Second Law. Kirchhoff's name is misspelt four times on the one page.

After this one is somewhat surprised to find a few pages further on the mathematical treatment of damped oscillations reproduced in full with differential equations, the exponential theorem, and j, without a word of explanation of what j is or where it has come from; perhaps it is better so.

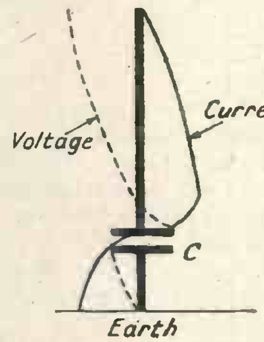
We then come to skin effect: "If the frequency is sufficiently high, only the surface of the conductor is operative, the current being confined to a thin-walled 'tube' at the surface of the conductor, with the central portions not conducting. Thus, the effective cross-sectional area of the conductor is greatly reduced, with a consequent increase in resistance. *Also, since the central portions are effectively 'insulated' from the current-carrying outer parts, they will give rise to eddy current losses due to the E.M.F.s induced in them by the rapidly changing currents near the surface.*" Whatever does this mean? On p. 26 we read: "For ultra-short-wave, or ultra-high-frequency work it is common practice to employ silver-plated copper wire or tube. Silver is, of course, a better conductor than copper, and as only the surface of the conductor is active, *it is thus possible to obtain conductors with very low effective resistance.*" This is very misleading since the conductivity of silver is only about 6 per cent. higher than that of copper, and this higher conductivity causes a reduction in the thickness of the "skin" of about 3 per cent., thus giving a net improvement of about 3 per cent.

We propose to skip about 300 pages devoted mainly to valves and valve circuits, and have a look at the final chapter which deals with "aerial systems and radiation." On p. 307 we read that "If waves of large amplitude are to be created in the ether, it is necessary that the radiating system must embrace a large amount of ether, and thus communicate a considerable amount of energy to the medium. This implies a circuit of large physical dimensions compared with the wavelength of radiation." Where is the aerial of such a height h or length l that one can say that either h or l is large compared with λ?

On p. 314 we read "Consider an earthed vertical quarter-wave aerial. The maximum current occurs at the earthed end, which is obviously an unsatisfactory place for radiation."

On p. 313, after stating correctly that the radiation resistance of a half-wave aerial is from 73 to 75 ohms and that of a quarter-wave aerial of the order of 35 ohms, the author adds that it is important to note that the half-wave aerial is a more efficient radiator than the quarter-wave aerial." Presumably because it has twice the radiation resistance, but no explanation is given.

Perhaps the prize should be given to Fig. 102b on p. 317, which we reproduce. It represents an aerial tuned to a wavelength shorter than the natural wavelength by means of a series condenser C. Apparently the current in the greater part of the aerial is unaware of the presence of the condenser, but, discovering the condenser, the current loses all control of itself and even reverses its direction in going through the condenser, so that when the current is flowing downwards from the aerial into the condenser, it is also flowing upwards from the earth into the condenser. The author is obviously completely out of his depth.



We suggest that the publishers might consider the advisability of withdrawing this book from circulation and reimbursing the guinea to those who have purchased it.

G. W. O. H.

"Dryair" Desiccating Elements

A SERIES of desiccating elements employing silica in colloidal form have been introduced by R. K. Dundas, Ltd., The Airport, Portsmouth, under the name of "Dryair." These components are made in a variety of forms for application to aero engines and ordnance in transit and have also been used in sealed instrument cases for chemical balances, etc.

There are many possible applications to radio instruments—standard air dielectric condensers for instance—and in the packing of goods for export.

The hygroscopic activity of the silica is readily renewable by heating and a colour indicator is incorporated to give warning of approaching saturation. The element also has an affinity for organic vapours and will remove petroleum, coal tar and chlorinated hydrocarbons, esters and alcohols from the air.

ABSTRACTS AND REFERENCES

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

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

PROPAGATION OF WAVES

3780. "PRACTICAL ANALYSIS OF ULTRA-HIGH-FREQUENCY TRANSMISSION LINES, RESONANT SECTIONS, RESONANT CAVITIES, WAVE GUIDES" [Review of R.C.A. Booklet].—J. R. Meagher & H. J. Markley. (*Proc. I.R.E.*, Aug. 1944, Vol. 32, No. 8, p. 501.)

3781. WAVE GUIDES: HOW TO VISUALISE THEIR ACTION AND CHARACTERISTICS: MODES IN CIRCULAR GUIDES: LAUNCHING AND COLLECTING DEVICES.—M. G. Scroggie. (*Wireless World*, Sept. 1944, Vol. 50, No. 9, pp. 258–261: Oct. 1944, No. 10, pp. 303–307.)

3782. ON THE PERTURBATION OF BOUNDARY CONDITIONS [with Results applicable to Acoustics, Elasticity, & Electromagnetic Theory (Acoustics of Irregularly-Shaped Rooms, Scattering from Irregularly-Shaped Objects, Propagation down Irregularly-Shaped Pipes, etc.)].—Feshbach. (*See* 4026.)

3783. THE NON-REFLECTING TERMINATION OF A CONCENTRIC LINE [Letter on Editorial dealt with in 3381 of November].—Willis Jackson & L. G. H. Huxley. (*Wireless Engineer*, Oct. 1944, Vol. 21, No. 253, p. 480.)

3784. ELECTRIC PROPAGATION ON LONG LINES TERMINATED BY LUMPED NETWORKS: PART I—LINE INITIALLY AT REST: PART II—LINE INITIALLY NOT AT REST.—M. G. Malti & M. Golomb. (*Journ. Franklin Inst.*, Jan. 1944, Vol. 235, No. 1, pp. 41–73: Feb. 1944, No. 2, pp. 101–118.)

Without restriction by any of the five assumptions, one or more of which have always been made in previous treatments. The solution is obtained by the Laplace transformation and its inversion. "The particular contribution in this paper, which renders the solution well adapted to easy numerical computations, consists in expanding the transformed solution in powers of the distortion parameter and inverting this series term-wise. Thus the coefficients of the resulting series are repeated convolution integrals of time functions. These functions can be either evaluated or actually measured by observations not involving the line but only the terminals. Moreover, the convolution integrals lend themselves easily to numerical evaluation by mechanical devices."

3785. UTILISATION OF THE ECLIPSES OF THE MOON FOR THE STUDY OF THE UPPER ATMOSPHERE [especially of the Ozone Layer].—D. Barbier, D. Chalonge, & E. Vigroux. (*Comptes Rendus* [Paris], 1st/29th June 1942, Vol. 214, No. 22/26, pp. 983–984.)

If I_λ and J_λ represent the intensities (corrected for atmospheric absorption) of the radiation λ arriving from a point on the moon during and before the eclipse, respectively, the value of the quantity $\delta_\lambda = \log J_\lambda/I_\lambda$ can easily be deduced from the lunar spectra (evaluated by spectrophotometric measurements) obtained by the writers around the time of the total eclipse of 2nd/3rd March, 1942. This quantity represents the optical density, for the radiation λ, of that part of the earth's atmosphere which was traversed by those solar rays which, after refraction, reached the particular point of the eclipsed moon, at the instant the spectrum was taken. The shape of the curve $\delta_\lambda = f(\lambda)$ can be explained qualitatively and quantitatively by taking into account the apparent absorption by diffusion and the absorptions by the ozone and the oxygen, and it is thus possible to calculate the values of the mass of air m and of the thickness of ozone ϵ which the rays have traversed in reaching the point considered.

Such values of m and ϵ having been determined for various points on the shadow, it is found that as one travels from the edge of the shadow in the direction of its centre (i) m increases continually, and the same applies to the intensity of the α band of oxygen (the only band to be observed quantitatively), and (ii) ϵ passes through a maximum at about 10′ from the edge of the shadow and then decreases rapidly. This special behaviour of the ozone is explained by the localisation of this gas in the upper atmosphere. The results obtained give approximate information as to the distribution with altitude of the ozone; but they also show that by means of suitably organised observations of lunar eclipses it will be possible to obtain exact results concerning the distribution of ozone at very great heights. "A knowledge of this distribution, about which there is at present no information, would be of great geophysical interest."

The absorption bands of the spectrum of the eclipsed moon, attributed by the writers to the atmospheric ozone, have hitherto been erroneously interpreted by most observers as due to water vapour. The bands due to water vapour could only appear on rays which have penetrated deeply into the earth's atmosphere, and their intensity could not show the maximum which the writers have found at 10′ from the edge of the shadow.

3786. Contribution to the Study of the Ultra-Violet Spectrum of the Nitrogen Molecule [Lower Levels of Kaplan and van der Ziel Bands are *Not* Identical: etc.].—Renée Herman & L. Herman. (*Comptes Rendus* [Paris], 6th/27th July 1942, Vol. 215, No. 1/4, pp. 83–84.) For earlier and later work *see* 641 of 1942, 2953 of 1943, 6 of January, and 2849 of September.

3787. Application of X-Ray Pulses to the Measurement of the Mobility of Electrons in Gases.—P. Herreng. (*Comptes Rendus* [Paris], 6th/27th July 1942, Vol. 215, No. 1/4, pp. 79–81.) Using the pulse-generating technique dealt with in 1586 of 1943. For subsequent developments *see* 2850 of September.

3788. The Mechanism of Fade-Outs of Radio-electric Waves.—R. Jouaust. (*Comptes Rendus* [Paris], 1st/29th March 1943, Vol. 216, No. 9/13, pp. 294–295.)

"It is to-day certain that the sudden fade-outs of short waves are provoked by chromospheric eruptions and are due to a considerable increase in the ionisation of the ionospheric region situated at a height of 80 km (region D). It must be asked how these eruptions, which affect only a limited portion of the sun's surface and have a brilliance (in the region of the visible radiations) only slightly above that of the surface, can have such a secondary effect on our atmosphere.

"Edlén [*cf.* 2348 of 1941] has concluded that this ionisation is due to the presence, above the faculae, of Fe_{13} and Ni_{15} atoms, emitting X-rays. But such rays would be very soft, very absorbable by the air, and likely to act on the E and F regions of the ionosphere—which are not modified in the courses of the fade-outs.

"The mechanism of the increase of the region-D ionisation seems to us to be as follows:—This altitude can be reached only by radiations longer than 1750 AU. Normally, these radiations can only come from the photosphere or the lower layers of the chromosphere; the upper layers of the chromosphere, composed almost entirely of ionised atoms, emit only the far ultra-violet rays and at the same time absorb the near ultra-violet emission from the photosphere which itself contributes to their ionisation.

"The eruptions bring to the surface of the chromosphere matter originating in the deep layers, as is shown by its spectrum . . . There is thus a production, in the eruptions, of near ultra-violet radiation which reaches our atmosphere without any absorption and is therefore capable of a more intense action than that produced by the identical radiations, partially absorbed, which are normally emitted from the sun."

3789. The Discontinuities of the Upper Atmosphere brought to Light by Crepuscular Photometry.—J. Gauzit & R. Grandmontagne. (*Comptes Rendus* [Paris], 4th/27th May 1942, Vol. 214, No. 18/21, pp. 799–801.)

The second writer has shown (ref. "2" [and *see* 2957 of 1943]) that the brilliance of the zenithal sky measured in red light (wavelengths between 5800 and 9000 AU) presents sharp discontinuities in its diminution as twilight comes on: "the curve which gives the variations of the magnitude of the sky as a function of the solar depression U is formed, when U varies from 5° to 18°, of four portions of straight lines cutting each other at acute angles. The existence of these angles is established with certainty, since from 12 to 16 points have been determined in each interval of one degree of depression. The following table indicates the slopes and limits of the straight lines, as well as the altitude of the limit of the shadow projected by the earth on the vertical at the point of observation. We give the altitude of the ray passing above the 'atmospheric mud,' assumed to be 3 km thick; we consider that this is the probable altitude of the atmospheric discontinuities. The limits vary slightly from day to day: we have likewise indicated this . . . We propose here an interpretation of these discontinuities."

The writers conclude: "It is seen that the observed kinks are due to discontinuities in the density of the air, produced by a sharp variation either of the thermal gradient or of the composition of the air. We assume that the variation of the thermal gradient is sufficient to explain the first discontinuity. Actually, a number of facts, such as the observation of meteors, propagation of sound to a great distance, and the determination of the temperature of the atmospheric ozone, agree in showing the probability of a temperature-maximum at about 50 or 60 km. Crepuscular photometry brings a new proof and also some added precision: it is a case of a sharp maximum resembling an angular point, but the slope of the thermal gradient is less steep than was supposed by Martyn & Pulley (2073 [and 3677] of 1936). We find a variation $\gamma - \gamma' = 16.5$ instead of 23.3 degrees per kilometre. The altitude is given by the table, 57.5 ± 7 km: Martyn & Pulley indicate a sharp minimum of temperature at 82 km. The existence of an angular point at this altitude is not suggested in the crepuscular measurements.

"We consider the second discontinuity to be connected with the rapid dissociation of molecules into atoms at about 95 km [the figure given in the table is 94 ± 10 km]. It is generally agreed that at about this altitude the oxygen gradually dissociates into atoms; but one of us (Gauzit, 1891 of 1942) has recently brought forward theoretical reasons for the conclusion that the nitrogen itself is dissociated in the upper atmosphere. The reasons for this dissociation and the probability of a strict frontier between the atomic and molecular regions will be considered in another publication: seeing that the causes of dissociation are probably different for the nitrogen and oxygen molecules, it is *a priori* surprising that the two gases should dissociate at the same altitude, but it will be shown that the degree of dissociation depends much less on the intensity of the dissociating action than on the frequency of the processes of recombination by triple collision, and these processes decrease extremely quickly for both gases at about 100 km. We consider that in the second discontinuity of the twilight sky we find precisely a confirmation of the fact that the atmosphere passes sharply, at around 95 km, from the molecular state to the atomic. The observed variation of slope shows that this passage is probably accompanied by a sudden rise of the thermal gradient, which is not surprising, since the atoms and molecules have different absorbing properties.

"Finally, the only hypothesis which would appear probable to explain the third discontinuity is that of a sharp maximum of temperature at about 160 km."

3790. Insolation in the Polar Atmosphere.—A. Court. (*Journ. Franklin Inst.*, Feb. 1943, Vol. 235, No. 2, pp. 169–178 and Chart.)

Construction of the chart, showing regions with constant sunshine and with no sunshine, resulted from studies undertaken as part of the analysis of results obtained in 1940/41 at Little America III, "and especially in an effort to explain the wide (40° C) annual variation in stratosphere temperatures which was observed there [*see* 3791, below] . . . Study of the diagram, in the light of these explanations [given in the present paper], should reveal many facts of interest to physicists in their studies of aurora and of ozone distribution and formation, and may conceivably be of benefit in the study of cosmic rays, as well as have a distinct bearing on the meteorology and climatology of polar regions."

3791. Tropopause Disappearance during the Antarctic Winter.—A. Court. (*Bull. Am. Met. Soc.*, Vol. 23, 1942, p. 220 onwards.) Mentioned in 3790, above: *see* also 943 of 1942.

3792. Seasonal Variations of Ultra-Violet Energy in Daylight.—M. Luckiesh, A. H. Taylor, & G. P. Kerr. (*Journ. Franklin Inst.*, July 1944, Vol. 238, No. 1, pp. 1–7.)

3793. The Earth's Magnetic Field and Long-Range Forecasts of the Weather [Magnetic Field provides Instant & Sensitive Index to Changes in Ultra-Violet Radiation (already correlated by Abbot with Weather Cycles)].—H. B. Maris. (*Science*, 9th June 1944, Vol. 99, No. 2580, Supp. p. 10.)

A century's accumulated magnetic records provides a vast store of information about solar radiations which can probably not be equalled by direct radiation measurements over 50 years. Analysis leads to the conclusion that while one-seventh of all magnetic disturbances are due to the gases from comets' tails, the remainder are due to u.v. fluctuations, dominated by three great eruptive disturbances which have persisted throughout the past century and whose periodicities have had close correlations with weather cycles.

3794. On Magnetic "Bay" Disturbances [Study of 885 Bays recorded near Paris, 1883/1941: Comparison with Short-Wave Fade-Outs (only Two Coincidences): Division into Three Categories, according to Duration (and Origin): etc.].—C. Maurain & J. Coulomb. (*Comptes Rendus* [Paris], 1st/29th March 1943, Vol. 216, No. 9/13, pp. 273–276.)

3795. Properties of the Magnetic "Bay" Disturbances [and the Inadequacy of Störmer's Theory].—C. Maurain & J. Coulomb. (*Comptes Rendus* [Paris], 1st/29th March 1943, Vol. 216, No. 9/13, pp. 327–329.)

Continuation of 3794, above. "We have already indicated the annual and diurnal distributions at Paris of the bays of length greater than 30 minutes, represented by us as 'PE_3's. Here are some other characteristics of these disturbances. . . ." In particular, since these disturbances are undoubtedly due to solar emissions the writers have plotted the declination of the sun corresponding to each at the moment of its maximum, well defined by the summit of the bay.

"Steiner, and above all Wiechert, consider that their results can be explained by Störmer's theory, although this theory, which involves only the action of the earth's magnetic field on the solar electrons, is revealed as inadequate by the fact that it gives too small dimensions for the auroral zone. The curve above-mentioned makes it clear that this theory allows no interpretation of our results. . . ." Three examples are given: for instance, there are many cases of negative "PB_3"s corresponding to a magnetic declination of the sun inferior to − 20°. According to Störmer's theory, for such a declination the electrons would not reach the earth.

3796. Different Kinds of Magnetic Disturbances.—L. Éblé. (*Comptes Rendus* [Paris], 1st/29th March 1943, Vol. 216, No. 9/13, pp. 305–306.)

"What is generally called 'magnetic disturbance' is in reality the superposition of at least two different disturbances, easily distinguished on the recorded curves as soon as the attention is drawn to the fact; the one, short and fairly regular, develops particularly in the morning; the other, ample and irregular, reaches its maximum at night. Magnetic storms constitute a third phenomenon. The first two types, while both connected with solar activity, must have different immediate causes: we would attribute the short disturbance to a direct action of the sun through its ultra-violet radiations, and the strong disturbance to a comprehensive action of the ionised atmosphere or of extra-terrestrial currents, for it seems to possess a more simultaneous and universal character. In any case, it is desirable to study these two types of disturbance separately: the diurnal variation of the magnetic character results from their superposition."

3797. ON THE DISTRIBUTION AND SECULAR VARIATION OF THE EARTH'S MAGNETISATION [" Some New Information " derived from the 1932/3 Polar Year Records: especially the Marked Asymmetry of the Field of Secular Variation], *and* ON THE DIRECTION OF THE EARTH'S MAGNETISATION. — P. Rougerie. (*Comptes Rendus* [Paris], 1st/29th March 1943, Vol. 216, No. 9/13, pp. 416–418: pp. 451–452.)

For a Note by J. Coulomb (" the principal part of the terrestrial field could equally be attributed to the radial magnetisation of a superficial layer . . ."), prompted by the first paper, *see* pp. 452–453.

3798. A MAGNETOMETER FOR THE DETERMINATION OF THE VERTICAL COMPONENT OF THE EARTH'S MAGNETIC FIELD [Sensitivity about ½ min. per γ].—S. L. Ting & S. T. Lin. (*Review Scient. Instr.*, July 1944, Vol. 15, No. 7, pp. 171–177.)

3799. ON THE ABSORPTION OF THE HARD COMPONENT OF THE COSMIC RADIATION [and the Probability of Appreciable Mesotron Production at Elevations comparable to That of Mt. Evans (4 300 Metres), in accord with Recent Observations].—M. E. Rose. (*Journ. Franklin Inst.*, July 1943, Vol. 236, No. 1, pp. 9–45.)

3800. REVERSED CYCLOTRON: COSMIC RAYS MAY BE SLOWED DOWN [for Study: but Cyclotron must first be developed to give Higher Particle Speeds].—L. E. Dodd. (*Sci. News Letter*, 22nd July 1944, Vol. 46, No. 4, p. 52.) *See* also " Post-War Betatron " (Almy), *ibid.*, 10th June 1944, p. 372; and *Phys. Review*, 1st/15th June 1944, Vol. 65, No. 11/12, p. 353 (summary of Am. Phys. Soc. paper). *Cf.* Iwanenko & Pomeranchuk, 3961, below.

3801. ON THE ASTRONOMICAL REFRACTION [Angle between Initial Direction of Ray from Outside the Atmosphere and Direction of Arrival at Earth's Surface: Simple Formula derived for Zenith Distance > 75°, where Usual Formula fails: Relation to the Density Distribution of the Air].—E. Esclangon. (*Comptes Rendus* [Paris], 4th/25th Jan. 1943, Vol. 216, No. 1/4, pp. 100–103.) For a supplementary Note, " On the Geodesic Refractions," see *ibid.*, pp. 137–139.

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY

3802. ELECTRIC PROPAGATION ON LONG LINES TERMINATED BY LUMPED NETWORKS: PART I —LINE INITIALLY AT REST: PART II—LINE INITIALLY NOT AT REST.—Malti & Golomb. (*See* 3784.)

3803. AN EIGHT-YEAR INVESTIGATION OF LIGHTNING CURRENTS AND PREVENTIVE LIGHTNING PROTECTION ON A TRANSMISSION SYSTEM.—E. Hansson & S. K. Waldorf. (*Elec. Engineering*, May 1944, Vol. 63, No. 5, Transactions pp. 251–258: Discussion in *Supp. to Elec. Engineering, Transactions Section*, June 1944, Vol. 63, pp. 463–466.)

In the Discussion, McCann remarks that the data reported " are of great value in furthering our knowledge of lightning phenomena."

3804. LIGHTNING [Short Survey of Current Knowledge].—J. M. Meek. (*Electronic Eng:g*, Aug. 1944, Vol. 17, No. 198, pp. 96–100 and 123.)

3805. INFLUENCE OF THERMAL CONVECTION ON THE TERRESTRIAL ELECTRIC FIELD.—P. Pluvinage. (*Comptes Rendus* [Paris], 1st/29th March 1943, Vol. 216, No. 9/13, pp. 303–304.)

PROPERTIES OF CIRCUITS

3806. " PRACTICAL ANALYSIS OF ULTRA-HIGH-FREQUENCY TRANSMISSION LINES, RESONANT SECTIONS, RESONANT CAVITIES, WAVE GUIDES " [Review of R.C.A. Booklet].—J. R. Meagher & H. J. Markley. (*Proc. I.R.E.*, Aug. 1944, Vol. 32, No. 8, p. 501.)

3807. THE NON-REFLECTING TERMINATION OF A CONCENTRIC LINE [Letter on Editorial dealt with in 3381 of November].—Willis Jackson & L. G. H. Huxley. (*Wireless Engineer*, Oct. 1944, Vol. 21, No. 253, p. 480.)

3808. THE INDUCTANCE OF A CIRCUIT CONSISTING OF TWO PARALLEL WIRES: A NEW TREATMENT OF THE PROBLEM.—G. W. O. H. (*Wireless Engineer*, Oct. 1944, Vol. 21, No. 253, pp. 461–463.)

Editorial giving a simple way of arriving at the formula $L = (4 \log_e D/r + 1)\,10^{-9}$ and showing that it is rigorously correct whatever the size of the conductors.

3809. NEW ADMITTANCE-DIAGRAMS FOR LONG LINES [giving " a particularly Simple Representation of the Powers at the Two Ends "].—H. Kafka. (*E.T.Z.*, 25th March 1943, Vol. 64, No. 11/12, pp. 153–157.)

3810. DETERMINATION OF THE " FORM FACTOR " OF CYLINDRICAL CONDUCTORS PLACED IN A UNIFORM ALTERNATING FIELD WHOSE DIRECTION IS PARALLEL TO THE AXIS [in connection with Induction Furnaces, etc.].—M. Leblanc. (*Comptes Rendus* [Paris], 1st/29th March 1943, Vol. 216, No. 9/13, pp. 375–377.)

Ribaud established the equation for the energy gathered by such a cylinder: $W = n^2I^2 \,.\, \pi d/h \,.\, \sqrt{2\pi\rho\omega}$: the substance placed inside the solenoid behaves to the latter as a supplementary resistance equal to n^2R, where R represents the resistance of the substance referred to a thin cylinder of thickness ϵ (ϵ = thickness of equivalent skin) so that $R = \pi d\rho/h\epsilon$. When the cylinder-diameter is sufficiently large, the induced currents are propagated only in a thickness small compared with the diameter. The quantity n^2R is the " equivalent resistance " of the charge introduced into the furnace.

Radulet showed that this method leads to practically usable results only when the height h of the cylinder is at least 10 times its diameter d. If this is not so, the energy W_h received by the cylinder of height h is, other things being equal, greater than the energy W_i which would be disengaged in a portion of the same height h, considered separately, in a cylinder of the same diameter and of infinite length. The ratio W_h/W_i is called the "form factor" relative to the value h/d.

The present work extends Radulet's experimental results to values of h/d below 0.1595 (Radulet's lowest value). It is found that the energy delivered, W_h, in the case of lead or brass discs passes through a minimum, then through a maximum, before reaching zero at $h = 0$. These minima and maxima are the more sharply marked, the greater the diameter of the discs compared with the skin thickness corresponding to the conditions of the test; they are consequently not found in the case of graphite discs at the test frequency employed, 100 kc/s. *See* also 3811, below.

3811. THE HEATING OF A THIN DISC WHOSE FACES ARE NORMAL TO AN ALTERNATING MAGNETIC FIELD [Theory of the Experimental Minima & Maxima found by Leblanc, 3810, above].—G. Ribaud. (*Comptes Rendus* [Paris], 1st/29th March 1943, Vol. 216, No. 9/13, pp. 377–379.)

3812. THE COURSE IN TIME OF NOISE VOLTAGES.—Mann. (*See* 3848.)

3813. FLUCTUATIONS DUE TO THERMOELECTRONIC EMISSION FROM THE PHOTOELECTRIC LAYER IN A MODULATED-LIGHT AMPLIFIER.—Blanc-Lapierre. (*See* 3914.)

3814. THE MECHANISM OF LEAKY-GRID DETECTION.—Amos. (*See* 3849.)

3815. MILLER EFFECT SIMPLIFIED [Treatment from a New Angle, "reducing Work involved in deriving Equations and giving Clear Picture of Precise Operation of Triode Amplifier"].—C. J. Mitchell. (*Electronic Eng:g*, June 1944, Vol. 17, No. 196, pp. 19–20.)

3816. AMPLIFIER WITH LOGARITHMIC RESPONSE [giving D.C. Output logarithmically proportional to Input Signal over Range of Three Decades: Characteristic is based on Charging & Discharging of a Condenser, and is thus Independent of the Valve Characteristics: Output consists of Series of Pulses which are Averaged and Filtered to yield D.C.].—J. A. Hipple & D. J. Grove. (*Phys. Review*, 1st/15th June 1944, Vol. 65, No. 11/12, p. 346: summary only.)

3817. A NOTE ON THE PHASE-SPLITTING AMPLIFIER CIRCUIT.—E. K. M. Bird; Schmitt. (*Electronic Eng:g*, Aug. 1944, Vol. 17, No. 198, p. 103.)

"Following on various articles dealing with the Schmitt phase-splitting amplifier circuit, no doubt many readers will be incorporating it in amplifiers": the present note discusses the precautions that must be taken to avoid over-biasing due to the flow of blocking-condenser leakage current through the grid leak. In a letter in the September issue (No. 199, p. 170) F. Butler describes how the difficulty can be overcome by a circuit in which the voltage causing the leakage current is balanced.

3818. LETTER ON "THE CATHODE-COUPLED DOUBLE-TRIODE STAGE" [Use of Similar Circuit for Measurement of Small Changes in R.F. Amplitude].—Noltingk: Williams. (*See* 3929.)

3819. CORRECTION TO "THE GRAPHICAL DESIGN OF CATHODE-OUTPUT AMPLIFIERS" [2870 of September].—D. L. Shapiro. (*Proc. I.R.E.*, Aug. 1944, Vol. 32, No. 8, p. 482.)

3820. PERFORMANCE OF COUPLED AND STAGGERED CIRCUITS IN WIDE-BAND AMPLIFIERS.—D. Weighton. (*Wireless Engineer*, Oct. 1944, Vol. 21, No. 253, pp. 468–477.)

From the Pye laboratories. For wide-band amplifiers the relative merits of different types of circuit cannot readily be assessed from the results of the various writers who have applied the general solution of coupled and staggered circuits to the design of narrow-band amplifiers (usually required to tune over a wide range of frequencies), since the important factors are different in the two cases. In particular, selectivity is of minor importance in the wide-band amplifier, since the gain requirement usually necessitates more than the number of circuits needed for adequate discrimination against signals lying outside the band. "Within certain reservations in the first and last stages of an amplifier, where the design may be modified by considerations of noise and detector-loading, the problem reduces to one of maximum gain per stage for a given over-all band width."

From the author's summary:—"Expressions are derived for stage gain in terms of band width, tuning capacitances, and the parameters of the response curve which define its shape . . . The effects of mis-tuning and unequal Q in the coupled-circuit amplifier are considered, with particular reference to practical difficulties of alignment. For comparison of performance it is not sufficient to consider single stages alone, since the response curves are not of identical form and the results will therefore depend on the gain ratio at which the band width is defined. The results are therefore presented in terms of an amplifier of any number of stages having constant band width at 3 db points on the over-all response.

"These curves form a convenient basis for the rapid estimation of the performance of particular amplifiers. It is concluded that coupled circuits may be made to give an improvement over staggered circuits, both in uniform and composite amplifiers [the latter having stages with different circuits, or circuits of the same type with different parameters], which varies from 1.5 to 3 db per stage according to the tolerances in variation of the response within the pass band and the apparatus available for carrying out the trimming operations."

3821. GEOMETRY OF PUSH-PULL AMPLIFICATION.—R. L. Russell. (*Wireless Engineer*, Oct. 1944, Vol. 21, No. 253, pp. 463–467.)

If the two valves of a push-pull system have identical characteristics and behave in exactly the same way, no even harmonics can be present in the output. "This follows at once from considerations of symmetry, and the situation is often briefly summarised by stating that the even harmonics cancel and the odd ones are additive. This suggests that the cause is inherent in the nature of the valve characteristics. It is comparatively rarely remarked that the amounts of odd harmonics are also dependent on the grid bias, and that they can be reduced to a minimum by choice of a suitable value. The author shows in this paper that all distortion can be avoided if valves which have dynamic characteristics of hyperbolic shape are employed together with a particular bias. . . ."

Author's summary :—" It is usual to regard the mutual-conductance characteristic for valve amplifiers below saturation as consisting of two parts. The upper part is sufficiently nearly linear to be treated as such for quantitative work, and it is almost universal to take the initial part as being of parabolic shape.

" There seems to be little justification for this assumption (except over small ranges), and in any event the discontinuity of treatment is not satisfactory. On the supposition that the curves are more nearly hyperbolic, a geometrical explanation for push-pull amplification is obtained. It is further shown that for such a shape of valve characteristic, and for a particular value of bias, there is complete freedom from distortion over an indefinite range. Experimental results are quoted and methods described by which this special shape can be identified. From the analysis emerges an algebraic expression

$$[I_A = \tfrac{1}{2}\tan\theta\,(V_g + \sqrt{V_g^2 + 4K\cos\theta})]$$

which may be regarded as an approximation to the mutual-conductance curves [for single valves] over ordinary working ranges : this is of interest because it is valid not only for the curved part but also over that portion of the characteristic which is sensibly linear, when, as V_g increases, the expression reduces approximately to $I_A = V_g \tan\theta$.

3822. An Analysis of a D.C. Galvanometer Amplifier [with Two Photocells].—D. I. Lawson. (*Electronic Eng:g*, Aug. 1944, Vol. 17, No. 198, pp. 114–116.)

It is found that :—the gain is independent of the photocell characteristics if a cathode-follower output stage is used : the gain is given by $\gamma = E\alpha/2x\,(R_2 + 1/g)$: if a fraction β of the output is reintroduced into the galvanometer circuit the gain is altered by a factor $1/(1 \pm \gamma\beta)$, when β is positive or negative according to the sign of the feedback : the apparent effect of feedback is to change the stiffness of the suspension by a factor $(1 \pm \gamma\beta)$, the positive sign referring to negative feedback (which thus increases the speed at which recordings can be made). The complete practical circuit is shown.

3823. System of Oscillation-Maintenance with Auto-Stabilised Amplitude.—J. Abelé. (*Comptes Rendus* [Paris], 4th/27th May 1942, Vol. 214, No. 18/21, pp. 841–842.)

" Consider a class of self-maintained oscillators governed by the system of equations $x\,dx + y\,dy + 2\,Ry\,dx = 0$ . . . (1), $\omega y = dx/dt$ . . . (2). When R is a function of x only or of y only, eqn. 1 can be integrated graphically by means of an elegant construction given by A. Liénard. I propose to call eqn. 1 in this case Liénard's equation. Liénard's equation is characterised by the periodicity of the function R, in conditions where the variables x and y are themselves periodic. Now it is possible to remove this character of periodicity from the function R and to compel it to follow the variations, no longer of the oscillatory variables x or y, but of the *amplitude* of these variables, with a view to stabilising this amplitude by the effect of its own variations, while at the same time preserving for the oscillation its rigorously sinusoidal form and its natural frequency. For this purpose it is necessary to generalise Liénard's equation by substituting a simultaneous function of x and y for the separate functions of x or y."

A study of this generalisation has led the writer to the result that a *necessary* condition for the system of equations 1 and 2 to yield a stationary régime at once sinusoidal and stable is that R should be a continuous function annulling itself on the circle $x^2 + y^2 = A^2$, and that a *sufficient* condition is that eqn. 3 (the equation for R given in 3824, below) should be satisfied. The amplitude is then " auto-stabilised " and the equation of the corresponding oscillator is formed by eliminating R between eqns. 1 and 3.

3824. Application of an " Oscillation-Sustaining System with Auto-Stabilised Amplitude " to an Elastic Pendulum.—J. Abelé. (*Comptes Rendus* [Paris], 1st/29th June 1942, Vol. 214, No. 22/26, pp. 875–877.)

" I have studied, under the name ' oscillator with auto-stabilised amplitude ' (3823, above) a type of oscillator defined by the addition, to the system of equations $x\,dx + y\,dy + 2Ry\,dx = 0$, $\omega y = dx/dt$, of the relation $R = -a + b\sqrt{x^2 + 2\,Rxy + y^2}$, where $0 < a < 1$, $0 < b$. The property of this oscillator, of giving a stationary régime both sinusoidal and stable, free from all influence of the maintaining mechanism on the form and frequency of the oscillation, recommends its adoption as a frequency-standard or as a chronometer. I have also essayed to make a practical example of it in the form of a continuously-driven elastic pendulum.

" The pendulum is composed of a magnet suspended by a helicoidal spring of elinvar. The magnet is made up of several pieces, some of which are in ferro-cobalt with high coercive field and the others in ferro-nickel of high permeability. The central bar plunges into a bobbin, with its axis vertical, carrying two windings with mid-point tapping. The first winding is connected between the plates of two valves with parabolic characteristics, mounted in opposition. The second winding is connected to the grids through two shunted capacitances which act as rectifiers and make the mean negative voltage of the grids proportional to the amplitude of the velocity of the pendulum." Here follow the six conditions necessary for the system to possess the properties mentioned above. The description of the arrangements made to fulfil these conditions, and further details, will be given in a later report.

3825. A Resistance–Capacity Oscillator.—S. S. West. (*Electronic Eng:g*, Aug. 1944, Vol. 17, No. 198, pp. 118–120.)

" *RC* oscillators appear to be the vogue. The literature has recently dealt with several variations on this theme. The possibilities of the 2-valve common-cathode arrangement, when suitably changed in concept to be applicable to a selective regenerative circuit, appear, however, thus far to have been overlooked. . . ."

3826. Willans Oscillator Circuit [and Its Priority : Its Outstanding Advantages as

Source for A.C. Bridge Work & as Generator of Frequencies below 100 c/s: a Particularly Successful Version with Low Resistances & High C_1C_2 Values (Frequencies down to 6 c/s)].—E. A. Hanney: Willans. (*Wireless World*, Oct. 1944, Vol. 50, No. 10, p. 300.) "Prompted by my belated discovery of Willans's work, after I had wrongly attributed it to Americans."

3827. Further Properties of Recurrent-Exponential and Probability-Function Pulse Wave-Forms.—F. F. Roberts & J. C. Simmonds. (*Phil. Mag.*, July 1944, Vol. 35, No. 246, pp. 459–470.)

"In the varied applications of pulse signals, both for the transmission of information and for actually obtaining it from the pulses themselves (as in ionosphere sounding and its recent developments), the chief interest shifts back and forth between the wave-form of the pulse and its corresponding frequency spectrum, as the viewpoint of design or application is altered. Any method for rapidly and accurately correlating the two views must, therefore, be of interest. It is the object of the present paper to describe and illustrate such a method, with particular reference to pulses of the 'recurrent-exponential' and 'probability-function' wave-forms defined and discussed in the previous contribution" (1158 of April).

In that paper the recurrent-exponential pulse was shown to be of practically identical form to a repeated probability-function pulse, though with advantages of its own. In the present work some general operations of the probability-function pulse are first given (addition of pulses, multiplication by an independent variable, multiplication of one pulse by another, theoretical use of this type of pulse in connection with cross-talk in multi-channel "time-division" multiplex systems such as those dealt with in 859 of 1940 and 2557 of 1941): it is also shown that the response of a network to the pulse can be determined by representing the frequency-characteristic of the network by the sum of a number of exponential functions.

Finally the special advantages of the other type of pulse, the recurrent-exponential, are illustrated by a more detailed consideration of the various possible types of modulation that may be applied (amplitude modulation, combined amplitude and pulse-width modulation, phase and frequency modulation) and by a discussion of the application of this type of pulse also to cross-talk analysis in "time-division" systems.

3828. Resonance: an Experimental Demonstration of Series and Parallel Resonant Circuits for Radio Training Classes.—T. J. Rehfisch. (*Electronic Eng:g*, July 1944, Vol. 17, No. 197, pp. 76–82.)

3829. A Modified Treatment of the Iterative Method [for determining the Natural Frequencies of Vibrating Systems, etc.].—Saibel. (*See* 4027.)

3830. Impedance Circle Diagrams: Their History, Construction, and Geometry [and Their Importance to Communications & Power Engineers].—H. L. Stewart: Shipley. (*Gen. Elec. Review*, Aug. 1944, Vol. 47, No. 8, pp. 20–25.)

3831. Multi-Circuit Filter Networks with Smoothed Resonance Curve.—A. Linnebach. (*E.N.T.*, Oct. 1943, Vol. 20, No. 10, pp. 238–250.)

Author's summary:—"In the following paper the problem of the calculation of multi-circuit filter networks for high frequencies will be dealt with, taking into account the loss resistances. The only case dealt with in full is that in which all the circuits are independent of each other, each one, for instance, being separated from the next by a valve [but *see* middle of l-h. column, p. 247: the modified procedure for the case where there are no separating valves is sketched: in any case the calculation is not greatly affected, for a single-stage amplifier whose anode circuit contains two circuits coupled by a loss-free link has the same properties as a two-stage amplifier with two separate circuits]. The point of departure of the investigation is the requirement of uniform amplification within a given frequency-band.

"This requirement leads to the real polynomial $f(z) = 1 + d^{4n} + 2d^{2n} \cos (2n \text{ arc} \cos z/z_g)$, which represents the reciprocal value of the amplification of the filter network with n separate circuits, as a function of the 'detuning' z (d is the 'ripple' [maximum deviation], z_g the limiting detuning at the edge of the transmission region) [for the further elucidation of this statement it may be mentioned that $f(z)$ represents $|\gamma|^2$, where γ is the complex polynomial identically equal to $\ddot{u}_n$, the transmission equivalent of the n-circuit filter, as given in eqn. 9. The requirement in question thus becomes that γ should be so chosen that $|\gamma|^2$ within a symmetrically lying range $< -z_g, +z_g >$ should have maxima and minima which are equally high, and should display as many extreme values as possible; further, that ϕ (= arc γ) should increase or decrease monotonically when z passes from $-\infty$ to $+\infty$. A discussion (pp. 239–240) of eqn. 23 thus arrived at for $f(z)$, and of the special properties of Tschebyscheff polynomials, leads to the conclusion that the only functions suitable to represent $f(z)$ are these polynomials, and that this representation is given unequivocally by eqn. 24, which, when A and B are replaced by $1 + d^{4n}$ and $2d^{2n}$ respectively, gives the equation for $f(z)$ quoted above].

"For calculating the circuit components and determining the frequency characteristic, $f(z)$ is split into conjugate complex functions $\gamma(z)$ and $\bar{\gamma}(z)$. This splitting is unequivocal if account is taken of the fact that the null-points of $\gamma(z)$ must all have a positive imaginary component, since this represents the time constant of the circuit. From such a determination of $\gamma(z)$ a monotonic course for the phase rotation as a function of the detuning follows of itself. An important result obtained is that the ratio of the time constants, and also the ratio of the resonance-detunings of the individual circuits, are independent of the 'ripple,' and the circuit is symmetrical (results II, III, IV [p. 242, l-h. column)]; that is, every two circuits are detuned symmetrically with respect to the mid-band frequency and have equal time constants.

"For determining the phase characteristic, formulae are derived for calculating the coefficients of $\gamma(z)$, by the use of symmetrical functions of the null-points. Finally, in section 8 some properties of the coefficients are pointed out which lead to a certain added ease in the calculation. All the equations needed for calculation are collected together. The calculation is carried through on an example [a 12-circuit filter with mid-band frequency of 478 kc/s, band-width 15.3 kc/s, and "ripple" $d = 0.4$]. The paper ends with an investigation of the smallest attainable band-width": eqn. 110 is derived, $\Delta\omega \geq \{4d/(1 - d^2)\} . \{1/\tau_0 \sin \pi/2n\}$, the second factor in which may be regarded as constant within certain limits (for τ_0 see eqn. 105), so that the attainable band-width depends only on the first, $D = 4d/(1 - d^2)$. This can be varied within wide limits by a "suitable choice" of d: the curve of Fig. 5 shows the course of D as d is varied between 0 and 1. "The 'suitable choice' of d is generally a matter of compromise, since 'small band-width' and 'ripple' are contradictory requirements."

3832. Historic Firsts : Quartz Crystal Filters.—E. Espenschied. (*Bell Lab. Record*, Aug. 1944, Vol. 22, No. 12, p. 504.)

3833. Filter Effect produced by Transformers in a Three-Phase Network [Band-Pass Action, with Pass Band dependent on Leakage of Transformers].—M. Parodi & F. Raymond. (*Comptes Rendus* [Paris], 4th/25th Jan. 1943, Vol. 216, No. 1/4, pp. 111–113.)

3834. Analogy between the Propagation of the Symmetrical Components in a Three-Phase System and That of Elastic Waves in a Solid.—M. Parodi. (*Comptes Rendus* [Paris], 4th/25th Jan. 1943, Vol. 216, No. 1/4, pp. 175–177.)

3835. Relaxation Oscillations in Power Plant [due to Series (and also Parallel) Connection of Capacitances & Iron-Cored Inductances: Their Effects & Their Elimination].—W. Koch. (*E.T.Z.*, 12th Aug. 1943, Vol. 64, No. 31/32, pp. 427–430.) Generally of low frequencies such as 1 c/s.

3836. Transformer-Magnetising Inrush Currents and Influence on System Operation [in the Rare Circumstances where These Transient Currents are Important].—L. F. Blume & others. (*Supp. to Elec. Engineering, Transactions Section*, June 1944, Vol. 63, pp. 366–375: Discussion pp. 423–424.)

3837. On the Transformation of a Single-Phase Current to Polyphase Current, and *vice versa*, by means of Static Apparatus.—J. Bethenod. (*Comptes Rendus* [Paris], 1st/29th June 1942, Vol. 214, No. 22/26, pp. 877–878.)

"In 1904 I showed that a perfectly circular rotating field could be obtained by means of a single-phase current, by taking advantage of the effects of mutual induction; this result corresponds actually to the transformation of a single-phase current into a balanced system of polyphase currents. Eight years later I established the inverse proposition, namely that these effects equally allowed the transformation, by purely static means, of a balanced system of polyphase currents into a single-phase current. Finally in 1924 I developed this proposition further, showing that the transformation did not require the presence of any capacitor or equivalent apparatus, but that in such a case the power factor of the polyphase system of supply could not be greater than 0.7. The arrangement then described, for a special purpose, is particularly simple, and in view of the theoretical importance of the above proposition, notably in questions relating to 'fluctuating power,' I think it desirable to give here the theory, which has not previously been published. . . ." If, on the other hand, the reactance in each of the component circuits is raised by a capacitor, the power factor can be brought up to unity: the arrangement is then the one proposed by the writer in 1912 for feeding an aerial by a two-phase h.f. alternator.

3838. Application of the Pulse Generator [497 of 1942] to the Starting-Up of Sub-harmonic Oscillation in an Oscillating Circuit of the Series Type [Ferromagnetic Frequency-Dividing Circuit without D.C. Polarisation, where Spontaneous Excitation can Not be counted on: New Results made possible by the Method].—R. Dehors. (*Comptes Rendus* [Paris], 1st/29th March 1943, Vol. 216, No. 9/13, pp. 407–409.)

3839. Periodic Processes in Free Pseudo-Linear Oscillatory Systems.—Bulgakov. (*See* 4029.)

3840. Some Aspects of Inductance when Iron is Present [but No Air-Gap: with Special Reference to Dynamo-Grade Silicon Steel].—L. T. Rader & E. C. Litscher. (*Elec. Engineering*, March 1944, Vol. 63, No. 3, Transactions pp. 133–139: Discussion in *Supp. to Elec. Engineering, Transactions Section*, June 1944, Vol. 63, pp. 431–432.)

3841. A Graphical Analysis of the Voltage and Current Wave-Forms of Controlled Rectifier Circuits [Thyratron & Ignitron, etc.].—P. T. Chin & E. E. Moyer. (*Elec. Engineering*, July 1944, Vol. 63, No. 7, Transactions pp. 501–508.)

3842. Characteristics of Voltage-Multiplying Rectifiers [for Use as D.C. H.T. Power Supply for Small Valve Devices & Other Instruments].—D. L. Waidelich & C. L. Shackelford. (*Proc. I.R.E.*, Aug. 1944, Vol. 32, No. 8, pp. 470–476.)

"The present shortage of certain types of transformer brings new attention to voltage-multiplying circuits and their operating characteristics. This paper presents the results of a combined experimental and theoretical analysis to determine some of the more important characteristics of two of the many rectifier circuits using vacuum-type diodes [namely the half-wave and the full-wave voltage-doubling rectifiers, with capacitance filters: the assumption of no voltage drop across the tubes when conducting, made for simplification in two earlier papers (998 of 1942 and 1053 of 1943) is here removed]. The operating characteristics were determined in the laboratory, while the limits of the characteristics, as a parameter of the circuits approached zero or infinity, were determined by mathematical means.

"The results of the study of the limits led to the solution of a general method of determining the limits for many voltage-multiplying circuits, and a way of using these limits as an aid in determining the approximate operating characteristics was found." For other papers on this subject by the first writer *see* also 34 & 3532 of 1942.

TRANSMISSION

3843. Current and Power in Velocity-Modulation Tubes.—L. J. Black & P. L. Morton. (*Proc. I.R.E.*, Aug. 1944, Vol. 32, No. 8, pp. 477–482.)

"The physical concepts which underlie the operation of velocity-modulation devices such as the klystron are relatively new and quite different from those applicable to the usual vacuum tube, and the already extensive literature on the subject does not seem to contain an adequate treatment of these concepts. Webster's mathematical analysis of the klystron, which has been commonly followed, gives correct results under certain limiting conditions, but the derivation is open to certain misinterpretations. Previous treatments also have neglected the effects of transit time between the grids which produce the velocity modulation and between those which utilise it, and the results, for some practical applications, are therefore only approximations.

"The present paper is intended to give a fairly complete physical and mathematical treatment of the mechanism of velocity modulation and an analysis of the process in which power is delivered to a tuned circuit by the modulated electron stream." The velocity modulation is expressed in terms of a variation with time of the density at any distance from the modulating source. This time-density variation is developed as a Fourier series having Bessel coefficients, and has the same form as Webster's expression for current. The h.f. current and power induced in a resonant circuit by the variable-density electron stream are calculated. The effects of transit time through the resonant circuit of the modulating source and of the output circuit are included in the calculations.

In a final paragraph the writer remarks :—"It will be noted that the input resistance is negative for certain transit angles. This shows the possibility of using a steady stream of electrons passing through a single resonator as a transit-time oscillator. . . ." This possibility is considered briefly [*cf.* Müller & Rostas, 406 of 1942] and finally the fact that a similar effect in a simple diode has been used by Llewellyn & Bowen to produce 10 cm. oscillations (3155 of 1939) is mentioned. For some of the comparatively few German papers on the subject *see* 407 of 1942 and 2175 of July, and back references.

3844. A Three-Phase Rotating-Field Transmitter for Ultra-Short Waves.—W. Dieterle. (*E.T.Z.*, 1st July 1943, Vol. 64, No. 25/26, pp. 358–359 : long illustrated summary.) Another summary was dealt with in 2879 of September.

3845. A Transmitter Drive Unit for F.M. Signals [to form the Nucleus of a Transmitter or Signal Generator, with Provision for Wide Variation of Radio & Deviation Frequencies].—F. Butler. (*Electronic Eng:g*, July 1944, Vol. 17, No. 197, pp. 58–61.)

3846. Noise Phenomena in Short-Wave Distribution Circuits [of Large Short-Wave Telegraph Transmitters].—G. S. Wasilieff [Vasil'ev]. (*E.T.Z.*, 17th Dec. 1942, Vol. 63, No. 49/50, pp. 586–587.) Long summary of the Russian paper dealt with in 413 of 1942.

3847. Class "C" Amplifiers : Reasons for Their High Efficiency in R.F. Circuits [including the Important Factor of Heat Dissipation].—R. W. Hallows. (*Wireless World*, Oct. 1944, Vol. 50, No. 10, pp. 309–312.)

RECEPTION

3848. The Course in Time of Noise Voltages.—P. A. Mann. (*E.N.T.*, Oct. 1943, Vol. 20, No. 10, pp. 232–237.)

From the Telefunken laboratories. Among the many recent papers on shot-effect and thermal-agitation noise, special attention should be given to one by Fränz (3026 of 1941) and one by Landon (2129 of 1941). Of particular importance for the study of the time-characteristics of noise voltages are certain papers by Fränz on linear rectification and similar problems, above all a quite recent one dealing with the amplitude distribution of noise voltages (3027 of 1941 and 2124 of 1943) : the latter work includes a bibliography of the literature so far published.

In the case of a noise whose band-width extends from $\omega_0 - \Omega$ to $\omega_0 + \Omega$ (such as the i.f. channel of an amplifier), this band may be split into a number of individual, closely adjacent frequencies, by developing the process in time of the noise, within an observation-period $-T < t < T$, into a Fourier series : $\vartheta(t) = \sum_{N}^{0} r_n \cos(n\pi \cdot t/T + \phi_n)$. The spacing between two frequencies is then given by π/T, and approaches zero as the observation-period is increased. All these frequencies have completely arbitrary phase relations among themselves : their amplitudes may assume any values whatever between zero and infinity, according to the appropriate probability law.

For the noise voltage of the frequency band $\omega_0 - \Omega$ to $\omega_0 + \Omega$ the above equation becomes

$$v(t) = \sum_{-N}^{N} r_n \cos[(\omega_0 + n \cdot \pi/T)t + \phi_n] \quad . . . \text{ eqn. 1.}$$

The quantities to be investigated, such as the probability distribution of the instantaneous values, etc., are functions of eqn. 1.

"The probability distribution of these instantaneous values must however be independent of the particular point in time considered : for this reason Fränz (*loc. cit.*) puts $t = 0$ in eqn. 1. This is where Fränz's treatment differs from ours : we wish to investigate the course in time of the noise voltages : that is, we wish for example to learn in what relation the amplitudes of the noise stand when we consider it at different moments. Special problems chosen for attention are : (a) What is the amplitude distribution of the noise voltage at a time t_1, if at time t_0 the amplitude U_0 is present ('coupling' between the voltage amplitudes) and (b) how often per unit time does the noise voltage exceed a given amplitude value A in the positive direction, or in the negative direction ?"

The treatment is based on the use of Dirac's "δ-function" (occurring in the study of thermal conduction, orthogonal function systems, etc :

for the present purposes its representation as given by Fourier-integral theory is sufficient: Fig. 1 and adjacent text) and on a formula for the probability that the noise voltage will lie between u and $u + du$ (eqn. 6, which could easily be derived from Fränz's paper but which the present writer arrives at in a simpler way).

Question (a) can already be answered qualitatively: since, for a finite band-width, the noise is a continuous function with continuous tangent, values adjacent in time can only differ by little from one another: only after the so-called "building-up" time can the noise regain any arbitrary value. For the quantitative answer, the probability must be found for the noise voltage at time t to lie between U and $U + dU$, if it has the value U_o at time $t = 0$. This probability is given by eqn. 10, from which it can be seen that for large values of t the probability distribution becomes identical with that given by the already known and simpler formula (eqn. 9) for the probability that the noise voltage will lie between U_o and $U_o + dU_o$, if U is written in place of U_o; and that the independence from the previously taken value U_o is practically attained as soon as $\sin\Omega t/\Omega t$ reaches its first null point, that is when $\Omega t = \pi$ or $t = 1/2f$, where $\Omega = 2\pi f$.

Question (b) is answered quantitatively by eqn. 12, giving S, the number of times per unit of time that the amplitude A is exceeded in the positive or negative direction. When the noise band stretches from 0 to the frequency f_1, this equation simplifies down to eqn. 13, $S = (f_1/\sqrt{3}) \cdot e^{-A^2/2\bar{v}^2}$: thus the amplitude "zero" is passed through (in the positive and negative directions) $2f_1/\sqrt{3}$ times. Landon (*loc. cit.*) gives a formula for the number of peaks exceeding a definite threshold, assuming that the peaks are of the shortest possible duration, namely, $\sin\Omega t/\Omega t$ ($f = \Omega/2\pi$ = band-width). His semi-empirical, semi-theoretical bases do not allow him to give formulae valid for an arbitrary threshold value: he calculates only the case where this value is four times the r.m.s. value, where his formula is $S = 6 . f. 32 . 10^{-6} = 1.92 . 10^{-4}$. For this particular case, eqn. 13 gives $S = (f/\sqrt{3}) . e^{-8} = 1.93 . 10^{-4}$, agreeing with Landon's value and confirming his assumption of the least possible duration of the peaks.

3849. THE MECHANISM OF LEAKY-GRID DETECTION [Contribution to the Theory, throwing Light on the Choice of Operating Conditions to obtain Optimum Performance: Experimental Investigations of Amount of Second-Harmonic Distortion introduced by the Detector].—S. W. Amos. (*Electronic Eng:g*, Aug. & Sept. 1944, Vol. 17, Nos. 198 & 199, pp. 104–108 and 116: pp. 158–161.)

3850. NEW THOUGHTS ON VOLUME EXPANSION: CONTRAST SHOULD BE PROPORTIONAL TO SIZE OF ROOM [and Contrast Compression rather than Expansion is usually Needed (except perhaps by the Fortunate Listener with No Traffic, No Neighbours, & No Aunt Fanny's Knitting Needles)].—T. Roddam. (*Wireless World*, Sept. 1944, Vol. 50, No. 9, pp. 286–287.)

3851. STATISTICAL RECORDERS AND, MORE GENERALLY, ELECTRO-MECHANICAL SYSTEMS [including Microphones & Loudspeakers) SUBJECTED TO A PHYSICAL QUANTITY WHICH IS A CONTINUOUS OR DISCONTINUOUS FUNCTION OF TIME.—Carbenay. (*See* 3963.)

3852. VALVE HUM [Causes, and Methods of Avoiding It].—Cooper. (*See* 3872.)

3853. SUPPRESSION OF RADIO INTERFERENCE FROM MAINS-VOLTAGE FLUORESCENT LAMPS.—J. N. Aldington. (*Electronic Eng:g*, Sept. 1944, Vol. 17, No. 199, p. 148: summary, from *Elec. Times*, 1944.) *Cf.* 52 of 1943 and 3461 of November.

3854. THREE-PHASE IN THE HOME [Welcome to "Supervisor's" Article (3465 of November): Pre-War Adoption of Three-Phase Supply in Germany: etc.].—"Diallist." (*Wireless World*, Sept. 1944, Vol. 50, No. 9, p. 283.)

3855. LEAKAGE CURRENTS IN SUSPENSION INSULATORS [on High-Voltage Systems: Experimental Investigation of the Effects of Moisture Deposits].—M. J. Cuilhé. (*E.T.Z.*, 15th July 1943, Vol. 64, No. 27/28, p. 381: summary, from *Bull. Soc. Franç. des Élec.*, 1942.)

3856. TAYLOR SIGNAL GENERATOR: AN A.C.-OPERATED MODULATED TEST OSCILLATOR FOR RECEIVER ALIGNMENT.—Taylor Elec. Instruments, Ltd. (*Wireless World*, Sept. 1944, Vol. 50, No. 9, p. 277.)

3857. MONTHLY COMMENTARY: PLEA TO SET DESIGNERS [Note on *Wireless Trader's* Appeal for Design for Easier Maintenance & Repair: Present Lack of Accessibility (*e.g.* of Multiple "Wafer" Switches, Trimmers, Electrolytic Condensers): Unnecessary Complications (Fanciful Tuning Scales, etc.)].—(*Wireless World*, Sept. 1944, Vol. 50, No. 9, p. 257.)

3858. EASIER SERVICING [Remarks prompted by Correspondence in *Wireless Trader* on the Serviceman's Difficulties: the Crime of employing Unnecessary Complicated Circuits: etc.].—"Diallist." (*Wireless World*, Oct. 1944, Vol. 50, No. 10, p. 308.) *See* 3857, above.

3859. "AMERICAN MIDGETS" [Notice of Booklet].—Radio Service Specialities. (*Electronic Eng:g*, July 1944, Vol. 17, No. 197, p. 86.)

AERIALS AND AERIAL SYSTEMS

3860. A GENERAL THEORY OF ANTENNAE.—J. Aharoni. (*Phil. Mag.*, July 1944, Vol. 35, No. 246, pp. 427–459.)

Author's summary:—"A general theory for calculating the transmitting and receiving properties of antennae is outlined. It contains Hallén's theory of antennae which consist of thin wires as a special case. As far as these are concerned it may be regarded, therefore, as a different derivation of his one-dimensional equations. The present discussion applies to any form of conductor."

The new approach to the problem is indicated by the following quotations: "The question to be answered is: can a method of calculating the electrical current be developed from Maxwell's equations, by making use, as in the circuit theory, of some knowledge about the current . . . It will be shown that if the lines of flow are stationary (or can be assumed so to a high degree of approximation) a general answer can be given to the above question. The density of the electric current obeys an integral equation, eqn. 1 . . . The method of obtaining eqn. 1 consists mainly in the following steps: (a) The derivation of a circuit theory which does not neglect the radiation, for networks which are small compared with the wavelength. These networks can consist either of a very small loop, or of a short and thin piece of wire . . . A circuit theory very similar to the ordinary one is obtained, the only difference is in the inductances and capacitances not being real as usual, but complex [containing real components connected with the radiated power]. . . (b) The calculation of the mutual effect between two short and thin pieces of wire, the distance between which is not restricted. Here again we obtain mutual inductances and capacitances of complex value, but otherwise the result is quite similar to that of ordinary circuit theory. For *n* small components (short pieces of wire or loops) we get *n* linear equations for the currents. (c) The final step is to regard any conductor as consisting of a great number of small line elements in the direction of current flow. The greater the subdivision the greater the number of the linear equations, until in the limit the system of equations becomes equivalent to an integral equation . . ."

3861. Aerials with Rotating-Field Phase Adjustment [Theoretical Comparison of the "Star-Group" & "Circle-Group" Types, both with Rotating-Field Feed].—H. Brückmann. (*E.N.T.*, Oct. 1943, Vol. 20, No. 10, pp. 227–232.)

By the "star-group" array the writer means radial arrangements such as the "tripole" and "quadrupole" (American "turnstile") aerials proposed by Tank in 1934 and further investigated by Hardung (2897 of September). By the "circle-group" array he denotes the system proposed by Chireix (3375 of 1936) and used at the Radio Paris (Allouis) long-wave broadcasting station (ref. "6" and Fig. 4: Fig. 5 shows a German 6-element group of the same type, but this aerial, used at the Stolp broadcasting station, is intended for co-phasal feed).

The two types differ in that the "circle-group" aerial has the axes of its individual elements parallel, while with the "star-group" aerial this is not the case: further, in the latter aerial the axes all lie in the same plane, whereas this is not so with the "circle-group" array ("at present the only 'circle-group' aerials known have their element-axes perpendicular to the plane of the circle"). A less important difference is that the "circle-group" array in practice has a radius comparable with the wavelength, or at any rate not very small compared with the wavelength, whereas "star-group" aerials may quite well be envisaged with over-all dimensions small compared with the wavelength.

"In the present paper we shall investigate certain important differences in the working of the two types, in particular the polarisation of the distant field. So far as the 'star-group' type is concerned Hardung's work (*loc. cit.*) can be utilised here, but his treatment is considerably simplified and to some extent extended": thus the influence of the ground, hitherto neglected, is taken into account by considering the image of the aerial below the surface of the ground, so that aerial and image form a radiating pair with a "group characteristic" given by eqn. 10, $\mathfrak{G}(\phi, \psi) = 2 \sin (\alpha a \sin \phi)$, where a is the height above the ground. Thus the only effect of the ground is to alter the amplitude of the field strength as a function of the angle of elevation, uniformly for all components. Eqn. 11 refers to the true American "turnstile" of several "star-group" systems stacked one above the other (Brown, 2595 of 1936): eqns. 12–14 refer to systems with more than four elements, and eqn. 15 and the adjacent text considers the special case where the individual conductors have no end-capacitances and are a quarter-wavelength long.

Section 3 deals with the radiation resistance of "star-groups" with rotating-field feed, and the influence of the ground on its value: Fig. 7 shows the calculated variation of the radiation resistance as a function of the height a above the ground.

Finally, the short section 4 deals with the distant field of a "circle-group" system with rotating-field feed. Unlike the "star-group" system, such an array produces a field which is everywhere linearly polarised. The radiation resistance cannot be given in closed form as it was for the other system; in general it is best obtained by graphical integration, as described in the writer's book (4443 of 1939).

3862. Heating of Aerials for De-Icing.—G. W. Schuleikin [Shuleykin]. (*E.T.Z.*, 11th March 1943, Vol. 64, No. 9/10, pp. 129–130.) Long summary of the Russian paper dealt with in 442 of 1942.

VALVES AND THERMIONICS

3863. Current and Power in Velocity-Modulation Tubes.—Black & Morton. (*See* 3843.)

3864. "Klystron Technical Manual" [Review of Booklet].—Sperry Gyroscope. (*Proc. I.R.E.*, Aug. 1944, Vol. 32, No. 8, p. 501.)

3865. Deflected Electron Beams [Continuation of Correspondence dealt with in 3164 of October & 3484 of November].—D. Gabor. (*Wireless Engineer*, Oct. 1944, Vol. 21, No. 253, p. 480.)

3866. Paths of Electrons and Ions in Non-Uniform Magnetic Fields.—N. D. Coggeshall & M. Muskat. (*Phys. Review*, 1st/15th June 1944, Vol. 65, No. 11/12, pp. 352–353: summary only.)

"The integration of the Lorentz force equations to give electron or ion paths has been reduced to simple quadratures for systems in which the electric field is zero and the magnetic field is a function of one Cartesian or cylindrical coordinate. For several interesting types of magnetic-field variation the quadrature can be carried through analytically, and even for complicated magnetic fields, or such as are known only empirically, the numerical integration can be effected without difficulty . . ."

3867. Energy Distribution of Electrons within Dense Electron Beams [and the Arrival of an Unstable Condition where the Current falls rapidly and a Virtual Cathode forms:

Calculations for Beams & Enclosures of Two- and Three-Dimensional Symmetry].—C. J. Calbick. (*Phys. Review*, 1st/15th June 1944, Vol. 65, No. 11/12, p. 353 : summary only.)

3868. Limiting Stable Current [beyond which a Virtual Cathode will form] in Electron Beams in the Presence of Ions [Calculation of Limiting-Current Density for Parallel Grids, and of Limiting Current for Conducting Tube of Infinite Length capped by Grids].—J. R. Pierce. (*Phys. Review*, 1st/15th June 1944, Vol. 65, No. 11/12, p. 353 : summary only.)

3869. Correspondence on a Comparison between "On the Currents carried by Electrons of Uniform Velocity" (Jaffé, 2577 of August) and "On the Theory of Space Charge between Parallel Plane Electrodes (Fay, Samuel, & Shockley, 1885 [and 3609] of 1938).—J. R. Pierce : G. Jaffé. (*Phys. Review*, 1st/15th July 1944, Vol. 66, No. 1/2, pp. 29–30.)

3870. Potential Nuclear Monochromatic Electron Sources [including Their Eventual Application in Electron Microscopes, Special Radio Valves, etc.].—M. L. Pool. (*Phys. Review*, 1st/15th June 1944, Vol. 65, No. 11/12, p. 353 : summary only.)

3871. Miller Effect Simplified [Treatment from a New Angle].—Mitchell. (*See* 3815.)

3872. Valve Hum [Examination of Its Various Causes, and Methods of Avoiding It : including a Circuit for Valve-Hum Analysis, set up for testing a Universal-Type Double-Diode-Triode].—C. E. Cooper. (*Electronic Eng:g*, July 1944, Vol. 17, No. 197, pp. 72–75.)

3873. Geometry of Push-Pull Amplification [and the Use of Dynamic Valve-Characteristics of Hyperbolic Shape].—Russell. (*See* 3821.)

3874. Pentodes as Dynatrons : Summary of the Negative-Resistance Characteristics of Various Commercial Pentodes [and the Usefulness of the Dynatron, particularly for Laboratory Work].—G. A. Hay. (*Wireless World*, Sept. 1944, Vol. 50, No. 9, pp. 271–273.)

"It is generally recognised that the best all-round dynatron oscillator is the Mazda AC/S2 screened tetrode, while for special purposes where low anode/earth capacitance is wanted the Mullard S4VA is useful. Both valves are now relatively inaccessible, and in this article it will be shown how modern r.f. pentodes may be used in their stead ; the optimum working conditions for various applications will also be discussed."

3875. Glass Bases for Radio Valves [including Recent Automatic Machines developed by Mitchell Glass Company].—M. A. Rowe. (*Electronic Eng:g*, Aug. 1944, Vol. 17, No. 198, pp. 101–103.)

3876. Technical Data on "Chance" Sealing Glasses.—Chance Bros. Ltd. (*Wireless Engineer*, Oct. 1944, Vol. 21, No. 253, p. 479.)

3877. Secondary Emission of Pure Metallic Films in the Disordered and Ordered States.—R. Suhrmann & W. Kundt. (*E.T.Z.*, 12th Aug. 1943, Vol. 64, No. 31/32, pp. 435–436 : summary, from *Zeitschr. f. Phys.*, Vol. 120, 1943.) For subsequent work *see* 1598 of May.

3878. Growth and Structure of the Tungsten Crystal [Further Investigation of the Johnson–Skaupy "D.C. Effect"].—H. W. Schmidt. (*E.T.Z.*, 12th Aug. 1943, Vol. 64, No. 31/32, p. 435 : summary, from *Zeitschr. f. Phys.*, Vol. 120, 1943.)

3879. Theory of Cathode Sputtering in Low-Voltage Gaseous Discharges.—C. H. Townes. (*Phys. Review*, 1st/15th June 1944, Vol. 65, No. 11/12, pp. 319–327.)

3880. Electronic Graphical Symbols Standardised [Note on "American Standard Z 32.10–1944"].—(*Elec. Engineering*, July 1944, Vol. 63, No. 7, p. 246.)

DIRECTIONAL WIRELESS

3881. The Development of a New Station-Location or Z-Marker Antenna System.—J. C. Hromada. (*Proc. I.R.E.*, Aug. 1944, Vol. 32, No. 8, pp. 454–463.)

Valuable as the existing Z markers have proved to be, the demand for increased stability, greater accuracy as a point of fix from which to begin the let-down procedure, and an increased height of signal zone (without a broadening of the beam at low altitudes, such as would occur in merely increasing the power to the existing aerial) to ensure reception at higher altitudes, has indicated the need for an improved aerial system : without, however, the electrical and mechanical complexity of the systems described by Green (2359 of 1938).

The present paper gives descriptive and flight-test information on such an improved aerial system consisting of two spaced-dipole arrays, crossed at right angles to each other and excited in quadrature time phase. The design of the arrays is based on the principle of proportioning dipole currents in accordance with the coefficients of the successive terms of the binomial expansion. The system is of simple and rugged design, which maintains high stability of the marker-zone under rain, snow, and sleet conditions, and also lends itself to prefabrication in units and sections of transmission line.

The zone width is considerably less than that of the old system, at all altitudes up to 10 000 feet (about the old limit). The zone can be extended to 20 000 feet without modification of the present transmitters. The apparent excessive broadening of the zone, previously noted during flights off-course or in conditions involving a large crab angle, is greatly reduced.

3882. Air Traffic Control [Limitations of Present Systems, and Future Planning].—G. A. Gilbert. (*Elec. Engineering*, April 1944, Vol. 63, No. 4, pp. 119–125.)

3883. Enemy Army Communications Equipment [Analysis by Signal Corps Laboratory and Comparison with American-Made Equipment].—R. B. Colton. (*Elec. Engineering*, April 1944, Vol. 63, No. 4, pp. 139–144.)

3884. FLUORESCENT LIGHTING OF AIRCRAFT INSTRUMENTS [including the Use of Iris Diaphragm to adjust the Floodlighting].—A. D. Dircksen. (*Elec. Engineering*, July 1944, Vol. 63, No. 7, pp. 247–249.)

3885. ELECTRIC CIRCUITS AND THE MAGNETIC COMPASS [Deviations caused by Electro-Magnetic Effects from Wiring of Aircraft, & Some Means for Correcting Them].—R. C. Burt & H. R. Beck. (*Elec. Engineering*, Jan. 1944, Vol. 63, No. 1, Transactions pp. 24–26.)

ACOUSTICS AND AUDIO-FREQUENCIES

3886. STATISTICAL RECORDERS AND, MORE GENERALLY, ELECTRO-MECHANICAL SYSTEMS [including Microphones & Loudspeakers] SUBJECTED TO A PHYSICAL QUANTITY WHICH IS A CONTINUOUS OR DISCONTINUOUS FUNCTION OF TIME.—Carbenay. (*See* 3963.)

3887. THE EMPLOYMENT OF ELECTRO-ACOUSTICAL CONVERTERS IN "VIVAVOX" LOUDSPEAKING INTERCOMMUNICATION EQUIPMENT [Theoretical Investigation of the Comparative Merits of Electro-Magnetic & Dynamic (Moving-Coil) Systems for the Dual Rôle of Microphone & Loudspeaker (1969 of June): Superiority of the M.C. Type].—O. Tschumi. (*Bull. Assoc. Suisse des Élec.*, 28th June 1944, Vol. 35, No. 13, pp. 349–352: in German.)

3888. MAINTENANCE OF QUALITY IN FILM-RECORDED SOUND: I—RECORDING AND PROCESSING: II—REPRODUCTION.—R. H. Cricks. (*Electronic Eng:g*, June 1944, Vol. 17, No. 196, pp. 12–15: July, No. 197, pp. 62–64 and 75.)

3889. MAGNETIC RECORDING [Some Additions to G. L. Ashman's Article (August Issue): Typical Wire or Tape Speeds: Life of Recordings: Supplementary Literature References: etc.].—D. W. Aldous: Ashman. (*Wireless World*, Sept. 1944, Vol. 50, No. 9, p. 269.)

3890. GRAMOPHONE "NEEDLE BUZZ" [also known as "Acoustic Buzz" & "Burring"]: AN INHERENT FORM OF DISTORTION: POSSIBLE CURES.—F. L. Devereux. (*Wireless World*, Oct. 1944, Vol. 50, No. 10, pp. 290–294.)

In "high-fidelity" reproduction of standard commercial records, and arising from the fact that the reproducing stylus has a shape differing from that of the cutter. The second half of the article discusses preliminary experimental work to overcome the difficulty by the use of a flat "needle" formed by a hairpin of fine wire. Improvement in quality was most promising; the remaining problem, that of the rapid wear of the wire, ought to be capable of solution by reducing the inertia of the moving parts to fly-weight proportions so that the pressure needed to hold the needle in the groove is not more than two or three grams; by chromium plating the hairpin wire; or by a continuous feed of wire.

3891. NEW THOUGHTS ON VOLUME EXPANSION: CONTRAST SHOULD BE PROPORTIONAL TO SIZE OF ROOM [and Contrast Compression rather than Expansion is usually Needed].—Roddam. (*See* 3850.)

3892. ON THE PERTURBATION OF BOUNDARY CONDITIONS [with Results applicable to Acoustics of Irregularly-Shaped Rooms, Scattering from Irregularly-Shaped Objects, Propagation down Irregularly-Shaped Pipes, etc.].—Feshbach. (*See* 4026.)

3893. CONTRIBUTIONS OF SCIENCE TO AN APPRECIATION OF MUSIC.—A. Pepinsky. (*Journ. Franklin Inst.*, April 1943, Vol. 235, No. 4, pp. 361–392.)

Among the many subjects considered (researches on the vibrato: masking—"probably the greatest *single* contribution to thought concerning the phenomenon of the perception of sound"; it implies that the listener "does not actually hear what the composer wrote and thought should be heard": consonance and dissonance, and the arguments of the ultra-modernist: timbre: etc.) is the electronic musical instrument. Of this it is remarked, *inter alia*, that "to do justice to such novel possibilities, if the older literature is to be played at all on these machines, the music must naturally be reconceived, that is, rearranged. But if the composer is sufficiently stimulated, he will now create with the new instrument in mind, instead of 'rehashing' conventionally accepted music . . . Phase relationships and their effects have already been mentioned: control of fine increments of frequency change associated with what are known as tendency tones offers a further heightening of interpretive effects. This is commonly known among musicians as psychological intonation . . . The new instruments, with the manufacturer's choice of tonal qualities and resultant psychological effects upon the buyer, beautifully reflect the trend of current opinion as to what is to-day acceptable in tone quality, for it is deemed wise to give the public what it thinks it wants . . ."

3894. THE FUTURE OF ELECTRONIC MUSIC.—S. K. Lewer. (*Electronic Eng:g*, June 1944, Vol. 17, No. 196, pp. 32–34.)

The writer ends: "The unchanging acoustic instruments may continue to fill a minority need, like the acoustic gramophone and the silent film." For correspondence *see* August issue, No. 198, pp. 124–126, and for the same writer's paper on "Problems in Electronic Organ Design," *see* September issue, No. 199, pp. 149–152 and 161.

3895. "AESTHETICS OF SOUND REPRODUCTION": REPLIES TO READERS' QUERIES, AND A POSTSCRIPT [including Some Points on Choosing Records].—H. A. Hartley. (*Wireless World*, Oct. 1944, Vol. 50, No. 10, pp. 318–319.) *See* also 3896/8, below.

3896. LETTER ON "AESTHETICS OF SOUND REPRODUCTION" [3178 of October].—V. W. Greenhough: Hartley. (*Wireless World*, Sept. 1944, Vol. 50, No. 9, p. 270.)

"Some degree of correction will probably always be necessary, if only for the listening-room acoustics, but I do emphasise that we must not try to build anything new from a programme ;. we must ensure that studio sounds are reproduced as accurately as possible in the listener's ear. Should any other balance of sound be more pleasing to the ear than the original orchestra, I feel that the instruments would have been designed by the musicians through the ages to give this improved balance . . ."

3897. CORRESPONDENCE ON "AESTHETICS OF SOUND REPRODUCTION" [see above & below].—E. K. M. Bird : D. Roe : Hartley. (*Wireless World*, Oct. 1944, Vol. 50, No. 10, pp. 298–299.)

3898. TOWARDS SYNTHETIC MUSIC : AVOIDING INTERMEDIATE PROCESSES.—P. Stevenson. (*Wireless World*, Sept. 1944, Vol. 50, No. 9, pp. 278–279.)

In this article, arising out of Hartley's "Aesthetics of Sound Reproduction" (3178 of October : *see* also 3895/7, above), the writer "urges the claim of truly synthetic music as opposed to 'doctored' receiver response." *Cf.* 1230 of April and 1976 of June. For a letter from Hartley, expressing "excruciating horror at the prospect unfolded," *see* October issue, No. 10, pp. 299–300 : he calculates that nearly 3×10^{22} stencils would be required for the dubious task of imitating a pianola.

3899. THE TRANSIENTS OF WAR [in the B.B.C.'s "War Reports" : the Impossibility of reproducing "the Loud & Angry Sounds of War"].—"Diallist." (*Wireless World*, Oct. 1944, Vol. 50, No. 10, p. 307.)

3900. THE *Wireless World* QUALITY AMPLIFIER WITH CATHODE FOLLOWER [3181 of October : Replies to Correspondents].—A. C. Robb. (*Wireless World*, Sept. 1944, Vol. 50, No. 9, pp. 268–269.)

3901. ON THE STATISTICAL PHONETICS OF THE FRENCH LANGUAGE [Lack of Information on the Subject : Results of a Literal & Phonetic Analysis of Texts from 15 Different Authors : with Application to Quality Tests & Telegraphy].—P. Chavasse. (*Comptes Rendus* [Paris], 1st/29th March 1943, Vol. 216, No. 9/13, pp. 314–316.)

3902. THE ELECTRIC MOTOR AS A SOURCE OF NOISE.—W. Ordinanz. (*E.T.Z.*, 25th March 1943, Vol. 64, No. 11/12, pp. 157–160.) From a report on Russian investigations in 1939.

3903. ON THE REFLECTION AND REFRACTION OF ACOUSTIC WAVES AT THE SURFACE OF SEPARATION OF TWO FLUIDS IN REPOSE OR IN RELATIVE MOVEMENT OF TRANSLATION.—E. Esclangon. (*Comptes Rendus* [Paris], 6th/27th July 1942, Vol. 215, No. 1/4, pp. 45–48.)

The writer concludes : "In the case of any wave, permanent or solitary, the 'conjugate wave' [superposed, in total reflection, on the 'identical' wave] may differ widely, in its physical structure, from the incident wave ; especially if, as in the case of explosions, for instance, the latter suffers rapid variations of evolution. The impression of 'detonation' resulting as it does from sharp variations of pressure, it may happen that incident waves which are not audible may become so, or may be reinforced, by total reflection. These circumstances appear to be present in the prolonged echoes generated at the clouds as a result of thunder claps, which are sometimes distinguished by unexpected 'reboundings' of intensity."

3904. FABRIC MEASURED BY SOUND [Elasticity of Taut Thread or Yarn measured by Vibrating It at 10 kc/s].—du Pont de Nemours. (*Sci. News Letter*, 22nd July 1944, Vol. 46, No. 4, p. 55.)

3905. THE ULTRASONIC TRANSPARENCY OF METAL PLATES [Summary of 1942 "Physikertagung" Lecture].—H. Götz. (*E.T.Z.*, 1st July 1943, Vol. 64, No. 25/26, p. 360.)

3906. ULTRASONICS : A METHOD OF DETERMINING THE ACOUSTIC PROPERTIES, ABSORPTION AND VELOCITY, FOR MATERIALS TO BE USED AS ULTRASONIC WINDOWS, LENSES, AND REFLECTORS.—D. Cochran & R. W. Samsel. (*Gen. Elec. Review*, Aug. 1944, Vol. 47, No. 8, pp. 39–41.)

3907. FOCUSED SUPERSONIC WAVES IN BIOLOGICAL EXPERIMENTS [Circuit using Quartz Crystal as Vernier-Adjusted Master Oscillator instead of *L* & *C* in 1st Grid Circuit : the Concave Generating Crystal is Ground to match This, so that Entire Unit can be tuned to Resonance & neutralised Once & for All : etc.].—J. G. Lyon & others. (*Electronic Eng:g*, Aug. 1944, Vol. 17, No. 198, pp. 122–123 : from *Journ. of Gen. Physiology*, Vol. 26.)

3908. APPARATUS FOR THE DETERMINATION OF DISPERSION AT SUPERSONIC FREQUENCIES [90–450 kc/s], *and* PRECISION MEASUREMENTS OF THE VELOCITY OF SOUND AT SUPERSONIC FREQUENCIES, USING A MICROPHONE.—L. N. Liebermann : E. G. Groth & L. N. Liebermann. (*Phys. Review*, 1st/15th June 1944, Vol. 65, No. 11/12, p. 350 : p. 350 : summaries only.)

PHOTOTELEGRAPHY AND TELEVISION

3909. BAIRD "TELECHROME" [Demonstration of Latest System of Stereoscopic Colour Television, using Special Double-Beam Tube with Internal Mica Screen coated on One Side with Blue-Green & on Other with Red-Orange Fluorescent Material].—J. L. Baird. (*Wireless World*, Sept. 1944, Vol. 50, No. 9, p. 279.) For a more detailed account *see* issue for October, No. 10, pp. 316–317, and *Electrician*, 18th Aug. 1944, Vol. 133, No. 3455, p. 136 : also *Electronic Eng:g*, Sept. 1944, Vol. 17, No. 199, pp. 140–141.

3910. PLANNING TOMORROW'S ELECTRONIC HIGHWAYS [Organisation & Work of the National Television System Committee & the Radio Technical Planning Board].—W. R. G. Baker. (*Gen. Elec. Review*, June 1944, Vol. 47, No. 6, pp. 15–21.) For an Editorial *see* p. 7, and *cf.* 2077 of June for articles on the R.T.P.B.

3911. Television after the War [Surveys show that 83% of the People want Receivers: a Billion-Dollar Industry? the 525-Line *versus* the 1000-Line Screen: Receiver Costs: etc.].—R. N. Farr. (*Sci. News Letter*, 22nd July 1944, Vol. 46, No. 4, pp. 58–59.)

3912. Performance of Coupled and Staggered Circuits in Wide-Band Amplifiers.—Weighton. (*See* 3820.)

3913. Theory of the Half-Tone Process: II—The Diffraction Theory: Calculation of the Light Distribution [by the Fresnel Diffraction Theory: Results agree with Experimental Findings, Very Different from Geometrical-Optical Results].—J. A. C. Yule. (*Journ. Franklin Inst.*, May 1943, Vol. 235, No. 5, pp. 483–498.) For I *see* 3533 of November.

3914. Fluctuations due to Thermoelectronic Emission from the Photoelectric Layer in a Modulated-Light Amplifier.—A. Blanc-Lapierre. (*Comptes Rendus* [Paris], 4th/25th Jan. 1943, Vol. 216, No. 1/4, pp. 42–44.)

This is the work referred to at the end of 3421 of November. "Sensitive photoelectric layers, of low work function, have a thermal emission which is not negligible. The corresponding current $\dot{I}$ (composed of electrons of charge e emitted at random) places a limit on the detection of very small photoelectric currents. I propose to study the effect of $\dot{I}$ on a linear amplifier characterised by a gain $f(\nu)$ and a phase displacement $\phi(\nu)$ for a frequency ν, and followed by a square-law receiver. The amplifier transforms the intensity $I(t)$ at the time t into $y(t)$, and the receiver is subjected to $Y(t) = y^2(t)$. Let $x(t)$ be the indication of the receiver. It is required to calculate the mean $\overline{x(t)}$ and the deviation $\sqrt{\overline{(x - \bar{x})^2}}$, and thus $\overline{Y(t)}$ and the contribution $\overline{Y_\nu^2 d\nu}$ of the band ν, $\nu + d\nu$ to the mean square $\overline{Y^2(t)}$ (Bernamont, 1715 of 1937: p. 84)." The present Note outlines the method of treatment and gives the results of the calculations. *See* also 3915, below.

3915. An Arrangement for the Amplification of Very Weak Photoelectric Currents.—A. Blanc-Lapierre & G. Goudet. (*Comptes Rendus* [Paris], 1st/29th March 1943, Vol. 216, No. 9/13, pp. 295–297.)

The d.c. amplifiers generally used for this purpose, with high input resistance, give a high gain and a background noise below that of the cell itself, owing to the considerable thermionic emission of the layers sensitive to visible and infra-red light (3914, above). But the high input resistance sets problems of insulation and of stability, and reduces in practice the theoretical possibilities of the apparatus, which is, moreover, very sensitive to fluctuations of the supply voltages. On the other hand, the use of an electron multiplier provides an arrangement of equal theoretical sensitivity and free from the above defects.

The writers used a caesium cell of 1.5 cm² surface, followed by a 10-stage multiplier with magnetic focusing: the a.c. mains provided, through a valve-type rectifier, a d.c. voltage V between 1000 and 2000 volts, and also an exciting current for the magnetic field, adjustable to suit V. The current amplification of the multiplier was found to range from 0.135×10^5 at 1200 v to 3.38×10^5 at 1870 v. Using a disc-modulated light beam, and amplifying the multiplier currents by a suitable tuned amplifier, investigations were made of the background noise, etc: results are tabulated, for three different values of V. The smallest r.m.s. photoelectric current detectable was 9×10^{-16} A, corresponding to a direct current (in the absence of the revolving disc) of 2×10^{-15} A: this was with $V = 1200$ or 1550 volts, for at 1870 volts the background noise was much higher (owing to secondary causes in the multiplier: Bruining, ref. "3") and the smallest r.m.s. current detectable was 26×10^{-16} A.

As a side experiment the multiplier was connected directly to a galvanometer: the smallest detectable current was 6×10^{-15} A, and the resolving power of the circuit three times poorer than that of the original arrangement. Theoretically, for the galvanometer employed the fluctuations due to the thermionic effect should allow of a resolving power below 4×10^{-16} A. The drifts of the supply voltages are probably the cause of the discrepancy, and the combination of multiplier and a.c. amplifier, which eliminates these, forms the most convenient and reliable arrangement.

MEASUREMENTS AND STANDARDS

3916. A New Spectral Method: the Hertzian Spectrum of Alcohol Molecules [Almost Complete Dispersion Curves, and Long Segments of Absorption Curves, plotted by Measurements on Wavelengths from 2.5 cm upwards].—P. Girard & P. Abadie. (*Comptes Rendus* [Paris], 6th/27th July 1942, Vol. 215, No. 1/4, pp. 84–86.)

Such dispersion curves bear an intimate relation to the shape of the molecules. They permit the determination of the angle of the permanent moment to a symmetry element, and provide information on the length of the carburetted chain. Thus the ratio τ_1/τ_2 (relaxation times in the two dispersion regions) increases with the length of the chain: it is nearly three times as large for octyl as for propyl alcohol. From this τ_1/τ_2 ratio the writers have derived, according to Perrin's theory on the extension of dielectric dispersion to ellipsoidal molecules, the ratio of the axes: here it is only stated that the values are large compared with X-ray-diffraction values, especially in the case of the long-chain molecules.

The method of measurement for the shortest waves was based on the observation of the stationary waves produced in a coaxial line holding the liquid, for different positions of a mobile piston (in principle, Drude's "first method"): between 17 cm and 4 m, Drude's "second method," modified, was employed, while above 4 m the resonance method was used. For results on benzylic alcohol and nitrobenzene see *ibid.*, 4th/25th Jan. 1943, Vol. 216, No. 1/4, pp. 44–46.

3917. A Resonant Cavity Method for measuring Dielectric Properties at Ultra-High Frequencies (50–1000 Megacycles).—Works & others. (*Phys. Review*, 1st/15th June 1944, Vol. 65, No. 11/12, p. 349: summary only.) *See* 3540 of November.

3918. A Method of measuring Complex Admittances in the Decimetric-Wave Region.—K. S. Knol & M. J. O. Strutt. (*E.T.Z.*, 15th July 1943, Vol. 64, No. 27/28, p. 382: summary only.) Another summary of this *Physica* paper was dealt with in 2635 of August.

3919. A Method of Measuring Very Small or Very Large Impedances in the Decimetric- and Centimetric-Wave Region.—A. Weissfloch. (*E.T.Z.*, 15th July 1943, Vol. 64, No. 27/28, pp. 377–379.)

This is the paper referred to in 3465 of 1943. In the ordinary Lecher-wire method of measuring impedances, if the impedance under test has a very small or a very large ohmic component the necessary ratio U_{max}/U_{min} takes on such a large value that it can be determined directly only with great difficulty. In such a case the method has been introduced (*cf.* Roosenstein, 1931 Abstracts, p. 36) of measuring the "node-breadth," the distance b between those points to the left and right of the minimum where the potential is equal to $\sqrt{2} \cdot U_{min}$. But for a 15 cm wavelength and a line characteristic impedance of 75 ohms, a 1.5 ohm terminating resistance (for example) would lead to a value for b of only 1 mm, and the same would occur with a resistance of 3750 ohms; while for smaller and larger resistances, respectively, the value of b would be still lower. The smaller the "node-breath" the less accurate the measurement, and the inaccuracy is increased by the fact that the exploring electrode generally takes the form of a pin which for mechanical reasons cannot be less than about half a millimetre in diameter.

The device, to overcome this difficulty, of increasing b by choosing points where the potential is not $\sqrt{2} \cdot U_{min}$ but (say) $\sqrt{5} \cdot U_{min}$, is of only limited usefulness. The writer's solution is to introduce, between the impedance to be measured and the Lecher system, a "transformation section" [*see*, for example, 3102 of 1943] which transforms that impedance into a value that can easily be measured: for if, for instance, the transformation ratio is 20, the node-breath b will be similarly magnified. The method is described with the help of Figs. 2–4, and the technique of ensuring the correct position for the "transformation section," and of correcting for small deviations, is discussed next.

Finally the application of the method to measure the ohmic resistance, at $\lambda = 14$ cm, of a copper coaxial section is described. Fig. 5 shows the copper section and the "transformation section" (a section of smaller characteristic impedance, 3.5 cm long—that is, about $\lambda/4$): the section-planes "B" and "A" show where this diagram fits into the general lay-out of Fig. 2. In this particular case it is a very small resistance that has to be measured: great care must therefore be taken that the introduction of the "transformation section" does not produce any serious damping. A sliding $\lambda/4$-section with metallic contact-surfaces would be liable to do so, and the section is therefore soldered to the inner conductor. This makes its adjustment to the exact correct position (previously stated to be important) a difficult matter: but the small deviation from the correct position can be counteracted by a small change in the test frequency—for it really does not matter whether the measurements are made on a 140 mm or a 140.5 mm wavelength.

A node-breadth using $U = \sqrt{5} \cdot U_{min}$ is employed, as suggested above. The transformation ratio is 19.6, practically constant between 143.8 and 144.2 mm. The measured value of resistance comes out to 3.1 ohm, so that the actual, un-transformed resistance would be $3.1/19.6 = 0.1582$ ohm. But because this resistance is so small, it is necessary to allow for the losses in the "transformation section" and the measuring system. On p. 379, r-h column, these are calculated (taking into account the complication that part of the whole apparatus is made of copper and part of brass): with the result that the above value has to be reduced by 0.0162 ohm, giving 0.142 ohm as the final figure.

Calculation, using Gundlach's formula $t = 6.7/\sqrt{f}$ (t in cm, f in c/s) for the penetration depth, and assuming a sinusoidal distribution of current along the copper coaxial section under measurement, gives 0.125 ohm to compare with this measured value.

3920. A Precision Wavemeter for the 14 cm Wavelength Range.—A. Weissfloch. (*E.T.Z.*, 7th Oct. 1943, Vol. 64, No. 39/40, p. 539.) *See* long abstract, 3102 of 1943.

3921. Current Measurement at High Frequencies [Short Survey: Thermal Methods (Hot-Wire, Thermoelectric Converter, Hot-Wire Air Thermometer, Bolometer, Photoelectric Converter): Frequency Errors of Thermal Ammeters (Skin Effect in the Hot Wire: Parallel & Earth Capacitances): Dynamometer Ammeters: Rectifier Ammeters: Range Extension by Toroidal Transformers, etc.].—H. F. Grave & O. Zinke. (*E.T.Z.*, 17th Dec. 1942, Vol. 63, No. 49/50, pp. 580–583.) For a companion paper on voltage measurement *see* 143 of January.

3922. Standard-Frequency Broadcast Service of National Bureau of Standards [Revision of Material dealt with in 3559 of November].—Nat. Bureau of Standards. (*Proc. I.R.E.*, Aug. 1944, Vol. 32, No. 8, pp. 493–494.)

3923. System of Oscillation-Maintenance with Auto-Stabilised Amplitude, *and* Application of an "Oscillation-Sustaining System with Auto-Stabilised Amplitude" to an Elastic Pendulum.—Abelé. (*See* 3823/4.)

3924. A Crystal Test Set [especially for Crystal Manufacturers: Type D-151288].—G. M. Thurston. (*Bell Lab. Record*, Aug. 1944, Vol. 22, No. 12, pp. 477–480.)

"It has been necessary until recently for crystal manufacturers to measure the frequency and activity of crystals in the circuits with which they are actually to be used [since the frequency, and particularly the activity, are affected by the circuit employed]. This has meant that they have had to carry a large stock of radio apparatus always available for use in calibrating a crystal." The new test set here described permits the circuit with which the crystal is to be used to be simulated accurately: activity is measured by a circuit incorporated in the set, frequency by an external measuring set.

3925. On the Measurement of the Residual Parameters of a "Q"-Meter.—W. F. Lovering: Simmonds. (*Phil. Mag.*, July 1944, Vol. 35, No. 246, pp. 491–495.)

"In a recent article (1260 of April) J. C. Simmonds described a method of measuring the self-inductance and resistance of the tuning condenser of a 'Q'-meter by measurements made on the 'Q'-meter itself. The measurement can be carried out only if the calibration of the tuning condenser alone is known, but in general the low-frequency calibration includes all stray capacities such as that of the valve voltmeter, and the formulae given are invalid. The unknown stray capacity and the other parameters may be measured by extensions of the original method." The analysis is applicable to frequencies below about 15 Mc/s; at higher frequencies the representation of circuit inductances and capacitances by "lumped" quantities is not justified, and any attempt at a solution must use methods appropriate to transmission lines.

3926. Method of Measuring the Apparent Capacitance of Barrier-Layer Rectifiers [and of Electrolytic Condensers, etc.].—P. Werly. (*Comptes Rendus* [Paris], 4th/27th May 1942, Vol. 214, No. 18/21, pp. 858–860.)

Schottky and others have shown that the Cu/Cu_2O rectifier behaves as a shunted condenser. If worked at p.ds of some millivolts only, to make the rectifying effect negligible, it can be shown by a.c. bridge measurements to behave exactly in this manner. The extremity of the impedance vector describes a semicircle in the complex plane of resistance and reactance, when the a.c. frequency is varied. The writer has devised a method of determining the apparent capacitance of the barrier layers by measuring the factor of attenuation which they produce in a circuit when they are subjected to a current of a given frequency.

A battery of accumulators, connected in series with the secondary winding of a transducer whose primary is fed by a constant-frequency source of a.c. current (a 1000 c/s frequency was actually employed), serves as a source of ripple current: it delivers this through an inductance L to the inverse resistance $R + r$ of the rectifier which represents the load of the circuit. This load is shunted by the apparent capacitance C which forms the unknown of the problem. Knowing the constants of the circuit and the ratio of the voltages (measured by a Moullin voltmeter) below and above the inductance L, the value of C may be calculated. But it is much better to work by a substitution method, replacing the rectifier by an equivalent circuit consisting of a standard variable condenser shunted by a variable resistance R. The resistance r offered to the passage of the current by the semiconductor is very small compared with that presented by the barrier layer, R, and may be neglected. To make the measurement easier a certain number of identical discs may be paralleled, thus increasing C and reducing R and r.

The procedure of the two steps of the substitution method is described. Measurements were made on selenium elements having a working surface of 6.5 cm². With five discs in parallel, passing a continuous current of 14 mA with 8 v across the discs, the equivalent circuit gave $R =$ 780 ohms and $C = 7 \times 10^{-1}$ μF. "In a general way, this method, which gives the variation of C as a function of the applied voltage, may be considered for the measurement of the apparent capacitances in analogous cases, and in particular for electro-chemical condensers."

3927. An Instrument for the Measurement of Small Capacitances [1 to 100 pF: Two (Pentode) Generating Stages feed a Common Hexode Stage and produce, when Balanced, a Zero Difference Frequency in Its Anode Circuit, as shown by Tuning-Indicator Valve connected as Audion].—R. P. Turner. (*E.T.Z.*, 12th Aug. 1943, Vol. 64, No. 31/32, p. 431: summary, from *Radio News* [Chicago], 1941.)

3928. Resistance and Capacitance Measurement with the Pentode-Diode Valve Voltmeter: Constructional Details of a Suitable Adaptor Unit.—T. A. Ledward. (*Wireless World*, Sept. 1944, Vol. 50, No. 9, pp. 262–265.) *See* 2664 of August & 3210 of October.

3929. Letter on "The Cathode-Coupled Double-Triode Stage" [2525 of August: Use of a Similar Circuit for Measurement of Small Changes in R.F. Amplitude, at Frequencies from Zero upwards]. — B. E. Noltingk: Williams. (*Electronic Eng:g*, June 1944, Vol. 17, No. 196, p. 34.)

3930. Willans Oscillator Circuit [Priority: Its Advantages for A.C. Bridge Work & as Generator of Frequencies below 100 c/s: etc.].—Hanney. (*See* 3826.)

3931. Taylor Signal Generator: an A.C.-Operated Modulated Test Oscillator for Receiver Alignment.—Taylor Elec. Instruments. (*Wireless World*, Sept. 1944, Vol. 50, No. 9, p. 277.)

3932. A Thermopile for Micro-Calorimetry [with a Sensitivity of 0.25 Microdegree per Millimetre at Scale Distance of Nine Metres]. —L. S. Mason. (*Phys. Review*, 1st/15th June 1944, Vol. 65, No. 11/12, pp. 345–346: summary only.)

3933. A Multiplied-Deflection A.C. Potentiometer.—R. B. Marshall. (*Elec. Engineering*, Feb. 1944, Vol. 63, No. 2, Transactions pp. 77–80.)

For remarks by P. A. Borden, particularly calling attention to the usefulness of the asynchronous method of detecting a balance condition, see *Supp. to Elec. Engineering, Transactions Section*, June 1944, Vol. 63, p. 460.

3934. An Instrument for the Measurement of Large Alternating Currents [as in Resistance & Flash Welding: Amplifier combined with Special Air-Core Transformer on Flexible (Rubber-Tubing) Core]. —W. Richter. (*Elec. Engineering*, Jan. 1944, Vol. 63, No. 1, Transactions pp. 38–40.)

3935. On an Effect of the Electric Wind [Ionised Molecules blacken an Incandescent Filament: Possible Application to form an Electrostatic Voltmeter].—M. Aubert. (*Comptes Rendus* [Paris], 4th/25th Jan. 1943, Vol. 216, No. 1/4, pp. 37–38.)

3936. Standardisation of Resistors [Pessimistic Support for W. Bowen's Suggestion (3567 of November): Added Plea for Alteration of Existing "Body-Tip-Dot" Convention].—C. R. Cosens: Bowen. (*Wireless World*, Sept. 1944, Vol. 50, No. 9, pp. 269–270.) *See* also 3937, below.

3937. Standardisation of Resistors [and the Wider Question of the Desirable Procedure in Standardisation & Other Rulings decided on by Committees].—(*See* 4049.)

3938. Radio Parts tested under Extreme Temperature Ranges [in the Kansas City "Cold Room"].—(*Journ. Franklin Inst.*, March 1943, Vol. 235, No. 3, pp. 325–326: summary, from *Refrigerating Engineering*, Vol. 44.)

3939. Self-Testing Relays [for Reducing the Time of Relay Testing: the Self-Testing Principle, and Suitable Valve Circuits for Applying It].—W. Bacon. (*Electronic Eng:g*, June 1944, Vol. 17, No. 196, pp. 36–37.)

For a suggested modification, to yield a "universal" instrument, *see* Spencer, September issue, No. 199, p. 170.

3940. Influence of Improved Magnetic Alloys on Design Trends of Electrical Instruments [2745 of August].—M. S. Wilson & J. M. Whittenton. (*Elec. Engineering*, March 1944, Vol. 63, No. 3, Transactions pp. 100–104.) For Discussion see *Supp. to Elec. Engineering, Transactions Section*, June 1944, Vol. 63, pp. 461–463, where "vertical *versus* horizontal shafts" forms one of the subjects.

3941. Magnetic Measurements on Iron Powders.—T. H. Oddie. (*Journ. of Scient. Instr.*, Sept. 1944, Vol. 21, No. 9, pp. 154–158.)

Author's summary:—"Measured results are given for the permeability and magnetic loss coefficients of carbonyl and hydrogen reduced iron powders, at frequencies from 200 c/s to 40 Mc/s. A method is described for testing cylindrical cores without air-gaps in the magnetic circuit." Tests were made on 14 powders, 11 of American and 3 of Australian manufacture: results are given for the best two, "carbonyl iron powder type E" and "hydrogen reduced iron powder type 14B," both obtainable in the United States.

The writer concludes by mentioning that *e*, the eddy-current loss coefficient, measured at high frequencies by the method described in section 2.3 (extension of a plan due to Glaisher: the flux travels through the cylindrical core without encountering any air-gaps), remained independent of frequency within the limits of error, while Foster & Newlon's measurements (3462 of 1941) gave values decreasing by a factor of from 2 to 7 with the frequency rising from 5 to 20 Mc/s. "Their method of measurement with air-gaps in the magnetic circuit may account for this discrepancy." The paper ends with a long bibliography and some patent references, chiefly Australian.

3942. Note on the Inductive [Absolute] Measurement of Magnetic Field Strength [4336 of 1937: Corrections for Small Effects of Twisted Leads & of Incorrect Orientations of Coil].—F. T. Rogers, Jr. (*Phys. Review*, 1st/15th June 1944, Vol. 65, No. 11/12, p. 354: summary only.)

3943. A Magnetometer for the Determination of the Vertical Component of the Earth's Magnetic Field [Sensitivity about ½ min. per γ].—S. L. Ting & S. T. Lin. (*Review Scient. Instr.*, July 1944, Vol. 15, No. 7, pp. 171–177.)

SUBSIDIARY APPARATUS AND MATERIALS

3944. The Avoidance of a Possible Error in the Recording by Sealed-Off Cathode-Ray Oscillograph of Transients.—Baxter. (*Journ. of Scient. Instr.*, Sept. 1944, Vol. 21, No. 9, pp. 159–160.)

When the beam is switched on, the load taken by the tube causes a fall in anode voltage, owing to the imperfect regulation of the h.t. supply unit; this fall gives rise to an increase in the deflectional sensitivity. Because of the energy stored in the smoothing condensers, the increase is exponential in character, and if recordings are made during this period of changing sensitivity they may be seriously in error. The difficulty can be avoided by initiating the beam a sufficient time before the arrival of the transient, or (as here adopted) by running the tube with the beam switched on but locked off the screen, until just before the test, by a potential applied to one of the *x*-plates and removed by the closure of an auxiliary contact on the test circuit breaker.

3945. Improved Cathode-Ray Curve Tracer: Plotting the X and Y Axes simultaneously with the Required Curve [thus Eliminating all Difficulty in Locating the Origin].—Walker. (*Wireless World*, Sept. 1944, Vol. 50, No. 9, pp. 266–268.)

"One very pleasing feature of the system is that the axes are always drawn just long enough for the curve being examined. If, for example, *R*7 and *R*8 are changed to alter the shape of the curve, then the axes expand and contract to accommodate the curve . . ." A standard vibrator unit is employed.

3946. Cathode-Ray-Tube Traces: a Series to illustrate Cathode-Ray-Tube Technique: Part I—Lissajous' Figures [Introduction to the Mathematical Theory, with Many Diagrams].—Moss. (*Electronic Eng:g*, June, July, August, Sept. 1944, Vol. 17, Nos. 196–199.)

3947. Electron-Microcinematography with the Universal Electron Microscope.—von Ardenne. (*E.T.Z.*, 1st July 1943, Vol. 64, No. 25/26, p. 360: summary of the paper mentioned in 178 of January.)

The full 15½-page paper is in *Zeitschr. f. Phys.*, Vol. 120, 1943, p. 397 onwards. Films of sinter processes, etc., at temperatures between 1000° and 1400° have been made at the Harnack House, with 20 000 magnification.

3948. THE RESOLVING POWER OF THE FIELD-EMISSION ELECTRON MICROSCOPE [and the Prospects of Improvement].—Müller. (*E.T.Z.*, 29th July 1943, Vol. 64, No. 29/30, p. 404: summary, from *Zeitschr. f. Phys.*, 1943.) *Cf.* 539 & 540 of 1943. One suggestion, as regards photography, is that since the suitable camera-lenses have only a small depth of focus, the use of a flat fluorescent screen instead of the usual curved type would be advantageous.

3949. POTENTIAL NUCLEAR MONOCHROMATIC ELECTRON SOURCES [including Their Eventual Application in Electron Microscopes, Special Radio Valves, etc.].—Pool. (*Phys. Review*, 1st/15th June 1944, Vol. 65, No. 11/12, p. 353: summary only.)

3950. PATHS OF ELECTRONS AND IONS IN NON-UNIFORM MAGNETIC FIELDS.—Coggeshall & Muskat. (*See* 3866.)

3951. DEFLECTED ELECTRON BEAMS [Continuation of Correspondence dealt with in 3164 of October & 3484 of November].—Gabor. (*Wireless Engineer*, Oct. 1944, Vol. 21, No. 253, p. 480.)

3952. ENERGY DISTRIBUTION OF ELECTRONS WITHIN DENSE ELECTRON BEAMS [and the Arrival of an Unstable Condition].—Calbick. (*See* 3867.)

3953. LIMITING STABLE CURRENT [beyond which a Virtual Cathode will form] IN ELECTRON BEAMS IN THE PRESENCE OF IONS.—Pierce. (*See* 3868.)

3954. CORRESPONDENCE ON A COMPARISON BETWEEN "ON THE CURRENTS CARRIED BY ELECTRONS OF UNIFORM VELOCITY" AND "ON THE THEORY OF SPACE CHARGE BETWEEN PARALLEL PLANE ELECTRODES."—Pierce: Jaffé. (*See* 3869.)

3955. A MECHANICAL THEORY OF ELECTRON-IMAGE FORMATION.—Schlesinger. (*Proc. I.R.E.*, Aug. 1944, Vol. 32, No. 8, pp. 483–493.)

"The purpose of this paper is not so much to supplement prior information as to present a method that may prove useful in the design and understanding of electron-optical instruments." Unlike the majority of previous treatments, the paper disregards all analogies with optics and deals with the electron motion as a purely mechanical problem, on the simple assumption of transversal deflection in true proportion to the radial distance off the axis. The analysis yields a correlation between magnification and transit time ($m = T_i/T_o$) which is particularly useful in the design of instruments with "thin" lenses, even those with combined electric and magnetic fields: some examples are discussed.

The reasoning is then applied to paraxial rays in extended fields ("thick" lenses): the above transit-time theorem (expressed in another form, eqn. 8a) then yields eqn. 30: "the electronic magnification of a thick lens is equal to the second-order integral of the deflection with respect to the total transit time, minus 1". This theorem makes it possible to find the picture size for any given image position without even knowing the object position. Another integral of the deflection with respect to transit time gives the focal length, another the positions of the corresponding object and image planes. All results are available in a graph of a family of hyperbolas for various operation parameters. The plane accelerating field, forming a virtual rather than a real image, is dealt with similarly. Appendix B gives an analytical function for the potential distribution in the electron gun, based on the fact that the data from the electrolytic trough may be represented fairly well by the hyperbolic tangent equation 60: it is seen that such systems exhibit positive-lens action under all circumstances (accelerating or decelerating systems). The question of the shortest focal length is discussed in the final lines.

3956. THEORY, DESIGN, AND APPLICATIONS OF A SHORT MAGNETIC LENS ELECTRON SPECTROMETER [for the Study of Radioactive Disintegration Schemes, etc.].—Deutsch & others. (*Review Scient. Instr.*, July 1944, Vol. 15, No. 7, pp. 178–195.)

3957. THE MECHANISM OF LUMINESCENCE OF PHOSPHORS: PART II.—Antonov-Romanovskij. (*Journ. of Phys.* [of USSR], Vol. 7, 1943, p. 153 onwards.) For Part I *see* 2804 [and 3106] of 1943.

3958. TECHNICAL DATA ON "CHANCE" SEALING GLASSES.—Chance Bros. (*Wireless Engineer*, Oct. 1944, Vol. 21, No. 253, p. 479.)

3959. VACUUM-TIGHT MECHANISMS: METHODS OF INTRODUCING MOVEMENT INTO EVACUATED SYSTEMS [Van de Graaf's Shaft: Cone Joints: Whipple's Gland: Wilson's Sliding Seal: the German Mercury U-Tube: Rubber-Tubing Devices (including Voglis's Flexible Wire System): Bellows: Magnetic Transmission: etc.].—Webster. (*Electronic Eng:g*, July 1944, Vol. 17, No. 197, pp. 53–57.)

3960. HIGH-VACUUM VALVE [Successful Modification of Standard Bronze Globe Valves to suit High-Vacuum Purposes].—Moore. (*Journ. of Scient. Instr.*, Sept. 1944, Vol. 21, No. 9, p. 162.)

3961. ON THE MAXIMAL ENERGY ATTAINABLE IN A BETATRON [Freedom from Cyclotron's Limitation to Non-Relativistic Region owing to Defocusing of Orbits, but Limitation due to Radiation of Electrons in Magnetic Field].—Iwanenko & Pomeranchuk. (*Phys. Review*, 1st/15th June 1944, Vol. 65, No. 11/12, p. 343.) An illustrative calculation leads to a limit only five times as great as the energy expected from the betratron now under construction. *Cf.* Dodd, 3800, above.

3962. ON THE ACTION OF ELECTROSTATIC ALTERNATORS [Detailed Analysis of of a Four-Symmetric Four-Carrier & a Trisymmetric Six-Carrier Type, Each a Prototype of a Whole Family of Such Machines].—Simon.

(*Journ. Franklin Inst.*, July 1944, Vol. 238, No. 1, pp. 39–48.) For previous work *see* 3588 of November.

3963. STATISTICAL RECORDERS AND, MORE GENERALLY, ELECTRO-MECHANICAL SYSTEMS SUBJECTED TO A PHYSICAL QUANTITY WHICH IS A CONTINUOUS OR DISCONTINUOUS FUNCTION OF TIME [with Application of Oscillographs, High-Speed Transmitters, Loudspeakers, etc.] —Carbenay. (*Comptes Rendus* [Paris], 4th/27th May 1942, Vol. 214, No. 18/21, pp. 825–826.)

"We have described several methods for the statistical recording of electromagnetic disturbances [long abstract, 1336 of 1942] and have indicated the principle of statistical recorders such that the differential equation of the motion of the moving system admits of the special integral $\Phi(t) = e^{-t/\tau}\int e^{t/\tau} f(t)dt$ ["playing a fundamental rôle in the study of interference": *loc. cit.*], where $f(t)$ is the physical magnitude attached to the phenomenon to be recorded, and τ the principal time constant of the recorder.

"The present Note has for its object the extension of the proposed method to phenomena making themselves manifest by any type of physical quantity, and, more generally, the adaptation of electro-mechanical systems to the phenomena to which these systems are submitted, by their subjection to the motion of the moving system on which is exercised a couple (or a force) proportional to the physical magnitude $f(t)$ connected with the phenomenon . . ."

The method, here outlined mathematically (and based on the application to the system, in addition to the active or motive couple, of a supplementary couple of special characteristics), is capable of being applied to the design of electro-mechanical apparatus, such as oscillographs, recorders, high-speed transmitters, microphones, loudspeakers, etc., having a mobile organ whose displacement must be defined, explicitly or otherwise, as a function of the physical quantity of the phenomenon to whose action the apparatus is submitted.

3964. AMPLIFIER WITH LOGARITHMIC RESPONSE [giving D.C. Output logarithmically proportional to Input Signal over Range of Three Decades].—Hipple & Grove. (*See* 3816.)

3965. CHARACTERISTICS OF VOLTAGE-MULTIPLYING RECTIFIERS [for Power Supply to Small Valve Devices & Other Instruments].—Waidelich & Shackelford. (*See* 3842.)

3966. ELECTRONICALLY CONTROLLED DRY-DISC RECTIFIER.—Rosenstein & Barnett. (*Elec. Engineering*, Jan. 1944, Vol. 63, No. 1, Transactions pp. 21–23: Discussion in *Supp. to Elec. Engineering, Transactions Section*, June 1944, Vol. 63, pp. 474–476.) A summary was dealt with in 2019 of June.

3967. THE BEHAVIOUR OF THE ELEMENTS OF DRY-PLATE RECTIFIERS AT LOW CURRENT-DENSITIES.—Theillaumas. (*Comptes Rendus* [Paris], 6th/27th July 1942, Vol. 215, No. 1/4, pp. 15–17.) A summary was dealt with in 3125 of 1943.

3968. METHOD OF MEASURING THE APPARENT CAPACITANCE OF BARRIER-LAYER RECTIFIERS [and of Electrolytic Condensers, etc.]. —Werly. (*See* 3926.)

3969. THEORY OF CATHODE SPUTTERING IN LOW-VOLTAGE GASEOUS DISCHARGES.—Townes. (*Phys. Review*, 1st/15th June 1944, Vol. 65, No. 11/12, pp. 319–327.)

3970. CORONA IN AIRCRAFT ELECTRIC SYSTEMS AS A FUNCTION OF ALTITUDE.—Wilson. (*Elec. Engineering*, April 1944, Vol. 63, No. 4, Transactions pp. 189–194: Discussion in *Supp. to Elec. Engineering, Transactions Section*, June 1944, Vol. 63, p. 457.)

3971. POTENTIAL BREAKDOWN OF SMALL GAPS UNDER SIMULATED HIGH-ALTITUDE CONDITIONS.—DeLerno. (*Elec. Engineering*, March 1944, Vol. 63, No. 3, Transactions pp. 109–112: Discussion in *Supp. to Elec. Engineering, Transactions Section*, June 1944, Vol. 63, pp. 456–457.)

3972. ELECTRIC-CIRCUIT BURNING-CLEAR AND DAMAGE PHENOMENA ON AIRCRAFT STRUCTURES.—Foust & Hutton. (*Elec. Engineering*, April 1944, Vol. 63, No. 4, Transactions pp. 198–204: Discussion in *Supp. to Elec. Engineering, Transactions Section*, June 1944, Vol. 63, pp. 457–458.)

3973. EFFECT OF ALTITUDE ON IMPULSE AND 60-CYCLE STRENGTH OF ELECTRICAL APPARATUS.—Bellaschi & Evans. (*Elec. Engineering*, May 1944, Vol. 63, No. 5, Transactions pp. 236–241: Discussion in *Supp. to Elec. Engineering, Transactions Section*, June 1944, Vol. 63, pp. 442–443.)

3974. EFFECT OF ALTITUDE ON ELECTRIC BREAKDOWN AND FLASHOVER OF AIRCRAFT INSULATION [including Table of Recommended Striking Distances & Creepage Distances, and Comparison with Certain Existing Standards: Precautions necessary in Testing at Sea Level: etc.].—Berberich & others. (*Supp. to Elec. Engineering, Transactions Section*, June 1944, Vol. 63, pp. 345–354: Discussion pp. 458–459.)

3975. BREAKDOWN AND TIME-LAG OF DIELECTRIC MATERIALS: BREAKDOWN OF LIQUID CARBON TETRACHLORIDE.—Attwood & Bixby. (*Journ. Franklin Inst.*, March 1943, Vol. 235, No. 3, pp. 259–272.)

Electric *versus* thermal types of breakdown: older theories of breakdown: modern theories (von Hippel, Seeger & Teller, Fröhlich), as applied to CCl_4: time-lag. "Experimental data on the electrical breakdown of liquid CCl_4 indicate, first, that modern theories of breakdown may be applicable to a wide range of dielectric materials provided their molecular constitution is ionic; and second, that the technically important time-lag follows a simple rule in its dependence on over-voltage."

3976. ON THE PASSAGE FROM THE LIQUID TO THE VITREOUS STATE [Investigation prompted by the Discovery that Certain Alums in the Crystalline State have

Dielectric Properties analogous to Those of Polar Liquids, and by the Behaviour of Their Absorption Coefficients, Dielectric Constants, & Specific Heats, at Various Temperatures: Measurements (at 1.27 Mc/s downwards) on Polar Liquids: Conclusions].—Guillien. (*Comptes Rendus* [Paris], 4th/27th May 1942, Vol. 214, No. 18/21, pp. 820–822.)

3977. A NEW SPECTRAL METHOD: THE HERTZIAN SPECTRUM [from 2.5 cm upwards] OF ALCOHOL MOLECULES.—Girard & Abadie. (*See* 3916.)

3978. EXPERIMENTS ON ELECTRETS [and the Relation between the Electret Effect & Other Kinds of Anomalous Behaviour in Solid Dielectrics].—Gross. (*See* 4055.)

3979. RECENTLY ACQUIRED KNOWLEDGE ABOUT HEATING AND DESTRUCTION PROCESSES IN STRATIFIED INSULATING MATERIALS [where the Ions have Different Velocities in the Different Layers: Solid/Gas & Solid/Liquid Combinations: an Oscillographic Investigation].—Liebscher. (*E.T.Z.*, 12th & 26th Aug. 1943, Vol. 64, Nos. 31/32 & 33/34, pp. 423–427 & 450–453.)

3980. SILICONE INSULATION: BRIEF DETAILS OF RECENT AMERICAN DEVELOPMENTS [in the Use of Silicone Resins & Varnishes].—Westinghouse. (*Electrician*, 25th Aug. 1944, Vol. 133, No. 3456, p. 159.)

3981. ORGANO-SILICON FILMS [and the General Electric "Dri-Film" (Methyl-Chloro-Silane) Treatment of Ceramic Insulators (2229 & 3549 of 1943): Surface Reaction: Method of Application: Method of Test: Previous Measurements on Surface Resistance: Tests on Various Types of Surface: *Q*-Factors of Treated & Untreated Coils: Precautions during Treatment: etc.].—Norton. (*Gen. Elec. Review*, Aug. 1944, Vol. 47, No. 8, pp. 6–16.)

3982. OPERATING CHARACTERISTICS OF CERAMIC DIELECTRICS WITH DIELECTRIC CONSTANTS IN EXCESS OF 1000 [recently introduced in Ceramic Condensers: Properties somewhat similar to those of Rochelle Salt, but Better: Aging, Voltage, & Humidity Effects: Ionic Conduction due to Certain Impurities: etc.].—Gray. (*Phys. Review*, 1st/15th June 1944, Vol. 65, No. 11/12, pp. 348–349: summary only.)

3983. GLASS FIBRE INSULATION USED FOR INDUCTION-TYPE BRASS FURNACES [in place of Mica].—(*Journ. Franklin Inst.*, Feb. 1943, Vol. 235, No. 2, p. 209: summary, from *Iron Age*, Vol. 150.)

3984. CEREX, A HEAT-RESISTANT PLASTIC WHICH RETAINS STRENGTH AND SHAPE.—Monsanto Chemical. (*Sci. News Letter*, 24th June 1944, Vol. 45, No. 26, p. 406.) Already used in military radio equipment.

3985. PREFORMED PLASTICS [Westinghouse Research on the Problem of producing a Plastic combining the Strength of Woven or Felted Fibre with the "Formability" of Powder Moulding].—Bates. (*Electrician*, 1st Sept 1944, Vol. 133, No. 3457, p. 180.)

3986. SUMMARIES OF WESTINGHOUSE PAPERS ON FOSTORITE, A NEW IMPREGNATING MATERIAL FOR MOISTURE-PROOFING: MICARTA 444: A PREFORMED PLASTIC: AND A SYNTHETIC RESIN REPLACING SHELLAC [*cf.* 3611 of November].—Westinghouse. (*Elec. Engineering*, July 1944, Vol. 63, No. 7, p. 274.) For some remarks on such new materials *see* Erikson, *ibid.*, Transactions p. 547.

3987. THE WELDING OF THERMOPLASTIC SYNTHETIC MATERIALS [particularly Polyvinyl-Chloride Derivatives such as Vinidur & Igelit].—Henning. (*E.T.Z.*, 17th Dec. 1942, Vol. 63, No. 49/50, pp. 594–595: summary, from *Kunststoffe*, Vol. 32.) *See* also 3733 of 1942.

3988. DEVELOPMENTS IN INSULATING MATERIALS [Letter on a Statement in Wall's Paper (3267 of October): the Manufacture of "Polythene" (Polyethylene) on a Large Scale by I.C.I.].—Rogerson: Wall. (*Engineering*, 28th July 1944, Vol. 158, No. 4098, p. 75.)

3989. PLASTIC ENAMELLED WIRE ["Thermex" Wire & Its Properties].—British Thomson-Houston. (*Electronic Eng:g*, June 1944, Vol. 17, No. 196, p. 35.)

3990. NYLON FOR SILK [especially for Magnet Wire].—Wood. (*Bell Lab. Record*, Aug. 1944, Vol. 22, No. 12, pp. 505–508.)

3991. CHARACTERISTICS OF RADIO WIRE AND CABLE: PART 2 [Magnet Wires: Litz Wires: Flexible-Lead Wires: Radio Hook-Up Wires].—Caller. (*Radio* [New York], June 1944, Vol. 28, No. 6, pp. 28–31 and 64, 66.)

3992. VACUUM CAPACITORS [and Their Advantages of Stable Dielectric Constant, Stable Internal-Breakdown Voltage, Low Loss, Ability to stand Overvoltages, Minimum of Maintenance, Compactness, Sturdiness (Mechanical & Thermal), etc: Details of the General Electric GL-1L38 & GL-1L22 Capacitors (50 $\mu\mu$F, 7500 V Peak & 25 $\mu\mu$F, 16 kV Peak, respectively) and Their Suitability for Aircraft Installations, as Blocking & By-Pass Capacitors for Induction-Heating Oscillators, etc.].—Floyd. (*Proc. I.R.E.*, Aug. 1944, Vol. 32, No. 8, pp. 463–470.)

3993. JELLY ACID CELLS [Hints on Maintenance: the Question of Tap Water for These & Other Accumulators].—"Diallist." (*Wireless World*, Oct. 1944, Vol. 50, No. 10, pp. 307–308.)

3994. MICROPOROUS RUBBER REPLACES WOOD IN STORAGE BATTERIES [and allows Them to be sent out Charged & Dry, retaining 75% of Charge for more than a Year].—U.S. Rubber. (*Sci. News Letter*, 8th July 1944, Vol. 46, No. 2, pp. 21–22.)

3995. FOX TOROIDAL POTENTIOMETERS.—Fox, Ltd. (*Wireless World*, Aug. 1944, Vol. 50, No. 8, p. 239.)

3996. Carbon-Brush Contact Films : Parts I & II.—Van Brunt & Savage. (*Gen. Elec. Review*, July & Aug. 1944, Vol. 47, Nos. 7 & 8, pp. 16–19 & 28–35.)

"Collector films largely determine brush performance : how they are critically affected by high altitudes : striking effect of oxygen on cuprous-oxide contact films : adjuvants, or substitutes, for film carbon lubrication at high altitudes ? What experiments with brass collectors have taught."

3997. Self-Testing Relays [for Reducing the Time of Relay Testing].—Bacon. (*See* 3939.)

3998. New Contacts for Electrical Technique [Special Apparatus for Testing Burning & Length of Life (Tests up to Three Million Make-&-Breaks) : Silver gives over 14 Times as Many as Copper : Improved Results with New Silver and New Copper Alloys, especially when Different Alloys are used for the Different Polarities].—Henker. (*E.T.Z.*, 1st July 1943, Vol. 64, No. 25/26, pp. 347–349.)

3999. Design of Variac Transformers.—Karplus. (*Elec. Engineering*, July 1944, Vol. 63, No. 7, Transactions pp. 508–513.)

4000. A Persistent-Current Electro-Magnet [using a Superconductive Ring].—Justi. (*See* 4056.)

4001. Influence of Improved Magnetic Alloys on Design Trends of Electrical Instruments [2745 of August].—Wilson & Whittenton. (*See* 3940.)

4002. Magnetic Measurements on Iron Powders.—Oddie. (*See* 3941.)

4003. G.A.W. Carbonyl Iron Powders, Types L, C, E, TH, and SF.—General Aniline. (*Review Scient., Instr.*, July 1944, Vol. 15, No. 7, p. 198.) Type L was referred to in 3594 of November.

4004. The Factor of Non-Linear Distortion of Sheet Iron Type IV at Note Frequencies.—Feldtkeller. (*T.F.T.*, Jan. 1944, Vol. 33, No. 1, pp. 10–12.) Investigations complementary to those dealt with in 2043 of June.

4005. The Effect of an Air Gap on the Permeability of a Coil Core at Low Frequencies [Theoretical & Experimental Investigation of the Effect on the Value & the Field-Strength Dependence of the Permeability, with Special Reference to Dynamo Sheet Iron Type IV).—Feldtkeller & Wilde. (*T.F.T.*, Jan. 1944, Vol. 33, No. 1, pp. 12–15.) Following on 4004, above.

4006. Silver Brazing Electrically : for Precise Electrical Measuring Devices [Potentiometers, Bridges, etc : So Firmly Bonds Lead-In Wires to Coils that Joint-Resistance is Stable : Simple in Application].—Ryan. (*Gen. Elec. Review*, June 1944, Vol. 47, No. 6, pp. 40–41.)

4007. The Stranded-Wire Welding Process [for Butt-Joints in Litz Wires, Cables, etc : Mains-Driven Apparatus requiring No Flux, Welding Material, or Solder].—Günther. (*E.T.Z.*, 17th Dec. 1942, Vol. 63, No. 49/50, pp. 587–591.)

4008. A New Research Tool : Irreversible Solution Potential Measurements [applicable to Study of Metallic & Non-Metallic Coatings, etc.].—Brown & Mears. (*Phys. Review*, 1st/15th June 1944, Vol. 65, No. 11/12, p. 351 : summary only.)

4009. Determination of Small Amounts of Arsenic, Antimony, and Tin in Lead and Lead Alloys [New Method].—Luke. (*Bell S. Tech. Journ.*, Jan. 1944, Vol. 23, No. 1, p. 132 : short summary.)

STATIONS, DESIGN AND OPERATION

4010. Projected Station at Olney to lead Post-War Frequency-Modulation Broadcasting Research.—Armstrong, Jansky, & Bailey. (*Elec. Engineering*, May 1944, Vol. 63, No. 5, p. 196 : note on application by "FM Development Foundation".)

4011. Conference on Radio Wave-Bands [Need for World Conference at Early Date after the War, for Allocation of Bands for Television, Frequency Modulation, Radar Devices, etc : the IRAC Proposals (now being distributed to Selected Organisations) : etc.].—Jett. (*Sci. News Letter*, 5th Aug. 1944, Vol. 46, No. 6, p. 84 : *Science*, 4th Aug. 1944, Vol. 100, No. 2588, Supp. p. 10.) *Cf.* 3286 of October.

4012. Frequency Spectrum Charts, showing Representative Electronic Tubes and Devices that operate at the Various Frequencies, and Pre-War Allocations to Radio Broadcasting, Television, and Radio Communications.—(Inset to Baker's paper, 4045, below.)

4013. Improving Inter-Continental Communications : Making the Best Use of Available Frequency Bands.—Roddam. (*Wireless World*, Oct. 1944, Vol. 50, No. 10, pp. 295–298.)

Suggestions for operating a world-wide short-wave network, planned on the lines of the proposed "equatorial radio girdle", 2345 of July [and 3281 of October and 3641 of November].

4014. Radio Suisse in the Year 1943.—(*Bull. Assoc. Suisse des Élec.*, 28th June 1944, Vol. 35, No. 13, p. 354 : in German.)

4015. Air Traffic Control [Limitations of Present Systems and Future Planning].—Gilbert. (*Elec. Engineering*, April 1944, Vol. 63, No. 4, pp. 119–125.)

4016. Enemy Army Communications Equipment [Analysis by Signal Corps Laboratory and Comparison with American-Made Equipment].—Colton. (*Elec. Engineering*, April 1944, Vol. 63, No. 4, pp. 139–144.)

4017. Building WERS Transceivers in the School Shop : a Construction Project for School or WERS Groups.—Metzger. (*QST*, May 1944, Vol. 28, No. 5, pp. 13–15.)

4018. A Portable Power Supply for WERS: Using a Motor-Cycle Storage Battery with a Vibrator Pack.—Long. (*QST*, May 1944, Vol. 28, No. 5, pp. 28–30.)

GENERAL PHYSICAL ARTICLES

4019. On the Extraction of Electrons from a Metal Surface by Ions and Metastable Atoms [Elementary Theory, leading to Results differing from Those of H. S. W. Massey].—Cobas & Lamb. (*Phys. Review*, 1st/15th June 1944, Vol. 65, No. 11/12, pp. 327–337.)

4020. The Effect of Adsorbed Gases on Contact Electrification [Experimental Investigation].—Debeau. (*Phys. Review*, 1st/15th July 1944, Vol. 66, No. 1/2, pp. 9–16.)

"The theory which explains contact potentials cannot explain contact electrification. Nor has there yet been published a theory which satisfactorily explains this phenomenon. . . Recently the importance of adsorbed gas in another contact phenomenon, friction, has been shown. It therefore seems strange that the few men who have studied contact electrification recently have paid little or no attention to the gases adsorbed by the solids used. . ." The writer concludes: "Further study of the phenomenon is needed before even a hypothesis for the mechanism can be made. In spite of the conflicts introduced by the ionic mechanism it still seems more likely than an electronic mechanism."

4021. A New Method for the Calculation of Heat Exchange by Radiation [Short Introduction to Pollak's "Flux (or "Radiation") Algebra", practically Unknown outside Russia].—Ordinanz: Pollak. (*Schweizer Arch. f. angew. Wiss. u. Tech.*, April 1944, Vol. 10, No. 4, pp. 113–115: in German.)

4022. Special Form of Coriolis' Compound Centripetal Acceleration due to the Rotating Earth, *and* The Path Equation for Motion on the Surface of the Rotating Earth in a Uniform Parallel Field of Force with Initial Velocity along the Field; *also* The Horizontal Path along the Earth's Surface of a Projectile or Plane under Constant Tangential Acceleration.—Kimball. (*Journ. Franklin Inst.*, Nov. 1942, Vol. 234, pp. 453–472: March 1943, Vol. 235, No. 3, pp. 273–283: July 1943, Vol. 236, No. 1, pp. 67–79.)

4023. Simplification of the Formulae of Electric and Magnetic Dimensions [Elimination of Troublesome Fractional Indices by taking as Fundamental the Electric Charge in the E.M. System, instead of Mass: Particularly Simple Results].—Bryliński. (*Comptes Rendus* [Paris], 6th/27th July 1942, Vol. 215, No. 1/4, pp. 103–104.)

4024. The Decomposition of Water by the So-Called Permanent Magnet, and the Measurement of the Intensity of the Magnetic Current.—Ehrenhaft. (*Phys. Review*, 1st/15th May 1944, Vol. 65, No. 9/10, pp. 287–289.) *Cf.* 3655 of November and back references, and 4025, below.

4025. Decomposition of Water with the Permanent Magnet, *and* Ponderomotive Forces on Matter in Electric and Magnetic Fields.—Ehrenhaft. (*Phys. Review*, 1st/15th June 1944, Vol. 65, No. 11/12, p. 349: 1st/15th July 1944, Vol. 66, No. 1/2, p. 38: summaries only.)

MISCELLANEOUS

4026. On the Perturbation of Boundary Conditions.—Feshbach. (*Phys. Review*, 1st/15th June 1944, Vol. 65, No. 11/12, pp. 307–318.)

"In the past, exact solutions were limited to those cases in which the boundary conditions were 'simple' and were satisfied on 'simple' surfaces. 'Simple' boundary conditions correspond to uniform physical properties of the surface involved. 'Simple' surfaces are coordinate surfaces of coordinate systems in which the partial differential equations will separate. As a result, a great many physical problems of interest have not been treated theoretically. This paper will discuss solutions of the scalar and vector wave equations satisfying non-simple boundary conditions on non-simple surfaces. . ."

Applications of the results of an earlier paper (3168 of 1941) have been made to the acoustics of irregularly-shaped rooms (3606 of 1942), yielding good agreement with experiment. The methods used in the present paper are not a continuation or extension of those employed in the former work: a new method based on the use of Green's functions is employed. "Formulae are given permitting the calculation not only of improved first-order results, but also of all the higher orders. The problem of discrete eigenvalues is reduced to the solution of a [Hermitian] secular determinant. . ."

"For example, our results can be used to treat the acoustics of irregularly-shaped rooms, scattering from irregularly-shaped objects, propagation down irregularly-shaped pipes. Moreover, simple boundary conditions need not be obeyed. For example, the walls of an irregularly-shaped room might be absorbing." In addition to the field of acoustics, the scalar and vector equations can be used to describe phenomena occurring in the fields of elasticity and electromagnetic theory. An appendix deals with the problem of moving boundary surfaces.

4027. A Modified Treatment of the Iterative Method.—Saibel. (*Journ. Franklin Inst.*, Feb. 1943, Vol. 235, No. 2, pp. 163–166.)

"One of the most powerful and useful methods for the determination of the natural frequencies of a vibrating system is the iterative method. This paper deals with a simple modification of the iterative method leading to the same accuracy in fewer steps with a consequent saving in time and labour." If eqn. 8 is employed instead of the usual eqn. 7, "the ratios of λ_1 to the other λs are raised to powers at least double what they were in eqn. 7, and consequently the approximation to λ_1 is considerably better. We note that eqn. 8 gives a lower bound to the value of λ_1.

The physical interpretation of eqn. 8 is readily apparent. It amounts to an application of Rayleigh's Principle in which the deflection $\{\psi\}_r$ is used as a loading to get the deflection $\{\psi\}_{r+1}$."

4028. PAPERS ON A SYSTEM OF OSCILLATION-MAINTENANCE WITH AUTO-STABILISED AMPLITUDE, AND ITS APPLICATION TO AN ELASTIC PENDULUM.—Abelé. (*See* 3823/4.)

4029. PERIODIC PROCESSES IN FREE PSEUDO-LINEAR OSCILLATORY SYSTEMS.—Bulgakov. (*Journ. Franklin Inst.*, June 1943, Vol. 235, No. 6, pp. 591–616.)

"The present paper deals with a mechanical or an electrical system with many degrees of freedom governed by pseudo-linear differential equations. On the basis of the theory due to H. Poincaré, periodic solutions representing an important type of steady oscillations are obtained. These solutions are then applied to explain the self-excited oscillations of the follow-up system": by such a system is meant "a contrivance which makes a certain 'follow-up' axis reproduce with minimum lag all angular displacements of another, 'leading' axis mechanically independent of the first. Such systems are employed, for instance, to support the bearings of the sensitive element of a gyro-compass in order to diminish the positional and frictional forces opposing the displacements of the element relative to the bearings."

4030. ON A PROBLEM OF GEOMETRY SUGGESTED BY THE STUDY OF BROWNIAN MOTION.—Ville. (*Comptes Rendus* [Paris], 6th/27th July 1942, Vol. 215, No. 1/4, pp. 51–52.)

"In the study of Brownian motion one is led, when the mean interval of time separating two collisions is made to tend towards zero, to consider the aleatory functions of a variable *t*, almost certainly continuous, with independent successive accretions. The physical significance of the problem is altered, the functions obtained being of an unlimited variation. The trajectories are curves which are almost certainly continuous, but without tangents. The object of the present Note is to show that, at any rate in the case of three dimensions [and probably also in the case of two], a given point on the trajectory is almost certainly a 'simple' point. . ."

4031. DETERMINATION, BY THE "CONDITION OF LEAST INACCURACY", OF A FORMULA DEPENDING LINEARLY ON PARAMETERS AND INTENDED TO REPRESENT AN EXPERIMENTAL CURVE, *and* REPRESENTATION OF AN EXPERIMENTAL CURVE, IN THE GENERAL CASE, BY THE "CONDITION OF LEAST INACCURACY".—Vernotte. (*Comptes Rendus* [Paris], 4th/25th Jan. 1943, Vol. 216, No. 1/4, pp. 33–35: pp. 148–150.)

For a further Note, "On the Systems of Equations arrived at by the Method of 'Least Inaccuracy'", see *ibid.*, 1st 29th March 1943, Vol. 216, No. 9/13, pp. 289–291.

4032. A VECTOR CALCULATING DEVICE [Conversion of Vectors of Complex Form to Polar Form, and *vice versa*, by Chart & Cursor].—Snowdon. (*Electronic Eng:g*, Sept. 1944, Vol. 17, No. 199, pp. 146–148.) Dispensing with special types of slide rule.

4033. MATHEMATICAL TRAINING FOR YOUNG ENGINEERS.—Powel. (*Elec. Engineering*, Feb. 1944, Vol. 63, No. 2, pp. 63–64.) For criticism *see* Strelzoff, *ibid.*, April 1944, No. 4, p. 158.

4034. FATHER-AND-SON NIGHT FOR I.R.E. SECTIONS [Suggestion, & Editorial Request for Views: the Desirability of Fostering the Interest of the Younger Generation].—Stote. (*Proc. I.R.E.*, Aug. 1944, Vol. 32, No. 8, p. 500.)

4035. CULTURAL TRAINING OF THE ENGINEER.—Boyajian. (*Elec. Engineering*, Jan. 1944, Vol. 63, No. 1, Transactions pp. 6–9: Discussion in *Supp. to Elec. Engineering, Transactions Section*, June 1944, Vol. 63, pp. 478–479.) For correspondence *see* May issue, No. 5, pp. 199–200.

4036. "SCIENCE REMAKES OUR WORLD" [Book Review].—Stokely. (*Journ. Franklin Inst.*, Feb. 1943, Vol. 235, No. 2, p. 207.) "This book is an essential tool to the well-informed person."

4037. THE ORGANISATION OF SCIENCE [after the War: the Plans under Discussion by the Joint Science Committee of Army, Navy, & Research Organisations].—(*Science*, 30th June 1944, Vol. 99, No. 2583, Supp. p. 10.)

4038. A [Second] LETTER ON THE MILGORE BILL, FROM VANNEVAR BUSH TO SENATOR H. M. KILGORE.—Bush. (*Elec. Engineering*, Feb. 1944, Vol. 63, No. 2, pp. 57–62.) For the first letter *see* 2375 of July. For a similar letter, from Upson, *see* May issue, No. 5, pp. 198–199.

4039. ELECTRICAL ENGINEERING IN THE POST-WAR WORLD: I—INFLUENCE OF WAR-TIME DEVELOPMENTS.—Funk. (*Elec. Engineering*, May 1944, Vol. 63, No. 5, pp. 161–163.) The president of the A.I.E.E. sounds the key-note of a new series of articles.

4040. POST-WAR [the Boomed "Wonders immediately after the War" would lead to Another 1929/32 Débâcle: and the Great Needs Abroad (*cf.* Bell, 3528 of November)].—Sayward. (*Electronics*, Feb. 1944, Vol. 17, No. 2, pp. 360–361.)

4041. ELECTRONICS IN POST-WAR INDUSTRIES [Extract from Report on Post-War Development].—British I.R.E. (*Electronic Eng:g*, Aug. 1944, Vol. 17, No. 198, p. 120.)

4042. RESEARCH AND THE FUTURE OF THE RADIO INDUSTRY.—Puckle. (*Electronic Eng:g*, Aug. 1944, Vol. 17, No. 198, p. 121.)

Neither the N.P.L. nor the E.R.A. deals exclusively with radio engineering, and "the tremendous growth of this industry throughout the Empire during the last decade, together with the importance of regaining world radio markets, makes it essential that such a body should immediately be formed. . ."

4043. YARDSTICK OFFERED FOR MEASURING THE VALUE OF INDUSTRIAL RESEARCH.—Ayres.

(*Journn. Franklin Inst.*, Jan. 1943, Vol. 235, No. 1, p. 40: summary only.)

4044. Military and Post-War Radio in Russia [Impressions gained by WPB Official during Six Weeks of Intensive Study].—Ellis. (*Elec. Engineering*, July 1944, Vol. 63, No. 7, pp. 275–276.)

4045. Planning Tomorrow's Electronic Highways [Organisation & Work of the National Television System Committee & the Radio Technical Planning Board].—Baker. (*Gen. Elec. Review*, June 1944, Vol. 47, No. 6, pp. 15–21.) For an Editorial *see* p. 7, and *cf.* 2077 of June for articles on the R.T.P.B.

4046. Frequency Spectrum Charts [showing Electronic Devices that operate at the Various Frequencies, and Pre-War Allocations to Broadcasting, Television, & Communications].—(Inset to Baker's paper, 4045, above.)

4047. Conference on Radio Wave-Bands [Need for World Conference at Early Date after the War: the IRAC Proposals: etc.].—Jett. (*See* 4011.)

4048. Extension of Patents [where War Loss can be Proved: Unfair Hardship of Necessity for High Court Proceedings].—Chartered Institute of Patent Agents. (*Electronic Eng:g*, June 1944, Vol. 17, No. 196, p 34.)

4049. Monthly Commentary: Standards and Regulations [What is the Moral behind the "Sad Little Story" referred to in 3936, above?].—(*Wireless World*, Oct. 1944, Vol. 50, No. 10, p. 289.)

The regretful key-note of all the correspondence on this particular matter (*see*, for example, p. 300) was "It is too late to make a change": indicating that the most august and competent committee, being composed of fallible human beings, is liable to make mistakes, particularly in a new art in which the accumulated experience of generations is lacking. "The widest possible publicity should be given to any proposed form of standardisation or similar ruling before it reaches the stage where the decisions arrived at are irrevocable. . ." The good example set by the F.C.C., with regard to post-war organisational problems, is discussed.

4050. Books in Translation for and from Latin America.—Science Service. (*Science*, 9th June 1944, Vol. 99, No. 2580, p. 464.) Particularly for books on science, medicine, and technology. Helped by a grant-in-aid by the Department of State.

4051. "Reading as a Visual Task" [Book Review].—Luckiesh & Moss. (*Journ. Franklin Inst.*, Feb. 1943, Vol. 235, No. 2, pp. 206–207.)

"The book is an effective tool for the betterment of eyesight, to be used by those responsible for the preparation of reading material." Among the points discussed are size of type, type-face, leading and line-length, papers and inks, and various duplicating materials.

4052. Trimetric-Projection Drawing Instrument [the M.V. Trimetric Scale for the System dealt with in 3304 of October and Back Reference].—Cooke Troughton & Simms. (*Journ. of Scient. Instr.*, Aug. 1944, Vol. 21, No. 8, p. 147.)

4053. Identifying Components [in Circuit Diagrams: Proposed Scheme of Representation by Combination of Reference Letters and Numbers indicating Property, Function, and Position in Circuit].—Hurran. (*Electronic Eng:g*, July 1944, Vol. 17, No. 197, p. 51.) For a letter from A. J. Pennell *see* September issue, No. 199, p. 170.

4054. Electronic Graphical Symbols Standardised. [Note on "American Standard Z 32.10-1944"].—(*Elec. Engineering*, July 1944, Vol. 63, No. 7, p. 246.)

4055. Experiments on Electrets [Systematic Study guided by the Idea that the Electret Effect must be related to the Various Other Aspects of Anomalous Behaviour in Solid Dielectrics].—Gross. (*Phys. Review*, 1st/15th July 1944, Vol. 66, No. 1/2, pp. 26–28.)

Influence of temperature on dielectric absorption (but no complete explanation can be reached along these lines, because electrets can be made *without* heat treatment): decomposition of the current into displacement and conduction currents: measurements on currents and charges in electrets: theory of electret behaviour (two mechanisms act simultaneously: (i) dielectric absorption related to the movement of ions or the orientation of dipoles, originating "heterocharges"; (ii) conduction in the interphase dielectric/electrode, originating "homocharges"). "The effect which manifests itself in the appearance of homocharges must interfere in many problems of dielectric behaviour, like increase of dielectric loss at high voltages and rupture. Its closer investigation may reveal further interesting features."

4056. A Persistent-Current Electro-Magnet [of Simple Construction, without Use of Liquid Helium: "Superconductivity can No Longer be regarded as fundamentally a Quantum Phenomenon restricted to the Lowest Temperatures"].—Justi. (*E.T.Z.*, 17th Dec. 1942, Vol. 63, No. 49/50, pp. 577–580.)

Author's summary:—"A persistent-current electro-magnet is described which is provided, in addition to the usual exciting winding, with a superconducting ring cooled by liquid hydrogen; in this, the inductively transferred 'break' impulse of the exciting current continues to flow without loss as a persistent current. First, the theoretical bases are discussed, then the construction of the magnet, its experimental testing, and the determination of the magnitude of the persistent current. This magnitude increases rapidly with falling temperature and already at 10° absolute exceeds 500 A. Finally, the question of the practical possibilities of this development is examined, and it is concluded that for the case of a further raising of the critical temperatures of superconductivity [say to the temperature of liquid air] there exist considerable energy-economising possibilities." A forthcoming book on electrical conduction in solid bodies is mentioned, based on a series of Berlin lectures (*see* pp. 595–596).

4057. On an Effect of the Electric Wind [Possible Application to form an Electrostatic Voltmeter].—Aubert. (*See* 3935.)

4058. Electric Circuits [in Aircraft] and the Magnetic Compass.—Burt & Beck. (*See* 3885.)

4059. Electronic Timer for Microsecond Intervals [Capacitor-Voltage measured by Valve-Voltmeter calibrated to read 0 to 140 μs with Accuracy better than ±2 μs: including Calibrating Methods].—Weisz. (*Electronics*, April 1944, Vol. 17, No. 4, pp. 108–112.) From the Bartol Research Foundation.

4060. Apparatus for Measuring Short Time Intervals [the "Microtimer", 2837 of August].—Dundas, Ltd. (*Engineering*, 9th June 1944, Vol. 157, No. 4091, pp. 445–447: *Journ. of Scient. Instr.*, Aug. 1944, Vol. 21, No. 8, pp. 144–145.)

4061. New Electronic Variable-Speed Drive [the General Electric Thy-mo-Trol System (*see*, for example, 2582 of 1943) and Its Advantages].—Fendley. (*Journ. Franklin Inst.*, June 1943, Vol. 235, No. 6, p. 656.) Summary of address to Am. Soc. of Tool Engineers.

4062. Theory of Rectifier/D.C. Motor Drive, *and* Electronic Control of D.C. Motors.—Vedder & Puchlowski: Puchlowski. (*Supp. to Elec. Engineering, Transactions Section*, Dec. 1943, Vol. 62, pp. 863–869: pp. 870–876.) For Discussions *see* pp. 960–962 & 985–986.

4063. Discussion on "Thyatron Motor Control" [2418 of July].—Moyer & Palmer. (*Supp. to Elec. Engineering, Transactions Section*, Dec. 1943, Vol. 62, pp. 962–963.)

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4070. Electronic Heat employed to give Permanent Twist in Rayon Cord for Tyres for Jeeps, Aircraft, etc.—(*Sci. News Letter*, 3rd June 1944, Vol. 45, No. 23, pp. 358–359.)

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4078. RADIO HEATING EQUIPMENT: V—DESIGNING A SMALL EXPERIMENTAL DIELECTRIC HEATER [for Limited Quantities of Thermosetting Moulding Material].—Langton. (*Wireless World*, Sept. 1944, Vol. 50, No. 9, pp. 274–277.) For previous parts *see* 3371 of October.

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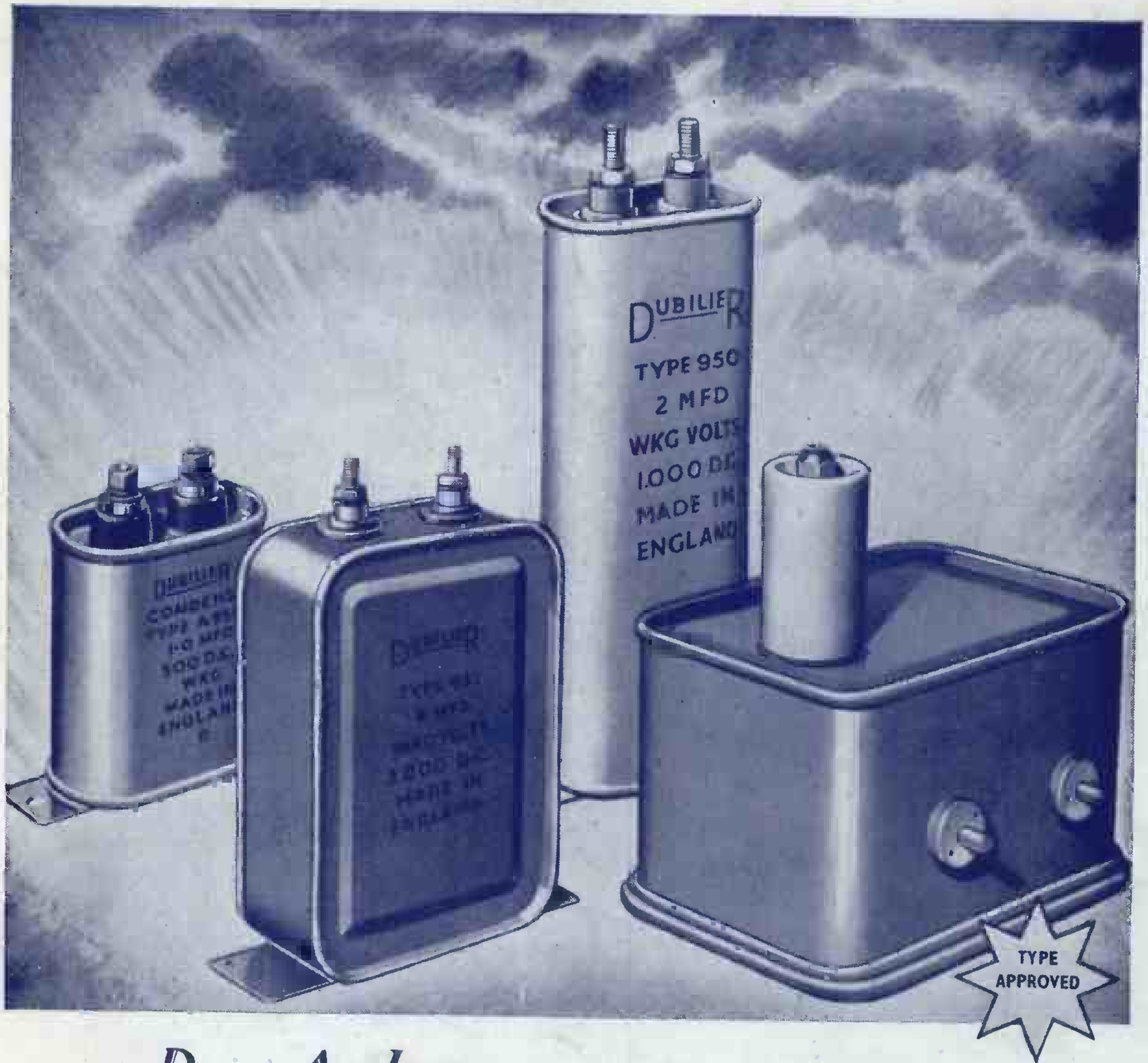

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