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WIRELESS ENGINEER

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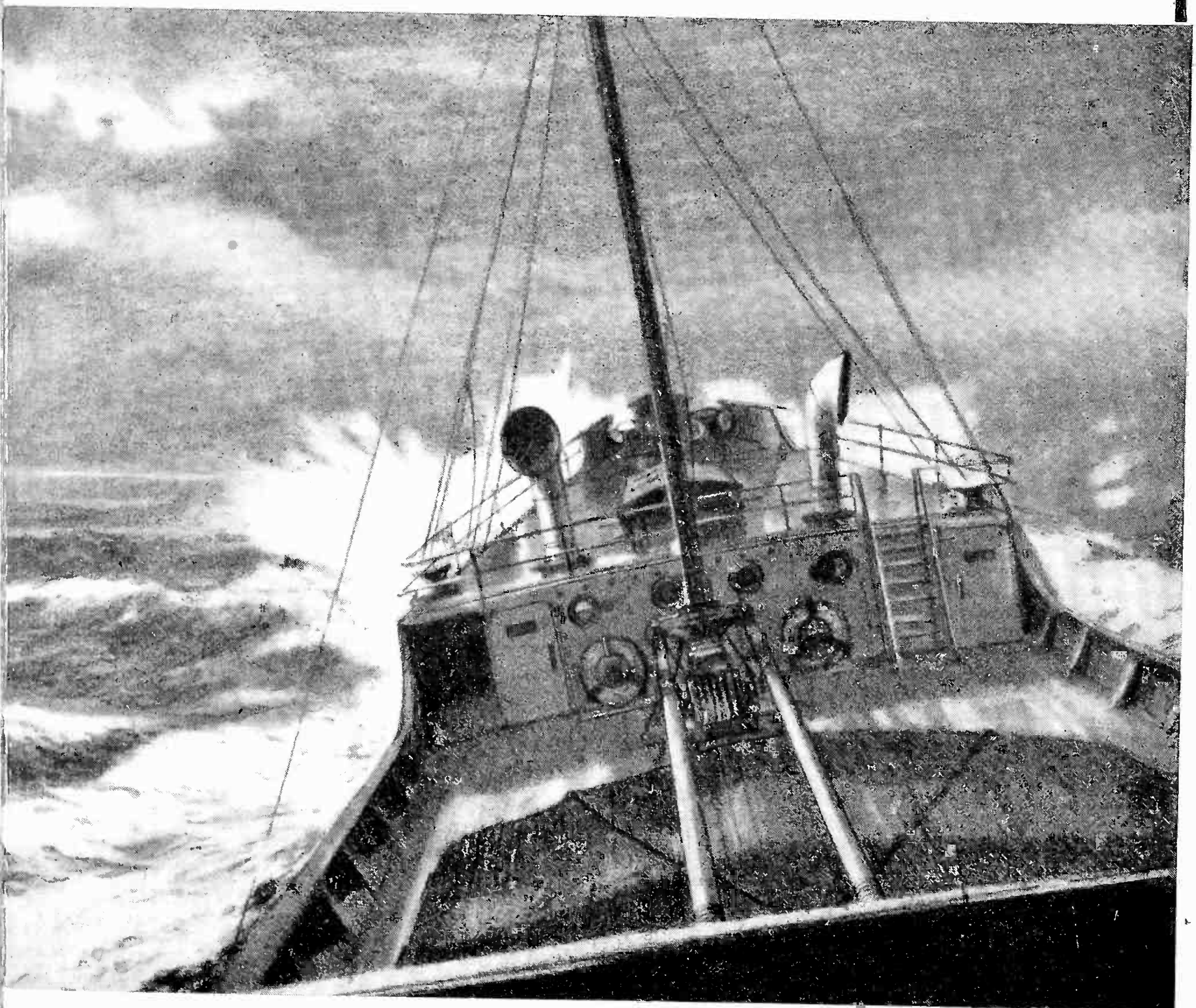

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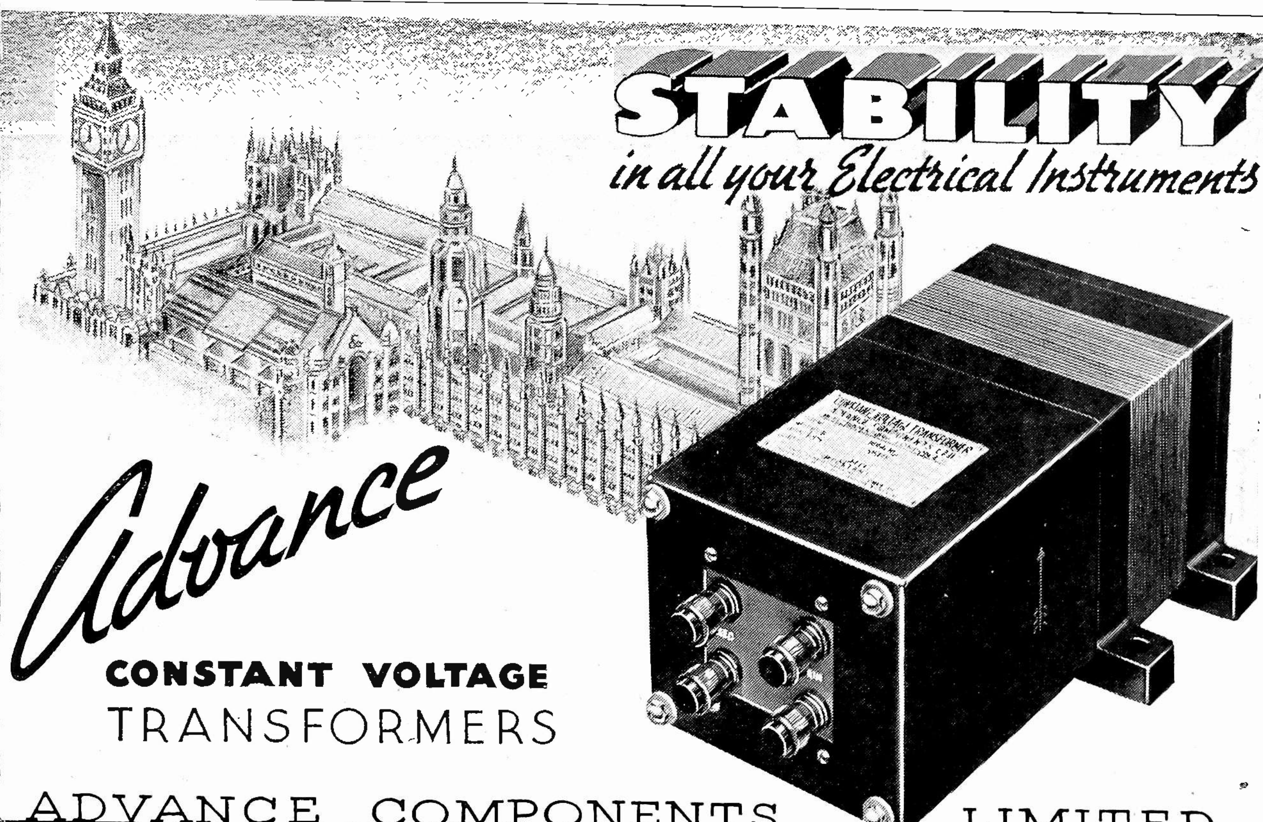

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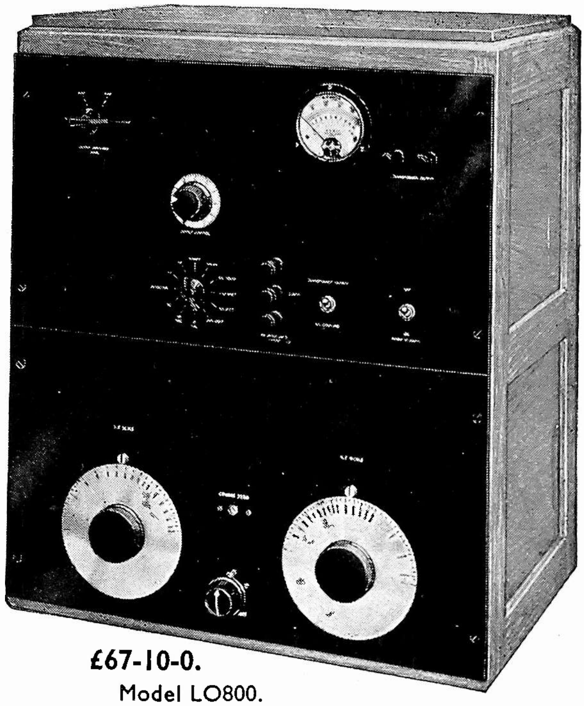

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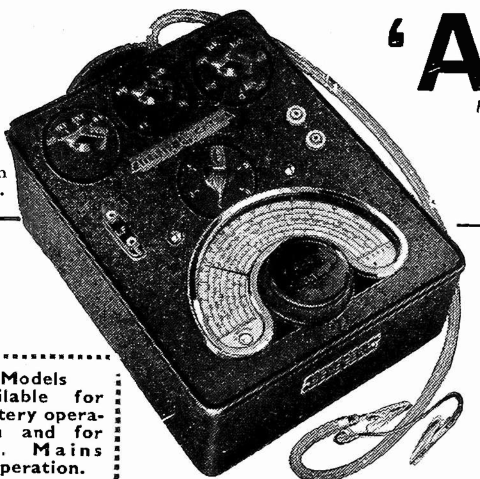

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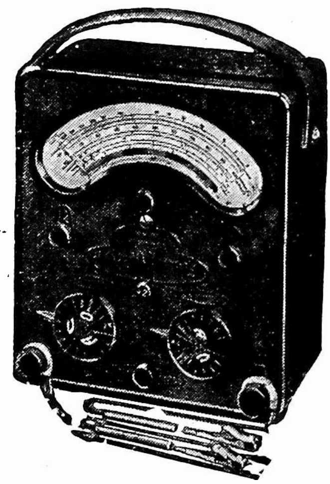

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(a) destroy any waste rubber

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(d) cause or permit any waste rubber awaiting or in the course of collection or sale to be or become mixed with any material or article other than waste rubber.

Provided that nothing in this Order shall prohibit or restrict the destruction of any waste rubber if and so far as necessary in the course of any process of manufacture, or for the purpose of saving property from immediate danger of destruction or damage by fire.

2 (1) The holder of any licence granted under this Order shall comply with any conditions contained or incorporated in the licence.

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4 This Order shall come into force on the 7th day of September, 1942, and may be cited as the Salvage of Waste Materials (No. 4) Order 1942.

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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. XIX OCTOBER 1942 No. 229

Editorial

The Equivalence of Parallel Wire and Square Mesh Grids

WE publish in this issue an interesting article entitled "Triodes with Square Mesh Grids" by C. C. Eaglesfield, in which the author describes the determination by experiments of the spacing of parallel wires in order to obtain effects equivalent to those obtained by a grid of square meshes of given size. The author adopted the experimental method because of the "very grave analytical difficulties" presented by the problem "even though all simplifying assumptions are made."

We wish, however, to draw attention to a mode of attack, applicable to this and many similar problems, in which the mathematical difficulties are largely overcome and the results obtained more than accurate enough for all practical purposes.

As the author states, it is usual when calculating the amplification factor $\frac{\partial V_a}{\partial V_g}$ to reduce the problem to an electrostatic one by assuming, not a constant current, but a constant electrostatic surface density on the cathode.

Consider two similar structures, except that one has a grid of parallel wires and the other a square mesh grid, and let the values of V_a and of V_g be the same in each case. We now wish to know what must be the relation between the pitch of the parallel wires and the side of the square mesh in order that σ_c, σ_g and σ_a may be the same in both cases, where σ_c and σ_a are the surface densities of the charges on the cathode and anode respectively, and σ_g the effective charge per sq. cm. of the grid regarded as a plane surface. If q is the charge per cm. length of grid wire and l the length of wire per sq. cm. of grid surface $\sigma_g = ql$. We assume the charges to be uniformly distributed over the isolated electrodes, and ask ourselves the converse question, viz., with the given charges what must be the dimensional relations between the two grids in order that the potentials of the electrodes may be exactly the same in the two cases. Now the potential of the cathode will be the resultant of its potential due to its own charge, that due to the charge on the anode, and that due to the charge on the grid. The only one of these that can depend at all on grid structure is the last and the effect will be very small in any practical case; for a given σ_g the average potential produced over the cathode surface will vary very little with variations in grid structure. The same is true of the anode potential. The average potential of the grid itself, in so far as it is due to σ_c and σ_a, will also be but slightly modified by variations in its structure, but the component of grid potential due to its own charge σ_g will vary considerably with variations in the grid structure. This then is the decisive factor. The anode and cathode can be left out of consideration and the grid alone considered as an isolated conducting network with an effective charge σ_g per sq. cm. The charge can be assumed as an approximation to be uniformly distributed over the wires and the resulting average potential calculated, first for the case of parallel wires and then for the case of a network of square meshes. As a matter

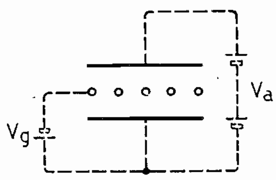

Fig. 1.

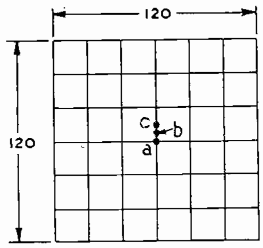

Fig. 2.

of fact, of course, it is the potential that is the same everywhere and the distribution of charge that is non-uniform, but the calculated average potential for an assumed uniform distribution of charge is a very close approximation to the actual potential with the same total charge. This method was developed for the calculation of the capacitance of antennae[1] and has proved of great utility.

As an example we take a square of 120 cm. side divided into 36 square meshes of 20 cm. side as shown in Fig. 2. We assume a charge of 1 unit per cm. of wire, i.e. a total charge of 1,680 units. The wire we assume to have a diameter of 2 cm. The scale of the model is of no importance; the result will be the same if all dimensions are divided by 100.

In the paper referred to, it is shown that the potential at the midpoint of a wire of length l and radius r due to the charge on the wire is approximately equal to $2 \log_e l/r$, assuming unit charge per cm of wire. Hence the potential at the midpoint a due to the charge on the middle vertical wire is $2 \log_e 120$. At a distance d from the middle of the wire the potential is $2 \log_e \left(\frac{l}{2d} + \sqrt{\frac{l^2}{4d^2} + 1}\right)$, so that the potential at a due to the two vertical wires 20 cm. away is

$$4 \log_e \left(\frac{120}{40} + \sqrt{10}\right).$$

[1] See *The Electrician*, LXXIII, 1914, pp. 829, 859, 906; LXXV, 1915, p. 870; LXXVI, 1915, p. 353; LXXVII, 1916, pp. 761, 880.

Similarly that due to the two vertical wires 40 cm. away is $4 \log_e \left(\frac{120}{80} + \sqrt{3.25}\right)$ and that due to the two vertical wires 60 cm. away $4 \log_e \left(\frac{120}{120} + \sqrt{2}\right)$. Adding these four potentials we have

$$(4.6 \times 2.079) + 9.2\,(0.79 + 0.519 + 0.383) = 25.15.$$

Now there will be a slightly smaller potential at a on the vertical wire due to the seven horizontal wires. Slightly smaller because, whether we assume the wire-crossings to be as shown in Fig. 3 or one set to be lying across the other as in the experiments, the nearest approach is 2 cm. Allowing for this we get a potential of 23.8, giving a total of $25.15 + 23.8 = 48.95$. Turning now to the point c 10 cm. from a, the potential due to the seven vertical wires will be practically unchanged (*loc. cit.* Fig. 2), but that due to the horizontal wires will be reduced because the nearest ones are now 10 cm. away, the next pair 30 cm., the next pair 50 cm. and the bottom wire 70 cm. away. Applying the above formula we find that the potential at c due to the horizontal wires is

$$9.2\,(1.082 + 0.627 + 0.441) + (4.6 \times 0.336) = 21.3.$$

The total potential at c is thus

$$25.15 + 21.3 = 46.45.$$

At the point b midway between a and c,

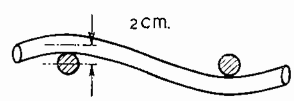

Fig. 3.

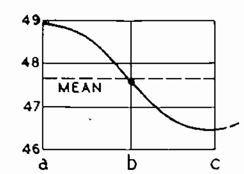

Fig. 4.

the potential due to the seven horizontal wires is

$$4.6\,(1.381 + 0.91 + 0.699 + 0.568 + 0.477 + 0.41 + 0.358) = 22.1.$$

The total potential b is thus

$$25.15 + 22.1 = 47.65.$$

The potential distribution over the wires near the centre of the grid is therefore as shown in Fig. 4 with an average of about 47.7.

If we now replace the square mesh grid by one of vertical parallel wires with a spacing of 10 cm., the charge still being one unit per cm. of wire, the charge per sq. cm. over the main area will still be the same. There will be 13 wires and for the same total length of wire and the same total charge the length of each wire will be $120 \times 14/13 = 129$ cm. This small extension of the vertical wires compensates at the edges for the removal of the top and bottom horizontal wire.

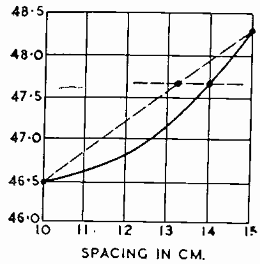

Fig. 5.

The potential at the centre of the middle wire will now be

$$2 \log_e 129 + 4 \log\left(\frac{129}{20} + \sqrt{\frac{129^2}{20^2} + 1}\right) + \text{etc.}$$

$$= (4.6 \times 2.111) + 9.2\,(1.113 + 0.82 + 0.655 + 0.546 + 0.465 + 0.406) = 46.5.$$

This will vary but little over the middle 20 cm. of the middle wire. It is less than the average potential over this piece of wire with the square mesh grid.

It may be objected that we are not justified in fixing our attention solely on this 20 cm. of wire at the centre of the grid. It is, however, fairly obvious that the relation between this potential and the average potential over the whole grid will be but little affected by details of grid structure. Let us now alter the spacing of the parallel wires from 10 to 15 cm.; to maintain the charge per sq. cm. constant, the charge per cm. of wire must be increased from 1.0 to 1.5, and for the same total charge the length of wire must be reduced from 1,680 to 1,120 cm. There will thus be 9 wires each 124.4 cm. long.

The potential at the centre will be made up as before of the components

$$2 \log_e 124.4 + 4 \log_e\left(\frac{124.4}{30} + \sqrt{4.15^2 + 1}\right) + \text{etc.}$$

$$= (4.6 \times 2.095) + 9.2(0.925 + 0.645 + 0.49 + 0.394) = 32.2.$$

But this is for unit charge per cm; for a charge of 1.5 units per cm the potential will be increased to

32.2×1.5, which is equal to 48.3.

Hence with 10 cm. spacing the potential is 46.5; with 15 cm. spacing 48.3. If one assumes a linear variation between these two values one finds that the potential of the square mesh, viz. 47.7, corresponds to a spacing of 13.3 cm., which is 0.67 of the side of the square mesh. Mr. Eaglesfield's experiments give a value of 0.6. A more detailed calculation shows, however, that the calculated potential does not vary linearly with the spacing but follows the curve shown in Fig. 5 from which the equivalent spacing would appear to be 14, i.e. 0.7 of the side of the square mesh. The ratio of the pitch to the diameter in our calculations varies between 5 and 10 which is practically the same range as in Mr. Eaglesfield's experiments.

Although the calculated values agree roughly with the experimental results, they certainly indicate slightly higher values of the ratio and the difference is too large to be ignored. Mr. Eaglesfield's experiments give a ratio of 0.6 to a high degree of consistency and our calculations should, if based on correct data, give results to a much closer approximation than that obtained above. In the first place, we have neglected the necessity of providing conducting connections between the parallel wires and in the second place Mr. Eaglesfield's Fig. 4 indicates a network in which the individual wires project beyond the square framework. We shall therefore now consider the two grids shown in Fig. 6.

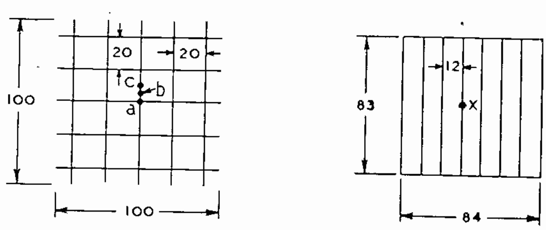

Fig. 6.

The square mesh grid consists of ten wires 100 cm. long with 20 cm. spacing, *i.e.* a total of 1,000 cm. of wire charged with 1 unit per cm. The parallel wire grid has a spacing of 0.6×20, *i.e.* of 12 cm. For the same charge per sq. cm. over the main area the wire must be charged with 1.2 units per cm., and therefore for the same total charge the length of wire must be 1,000/1.2, *i.e.* 833 cm. With eight vertical wires each 83 cm. long and two horizontal wires 84 cm. long, the total length is 832. We thus have the two grids with the same total charge and the same charge per sq. cm. over the main area. One cannot compare the total areas because that of the square is so indefinite and edge effects make the actual physical area of doubtful value.

The potential at the midpoint a of the square is found as before. Due to the wire itself it is

$$2 \log_e 100 + 4 \log_e\left(\frac{100}{40} + \sqrt{\frac{29}{4}}\right)$$

$$+ 4 \log_e\left(\frac{100}{80} + \sqrt{\frac{41}{16}}\right)$$

$$= 9.2\ (1 + 0.715 + 0.455)$$

$$= 9.2 \times 2.17 = 20.$$

That due to the cross wire is the same except that the first term is $2 \log_e 50$ giving a potential of 18.6. The total potential at the centre is thus 38.6.

The potential at c due to the vertical wire is practically unchanged at 20, while that due to the horizontal wires is 9.2 (1.004 + 0.557) + (4.6 × 0.383) = 16.1, giving a total of 36.1. The potential at the intermediate point b is similarly found to be 36.9.

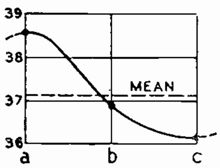

Fig. 7.

The distribution of potential over this 10 cm. of wire is therefore somewhat as shown in Fig. 7 from which the mean value is found to lie between 37.1 and 37.2.

Turning now to the parallel wire grid we calculate the potential at x. That due to the eight vertical wires (assuming unit charge per cm.), would be given by the formula

$$2 \log_e 83 + 4 \log_e\left(\frac{83}{24} + \sqrt{\left(\frac{83}{24}\right)^2 + 1}\right)$$

$$+ 4 \log_e\left(\frac{83}{48} + \sqrt{\left(\frac{83}{48}\right)^2 + 1}\right)$$

$$+ 4 \log_e\left(\frac{83}{72} + \sqrt{\left(\frac{83}{72}\right)^2 + 1}\right)$$

$$+ 2 \log_e\left(\frac{83}{96} + \sqrt{\left(\frac{83}{96}\right)^2 + 1}\right)$$

and that due to the two horizontal wires by the formula

$$4 \log_e\left(\frac{84}{83} + \sqrt{\left(\frac{84}{83}\right)^2 + 1}\right)$$

giving a total of

$$(4.6 \times 1.919) + 9.2\ (0.849 + 0.572 + 0.428) + (4.6 \times 0.339) + (9.2 \times 0.386) = 30.95.$$

We have seen, however, that the charge on this parallel wire grid must be 1.2 units per cm.; this will increase the potential at the point x to 30.95 × 1.2; *i.e.* to 37.14, which agrees exactly with that calculated for the square mesh. Hence we see that if the two grids are raised to the same potential, the total charges will be equal and also the charges per sq. cm. over the main areas regarded as plane surfaces. One can therefore replace the other in the electrode arrangement of a valve without affecting the relations berween the charges and potential differences. The calculations thus lead to exactly the same result as found experimentally by Mr. Eaglesfield.

G. W. O. H.

Triodes with Square Mesh Grids*

Calculating the Amplification Factor

By C. C. Eaglesfield

(The Mullard Radio Valve Company)

SUMMARY.—The only grid structure for which satisfactory analytical formulae are available is a grating of parallel circular wires.

The mathematical treatment of any form of mesh is very difficult.

An empirical result is given for a square mesh of circular wires. This is in the form that the square mesh is equivalent to a grating of the same wire diameter, but of a pitch equal to 0.6 times the pitch of the mesh.

1. Introduction

THE amplification factor of a triode is defined as

$$\frac{\partial i_a}{\partial V_g} \Big/ \frac{\partial i_a}{\partial V_a}$$

It is usual when attempts are made to calculate the amplification factor of an electrode structure to assume that the quantity $\frac{\partial \sigma}{\partial V_g} \Big/ \frac{\partial \sigma}{\partial V_a}$ is equivalent, where σ is the electrostatic charge density at the cathode.

This procedure ignores space charge in the system, and reduces the problem to an electrostatic one.

Two types of structure have received much attention; the first in which anode grid and cathode are unbounded parallel planes, and the grid is composed of parallel, equally spaced circular wires; and the second in which anode grid and cathode are infinitely long concentric cylinders, and the grid is composed of circular wires parallel to the axis, and evenly disposed about it.

Clearly the first type is a limiting case of the second type.

These structures have received so much attention because they represent reasonably accurately many types of valve as constructed in practice, and it happens that analytical solutions are possible.

The solution is not however exact.

The method usually followed is to make a conformal transformation in a plane perpendicular to the grid wires. This transformation is chosen so that the cross-sections of all the wires transform into the same figure. The result is that either of the two types of structure mentioned are transformed into a structure in which anode and cathode are concentric cylinders and the many circular grid wires become a single cylinder situated between cathode and anode.

The following approximations are then introduced: the cathode cylinder is supposed to be of negligible diameter, and the figure into which the grid wires transform is supposed circular. This simplified electrostatic problem can be solved, and then by transforming back to the original structure, the solution for that is obtained.

From what has been said it is clear that the analytical solution of the simplest structure is only reached with some difficulty and even then only approximately. Any extension of the problem by a complication of the geometry of the structure may easily make it practically insoluble.

Now the two structures mentioned, the parallel plane case and the concentric cylinder case, are really problems in two dimensions only, since both structures are uniform in one direction, that is the direction of the axes of the grid wires. For these structures it is only necessary to consider the plane perpendicular to the grid wires.

When the grid consists not of parallel wires, but of a mesh of wires, the problem is one of three dimensions, which increases its difficulty enormously.

The conformal transformation previously found so useful is no longer of value, since it only applies to a plane. There appears to be no transformation applicable to three

* MS. accepted by the Editor, July 1942.

dimensions with the exception of inversion, and inversion leads to a more complicated structure and not to a simpler structure.

There seems to be no doubt at all that the problem of the mesh grid presents very grave analytical difficulties, even though all simplifying assumptions are made.

Now the mesh grid is a case of some practical importance, and it is very desirable that design formulae should be available.

Since analysis appears to be impractical, the only method of obtaining such formulae is to make measurements with such grids and attempt to base empirical expressions upon the experimental results. The purist might regard this course as a confession of defeat, but it has the very important practical advantage of being as readily applicable to one form of mesh as another, whereas a mathematical treatment (if it could be obtained) of one form of mesh would almost certainly not be easily varied to suit another form of mesh. The point is rather important, as there are clearly many practical forms of mesh.

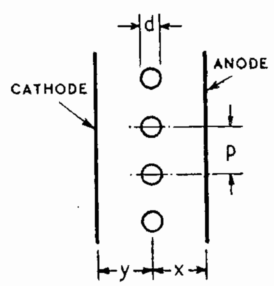

Fig. 1.

Broadly, three experimental methods are available: a range of actual valves with such grids, conduction measurements in an electrolytic tank, and measurements of the electrostatic screening effect.

The third method has been used by the writer as happening to be most convenient at the time. The experiment consists of two plates facing each other through a grid; a source of high frequency is applied to one plate, and an amplifier and indicator is connected to the other plate. The attenuation produced by the grid is measured, from which the amplification factor can be deduced.

This procedure was followed using gratings of parallel circular wires, and also wlth a square mesh of circular wires. The mesh grids were constructed with one set of wires lying on top of the other set of wires, that is the two sets were not interleaved to form a net. The method of forming the meshes must have an effect, although probably a small effect, on the amplification factor.

Within the limits of accuracy caused by the above and other imperfections of construction, the experimental results are consistent with assuming that the square mesh is equivalent to a grating made of the same wire diameter and a pitch equal to a constant fraction of the pitch of the square mesh. The fraction arrived at experimentally is 0.60.

By expressing the square mesh in terms of an equivalent grating, either plane or cylindrical structures using square mesh grids can be calculated. The probable accuracy is better than 10 per cent., which is quite sufficient for the purpose of valve design.

2. Infinite Plane Structure (Parallel Wire Grids)

The most complete formula available for this structure is given by Salzberg (*Proc. I.R.E.*, March 1942):—

$$\mu = \frac{2\pi x/p - ln \cosh \pi d/p}{ln \coth \pi d/p + ln\{1 - \exp(-4\pi x/p) \cdot \cosh^2 \pi d/p\}} \quad \ldots \quad (1)$$

For dimensions see Fig. 1.

The second term in the denominator is only appreciable when $x < p$, and is negligible for instance when $x = p$ for any likely value of p/d. Thus, if the reservation is made that $x \nless p$, the second term in the denominator can be omitted.

The second term in the numerator is only of secondary importance.

It is sometimes desirable to put equation 1 into a simpler form; for instance, when the dependence of μ on small changes of p and d is required. The following equations are

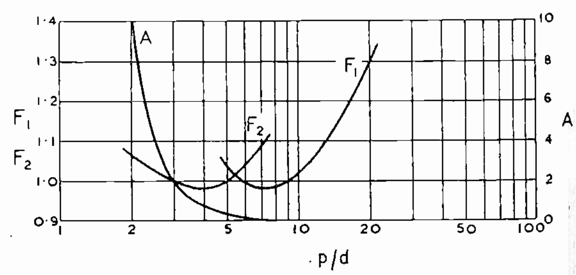

Fig. 2.

equivalent to equation 1 (neglecting the second term in the denominator):—

$$\mu = 52 \frac{xd}{p^2} \cdot F_1 - A \quad \ldots \quad \ldots \quad (2a)$$

$$\mu = 34 \frac{xd}{(p-d)^2} \cdot F_2 - A \quad \ldots \quad (2b)$$

where F_1, F_2, and A are functions of p/d and are given in Fig. 2.

The usefulness of these equations lies in the fact that F_1 and F_2 are nearly unity for certain ranges of value of p/d. Thus equation 2a is suitable for values of p/d ranging from 5 to 11, and equation (2b) for values from 2 to 6. This covers the range of values of p/d normally used in actual valves.

3. Measurements

The arrangement of the experiment is shown in Fig. 3. Two circular plates, of diameter 50 mms and 30 mms respectively (all dimensions are given in mms) are mounted inside a metal box, and connected by 80 ohm concentric lines to an oscillator and amplifier. The larger plate represents the anode, and the smaller plate represents the cathode.

The grid is formed on a plate, shown separately in Fig. 4, and the whole plate slides into sprung grooves so that it is readily removed.

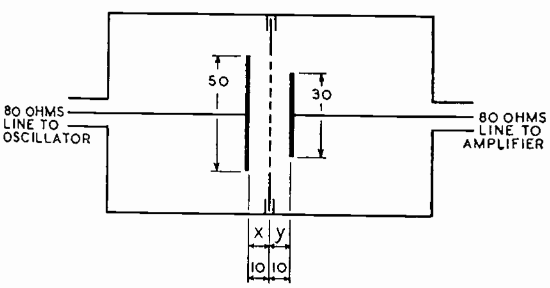

Fig. 3.

A number of grid plates were made with different sizes of pitch and wire diameter; there was also a plate with no wires on it, but merely the window. This plate was used for the "grid removed" condition.

The frequency of operation was 200 Mc/s. This frequency was chosen because apparatus happened to be available, and because it led to convenient sizes of grid, etc. The source was a Marconi Ekco 150-300 Mc/s signal generator, which has a conveniently high maximum output (0.3 volt) and a reliable piston attenuator.

The procedure was to insert the grid plate and adjust the indicator to a standard level. Having read the attenuator setting the grid plate was removed and the open window plate put in its place. The attenuator was adjusted to bring the indicator back to the standard level.

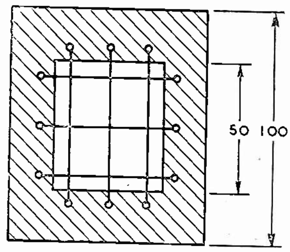

Fig. 4.

The ratio of the second voltage to the first voltage may be called R.

The next step is to find the relation between R and μ. A little consideration shows that with x and y constant, μ will be approximately proportional to R. The following equation has been derived:—

$$\mu \doteq (R-1)\frac{x+y}{y} \quad \ldots \quad \ldots \quad (3)$$

The derivation of equation 3 is not however very satisfactory and therefore a different method of procedure will be followed.

Under the conditions of the experiment x and y were constant—in fact equal.

From equation 1, neglecting the second terms in numerator and denominator, μ is inversely proportional to $p \log \coth \pi\, d/p$ for a grating.

R must be a function of p and d only, since x and y are constant.

It is therefore to be expected that R should be a function of $p \log \coth \pi d/p$.

Table I gives the values of R and $p \log_{10} \coth \pi d/p$ for the experimental gratings measured, and these values are plotted in Fig. 5. Since the points lie reasonably on a smooth curve, this relationship appears to hold.

TABLE I

Experimental Results on Gratings

p	d	$p \log_{10} \coth \pi d/p$	R
10	1	5.17	10.5 db
5	1	1.26	20.5
5	0.6	2.22	16.5
5	0.3	3.65	12.6
3	1	0.324	37.0
3	0.6	0.76	26.2
3	0.3	1.55	19.2
2	0.3	0.715	26.2

In Table II are given the values of R and $p' \log_{10} \coth \pi d/p'$ for the square mesh grids, where $p' = 0.6\ p$, and p is the pitch in either direction of the square mesh. These points are also plotted in Fig. 5.

TABLE II

Experimental Results on Square Mesh Grids

p	d	$p' \log_{10} \coth \pi\, d/p'$	R
10	1	1.91	17.2 db
10	0.6	3.10	14.0
10	0.3	4.85	11.0
5	1	0.321	32.3
5	0.6	0.76	25.0
5	0.3	1.55	19.0
3	0.3	0.572	27.9

N.B. $p' = 0.6p$.

The fraction $p'/p = 0.6$ has of course been chosen to bring the points for the square meshes on to the same curve as those for the gratings.

Inspection of Fig. 5 shows that there is little to choose between the two sets of points except for large values of R. The points on this portion of the curve also have appreciable values of d/p.

Now equation 1, and in particular the term $\log \coth \pi d/p$, is known to be inaccurate for large values of d/p; so that discrepancies in this region are to be expected.

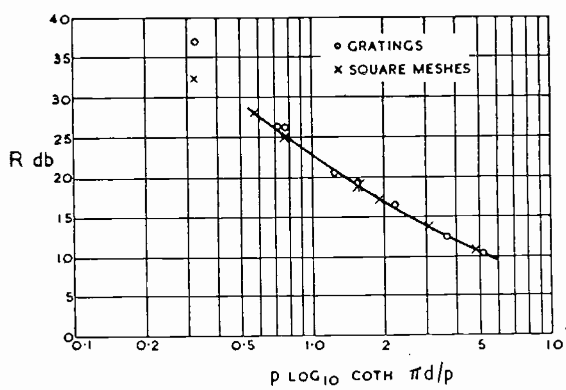

Fig. 5.

Fig. 5 appears to establish that the square mesh is equivalent to a grating of 0.6 times the pitch, when d/p is small. The value of d/p at which discrepancies appear is not very well established by the experiment, but seems to be of the order of 0.1 to 0.2.

Put in an explicit form, the equation for the amplification factor with a square mesh is :—

$$\mu = 4.55 \frac{x}{p \log_{10} \coth 5.24\, d/p} \quad .. \quad (4)$$

The author is grateful to the Mullard Radio Valve Company for permission to publish this article, and to several members of the Research and Development Department of the Company for help and advice.

Correspondence

Signal/Noise Ratio of the Cathode Follower

To the Editor, "Wireless Engineer"

SIR,—I should like to comment on Mr. D. A. Bell's letter on the signal/noise ratio of the cathode follower on p. 360 of the August issue.

The impedance Z_c should not be shown in Fig. 2 as an impedance connected in parallel with the primary of the transformer, but as the apparent impedance looking into the primary, for otherwise the equations in the earlier part of the text are incorrect. It is clear that there is no need for such a shunt impedance as shown in Fig. 2, since the impedance reflected into the primary from Z forms the required cathode load.

Using Z_g to denote the grid-cathode impedance $R_g/(1 + j\omega CR_g)$ the input current i_g is the ratio of $(E - V_c)$ to this impedance Z_g and not to the $(Z_c + Z_g)$ of equation (2), which is erroneously given as the total impedance of the grid-cathode circuit.

Equation (1) has the form appropriate to an infinite grid-cathode impedance; retaining Bell's assumption that the valve impedance $R_a \gg Z_c$ the correct equation for a finite Z_g is

$$E - V_c = \frac{E\, Z_g}{(1 + GZ_c)Z_g + Z_c}$$

from which the value of the input admittance is

$$Y = \frac{i_g}{E} = \frac{1}{(1 + GZ_c)Z_g + Z_c}$$

in place of $1/(1 + GZ_c)(Z_g + Z_c)$ given by equation (3). Similarly equations (4), (5) and (6) are in error.

Although the ratio of shot currents of a pentode and triode of the same slope may be of the order of 2 to 1, the overall improvement due to the use of a triode in an amplifier instead of a pentode will be less than this owing to the thermal noise in the input circuit and in the output impedance Z. Suppose the dynamic resistance of the signal source connected to the input of the amplifier be R_0. Then if R_0 is large compared with the equivalent noise resistance of a high-slope pentode (i.e. about 1500 Ω) there is little advantage in using a triode instead of a pentode. On the other hand, if R_0 is small compared with the equivalent noise resistance of a high-slope triode (say 300 Ω) either type of amplifier will give a serious loss of signal/noise ratio due to the valve noise. For R_0 below a certain value, a transformer stepping-up directly from R_0 to Z would give a better signal/noise ratio than any valve circuit.

R. E. BURGESS.

Slough, Bucks.

Harmonic Distortion in Audio-Frequency Transformers—2

By Norman Partridge, Ph.D., B.Sc. (Eng.), A.M.I.E.E.

(Part 1 of this article was published in the September 1942 issue)

SINCE $I_f Z_f = V_f$, equation (5) may be rewritten in the following form :—

$$\frac{V_h}{V_f} = \frac{I_H R}{V_f}\left(1 - \frac{R}{4Z_f}\right) \quad \ldots \quad (6)$$

Let I_H and V_f have values applicable at a frequency of f_1 cycles per second to a transformer having N_1 turns, a core area of A_1 sq. cms. and a magnetic circuit l_1 cms. in length. If the parameters be altered to f_2, N_2, A_2 and l_2, the new values of I_H and V_f can be deduced providing B_m remains unchanged. Let these new values be I_H'' and V_f''. Then, for constant peak flux density :—

$$I_H'' = I_H \cdot \frac{N_1}{N_2} \cdot \frac{l_2}{l_1}$$

and $$V_f'' = V_f \cdot \frac{N_2}{N_1} \cdot \frac{A_2}{A_1} \cdot \frac{f_2}{f_1}$$

By substitution in equation (6) we can find the distortion produced under the new conditions (B_m unchanged) :—

$$\frac{V_h''}{V_f''} = \frac{I_H'' R}{V_f''}\left(1 - \frac{R}{4Z_f''}\right)$$

$$= \frac{I_H}{I_f} \cdot \frac{N_1^2 A_1 f_1}{Z_f l_1} \cdot \frac{l_2}{N_2^2 A_2} \cdot \frac{R}{f_2}\left(1 - \frac{R}{4Z_f''}\right)$$

The second factor $(N_1^2 A_1 f_1 / Z_f l_1)$ is of particular interest. At first sight it suggests the admittance at a frequency of 1 c/s of an imaginary transformer having $N = 1$, $A = 1$ and $l = 1$. But this is not strictly correct. Hysteresis and eddy losses do not vary in the same way with frequency and therefore a true impedance conversion could not be so simply performed. The factor is, in fact, a purely fictitious quantity so related to I_H/I_f that the product of the two factors is a constant for any one core material at any one value of B_m.

$$\frac{I_H}{I_f} \cdot \frac{N_1^2 A_1 f_1}{Z_f l_1} = \frac{I_H N_1^2 A_1 f_1}{V_f l_1} = \text{a constant} \quad (B_m \text{ fixed})$$

The value of this constant is dependent only upon the shape of the hysteresis loop and is independent of the form of the test sample, of the test frequency, and of the lamination thickness (skin effect excluded). In view of the relationship existing between the factors $\frac{I_H}{I_f}$ and $\frac{N_1^2 A_1 f_1}{Z_f l_1}$, the latter may conveniently be referred to as the reciprocal of the "relative specific choke impedance" $(1/Z_{Sp})$.

It may be noted that if the true impedance at 1 c/s of the specific choke were substituted in place of Z_{Sp}, then I_H/I_f would require a correction. This results from the fact that at a constant peak flux density I_f varies with frequency while I_H does not, since there is an eddy loss component in I_f but not in I_H ($R = 0$, therefore no flux distortion). The product of the true specific choke impedance and the corrected value of I_H/I_f would be exactly the same as that of the measured value of I_H/I_f and its *relative* specific choke impedance. Thus the artifice employed in the equation avoids any modification to the measured value of I_H/I_f and renders the conversion of Z_f to Z_{Sp} very simple to perform.

Since $\frac{I_H}{I_f} \cdot \frac{N_1^2 A_1 f_1}{Z_f l_1}$ is a constant, it is clearly unnecessary to specify the parameters f_1, N_1, A_1 and l_1. The above equation may therefore be expressed :—

$$\frac{V_h}{V_f} = \frac{I_H}{I_f} \cdot \frac{1}{Z_{Sp}} \cdot \frac{l}{N^2 A} \cdot \frac{R}{f}\left(1 - \frac{R}{4Z_f}\right) \quad \ldots \quad (7)$$

Equation (7) provides a simple and eminently practical method of calculating transformer distortion. When a transformer of known design is employed in a given circuit the factors appearing to the right of the equation are at once fixed. N, A and f are known. R can be calculated from a knowledge of the series and shunt resistances. I_H/I_f and Z_{Sp} can be taken from suitable curves (see Fig. 8), the value of B_m being deduced from the known fundamental voltage across the transformer winding. The product $\frac{1}{Z_{sp}} \cdot \frac{l}{N^2 A} \cdot \frac{1}{f}$, which appears in equation (7), approximates to the admittance of the transformer and provides the value to be assigned to I/Z_f in the final factor of the equation.

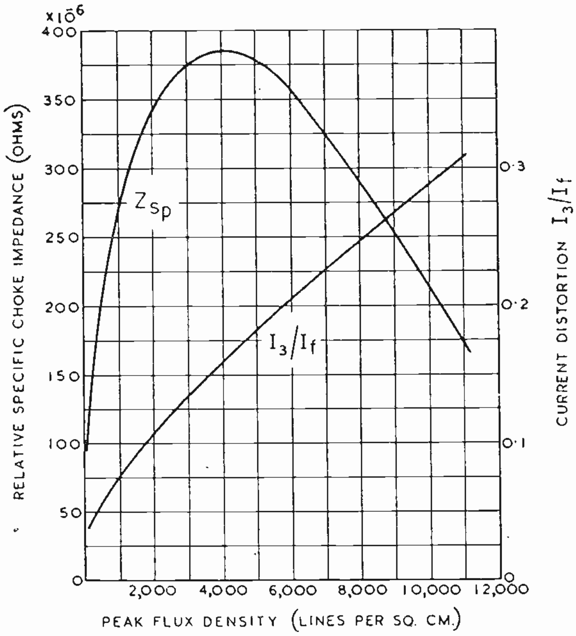

Fig. 8. *Variation of I_3/I_f and Z_{Sp} with B_m for Silcor 1, 0.014" thick at 50 c/s.*

Typical relative values of I_3/I_f and Z_{Sp} obtained from a sample of Silcor 1 operating in the normal cyclic condition are given in Fig. 8. Values obtained from typical (not necessarily average) samples of Vicor, Silcor 2, Silcor 3 and Silcor 4 are given in Table IV.

In the experience of the author, equation (7) provides the simplest method of dealing with distortion problems in practice. It also possesses the great advantage that a knowledge of the $Z_{sp} - B_m$ curve enables a rapid approximation to be made to the impedance of a transformer at any low frequency. But there is another approach which is perhaps more orthodox and possesses certain advantages from the purely theoretical aspect.

Since we are concerned only with very small distortions of the flux wave-form, V_f can be expressed by the well-known formula :—

$$V_f = \frac{4.44 \, B_m \, N \, A \, f}{10^8}$$

where $4.44 = \pi\sqrt{2}$

Substituting in equation (6) :—

$$\frac{V_h}{V_f} = \frac{I_H R \, 10^8}{4.44 \, B_m \, N \, A \, f}\left(1 - \frac{R}{4Z_f}\right)$$

Multiplying numerator and denominator by 10 . N . l and rearranging :—

$$\frac{V_h}{V_f} = \frac{I_H N}{0.56 \, B_m l} \cdot \frac{10^9}{8\pi^2} \cdot \frac{l}{N^2 A} \cdot \frac{R}{f}\left(1 - \frac{R}{4Z_f}\right) \quad \quad (8)$$

where $0.56 = \frac{10}{4\pi\sqrt{2}}$

The significance of the first factor appearing

TABLE IV

B_m lines per sq. cm.	S_3	Z_{Sp}	I_3/I_f	S_3	Z_{Sp}	I_3/I_f	S_3	Z_{Sp}	I_3/I_f	S_3	Z_{Sp}	I_3/I_f
	Vicor			Silcor 2			Silcor 3			Silcor 4		
	$\times 10^{-6}$	$\times 10^{-6}$		$\times 10^{-6}$	$\times 10^{-6}$		$\times 10^{-6}$	$\times 10^{-6}$		$\times 10^{-6}$	$\times 10^{-6}$	
45	45.5	81	0.0465	39.5	60	0.030	28	56	0.020	69	33	0.029
90	31	103	0.0405	40	72	0.0365	32	70	0.0285	82	36.5	0.038
180	25.5	126	0.041	39.5	89	0.0445	36	92	0.042	85	54	0.058
360	20.5	163	0.0425	40	112	0.057	35	112	0.050	75	69	0.066
675	19.2	205	0.050	37	155	0.073	35.5	144	0.065	62	96	0.075
1125	20	260	0.066	36.5	200	0.093	37	182	0.085	58	123	0.091
1575	22.5	285	0.081	36.5	240	0.111	37.5	220	0.105	56	146	0.104
2250	24	330	0.101	37	275	0.130	37.5	255	0.122	53	172	0.116
3600	30	350	0.133	42	320	0.170	40	315	0.161	52	215	0.143
5400	39	350	0.173	53	330	0.220	47.5	330	0.20	56	245	0.173
7200	52	310	0.205	69	305	0.265	59	320	0.24	69	240	0.21
9000	76	255	0.245	96	260	0.315	78	285	0.28	86	215	0.235
10 800	111	195	0.275	142	200	0.36	113	230	0.33	118	180	0.27

Test frequency 50 c/s. For lamination thickness see Table I.

on the right of the equation will be made clear by the following considerations :—

$$\text{Magnetomotive force} = \frac{4\pi N I_{mg}}{10}$$

$$\text{hence} \quad B = \frac{4\pi N I_{mg}}{10} \cdot \frac{\mu}{l}$$

Applying this to the case of a sinusoidal magnetising current we find :—

$$B_m = \frac{4\pi\sqrt{2} N I_{mg}}{10} \cdot \frac{\mu}{l}$$

where B_m = peak flux density
I_{mg} = r.m.s. magnetising current
and μ = effective permeability

$$\text{therefore} \quad I_{mg} = \frac{0.56 \, B_m l}{N\mu}$$

But the factor in which we are interested can be written :—

$$\frac{I_H N}{0.56 \, B_m l} = \frac{I_H}{\dfrac{0.56 \, B_m l}{N}} = \frac{I_H}{I_{mg, \mu = 1}}$$

It is at once apparent that this factor is the ratio of the harmonic current contained in the actual magnetising current drawn by a transformer to the imaginary magnetisng current (at the fundamental frequency) that would be drawn if the core material had a constant permeabiluty of 1. It can be shown that this ratio is constant for any given material operating at any one value of B_m. Like the product $\frac{I_H}{I_f} \cdot \frac{1}{Z_{Sp}}$, it is dependent only upon the shape of the hysteresis loop and is independent of test frequency, lamination thickness, winding data, physical shape or size of the transformer tested, etc., always providing the flux density is substantially constant throughout the magnetic circuit and the frequency is below that at which skin effect becomes important, say below 100 c/s for laminations of the normal thickness.

This specific quantity ($I_H/I_{mg, \mu = 1}$), which is a function of B_m, can be defined both logically and conveniently as the distortion coefficient of a magnetic material (S_H).

Every material will have a number of distortion coefficients associated with it. Apart from S_H being a function of B_m, it will be different for each harmonic frequency taken separately. The particular coefficient to which reference is made can be indicated by an appropriate suffix such as S_3 for the third harmonic, $S_{r.m.s.}$ for the r.m.s. sum of all harmonics, etc. The presence of a polarising field changes the magnitude and the nature of the distortion, as will be seen later. Thus a fresh series of distortion coefficients arises with every change in the value of the polarising field.

Applying the above definition of the distortion coefficient to equation (8) we obtain :—

$$\frac{V_h}{V_f} = S_H \cdot \frac{10^9}{8\pi^2} \cdot \frac{l}{N^2 A} \cdot \frac{R}{f}\left(1 - \frac{R}{4Z_f}\right) \qquad (9)$$

$$\text{where} \quad S_H = \frac{I_H N}{0.56 \, B_m l}$$
= distortion coefficient.

Equation (9) is exact at any one harmonic frequency in the limiting case when $R = 0$. When R is small by comparison with Z_f the equation provides a close approximation to the truth at any one harmonic frequency. But when R is appreciable by comparison with Z_f, the equation is subject to the same limitations as those applying to equation (4).

It is interesting to note in passing that the constant $10^9/8\pi^2$ is the reciprocal of the reactance at 1 c/s of a choke in which $N = 1$, $A = 1$, $l = 1$ and $\mu = 1$. Thus the product of the three factors $\frac{10^9}{8\pi^2}$, $\frac{l}{N^2 A}$ and $\frac{R}{f}$, which occurs in equation (9), is the ratio of the equivalent series resistance (R) to the reactance of the transformer at the fundamental frequency when using an imaginary core material having the hypothetical permeability of 1. These considerations suggest that the constant $10^9/8\pi^2$ should properly be associated with the factors l/N^2A and R/f, and that it was correctly excluded from the definition of the distortion coefficient.

The $S_3 - B_m$ curve for Silcor 1 in the non-polarised state is given in Fig. 9. Corresponding curves for Vicor, Silcor 2, Silcor 3 and Silcor 4 can be obtained by plotting the figures to be found in Table IV.

One minor difficulty arises when employing equation (9). Appropriate values are readily assigned to all the factors with the single exception of Z_f, which appears in the final correction factor. If the relevant $Z_{Sp} - B_m$ curve (see Fig. 8) is available the difficulty vanishes. Alternatively, no serious error will arise by substituting ωL in place of Z_f. L can be estimated by means of the well-known formula :—

$$L = \frac{4\pi N^2 A\mu}{10^9 l}$$

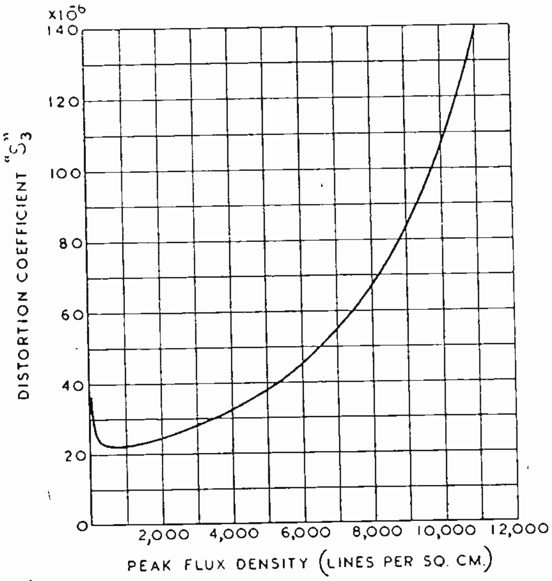

Fig. 9. *Variation of S_3 with B_m for Silcor* 1.

Equations (7) and (9) provide two expressions for the voltage distortion produced by a transformer. Equating these we find :—

$$S_H \cdot \frac{10^9}{8\pi^2} = \frac{I_H}{I_f} \cdot \frac{1}{Z_{sp}}$$

Expressed in words :—The product of the distortion coefficient and the reciprocal of a specific reactance (N, A, l, f and $\mu = 1$) is equal to the product of the fractional current distortion and the reciprocal of the relative specific choke impedance (N, A, l and $f = 1$). It follows that the distortion coefficient is given by the product of the fractional current distortion and the ratio of the magnitudes of a specific reactance to the relative specific choke impedance. The latter ratio clearly approximates to $1/\mu$ when the power factor is low.

Space will not permit a comprehensive review of the many applications of the above data to problems arising in the design, and in the use, of audio-frequency transformers. A single example in the form of problem and solution will have to suffice.

Problem :—An amplifier having a balanced push-pull output stage is required to feed 7 watts at 30 c/s into a resistive load of 6000 ohms. The output valves have an A.C. resistance of 1000 ohms each and the optimum load for the power stage is 6000 ohms (A to A). The output transformer has a ratio of 1 : 1 and a closed magnetic circuit of Silcor 1. Nothing more is known of the transformer design data, but the following r.m.s. no-load currents were observed by connecting the full primary to the 50 c/s power supply via a multi-tapped auto-transformer :—

V volts	I mA	V volts	I mA
150	1.2	350	2.6
200	1.5	400	3.0
250	1.85	450	3.4
300	2.2	500	4.0

Estimate the harmonic distortion produced by the transformer when used for the purpose suggested above.

Solution :—The impedance of the transformer at 50 c/s with various applied voltages can be calculated from the figures given in the question.* These are found to be :—

V	Z_f ohms	V	Z_f ohms
150	125 000	350	135 000
200	133 000	400	133 000
250	135 000	450	132 000
300	136 000	500	125 000

Plotting the above values of Z_f against V shows that the maximum impedance is attained when 290V. is applied to the primary. Since Z_f is proportional to Z_{sp}, the flux density at which the maximum value occurs can be taken from Fig. 8 and is seen to be 4100 lines per sq. cm. Hence the application of 290V. at 50 c/s corresponds to a peak flux density of 4100 lines per sq. cm.

The voltage required to dissipate 7 watts in a 6000 ohm resistance is $\sqrt{6000 \times 7} = 205$ volts r.m.s. The peak flux density in the core of the transformer resulting from the application of this voltage at 30 c/s will be $4100 \times \frac{205}{290} \times \frac{50}{30} = 4800$ lines per

* The values quoted in this example are taken from a practical design employing a 1½in. stack of No. 4 stampings wound with a primary of 4000 turns.

sq. cm., since B_m is directly proportional to voltage and inversely proportional to frequency.

It is now possible to assign values to the various quantities appearing in equation (7). $I_3/I_f = 0.18$ (from Fig. 8). Z_{sp} could also be taken from Fig. 8 but it would not be useful since l, N and A are unknown. Instead, Z_{sp} can be calculated from the known impedance of the transformer at 50 c/s. It has been shown that 290V. at 50 c/s corresponds to a peak flux density of 4100 lines per sq. cm., therefore the applied voltage at 50 c/s corresponding to $B_m = 4800$ lines per sq. cm. will be $290 \times \frac{4800}{4100} = 340$ volts r.m.s. The primary impedance at this voltage is seen from the above table to be approximately 135 000 ohms. Therefore :—

$$Z_{sp} = 135\,000 \cdot \frac{l}{N^2A} \cdot \frac{1}{50}$$

The unknown factor, l/N^2A, will be found to cancel out when substituted in equation (7).

R is the combined resistance of the load (6000 ohms) and of the valve A.C. resistance (1000 × 2 ohms) in parallel, i.e. 1500 ohms.

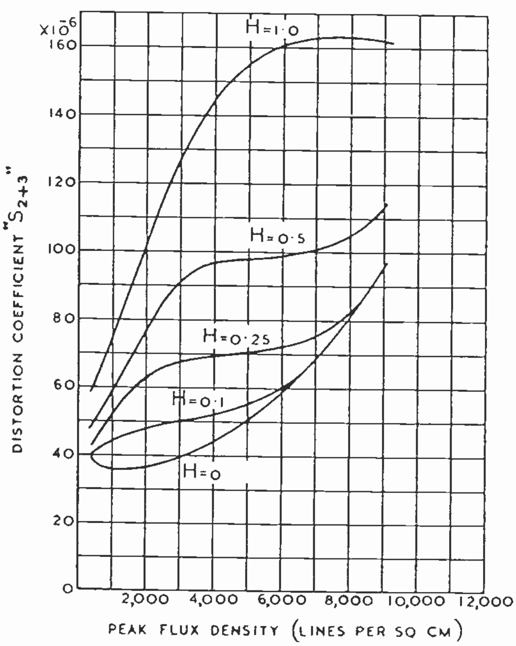

Fig. 10. *Effect of a Polarising Field upon the Distortion Coefficient of Silcor 2.*

An approximation to Z_f at 30 c/s can be obtained from Z_{sp} above :—

$$Z_f \approx Z_{sp} \cdot \frac{N^2Af}{l} = 135\,000 \times \frac{30}{50}$$
$$= 81\,000 \text{ ohms approx.}$$

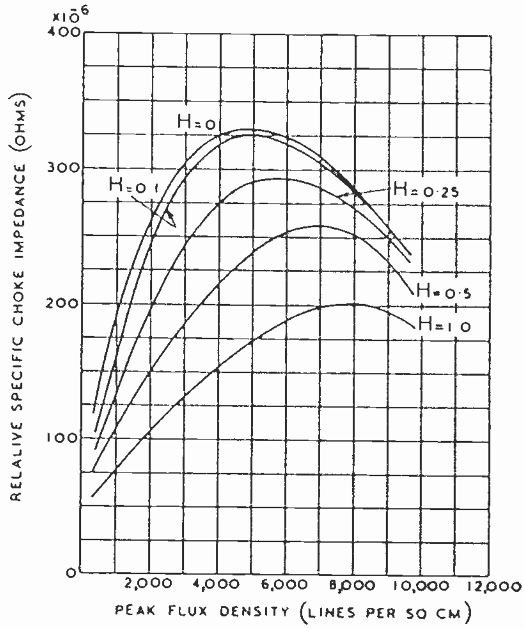

Fig. 11. *Effect of a Polarising Field upon the Relative Specific Choke Impedance for Silcor 2.*

Substituting in equation (7) :—

$$\frac{V_h}{V_f} = 0.18 \cdot \frac{N^2 \cdot A \cdot 50}{135\,000 \cdot l} \cdot \frac{l}{N^2A} \cdot \frac{1500}{30}$$
$$\times \left(1 - \frac{1500}{4 \times 81\,000}\right) = 0.0033 \text{ approx.}$$

The required harmonic distortion therefore approximates to $\frac{1}{3}$ per cent.

The example cited is one that may be of great use in practice. No knowledge of the transformer design is required except that the core material must be known. The experimental data needed is such that can be obtained by means of the most rudimentary equipment. Two possible sources of error must be watched. (1) The transformer must not only have a nominally closed magnetic circuit, but the laminations must be properly butted together. Otherwise false values of the relative specific choke impedance will be obtained. (2) The presence of a polarising current may materially increase the distortion.

The preceding subject matter relates specifically to the normal cyclic condition and is applicable to all types of chokes and transformers in which no polarising field exists. In theory push-pull transformers fall within this category, but an exact balance between the anode currents in the two halves of the primary winding is rarely attained in practice. A brief account of the effects of polarisation will therefore be given.

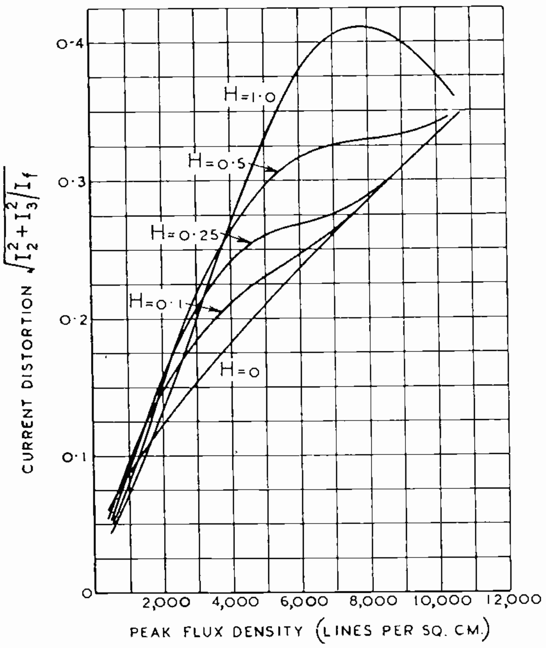

Fig. 12. *Effect of a Polarising Field upon the Current Distortion produced by Silcor 2.*

The existence of a constant component in the magnetising force results in an unsymmetrical hysteresis loop. Hence even, as well as odd, harmonics make their appearance. At any flux density below say 10 000 lines per sq. cm. the r.m.s. sum of the 2nd and 3rd harmonic currents approximates to the r.m.s. sum of all the harmonic currents. Whereas in the normal cyclic condition it was necessary only to consider I_3, in the polarised condition is it necessary to work in terms of $\sqrt{I_2^2 + I_3^2}$.

Neither the second nor the third harmonic current, taken separately, follows the empirical law stated by equation (4); but the composite current $\sqrt{I_2^2 + I_3^2}$ does so with sufficient accuracy for practical purposes at low values of the polarising field. Hence all that has been said in connection with the normal cyclic condition can be applied to the polarised condition by substituting $\sqrt{I_2^2 + I_3^2}$ in place of I_3. The appropriate distortion coefficient therefore becomes :—

$$S_{r.m.s.} \approx S_{2+3} = \frac{\sqrt{I_2^2 + I_3^2}\,N}{0.56\,B_m\,l}$$

The values of S_{2+3}, Z_{Sp} and $\sqrt{I_2^2+I_3^2}/I_f$ obtained from a sample of Silcor 2 with polarising fields of 0, 0.1, 0.25, 0.5 and 1.0 oersteds are given in Figs. 10, 11 and 12 respectively. The separate values of I_2/I_f and I_3/I_f are indicated in Table V. The method of applying this data to components having an air gap in the magnetic circuit will be touched upon in Part 3.

TABLE V

B_m lines per sq. cm.	$H_{DC} = 0.1$		$H_{DC} = 0.25$		$H_{DC} = 0.5$		$H_{DC} = 1.0$	
	I_2/I_f	I_3/I_f	I_2/I_f	I_3/I_f	I_2/I_f	I_3/I_f	I_2/I_f	I_3/I_f
360	0.012	0.051	0.0135	0.049	0.013	0.044	0.014	0.040
675	0.031	0.063	0.031	0.057	0.033	0.056	0.033	0.046
1125	0.058	0.077	0.063	0.065	0.064	0.063	0.064	0.051
1575	0.081	0.097	0.098	0.074	0.095	0.065	0.093	0.056
2250	0.097	0.123	0.143	0.093	0.147	0.074	0.143	0.064
3600	0.099	0.176	0.175	0.150	0.225	0.114	0.23	0.085
5400	0.073	0.225	0.173	0.200	0.25	0.175	0.325	0.153
7200	0.048	0.255	0.129	0.245	0.23	0.24	0.35	0.21
9000	0.037	0.295	0.096	0.290	0.175	0.28	0.30	0.265

Radiation Energy and Earth Absorption for Dipole Antennae

By A. Sommerfeld and F. Renner

(Concluded from page 414 of the September, 1942, issue)

7. Comparison of the Ideal Dipole with a real Antenna. The Radiation Resistance

IF we neglect the ohmic loss in the antenna wire and possible spark losses, the energy L fed to the antenna is transformed completely into radiation, which in turn consists of the utilisable radiation transmitted to the air space and the radiation energy absorbed within the earth. Accordingly, we write in equations (23) and (29) :—

$$S = L$$

and obtain s_r and s_H, having the meaning indicated in Figs. 4 and 5 * :—

$$L = \tfrac{1}{2}ck_1^4A^2s_r,\ L = \tfrac{1}{2}ck_1^4B^2s_H \qquad (53)$$

These equations show how the "dipole strengths" A and B introduced in (6) and (11) must be chosen to suit a vertical or horizontal antenna of given energy L. In particular A_1 and B_1 may be those dipole strengths which correspond to the energy of 1 kW = 10^{10} Erg./sec. If we chose also $k = \frac{2\pi}{\lambda}$, λ measured in centimetres, we obtain :

$$A_1 = \frac{\lambda^2}{\sqrt{s_r}}\frac{10^5}{(8\pi^4c)^{\frac{1}{2}}},\quad B_1 = \frac{\lambda^2}{\sqrt{s_H}}\frac{10^5}{(8\pi^4c)^{\frac{1}{2}}}. \qquad (53a)$$

With an arbitrary energy expressed in kilowatts we obtain :

$$A = A_1\sqrt{L},\quad B = B_1\sqrt{L} \qquad (53b)$$

With the numerical values of A and B thus obtained, the equations (9) and (10) furnish the field components in ordinary Gaussian units, that is to say H in Oersteds and E in electrostatic units, or, after multiplication by 300, in Volt/cm.

In practice, it is customary to pass from the radiation S to the radiation resistance R by means of the relation

$$S = R\bar{J}^2 = \tfrac{1}{2}RJ_0^2 \qquad (54)$$

J_0 being the current amplitude. In this equation, if R is to be computed in ordinary electromagnetic CGS units, J_0 has to be expressed in the same units. Since we have neglected the ohmic resistance in the antenna we write :

$$L = \tfrac{1}{2}RJ_0^2 \qquad (54a)$$

Although A and B, according to (53a, b), depend only on λ and L and, because o s_r, s_H, also on ζ and $\frac{k_1}{k_2}$, R is dependent, through J_0, on the antenna length l and the current distribution. As current distribution, we need only consider the uniform distribution along the entire length of the linear antenna, that is to say the case of large end capacitances, since any other distribution can be reduced thereto in known manner by a "form factor."

In order to find the relation between the pole strengths A, B and the current amplitude J_0 of (54, 54a), we remember that Hertz in his classical paper[12] of 1888, has called the units corresponding to our A, B "electric moment of the dipole." If we write for this ea, then e is the oscillating charge which Hertz assumed to be a point and a the amplitude of vibration. e is measured electrostatically by Hertz. If we consider an arbitrary section perpendicular to the dipole axis we can define e as that charge which crosses this section in the time $\frac{\tau}{2}$ of half the duration of one vibration.

In our case, a equals half the length of the antenna, that is to say equals $l/2$. If we indicate the antenna current by :—

$$J = J_0 \sin \omega t = J_0 \sin 2\pi\frac{t}{\tau},$$

* Published in the previous instalment.

[12] (The forces of electrical vibrations treated according to Maxwell's theory), *Ges. Werke*, Vol. II, p. 151.

the charge that passes a section in the time $\frac{\tau}{2}$ is :—

$$\int_0^{\frac{\tau}{2}} J dt = J_0 \int_0^{\frac{\tau}{2}} \sin 2\pi \frac{t}{\tau} dt = J_0 \frac{\tau}{\pi} \quad .. \quad (55)$$

However, this current, or its amplitude J_0, should be measured electromagnetically. In order to transfer it into the electrostatic system we have to multiply it by c. Likewise, the e in Hertz's nomenclature is :—

$$e = cJ_0 \frac{\tau}{\pi} = J_0 \frac{\lambda}{\pi}.$$

Thus, Hertz's "electric moment" ea is :—

$$ea = J_0 \frac{\lambda l}{2\pi}.$$

Thus, it is also :—

$$\left.\begin{matrix} A \\ B \end{matrix}\right\} = J_0 \frac{\lambda l}{2\pi} \quad .. \quad .. \quad .. \quad (55a)$$

If we equate the expressions for L from (53) and (54a) and use for A, B the value (55a), $\frac{1}{2}J_0^2$ disappears and, in view of $k_1 = \frac{2\pi}{\lambda}$, we obtain :—

$$R = 4\pi^2 c \frac{l^2}{\lambda^2} \left\{\begin{matrix} s_V \\ s_H \end{matrix}\right. \quad .. \quad .. \quad .. \quad (56)$$

as the value of the radiation resistance in electromagnetic CGS units. Finally, we convert to ohms by multiplication by 10^{-9} and introduce the form factor α referred to above, which has the value 1 for our uniform current distribution (for a sinusoidal distribution $\alpha = \frac{2}{\pi}$). Thus we obtain :—

$$R = 120\,\pi^2 \left(\frac{\alpha l}{\lambda}\right)^2 \left\{\begin{matrix} s_V \\ s_H \end{matrix}\right. \Omega \quad .. \quad .. \quad (56a)$$

For an antenna at a great distance from the earth it follows therefore, that with $s_V = s_H = \frac{2}{3}$ (equation (48a)) :—

$$R = 80\,\pi^2 \left(\frac{\alpha l}{\lambda}\right)^2 \Omega \quad .. \quad .. \quad (56b)$$

The same value was obtained from Hertz's paper by Zenneck[13] for an antenna in free space.

[13] J. Zenneck, *Lehrbuch der drahtlosen Telegraphie*, (Textbook of Wireless Telegraphy), Stuttgart 1916, p. 49.

It is, however, of importance to note that equation (56a) covers more than this particular case, and, by means of the factors s_V, s_H, includes the influence of the direction of the antenna and its distance from the earth as well as the influence of the characteristics of the earth. Particularly, the rapid increase of s_V and s_H at small antenna heights h (see Figs. 4 and 5) influences, as can be seen from (56a), the radiation resistance R. Figures 4 and 5 can be considered as direct illustration of the radiation resistance R if one inserts in ordinate scale the factor $120\,\pi^2\left(\frac{\alpha l}{\lambda}\right)^2$ from equation (56a), which is dependent on the position of the antenna and the characteristics of the earth.

In this connection, it becomes clear that the efficiency of an antenna near the earth is favourably influenced if immediately below the antenna, where the field, and thus the absorption by the earth, would be the strongest, a network of metallic wires is provided, which network decreases the effective value of $\frac{k_1}{|k_2|}$ and thus also of S_{abs}.

In the very numerous textbooks which substantially agree with the Hertz-Zenneck formula (56), no mention is made of this influence of the earth on the radiation resistance and of the position of the antenna relative to the earth. Therefore, we consider the main value of our paper to lie in the clarification of these conditions.

APPENDIX 1

Formulae for the Medium II

In section 1 we have given the potentials and the field intensities derived therefrom only for the medium I (air). We shall now give the corresponding formulae for the medium II :

First, the generalisation of equation (4) for a medium of the wave constant k_2 is :—

$$\left.\begin{aligned} &\Delta\vec{\Pi} + k_2^2\vec{\Pi} = 0 \\ &\underline{E} = k_2^2\vec{\Pi} + \text{grad div}\,\vec{\Pi},\ \underline{H} = -i\frac{k_2^2}{k_1}\text{rot}\,\vec{\Pi} \end{aligned}\right\} \quad (4')$$

For the vertical dipole as we know the vector $\vec{\Pi}$ is reduced to the component Π_z. This component in medium II is :—

$$\frac{\Pi_z}{A} = 2k_1^2 \int_0^\infty J(\lambda r) e^{\mu_2 z - \mu_1 h} \frac{\lambda d\lambda}{N} \quad .. \quad .. \quad (8')$$

This expression is simpler than the corresponding one for the medium I. The reason for this is that in medium II no primary excitation is present, and that one need not distinguish between $z < h$ and $z > h$.

According to (4′)

$$E_r = \frac{\partial^2 \Pi_z}{\partial r \partial z}, \quad H_\phi = \frac{ik_2^2}{k_1}\frac{\partial \Pi_z}{\partial r} \quad \ldots \quad \ldots \quad (5')$$

Now it is easy to verify that the components E_r and H_ϕ obtained from (8) or (8′), according to (5) or (5′) respectively merge into each other continuously for $z = o$.

In the case of the horizontal dipole one needs, as before, two components Π_x and Π_z of the Hertzian vector. These are :—

$$\frac{\Pi_x}{B} = 2\frac{k_1^2}{k_2^2}\int_o^\infty J(\lambda r)e^{\mu_2 z - \mu_1 h}\frac{\lambda d\lambda}{\mu_1 + \mu_2}$$

$$\frac{\Pi_z}{B} = 2\frac{k_1^2}{k_2^2}(k_1^2 - k_2^2)\cos\phi\int_o^\infty J_1(\lambda r)e^{\mu_2 z - \mu_1 h}\frac{\lambda^2 d\lambda}{(\mu_1 + \mu_2)N} \quad \ldots \quad \ldots \quad (13')$$

According to (4′)

$$\left.\begin{aligned} E_r &= \cos\phi\frac{\partial^2 \Pi_x}{\partial r^2} + \frac{\partial^2 \Pi_z}{\partial r \partial z} + k_2^2\cos\phi \Pi_x \\ E_\phi &= -k_2^2\sin\phi\Pi_x - \frac{\sin\phi}{r}\frac{\partial \Pi_x}{\partial r} + \frac{1}{r}\frac{\partial^2 \Pi_z}{\partial\phi\partial z}\end{aligned}\right\} (10')$$

$$\left.\begin{aligned} H_r &= \frac{k_2^2}{ik_1}\left(\frac{1}{r}\frac{\partial \Pi_z}{\partial\phi} + \sin\phi\frac{\partial \Pi_x}{\partial_z}\right) \\ H_\phi &= \frac{k_2^2}{ik_1}\left(\cos\phi\frac{\partial \Pi_x}{\partial z} - \frac{\partial \Pi_z}{\partial r}\right)\end{aligned}\right\}\ldots \quad (10a')$$

Also in this case, one can easily ascertain that the four boundary conditions are complied with for $z = o$. (In E_r and H_ϕ all members comprise the common factor $\cos\phi$, in E_ϕ and H_ϕ the common factor is $\sin\phi$).

APPENDIX 2

A closer approximation for the Vertical Dipole at very great heights

In equation (35a) the lower limit $-\zeta(i + u_0)$ was replaced by $-i\zeta$, and furthermore exp. $(-\zeta u_0)$ by 1 in view of u_0 being small. The first approximation is always admissible, the second obviously only if $|\zeta u_0| \ll 1$. In our numerical example $\frac{k_1}{|k_2|} = \frac{1}{100}$, this is no longer the case for $h > 5\lambda$. We, therefore, shall give here the result for Re $\left\{\frac{iK}{k_1^3}\right\}$, which is obtained if the approximation $|\zeta u_0| \ll 1$ is not made.

Instead of (37), one obtains :—

$$\text{Re}\left\{\frac{iK}{k_1^3}\right\} = \text{Re}\left\{\frac{iL}{k_1^3}\right\} - 2\frac{k_1}{|k_2|}\text{Re}\left\{ie^{-(\zeta u_0 + i\delta)}G\right\},$$

wherein, as before, G is given by (36a).

In the same manner, we will also supplement the computation of Re $\{iK_{k1}^\infty\}$ which we used in equation (44) for determining the absorption by the earth. We have

$$\text{Re}\left\{\frac{iK_{k_1}^\infty}{k_1^3}\right\} = \text{Re}\left\{\frac{iL_{k_1}^\infty}{k_1^3}\right\} - 2\frac{k_1}{|k_2|}$$

$$\text{Re}\left\{ie^{-(\zeta u_0 + i\delta)}\left(G_0^\infty + \int_{-\zeta u_0}^\infty (e^{-y} - 1)\frac{dy}{y}\right)\right\}$$

In this equation L_{k1}^∞ and G_0^∞ have the same meaning as the expressions (32c) and (44b) respectively. The remaining integral can be dealt with by a series development of e^{-y} or, if ζu_0 is great, by reducing it to the logarithm.

Now, one sees immediately that for the vertical dipole $S_{abs.}$ only appears to become logarithmically infinite for $\zeta \to \infty$, equation (46), as we mentioned previously. Since the real part of u_0 is positive, exp.$(-\zeta u_0)$ decreases for $\zeta \to \infty$ to such a degree that log ζ, which occurs in G_0^∞, becomes harmless. Moreover, it may be noticed that this logarithm is compensated by the additional integral in the ( ) of the last equation.

APPENDIX 3

Comparison with Niessen, "Ann. d. Phys.," Series 5, Vol. 22, p. 162, and Vol. 24, p. 31, 1935.

For purely imaginary k_2^2 and $|\zeta u_0| \ll 1$, the correcting member of the first order for the vertical dipole is given by Niessen, if our symbols are used as follows (*loc. cit.* p. 180) :—

$$\left.\begin{aligned}\text{Re}\left\{\frac{iK}{k_1^3}\right\} &= \frac{\sqrt{2}}{\zeta^2}\frac{k_1}{|k_2|}[-1 + (1 - \zeta)\cos\zeta \\ &+ (1 + \zeta)\sin\zeta] - \sqrt{2}\frac{k_1}{|k_2|}\left(Ci(\zeta)\right. \\ &\left.+ Si(\zeta -)\frac{\pi}{2}\right)\end{aligned}\right\} \quad (a)$$

This agrees with our result given in (37) and (33) if we put $\delta = -\frac{\pi}{4}$ (which corresponds to a purely imaginary k_2^2), *except for the member* -1 *in the square brackets which is missing in our equations.* We shall show in the following that this difference is caused by an approximation made by Niessen which is certainly inadmissible for $h < \frac{\lambda}{2\pi}$.

In Niessen's paper p. 174, the following integral appears :—

$$\left.\begin{aligned} U &= \gamma\int_1^\infty \frac{x^3 e^{-2hk_1\sqrt{x^2-1}}}{x^2 - 1 - \gamma\sqrt{x^2 - 1} + \delta}dx, \\ \gamma &= \frac{\sqrt{2}k_1}{|k_2|}, \quad \delta = \frac{k_1^2}{|k_2|^2} \quad \ldots\end{aligned}\right\} \quad (b)$$

if we replace his p by our k_1, and his P by our $|k_2|$. With the substitution $\sqrt{x^2 - 1} = \frac{1}{2}\gamma u$ we obtain :—

$$U = \gamma\int_0^\infty \frac{(1 + \frac{\delta}{2}u^2)e^{\kappa u}}{u^2 - 2u + 2}udu, \quad \kappa = h\gamma k_1 \quad \ldots \quad (c)$$

Now, in this equation Niessen neglects $\frac{\delta u^2}{2}$ compared with 1. That this is not always admissible can be shown by using the numerical example $\delta = 10^{-4}$ illustrated in our Figs. 3 and 4. If we assume $u = 100$, then the term neglected by Niessen equals approximately 1. However, in the proximity of $u = 100$, an essential addition to the integral is obtained for $h < \frac{\lambda}{2\pi}$, because here exp. $(-\kappa u)$ is not at all small. Moreover, we can show directly that this leads to the difference mentioned between Niessen's and our results.

We revert to the formula (b), make the substitution $y = \sqrt{\kappa^2 - 1}$ and split U into two parts :

$$U = \gamma\int_0^\infty e^{-\zeta y} y dy + \gamma\int_0^\infty e^{-\zeta y}\frac{1-\delta+\gamma y}{y^2 - \gamma y + \delta} y dy \quad \ldots \quad \ldots \text{(d)}$$

In the second integral, we effect Niessen's substitution $y = \frac{\gamma}{2}u$ already mentioned, and obtain :—

$$U = \gamma\int_0^\infty e^{-\zeta y} y dy + \gamma\int_0^\infty \frac{e^{-\kappa u} u du}{u^2 - 2u + 2}(1 - \delta + u\delta) \quad \ldots \quad \ldots \text{(e)}$$

If we neglect in the last bracket $-\delta$ and $u\delta$ compared with 1 (according to our assumption, δ is approximately 10^{-4} and therefore $u\delta$ approximately 10^{-2} for $u = 100$), the approximate value obtained from (e) differs by the first integral in (e) from Niessen's approximate value obtained from (e) by neglecting $\frac{\delta}{2}u^2$. This amounts to :—

$$\frac{\gamma}{\zeta^2} = \frac{\sqrt{2}}{\zeta^2}\frac{k_1}{|k_2|}.$$

If one now corrects Niessen's result (a) by this amount, the term in question, viz. -1 in the square brackets of (a), is compensated, and the difference from our result given in (32) and (33) disappears.

The same remarks also hold good for the second paper by Niessen referred to in the heading of this appendix. In that paper the limitation to imaginary $k_2{}^2$ was dispensed with.

We have dealt with this point in detail because it is decisive for the shape of the curves given in our Figs. 4 and 5. According to Niessen, the member $\frac{1}{\zeta^2}$ in our equation (49b) would disappear, and only the logarithmic member would remain. This would mean that the increase of the radiation resistance when approaching the surface of the earth would have no practical influence, and thus the main result of our paper would be lost.

Mr. Niessen himself mentions the difficulties existing when approaching the limit $h \to 0$ (divergent integrals), see *loc. cit. Ann. d. Phys.*, Vol. 22, p. 176.

APPENDIX 4

Intermediate calculation relating to the Absorption by the Earth for the Horizontal Dipole.

We will show how one obtains equations (41) and (41a) from equation (39). If one introduces in (39) the expressions (16), (17) for $f_1 \ldots f_4$ and uses that part which was already calculated in (26) one obtains :—

$$\frac{8\,S_{\text{abs.}}}{ck_1B^2} = \text{VI} + \text{VII} + \text{VIII} + \text{IX} + \frac{4S}{ck_1B^2} \quad \ldots \quad \ldots \text{(a)}$$

wherein VI-IX mean the following abbreviations :—

$$\text{VI} = -4\,\text{Re}\left\{i\int_0^\infty e^{-2h(\mu_1+\mu_1^*)}\left|\frac{\mu_1-\mu_2}{N}\right|^2\mu_1\lambda^5 d\lambda\right\}$$

$$= -4\int_0^{k_1}\left|\frac{\mu_1-\mu_2}{N}\right|^2\sqrt{k_1{}^2-\lambda^2}\,\lambda^5 d\lambda,$$

$$\text{VII} = 4\int_0^{k_1}|\mu_1-\mu_2|^2\,\text{Re}\left\{\frac{1}{(\mu_1+\mu_2)N^*}\right\}\sqrt{k_1{}^2-\lambda^2}\,\lambda^3 d\lambda,$$

$$\text{VIII} = \text{Re}\left\{i\int_0^\infty e^{-2h(\mu_1+\mu_1^*)}\left|\frac{\mu_1-\mu_2}{\mu_1+\mu_2}\right|^2\frac{2k_1{}^2-\lambda^2}{\mu_1}\lambda d\lambda\right\}$$

$$= -\int_0^{k_1}\left|\frac{\mu_1-\mu_2}{\mu_1+\mu_2}\right|^2\frac{2k_1{}^2-\lambda^2}{\sqrt{k_1{}^2-\lambda^2}}\lambda d\lambda,$$

$$\text{IX} = 2\,\text{Re}\left\{i\int_0^\infty e^{-2h\mu_1^*}\frac{\mu_1^*-\mu_2^*}{N^*}\mu_1\lambda^3 d\lambda\right\}$$

$$+\,\text{Re}\left\{i\int_0^\infty e^{-2h\mu_1^*}\frac{\mu_1^*-\mu_2^*}{\mu_1^*+\mu_2^*}\frac{2k_1{}^2-\lambda^2}{\mu_1}\lambda d\lambda\right\}$$

If one first combines VI and VII and uses the expression ϕ_1 from (41), one obtains almost directly :—

$$\text{VI} + \text{VII} = -4\int_0^{k_1}\phi_1(\lambda)\lambda^3 d\lambda \quad \ldots \quad \ldots \text{(b)}$$

Making use of the first expression for $\phi_2(\lambda)$ in equation (41a), VIII can he written as follows :—

$$\text{VIII} = -\int_0^{k_1}\left(\frac{2k_1-\lambda^2}{\sqrt{k_1{}^2-\lambda^2}} + 4\,\phi_2(\lambda)\right)\lambda d\lambda$$

$$= -\frac{4}{3}k_1{}^3 - 4\int_0^{k_1}\phi_2(\lambda)d\lambda \quad \ldots \quad \ldots \text{(c)}$$

Furthermore, it is advisable to subdivide IX into two parts :—

$$\text{IX} = U + V.$$

U and V are those integral sums which one obtains if in the equation defining IX the upper and lower limits respectively are replaced by k_1. The same integral sums appear in the expression for S, equations (26) and (26a), which by similar subdivision and the use of equation (40) can be written

$$\frac{4S}{ck_1B^2} = \frac{4}{3}k_1{}^3 - U + V.$$

Consequently, the last two members of (a) can be combined as follows :—

$$\text{IX} + \frac{4S}{ck_1B^2} = \frac{4}{3}k_1{}^3 + 2V \quad \ldots \quad \ldots \quad \ldots \text{(d)}$$

By adding together (b), (c) and (d), we obtain according to (a) :—

$$\frac{8\, S_{abs.}}{ck_1B^2} = 2V - 4\int_0^{k_1} \phi_1(\lambda)d\lambda - 4\int_0^{k_1} \phi_2(\lambda)d\lambda \qquad (f)$$

This is identical with (41), because we can ascertain that V can be written, according to equation (27a), as follows :—

$$V \equiv \text{Re}\,\{-2i\int_{k_1}^{\infty} e^{-2h\mu_1}F(\lambda)d\lambda\} \quad .. \quad .. \quad (e)$$

To complete the calculation following (41) we have to show how the approximate expression for ϕ_2 appearing in the second equation in (41a) has been derived. For this purpose it is sufficient to approximate $\frac{\mu_1 - \mu_2}{\mu_1 + \mu_2}$ by

$$-1 + \frac{2\mu_1}{\mu_2} = -1 - 2i\frac{\sqrt{k_1^2 - \lambda^2}}{\mu_2}$$

and consequently :

$$\left|\frac{\mu_1 - \mu_2}{\mu_1 + \mu_2}\right|^2 - 1 \text{ by } 2i\sqrt{k_1^2 - \lambda^2}\left(\frac{1}{\mu_2} - \frac{1}{\mu_2^*}\right)$$

$$= \frac{4\sqrt{k_1^2 - \lambda^2}}{|\mu_2|^2}\,\text{Re}\,\{-i\mu_2\}.$$

APPENDIX 5

The utilisable Radiation in the Limiting Case $\zeta \to 0$

We will prove here that, as stated in section 6, S_+ is always strictly finite and remains finite in the limiting case $\zeta \to 0$. We start from the expression for the vertical dipole, equations (20), (20a) :—

$$\frac{4S_+}{ck_1A^2} = \text{Re}\,\{-i\int_0^{\infty} \lambda^3 d\lambda f_1^*(\lambda)f_2(\lambda)\}.$$

For f_1 and f_2 we introduce the values from (9a) (taken with the upper sign), multiply out, and take care of the reality condition. We obtain :—

$$\frac{4S_+}{ck_1A^2} = -\int_0^{k_1}\frac{\lambda^3 d\lambda}{\sqrt{k_1^2 - \lambda^2}} + \int_0^{k_1}\left|\frac{M}{N}\right|^2\frac{\lambda^3 d\lambda}{\sqrt{k_1^2 - \lambda^2}}$$

$$-2\,\text{Re}\left\{\int_0^{k_1} e^{-2h\mu_1}\frac{M}{N}\frac{\lambda^3 d\lambda}{\sqrt{k_1^2 - \lambda^2}}\right\}$$

The first two integrals are independent of h. In the last integral, one can pass to the limit $h \to 0$ because the integration limits are 0 and k_1. Thus, also this integral retains a finite value for $\zeta \to 0$. (The same integral appeared for S_-, but the integration limits were in that case k_1 and ∞, so that in that case one could not pass to the limit $\zeta \to 0$). We shall not give here the corresponding, but somewhat more cumbersome calculation for the horizontal dipole.

APPENDIX 6

(a) The second approximation for the Horizontal Dipole

When calculating the total radiated energy in section 3 we represented the correcting member by $\text{Re}\left\{i\frac{L}{k_1}\right\}$, wherein L was defined by (30) and the expression $F(\lambda)$ appearing therein by (27b). By multiplying the numerator and denominator in (27b) by M, and dispensing with the members of the order $\frac{k_1^3}{k_2^3}$ and $\frac{k_1^4}{k_2^4}$ we obtain :—

$$F(\lambda) = -2\frac{k_1^2}{k_2^2}\mu_2 - \frac{k_1^2}{k_2^2}\frac{2k_1^2 - \lambda^2}{\mu_1}.$$

In section 4 we considered only the first member. Now we shall compute the amount of the second approximation. The integral in question appeared already in section 3, equation (28), but there with the limits 0 and k_1, while here the reality conditions are altered by the factor $\frac{k_1^2}{k_2^2}$ and the limits have to be replaced by 0 and ∞. One can easily confirm that :—

$$\int_0^{\infty}\frac{2k_1^2 - \lambda^2}{\mu_1}e^{-2h\mu_1}\lambda d\lambda = 2\frac{k_1^3}{\zeta^3}e^{i\zeta}(\zeta^2 + i\zeta - 1).$$

Thereupon, a second approximation of the correcting member is :—

$$\frac{2}{\zeta^3}\text{Re}\left\{i\frac{k_1^2}{k_2^2}e^{i\zeta}(\zeta^2 + i\zeta - 1)\right\}$$

$$= \frac{2}{\zeta^3}\frac{k_1^2}{|k_2|^2}[(\zeta^2 - 1)\sin(\zeta - 2\delta) + \zeta\cos(\zeta - 2\delta)].$$

Furthermore, we will give the second approximation for the three members I, II, III, which appeared in equation (41) for the absorption by the earth for the horizontal dipole.

With regard to I. Taking for $F(\lambda)$ the expression of this appendix we obtain for the term of second approximation :—

$$-\frac{k_1^2}{|k_2|^2}\frac{k_1^3}{\zeta}\left(\frac{2}{\zeta^2} - 1\right)\sin 2\delta.$$

With regard to II. One ascertains easily that equations (41c) have to be replaced by the following values, which are more correct by a power of $\frac{k_1}{|k_2|}$:—

$$\text{Re}\frac{-N}{\mu_1 + \mu_2} = \sqrt{k_1^2 - \lambda^2}\,|k_2|\sin\delta - \lambda^2,$$

$$\left|\frac{\mu_1 - \mu_2}{N}\right|^2$$

$$= \frac{1}{|k_2|^2(k_1^2 - \lambda^2)}\left(1 + \frac{2}{|k_2|}\frac{2k_1^2 - \lambda^2}{\sqrt{k_1^2 - \lambda^2}}\sin\delta\right).$$

Thus, one obtains for the term of second order in II :—

$$2\frac{\sin 2\delta}{|k_2|^2}\int_0^{k_1}\frac{2k_1^2 - \lambda^2}{\sqrt{k_1^2 - \lambda^2}}\lambda^3 d\lambda = \frac{8}{5}\frac{k_1^2}{|k_2|^2}k_1^3\sin 2\delta.$$

With regard to III. For ϕ_2, one obtains by completing the calculation given at the end of appendix 4 as additional term of second approximation :—

$$2\frac{2k_1^2 - \lambda^2}{|k_2|^2}\sqrt{k_1^2 - \lambda^2}\sin 2\delta.$$

When integrated, this furnishes the corresponding correction for III :—

$$\frac{16}{15}\frac{k_1^2}{|k_2|^2}k_1^3\sin 2\delta.$$

By comparison with the terms of the first order one sees that those of the second order appearing in II and III can be neglected throughout. The newly added term in I becomes only essential for very small antenna heights, namely, if

$$\frac{k_1}{|k_2|}\frac{1}{\zeta} \simeq 1.$$

In our numerical example one can, therefore, be completely satisfied with the first approximation if $h > \frac{\lambda}{100}$.

(b) Second approximation for the Vertical Dipole

In section 4, for the correcting term $\mathrm{Re}\left\{\frac{iK}{k_1^3}\right\}$ only the term of the order $\frac{k_1}{|k_2|}$ was computed in the expression for the total radiation energy S. We shall now give the term involving $\frac{k_1^2}{|k_2|^2}$. This results from the expression $\frac{k_1}{\sqrt{\lambda^2 - k_2^2}}$ which was neglected in (34c), and which is :—

$$2\,\mathrm{Re}\left\{ i\frac{k_1^2}{k_2^2}\int_{-i}^{\infty} e^{-\zeta u}du \right\} = \frac{2}{\zeta}\frac{k_1^2}{|k_2|^2}\sin(\zeta - 2\delta).$$

From the expression designated by V in section 5 no second order term arises.

By comparison with the corresponding terms of the first approximation one sees that for the vertical dipole the second order terms are of no importance whatever.

Errata

In the first instalment of the article "Radiation Energy and Earth Absorption for Dipole Antennae" in the August issue, the following corrections should be made.

p. 351. Foot of second column, *for* $I - \sigma$ *read* $I - o$.

p. 352. First line, *for* n_1 *read* n', and, *for* σ *read* o.
Second column, line 4, *should read* $\vec{\Pi} = (\Pi_x, o, \Pi_z)$.

p. 353. Second line, *for* σ *read* o.
Equation (9a), *for last* N *read* $\bar{N}$.
Two lines before equation (10), *should read* $\vec{\Pi} = (\Pi_x, \Pi_z)$.
In equation (10a), *for* Π_3 *read* Π_z.

p. 354. Ninth line, *for* σ *read* o.
Equations (14) and (15), *should read*

$$-\frac{Er}{B\cos\phi} = \int_0^\infty J''(\lambda r)f_1(\lambda)\lambda^3 d\lambda - \int_0^\infty J(\lambda r)f_2(\lambda)\lambda d\lambda$$

$$-\frac{E\phi}{B\sin\phi} = -\frac{1}{r}\int_0^\infty J'(\lambda r)f_1(\lambda)\lambda^2 d\lambda - \int_0^\infty J(\lambda r)f_2(\lambda)\lambda d\lambda \quad \ldots \ldots (14)$$

$$\left.\begin{aligned} -\frac{i}{k_1}\frac{H_r}{B\sin\phi} &= \frac{1}{r}\int_0^\infty J(\lambda r)f_3(\lambda)\lambda^2 d\lambda + \int_0^\infty J(\lambda r)f_4(\lambda)\lambda d\lambda \\ -\frac{i}{k_1}\frac{H\phi}{B\cos\phi} &= \int_0^\infty J''(\lambda r)f_3(\lambda)\lambda^3 d\lambda - \int_0^\infty J(\lambda r)f_4(\lambda)\lambda d\lambda \end{aligned}\right\} \quad \ldots (15)$$

p. 354. Second column, line 10, *for* Π *read* π.

p. 355. Second column, line 5, *for* σ *read* α.
Equation (22d) *for* $ik_1\mu$ *read* $ik_1\mu$.
In final paragraph of footnote, *for* σ *read* o, and, *for* Π *read* π.

p. 356. Line 10, *for* Π_1 *read* π.
Equation (24), *for* $S_{\mp}$ *read* $S_{\pm}$.
Fifth line after equation (24) *for* $f_1^*(\lambda)f_4(l)$ *read* $f_1^*(\lambda)f_4(l)$.

p. 357. Second column, line 8, *for* σ *read* o.
Equation (33), *for* k_2 *read* $|k_2|$.
Equation (34), *for* Π *read* π.

p. 358. Equation (36a), *for* Π *read* π.

p. 359. Equation (37), *for* Π *read* π, and, *for* $1/k_1^3$ *read* i/k_1^3.

The Industry's Target

LIKE many other trades and professions the wireless industry has, in co-operation with the Waste Paper Recovery Association organised a waste-paper salvage drive. The target is 5,000 tons by Christmas. The disposal of the paper collected can be made through the usual channels or through the Organising Committee, who in any case ask to be advised of the details of the collections so that figures can be published. The address is the Radio Industry Waste Paper Salvage Appeal, c/o R.M.A., 59, Russell Square, London, W.C.1.

Book Received

Reference Data for Radio Engineers. This compact reference book was originally compiled for the use of radio engineers on the staff of Standard Telephones and Cables, but in response to numerous requests it is now made available to those outside that organisation. The various data has been collected together to meet the requirements of the Company's engineers engaged in the development of radio communications. A very wide field is covered and there are such useful items as curves for propagation calculations, water cooling data, etc., for transmitting engineers; formulae for attenuator design with curves giving hyperbolic functions in terms of power ratio in db., and tables of Bessel functions, the need for which has grown so rapidly with the employment of phase- and frequency-modulation systems, as well as the more usual conversion tables and general formulae. Pp. 60. Published by Standard Telephones and Cables Ltd., Connaught House, Aldwych, London, W.C.2. Price 2/-.

Transformed Networks*

By H. J. Griese

WHEN employing filtering circuits it has been found that it is often advantageous to construct them as networks of the recurrent circuit type. Such networks have the advantage of a simple construction and easy computation. Moreover, the requirements with regard to the loss angle and constancy of coils and condensers are easily complied with. This has already been indicated by H. Epheser and H. Glubrecht.[1] Difficulties may, however, be encountered when one endeavours to construct the filters with as little material and within as little space as possible. For example, for band-pass filters of comparatively small band width and low impedance one needs comparatively large condensers in the shunt circuits, or, if the impedance is high, very large coils in the series circuits. Such large condensers or coils make the filters unnecessarily expensive or decrease the quality of the filters. In

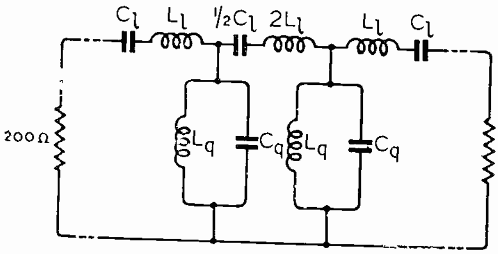

Fig. 1.—*Normal band-pass filter.*

such cases, the so-called transformed networks, in which the tuned circuits are transformed, and which will now be described, provide a remedy.

The problem will be best explained with reference to a practical example. To construct a band-pass filter according to Fig. 1 having a medium frequency of 2,000 c/s, a band width of 200 c/s, and an impedance of 200 ohms, the computation leads to the following values for the inductances and capacitances :

$$C_l = 0.0318\ \mu\text{F} \quad \tfrac{1}{2}C_l = 0.0159\ \mu\text{F}$$
$$C_q = 6.37\ \mu\text{F}$$
$$L_l = 199\ \text{mH} \quad 2L_l = 398\ \text{mH}$$
$$L_q = 1.0\ \text{mH}.$$

Now the value of 6.37 μF, for the capacitance of the condenser C_q in the shunt circuit is extremely large. For a frequency of 2,000 c/s it is possible to employ paper condensers, since the loss angle of such condensers is still small compared with those of the coils, but the necessary constancy is obtained only with condensers subjected to a relatively high test voltage (500-1,500 volts). Such high voltages seldom occur in the filter and, in particular, they do not occur in the shunt circuits. Thus, the large condenser C_q in the shunt circuit is badly utilised, makes the filter expensive and increases its dimensions considerably. If one computes the filter for a higher impedance, this capacitance and all the others are decreased, but all the inductances are correspondingly increased. For example, if the filter is adapted to an impedance of 2,000 ohms, the shunt circuit, for which now $C_q = 0.637\ \mu$F and $L_q = 10$ mH, is easily realised. The series circuit, for which now $2L_l = 3.98$ H and $\frac{1}{2}C_l = 1{,}590\ \mu\mu$F is, however, no longer realisable with simple means. These series circuits can operate properly only if the self-capacitance of the coils is small compared with the capacitance of the condensers. Thus, if the series circuit inductances are increased and the series circuit capacitances are decreased, the filter deteriorates. Therefore, as far as possible the values in the series circuits should not be altered and only the resonant resistance of the shunt circuit should be increased, and should be properly fitted into the filter by transformation. To this end, it is only necessary to provide the coils with a tapping point. The circuit of such a transformed

* Translated by Dr. Walther Wolff from the original article which appeared in *T.F.T.*, Vol. 30, No. 9, p. 263, September 1941.

[1] Die Grundlagen der Siebschaltungstheorien und ihre Anwendungen. (The Principles of Filtering Circuit Theories and their Applications). *ENT*, Vol. 17, p. 167, 1940.

filter is shown in Fig. 2. The inductance L_q in Fig. 2 is identical with that in Fig. 1.

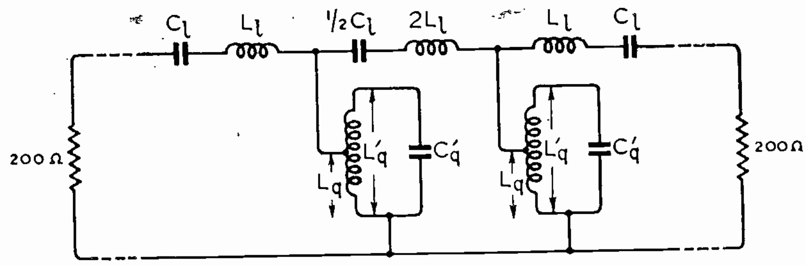

Fig. 2.—*Transformed band-pass filter.*

The capacitance C_q' can be given any suitable value. When a particular value C_q' has been chosen the value for Lq' becomes:

$$L_q' = L_q \cdot \frac{C_q}{C_q'}.$$

In practice, the filter is built up in such a way that the number of turns in L_q' is made slightly too small, the number of turns in a small winding on top of the coil being adjusted to obtain the inductance L_q. Subsequently, the total inductance L_q' of the first winding is ascertained, and the capacitance C_q', which has to be increased slightly in view of the value of L_q' being slightly too small, is increased by adding a small condenser. For example, C_q' and L_q' can be given the following values:—

$C_q' = 0.1$ μF, approx.
$L_q' = 60$ mH. approx.

These are values which are easily manufactured, and which occupy little space.

By this transformation neither the loss angle of the coil nor that of the condenser in the shunt circuit is altered. Thus, it may be expected that the attenuation characteristic of the transformed filter corresponds to that of the original filter, since the qualities of the circuit remain unaltered.

For testing purposes, filters having the values of the above example were made. In order to determine the influence of the coil material on the attenuation characteristic of the filter, each filter was built up with coils of different qualities. Siemens "Dynamo Iron IV" (silicon iron) and "M 89" (nickel iron) were used in the size "Röh tr 1". A coil with pressed "Amenal" core has approximately the same total weight. The attenuation characteristics of the filters are reproduced in Fig. 3.

The filters were made in the transformed manner (Curves 1) and in the normal manner (Curves 2), and, furthermore, in the transformed filter, the condensers C_q' were removed and replaced by the condensers C_q connected to the coils L_q. Thereby, non-transformed filters were formed in order to show the influence of the space factor of the shunt circuit coil on the qualities of the filters (Curves 3). In this manner, it was proved that the small differences between the attenuation in the transmission range of

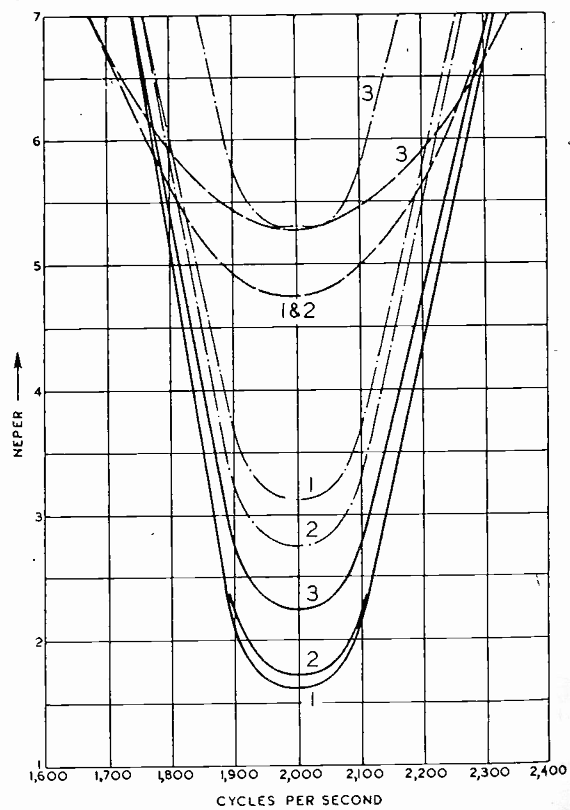

Fig. 3.—*Attenuation characteristic of corresponding transformed and non-transformed filters. Curves 1, Transformed filters (circuit Fig. 2); Curves 2, Normal, non-transformed, filters (circuit Fig. 1); Curves 3, Normal filters with decreased utilisation of the winding space.*

Full line curves. Filter with iron cores of "M 89 green." Thickness of the laminations 0.05 mm. air gap 0.5 mm.

Dash-dash curves. Filter with cores of 0.35 mm. "Dynamo iron"; air gap 0.5 mm.

Dash-dot curves. Filter with iron cores of "Amenal" (Görler).

the transformed and that of the non-transformed filters are due entirely to the small differences in the utilisation of the winding space.

Summary

If the computation of band pass filter networks leads to too large inductance in the shunt circuits, the series circuits and the shunt circuits can be transformed relatively to each other.

As has been explained with reference to the example, it is possible in this manner to transform the inductances and capacitances to values which are easily realised.

Attenuation measurements made on corresponding transformed and non-transformed filters show that the qualities of the filters are not changed by the transformation.

Institution of Electrical Engineers

As announced last month, the first meeting of the Institution, at which Prof. C. L. Fortescue, O.B.E., M.A., will give his presidential address, will be held on October 1st at 5.30.

The inaugural address of Dr. R. L. Smith-Rose, D.Sc., Ph.D., M.I.E.E., D.I.C., A.R.C.S., as chairman of the Wireless Section, will be given on October 7th at 5.30. On November 4th Dr. Smith-Rose and Miss A. C. Stickland, M.Sc., will deliver a paper entitled " A Study of Propagation over the Ultra-Short-Wave Radio Link between Guernsey and England on wavelengths of 5 and 8 metres (37.5 and 60 Mc/s.)."

Cored Solder

In view of the recent steps taken to effect economy in the preparation of tin used in solders a war emergency revision slip, P.D.21, has been issued to the British Standard Specification 441, which specifies that the grade of solders used in cored solders should conform to one of the five grades covered by the War Emergency British Standard No. 219. The scope of the specification has been extended to include multicore solders and to modify the requirements as to the composition of the resin used for filling the core.

Copies of the amendment slip may be obtained from the British Standards Institution, 28, Victoria Street, London, S.W.1, on receipt of a stamped addressed envelope.

Wireless Patents

A Summary of Recently Accepted Specifications

The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each

ACOUSTICS AND AUDIO-FREQUENCY CIRCUITS AND APPARATUS

545 712.—Moving-coil loudspeaker with an outer cone and a central tubular portion associated with the moving coil.

A. C. Woods. Application date 2nd January, 1941.

545 879.—Variable-reactance network, particularly for use in frequency-modulating systems.

Marconi's W.T. Co. (assignees of L. C. Smith). Convention date (U.S.A.) 27th January, 1940.

545 790.—Directional type of microphone comprising groups of pick-up tubes of graded length to give a constant frequency characteristic.

Marconi's W.T. Co. (assignees of F. Massa). Convention date (U.S.A.) 31st January, 1940.

545 826.—Negative feed-back circuit for stabilising the gain of an amplifier subject to temporary overload and similar operating variations.

Standard Telephones and Cables (assignees of F. B. Llewellyn). Convention date (U.S.A.) 22nd March, 1940.

545 827.—Wide-band amplifier in which phase-shift and amplitude variations are minimised whilst maintaining a constant frequency characteristic.

The British Thomson-Houston Co. Convention date (U.S.A.) 5th April, 1940.

DIRECTIONAL WIRELESS

545 880.—Radio-navigational system for aircraft in which a straight-line guiding path is characterised by the absence of signals in the aircraft receiver.

Standard Telephones and Cables (assignees of A. G. Kandoian). Convention date (U.S.A.) 31st January, 1940.

545 778.—Indicating the direction and distance of reflecting bodies by frequency-modulated waves.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date 20th June, 1940.

545 876.—Minimising the undesirable effects of

backward radiation in an aerial system for producing an approach path of the overlapping-beam type.

Standard Telephones and Cables (assignees of A. G. Kandoian). Convention date (U.S.A.) 3rd January, 1940.

546 021.—Aerial arrangement for changing the shape or contour of a guiding path used for blind landing.

Standard Telephones and Cables and H. P. Williams. Application date 20th November, 1940.

RECEIVING CIRCUITS AND APPARATUS

(*See also under Television*)

545 577.—Detecting frequency- or amplitude-modulated signals by utilising the phase-relation between the primary and secondary voltages of a coupling transformer.

Marconi's W.T. Co. (assignees of W. R. Koch). Convention date (U.S.A.) 30th November, 1939.

545 599.—Carrier-wave telegraph receiver with a biased relay to reduce the effect of variations in signal " duration " caused by the line characteristics.

Standard Telephones and Cables (assignees of J. R. Davey). Convention date (U.S.A.) 1st May, 1940.

545 714.—Single-valve arrangement adapted to serve either as a telephonic or telegraphic amplifier as required.

Rediffusion and P. M. Brand. Application date 15th January, 1941.

546 011.—Frequency-modulated receiver in which the pass-band width of one or more stages is automatically varied with the carrier frequency.

Marconi's W.T. Co. (assignees of H. Tunick). Convention date (U.S.A.) 22nd December, 1939.

546 062.—Means for adjusting the band-pass characteristic of an intervalve coupling without affecting the response of a rejector circuit included therein.

Hazeltine Corpn. (assignees of L. R. Malling). Convention date (U.S.A.) 18th April, 1940.

TELEVISION CIRCUITS AND APPARATUS

FOR TRANSMISSION AND RECEPTION

545 591.—Relay or repeater which responds only to predetermined impulses, but not to casual or fortuitous impulses, particularly for synchronising systems in television.

Hazeltine Corporation (assignees of J. C. Wilson). Convention date (U.S.A.) 20th January, 1940.

545 603.—Producing colour effects in television by the use of a rotary drum, which carries different light filters, and surrounds a cathode-ray transmitting or receiving tube.

J. L. Baird. Application date 23rd October, 1940.

545 690.—Transmission line with spaced " feeder " values for use as a frequency converter or as a frequency modulator in television.

*Marconi's W.T. Co. (assignees of F. H. Kroger) Convention date (U.S.A.) 6th December,*1939.

545 756.—Television receiver in which a backstroke eliminating voltage for the cathode-ray tube is derived from the signal-separating stage.

Hazeltine Corporation (assignees of J. C. Wilson). Convention date (U.S.A.) 23rd July, 1940.

545 803.—Circuit for separating the sound and picture signals in a television receiver.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date 12th June, 1940.

TRANSMITTING CIRCUITS AND APPARATUS

(*See also under Television*)

545 586.—Circuit arrangements for improving the characteristics of frequency- or phase-modulated signals both for transmission and reception.

Hazeltine Corporation (assignees of R. L. Freeman). Convention date (U.S.A.) 1st March, 1940.

545 866.—Gain-control circuit for a transmission line which normally depends upon a pilot frequency current to indicate the operating conditions.

Standard Telephones and Cables (assignees of B. J. Kinsburg). Convention date (U.S.A.) 14th September, 1940.

545 881.—Frequency-multiplying arrangement in which straight-line amplifiers are fed in phase-quadrature.

Farnsworth Television and Radio Corporation. Convention date (U.S.A.) 18th January, 1940.

CONSTRUCTION OF ELECTRONIC-DISCHARGE DEVICES

545 689.—Electrode system for collimating, focusing, and modulating the electron stream in a cathode-ray tube, particularly for television.

Electrical Research Products Inc. Convention date (U.S.A.) 2nd December, 1939.

545 835.—Arrangement of the " gun " electrodes in a cathode-ray tube for producing and controlling a concentrated stream of electrons.

Electrical Research Products Inc. Convention dates (U.S.A.) 2nd December, 1939; *and 17th February and 4th April,* 1940.

545 926.—Indirectly-heated cathode made in two layers of specified metals in order to minimise the loss of heat which normally occurs at both ends.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date 9th September, 1941.

545 931.—Blocking-layer rectifying cell of the kind in which one or more control grids are incorporated.

Philips Lamps (communicated by N. V. Philips Gloeilampenfabrieken). Application date 31st October 1941.

546 029.—Valve which can be used to handle either high or low frequencies, as an economy measure, particularly in an aircraft installation.

Standard Telephones and Cables; J. D. Holland and D. D. Robinson. Application date 20th December 1940.

Abstracts and References

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

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

PROPAGATION OF WAVES

2932. The Propagation of Electric Waves through a Metallic Tube and between Two Parallel Metallic Plates.—K. F. Lindman. (*Zeitschr. f. tech. Phys.*, No. 4, Vol. 23, 1942, pp. 95–100.)

Experiments between 1895 and 1902 agreed in showing that the wavelength in the tube—independent of the natural wavelength of the exciter—bore a constant ratio to the tube diameter: but whereas Drude found that it was almost twice the diameter, other workers maintained that the ratio was considerably less than two to one: further, while Becker found that the wavelength of the radiation emerging from the tube was three-quarters of that inside the tube, Drude (without quoting any data) concluded that the two wavelengths were the same. Weber showed theoretically from Maxwell's equations that the repeated reflections from the tube walls caused diagonal electrical oscillations which formed a wave motion progressing along the tube: on the assumption that these waves were propagated in an air-filled tube with the same velocity as in free air, he found that the wavelength λ of this "natural oscillation" of the tube must bear to the diameter d the relation $\lambda = d\pi/1.84 = 1.71d$. The question of the wavelength of the oscillations emerging into the open air he left untouched, nor does it appear to have been treated theoretically elsewhere. The $\lambda = 2d$ relation for tubes, given by Drude, above, was found theoretically by Weber for the case of waves between two metal plates parallel to each other and to the electric vector. The writer is unaware of any experimental work on this point, except Bergmann & Doerfel's experiments (1932 Abstracts, p. 453) on the radiation field of a vertical aerial between two completely conducting horizontal planes. Weber confirmed his theoretical relation $\lambda = 1.71d$ by experiments with interference tubes, like the Quincke tubes of acoustics, and Becker with a similar method found approximate agreement also. Recently many papers on the propagation of waves in hollow metallic cylinders have appeared: Riedinger, in the Vilbig-Zenneck book (*see* 577 of February), has given a survey of these and has also published work of his own—*see* 926 of April: but these researches have for the most part dealt with "other questions, more directly connected with h.f. technique, than those discussed above."

In view of this, and of the fact that the older results were obtained with exciters of doubtfully known wavelength, with more or less unreliable coherer methods of measurement, and with branched tubes: in view also of the fact that it is still not certain whether, contrary to Drude's ideas, the wavelength of the emerging oscillations is different from that inside the tube, the writer has undertaken the experimental work anew, with a new technique, using his often employed rod-shaped vertical Hertzian oscillator of variable natural wavelength (about 14–30 cm), the straight metal tube arrangements of Fig. 1, and an exploring thermojunction and galvanometer combination as detector and measuring instrument. By careful adjustment of the exciter and Tesla-transformer spark-gaps, etc., the exciter was rendered extremely constant throughout each series of measurements, so that the first swing of the galvanometer served as a measure of the intensity of the oscillations. With a tube length of 58 cm and diameter of 13 cm, it was found that the principal component of the radiation emerging into the open air had a wavelength of 17.2 cm. "Objective" measurements inside the tube (with the specially damped exploring circuit which the writer classifies as an "indifferent" measuring instrument, as opposed to his "selective" circuit: *see* p. 97, r-h column) gave a wavelength there of 22.4 cm: this is the wavelength of the "natural oscillation" of the tube, and by Weber's theoretical result, mentioned earlier, it should be 1.71 times the tube diameter; that is, 22.23 cm, very close to the measured value. Becker's statement that the wavelength in open air is three-quarters of that inside the tube would lead to an open-air wavelength of $\frac{3}{4} \times 22.4$, or 16.8 cm, which is also quite near the measured 17.2 cm. This open-air wavelength was independent of the length of the tube and also of the natural wavelength λ_0 of the exciting dipole, provided $\lambda_0/2$ was greater than about $2d/3$: but if, on the other hand, $\lambda_0/2$ was less than $2d/3$, the emerging radiation was predominantly of wavelength λ_0. Even in the first case ($\lambda_0/2 > 2d/3$) a small amount of λ_0 radiation was present among the open-air oscillations, but it practically disappeared when the tube was lengthened to 93 cm.

Similarly, the principal component of the radiation emerging from between two parallel plates 10 cm apart, instead of the tube, was found to have a wavelength three-quarters of that "objectively" measured between the plates, which was 19.2 cm—almost twice the distance between the plates, whereas by Weber's theory it should be exactly twice. This principal component (14.4 cm) had mixed with it a small amount of radiation of the natural wavelength of the exciter, 26 cm.

Both in the case of the tube and of the parallel plates, measurements (with the "selective" resonator) on the intervals between maxima showed that the velocity of propagation was the same as in open air. A full report of the work, including further researches on plates more or less inclined to each other, instead of parallel, will appear in *Acta Acad. Aboensis, Math. & Phys.*

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It was pointed out in a previous paper (964 of April) that the surface wave given by Norton's distribution is not fully identical with the Zenneck surface wave. In the present paper the writer sets himself to derive the Zenneck rotating field from the reflection formula, which is known to give the radiation field of a transmitter at great distances to a first approximation (Schriever, 375 of February). In this reflection formula, as various writers have shown, the resultant distant field is due to the interference of a wave coming down to earth with one reflected from the earth's surface, the reflection coefficient corresponding to the Fresnel coefficient for plane waves. Weyl has shown that the reflection formula is merely the first term of an asymptotic development of the field in powers of $1/R$. But in the immediate proximity of the earth the second term of this development, the "correcting term" of the reflection formula, is of the same order of magnitude as the first, so that it cannot be neglected in calculating the surface wave. It is only by taking this term into account that the characteristic properties of a surface wave are obtained, and a form arrived at which comes much nearer to the Zenneck type of wave than does the interference wave derived from the "uncorrected" reflection equation: the latter wave, in fact, cannot really be described as a surface wave.

The writer therefore calculates in turn (I) the Zenneck field according to the "uncorrected" reflection formula (which is once again seen to be invalid for very small angles of elevation: "it is therefore incorrect to deduce from this interference field, as Schriever [*loc. cit.*] has done, the measuring instrument, as opposed to his "selective" circuit: *see* p. 97, r-h column) gave a wavelength there of 22.4 cm: this is the wavelength of the "natural oscillation" of the tube, and by Weber's theoretical result, mentioned earlier, it should be 1.71 times the tube diameter; that is, 22.23 cm, very close to the measured value. Becker's statement that the wavelength in open air is three-quarters of that inside the tube would lead to an open-air wavelength of $\frac{3}{4} \times 22.4$, or 16.8 cm, which is also quite near the measured 17.2 cm. This open-air wavelength was independent of the length of the tube and also of the natural wavelength λ_o of the exciting dipole, provided $\lambda_o/2$ was greater than about $2d/3$: but if, on the other hand, $\lambda_o/2$ was less than $2d/3$, the emerging radiation was predominantly of wavelength λ_o. Even in the first case ($\lambda_o/2 > 2d/3$) a small amount of λ_o radiation was present among the open-air oscillations, but it practically disappeared when the tube was lengthened to 93 cm.

Similarly, the principal component of the radiation emerging from between two parallel plates 10 cm apart, instead of the tube, was found to have a wavelength three-quarters of that "objectively" measured between the plates, which was 19.2 cm—almost twice the distance between the plates, whereas by Weber's theory it should be exactly twice. This principal component (14.4 cm) had mixed with it a small amount of radiation of the natural wavelength of the exciter, 26 cm.

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The comparison between the three cases is summed up as follows:—the rotating field of the electric vector in all three cases has practically the same parameters at the earth's surface. The height-dependence of the rotating field is the same for the interference field as for the ground wave according to the exact solution (gradual transition from one field to the other), while for the "Zenneck" wave it is altogether absent ["the chief difference between the interference wave given by the reflection formula and the Brewster or Zenneck wave is that for grazing incidence and closeness to the ground—the conditions of particular interest for these investigations—the interference wave disappears, whereas the Zenneck wave reaches its greatest value just in those conditions": *see* end of II]. Further, while the phase velocity of the "exact-solution" ground wave along the earth's surface is equal to that of light (eqn. 39), that of the Zenneck wave is greater than the velocity of light (eqn. 19). Thus the Zenneck wave, which has in common with the "exact-solution" ground wave the character of a surface wave, differs from the "exact-solution" wave to a not unimportant extent. In the previous paper (964 of April) it has been shown how the Zenneck wave must be "modified" to obtain the necessary agreement, so that the advantages and simplifications which the plane Zenneck wave brings to the mathematical treatment of many propagation problems may be fully utilised. It was there shown that the rotating-field parameters, and their dependence on the ground properties, are not affected by this modification of the Zenneck wave.

In section IV the writer points out that for the practical use of the rotating field for measuring the properties of the ground, it is necessary to investigate the limits of validity, as regards height and distance, of the original Zenneck formula 11. The limitation regarding distance has been dealt with theoretically and experimentally in the paper dealt with in 2953, above: at a distance of about 3λ the transition from the rotating field near the transmitter to the Zenneck field is practically complete. The height-dependence of the Zenneck field is now investigated, starting from the Norton formulae but confining the treatment to distances of not less than 3λ, so that the very complicated formulae become greatly simplified. On the assumption that the height y is much less than $r\sqrt{\epsilon'}$, eqn. 47 is obtained: $E_y/E_x = \sqrt{\epsilon'} + (\epsilon'/F) \cdot (y/r)$, where r is the distance and F the Sommerfeld attenuation factor: and it is found that to use the Zenneck formula for the measurement of ground properties the limiting condition is that $k_0 y = 2\pi y/\lambda \ll \sqrt{\epsilon'}$, which is more favourable, by more than one order of magnitude, than that given by Schriever ($4\pi y/\lambda \ll 1$). For small dielectric constants and high frequencies, however, the assumptions leading to eqn. 47 are no longer valid, and this equation is replaced by the more accurate eqn. 54. In Fig. 3 the variation with height of E_y/E_x and of ϕ, calculated according to eqn. 47, are shown in curves for various frequencies (10^6, 10^7, and 10^8 c/s) and two values of σ; ϵ throughout being taken as 9. "An interesting point here is the phase reversal [see broken-line curves] at certain heights, indicating a change in the sense of rotation of the rotating-field ellipse."

Finally, Fig. 4 gives curves of the Sommerfeld attenuation factor F, with the logarithms (base 10) of the absolute value of the complex numerical distance as abscissae and its argument b as parameter (curves are given for $b = 0°$, $30°$, $60°$, and $90°$): the ordinates are the logarithms (base 10) of F. With the help of these curves, and of eqn. 58 ($F = 100\sqrt{\epsilon'} \cdot y/ar$) it is easy to calculate, for arbitrary ground constants and arbitrary heights y, the critical distance which must not be understepped if the rotating field is to correspond to the (simple-formula) Zenneck field to an accuracy within a%. For this purpose the numerical distance w is introduced into eqn. 58 in place of the actual distance r, and the equation is represented in the Fig. 4 family of curves as a straight line whose point of intersection with the appropriate F curve gives the required numerical distance, and hence the required critical distance. In the numerical example given ($\epsilon = 5$, $\sigma = 10^7$), on a 300 m wave with a receiving-dipole height of 3 m a value within 10% can be expected at a distance not less than 700 m, that is, between 2 and 3 wavelengths. For a 30 m wave and $\epsilon = 9$, $\sigma = 10^7$, with a dipole height of 1 m, the same 10% accuracy would be given at or beyond a critical distance of 90 m, 3 wavelengths. For a 2 m height, however, this 10% accuracy cannot be reached at any distance: the straight line of eqn. 58 no longer cuts the F curves.

2955. On the Measurement of Ground Conductivity [Simplified Technique for the "Dipole" Measuring Method].—J. Grosskopf & K. Vogt. (*T.F.T.*, Jan. 1942, Vol. 31, No. 1, pp. 22–23.)

In the method used in the researches described in two previous papers (1833 of 1941 and 964 of April: *see* also *T.F.T.*, Dec. 1941, Vol. 30, No. 12, pp. 352–353, where an outline of the method is given: the advantages claimed over Smith-Rose & Barfield's original method are mentioned) the measurements on the rotating-field ellipse were carried out with a receiving dipole which could be swung in all directions: the voltages induced in the dipole in the a and b directions were taken to a receiver, as indicating instrument, and measured with an auxiliary local transmitter and calibration line. This procedure, which really forms the basis of all field-strength-measuring apparatus, is correct in itself, but requires a fair amount of apparatus in addition to the receiver. It also has two other disadvantages: that due to the limited accuracy of the calibrated h.f. line (particularly at short waves) and its liability to be influenced by matching errors, and that due to the need for coincidence between the signal-generator frequency and that of the distant station. As regards time, too, the previous technique involves two field-strength measurements in succession.

It might be suggested that the signal generator should be dispensed with and the receiver, by the addition of a calibration line, used as a calibrated, tunable thermionic voltmeter. But the insertion of this calibration line between dipole and receiver introduces difficult matching conditions calculated to cause, as a general rule, considerable values of net transmission loss. This disadvantage could no doubt be avoided, for instance by introducing a voltage divider in the i.f. stages of a superheterodyne receiver: but in any case a calibrated receiver involves considerable outlay.

To overcome these difficulties and keep the apparatus as simple as possible, the writers use the dipole itself as a calibrated voltage-divider, and the receiver merely as a sensitive indicating instrument. The receiving characteristic of a dipole rotated, about its horizontal axis, in a plane at right angles to the direction of incidence of a wave, is known to be an exact figure-of-eight diagram. In the first of the papers cited above this diagram has been measured (Figs. 1 and 2). In particular, Fig. 2 shows the complete agreement of the measured values with the expected sinusoidal course at small angles of inclination of the dipole. Thus from the measurement of the amplitude for a given dipole-inclination to the horizontal, the amplitudes at any arbitrary inclination (for instance the amplitude in the vertical position) can be deduced.

The procedure for determining the axes-ratio of the ellipse is then as follows: the dipole is set horizontally and swung to take a bearing of the distant broadcasting station, as described fully in the first paper. It is then turned about its vertical axis through 90° so that it now lies in the plane of incidence: in this plane it is adjusted about its horizontal axis till it lies in the direction of minimum reception (minor axis of ellipse), and the signal indication taken. Then it is returned to its d.f. position (at right angles to direction of incidence) and its inclination to the horizontal is increased until the indicating instrument shows the same deflection as it did in the minimum (minor-axis) direction. If the inclination thus read is $\alpha°$, and the field-strength of the incoming wave is $\mathfrak{E}$, then at its inclination $\alpha°$ the dipole has an induced voltage proportional to $\mathfrak{E} . \sin \alpha$, while at 90° (vertical position) the induced voltage would be $\mathfrak{E}$. The ratio of these voltages (and thus the axes-ratio a/b) is thus $1/\sin \alpha$. Here it is assumed that the inclination γ of the field vector to the vertical (inclination of the minor axis to the horizontal) is not greater than 10°. If it is greater, the ratio must be multiplied by $1/\cos \gamma$ (this correction amounts to 1.5% for $\alpha = 10°$ and 6% for $\alpha = 20°$), so that the general formula is $a/b = (1/\sin \alpha) . (1/\cos \gamma)$.

Measurements on the Berlin 841 kc/s wave and the 191 kc/s wave of the Deutschlandsender, carried out by the old and the new techniques, gave consistent results within the limits of accuracy. The new method requires only the dipole and an indicating amplifier of some type. The angle reading to which the process of measurement reduces can easily be carried out to within 1/20th degree by the use of a vernier, so that the over-all accuracy is similar to that of the older method. It is an obvious thought to apply the new method in the design of field-strength-measuring equipment, whose difficulties generally lie in the voltage-dividing part. "A simple portable equipment for combined d.f., field-strength measurement, and ground-constants determination will be reported on soon": *see* 2956, below.

2956. A New Conductivity Meter.—J. Grosskopf, W. Pützer, & K. Vogt. (*T.F.T.*, April 1942, Vol. 31, No. 4, pp. 112–114.)

This is the equipment spoken of at the end of 2955, above. The "indicating amplifier" mentioned in that abstract takes the form of a miniature receiver with an indicating instrument giving a full-scale deflection (25 μA current) for a voltage at the receiver input of about 20 μV on broadcast and long waves: the sensitivity on short waves is about 20 times lower. The four-valve receiver is mounted on the horizontal axis of the rotatable dipole, so that no connecting cables are necessary. It consists of a tuned r.f. stage, an audion with retroaction, a transformer-coupled a.f. stage, and a resistance-coupled output stage. There is no band-switching for the r.f. portion, the r.f. transformer taking the form of plug-in coils for the bands 20–40 m and 200–2000 m. The grid leads of the tuning condensers are not connected directly to their respective grids: it is possible to add, if desired, parallel and series condensers to the tuning condensers so as to obtain band-spreading, particularly for the short waves. The sensitivity of the receiver is adjustable from zero to its full value by regulating the space-charge-grid bias of the r.f. valve: the leaky-grid detector is back-coupled by way of the space-charge grid (negadyne connection: it was found that for short waves this was the only connection to give a reliable back-coupling). With headphones in parallel to the indicating instrument, a full-scale deflection requires an output from the amplifier of about 10 μW: at this small power no negative grid bias is necessary.

To obtain low weight, small size, and low current consumption, all the valves are of the battery-driven type DAH50, of which the heptode systems are used while the additional diode systems are left idle. Thanks to the space-charge grid between cathode and control-grid, the anode voltage can fall to about 12 v without too much loss of power. The whole receiver with its dry cells weighs $2\frac{1}{2}$ kg and measures $6 \times 13 \times 33$ cm³. While for the sake of simplicity tuning and retroaction adjustments are included in the receiver itself, the volume control, battery-voltage testing arrangements, and the indicating instrument are mounted (together with the output transformer) at the bottom of the vertical shaft. As could be expected from the amplifier data given above, practical tests show that, for ground of medium conductivity, measure-properties of the ground wave"): (II) the Zenneck field for inhomogeneous waves, where all the constants α, β, γ of eqn. 12 are complex, giving "a new type of wave, the inhomogeneous or surface wave," which under certain conditions is identical with the original Zenneck surface wave: the apparent contradiction found by Schriever [*loc. cit.*] for an inclination of 45° is explained: and (III) the Zenneck field according to the exact solution of the wave equation, spoken of above ("corrected" reflection formula): the treatment is for a dipole at ground level, but with the help of the transformation formulae given by Niessen (1934 Abstracts, pp. 259–260) it can easily be shown that the results apply also to suspended dipoles.

The comparison between the three cases is summed up as follows:—the rotating field of the electric vector in all three cases has practically the same parameters at the earth's surface. The height-dependence of the rotating field is the same for the interference field as for the ground wave according to the exact solution (gradual transition from one field to the other), while for the "Zenneck" wave it is altogether absent ["the chief difference between the interference wave given by the reflection formula and the Brewster or Zenneck wave is that for grazing incidence and closeness to the ground—the conditions of particular interest for these investigations—the interference wave disappears, whereas the Zenneck wave reaches its greatest value just in those conditions": *see* end of II]. Further, while the phase velocity of the "exact-solution" ground wave along the earth's surface is equal to that of light (eqn. 39), that of the Zenneck wave is greater than the velocity of light (eqn. 19). Thus the Zenneck wave, which has in common with the "exact-solution" ground wave the character of a surface wave, differs from the "exact-solution" wave to a not unimportant extent. In the previous paper (964 of April) it has been shown how the Zenneck wave must be "modified" to obtain the necessary agreement, so that the advantages and simplifications which the plane Zenneck wave brings to the mathematical treatment of many propagation problems may be fully utilised. It was there shown that the rotating-field parameters, and their dependence on the ground properties, are not affected by this modification of the Zenneck wave.

In section IV the writer points out that for the practical use of the rotating field for measuring the properties of the ground, it is necessary to investigate the limits of validity, as regards height and distance, of the original Zenneck formula 11. The limitation regarding distance has been dealt with theoretically and experimentally in the paper dealt with in 2953, above: at a distance of about 3λ the transition from the rotating field near the transmitter to the Zenneck field is practically complete. The height-dependence of the Zenneck field is now investigated, starting from the Norton formulae but confining the treatment to distances of not less than 3λ, so that the very complicated formulae become greatly simplified. On the assumption that the height y is much less than $r\sqrt{\epsilon'}$, eqn. 47 is obtained: $E_y/E_x = \sqrt{\epsilon'} + (\epsilon'/F) \cdot (y/r)$, where r is the distance and F the Sommerfeld attenuation factor: and it is found that to use the Zenneck formula for the measurement of ground properties the limiting condition is that $k_0 y = 2\pi y/\lambda \ll \sqrt{\epsilon'}$, which is more favourable, by more than one order of magnitude, than that given by Schriever ($4\pi y/\lambda \ll 1$). For small dielectric constants and high frequencies, however, the assumptions leading to eqn. 47 are no longer valid, and this equation is replaced by the more accurate eqn. 54. In Fig. 3 the variation with height of E_y/E_x and of ϕ, calculated according to eqn. 47, are shown in curves for various frequencies (10^6, 10^7, and 10^8 c/s) and two values of σ; ϵ throughout being taken as 9. "An interesting point here is the phase reversal [see broken-line curves] at certain heights, indicating a change in the sense of rotation of the rotating-field ellipse."

Finally, Fig. 4 gives curves of the Sommerfeld attenuation factor F, with the logarithms (base 10) of the absolute value of the complex numerical distance as abscissae and its argument b as parameter (curves are given for $b = 0°$, 30°, 60°, and 90°): the ordinates are the logarithms (base 10) of F. With the help of these curves, and of eqn. 58 ($F = 100\sqrt{\epsilon'} \cdot y/ar$) it is easy to calculate, for arbitrary ground constants and arbitrary heights y, the critical distance which must not be understepped if the rotating field is to correspond to the (simple-formula) Zenneck field to an accuracy within a%. For this purpose the numerical distance w is introduced into eqn. 58 in place of the actual distance r, and the equation is represented in the Fig. 4 family of curves as a straight line whose point of intersection with the appropriate F curve gives the required numerical distance, and hence the required critical distance. In the numerical example given ($\epsilon = 5$, $\sigma = 10^7$), on a 300 m wave with a receiving-dipole height of 3 m a value within 10% can be expected at a distance not less than 700 m, that is, between 2 and 3 wavelengths. For a 30 m wave and $\epsilon = 9$, $\sigma = 10^7$, with a dipole height of 1 m, the same 10% accuracy would be given at or beyond a critical distance of 90 m, 3 wavelengths. For a 2 m height, however, this 10% accuracy cannot be reached at any distance: the straight line of eqn. 58 no longer cuts the F curves.

2955. On the Measurement of Ground Conductivity [Simplified Technique for the "Dipole" Measuring Method].—J. Grosskopf & K. Vogt. (*T.F.T.*, Jan. 1942, Vol. 31, No. 1, pp. 22–23.)

In the method used in the researches described in two previous papers (1833 of 1941 and 964 of April: *see* also *T.F.T.*, Dec. 1941, Vol. 30, No. 12, pp. 352–353, where an outline of the method is given: the advantages claimed over Smith-Rose & Barfield's original method are mentioned) the measurements on the rotating-field ellipse were carried out with a receiving dipole which could be swung in all directions: the voltages induced in the dipole in the a and b directions were taken to a receiver, as indicating instrument, and measured with an auxiliary local transmitter and calibration line. This procedure, which really forms the basis of all field-strength-measuring apparatus, is correct in itself, but requires a fair amount of apparatus in addition to the receiver. It also has two other disadvantages: that due to the limited accuracy of the calibrated h.f. line (particularly at short waves) and its liability to be influenced by matching errors, and that due to the need for coincidence between the signal-generator frequency and that of the distant station. As regards time, too, the previous technique involves two field-strength measurements in succession.

It might be suggested that the signal generator should be dispensed with and the receiver, by the addition of a calibration line, used as a calibrated, tunable thermionic voltmeter. But the insertion of this calibration line between dipole and receiver introduces difficult matching conditions calculated to cause, as a general rule, considerable values of net transmission loss. This disadvantage could no doubt be avoided, for instance by introducing a voltage divider in the i.f. stages of a superheterodyne receiver: but in any case a calibrated receiver involves considerable outlay.

To overcome these difficulties and keep the apparatus as simple as possible, the writers use the dipole itself as a calibrated voltage-divider, and the receiver merely as a sensitive indicating instrument. The receiving characteristic of a dipole rotated, about its horizontal axis, in a plane at right angles to the direction of incidence of a wave, is known to be an exact figure-of-eight diagram. In the first of the papers cited above this diagram has been measured (Figs. 1 and 2). In particular, Fig. 2 shows the complete agreement of the measured values with the expected sinusoidal course at small angles of inclination of the dipole. Thus from the measurement of the amplitude for a given dipole-inclination to the horizontal, the amplitudes at any arbitrary inclination (for instance the amplitude in the vertical position) can be deduced.

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To obtain low weight, small size, and low current consumption, all the valves are of the battery-driven type DAH50, of which the heptode systems are used while the additional diode systems are left idle. Thanks to the space-charge grid between cathode and control-grid, the anode voltage can fall to about 12 v without too much loss of power. The whole receiver with its dry cells weighs 2½ kg and measures $6 \times 13 \times 33$ cm³. While for the sake of simplicity tuning and retroaction adjustments are included in the receiver itself, the volume control, battery-voltage testing arrangements, and the indicating instrument are mounted (together with the output transformer) at the bottom of the vertical shaft. As could be expected from the amplifier data given above, practical tests show that, for ground of medium conductivity, measurements can be made at field strengths of the order of 1 mv/m in the medium-wave band and of 20 mv/m for short waves.

2957. ON THE DISTRIBUTION OF ELECTRICITY ON THIN OPEN CONDUCTING SURFACES.—G. A. Grinberg [Grünberg]. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 5, Vol. 11, 1941, pp. 536–543.)

For previous work *see* 378 of February. A theoretical method is proposed for determining the distribution of electric charges on the surface of a thin open conductor (Fig. 1) when this is placed in an electric field. The method is also applied to the cases of (a) thin plates of any configuration (Fig. 3) and (b) portions of thin spherical layers also of any configuration (Fig. 8).

2958. THE LIGHT SCATTERING AND KERR CONSTANTS OF SPHERICALLY SYMMETRICAL MOLECULES [by Quantum Mechanics].—Th. Neugebauer. (*Zeitschr. f. Phys.*, 31st March 1942, Vol. 119, No. 1/2, pp. 114–135.)

For asymmetrical molecules the difference between the classical and the quantum-mechanical results are too small to be worth considering. In the case of spherical symmetry, however, where classical theory gives a disappearance of depolarisation and Kerr constant, the additional terms in the quantum-mechanical equations are solely responsible for the observed, though small, effects: hence the importance of the present work.

2959. LIGHT DIFFRACTION AT BLACK SCREENS [Kirchhoff's Integral Law replaced by "a More Illuminating and Productive Law, which also allows the Polarisation State of the Diffracted Light to be determined"].—K. F. Novobatzky. (*Zeitschr. f. Phys.*, 31st March 1942, Vol. 119, No. 1/2, pp. 102–113.)

2960. ULTRA-FAST OSCILLOGRAPH FOR LIGHTING-ARRESTER RESEARCH, *and* APPARATUS FOR THE DEMONSTRATION OF SURGES ALONG LINES.—Wade: Goubau. (*See* 2964 & 3073.)

2961. DAMPING OF WAVES BY SURFACE-ACTIVE SUBSTANCES: II.—V. Levich. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 2/3, Vol. 11, 1941, pp. 340–345.) For I *see* 2362 of 1941.

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY

2962. THE LIGHTNING PROTECTION OF BUILDINGS [with Particular Reference to Those containing Explosive or Inflammable Material].—E. H. W. Banner. (*Engineer*, 17th & 24th July 1942, Vol. 174, pp. 48–51 & 66–67.)

2963. LINE PROTECTOR FOR TELEPHONE INSTALLATIONS [New Design of Inert-Gas Lightning & Surge Protector, with Advantages of Small Size, Cheapness, All-Metal Construction (stands up to Larger Powers than Glass Types), Freedom from Polarity, Efficiency].—G. Maerkisch. (*E.T.Z.*, 4th June 1942, Vol. 63, No. 21/22, pp. 257–259.)

2964. ULTRA-FAST CATHODE-RAY OSCILLOGRAPH FOR LIGHTNING-ARRESTER RESEARCH [Recording Speed of 18 000 Miles/Second].—E. J. Wade & others. (*Sci. News Letter*, 4th July 1942, Vol. 42, No. 1, p. 3.) From the General Electric Company.

2965. LIGHTNING CONDUCTOR EARTHS ON GAS AND WATER PIPES [Desirable for Effective Protection of Building: Precautions Necessary: Measurements: etc.].—V. Fritsch. (*Gas- und Wasserfach* [Munich], 4th July 1942, Vol. 85, No. 27/28, pp. 303–309.) The necessity for the h.f. testing of lightning earths (41, 158, & 2367 of 1941) is again stressed.

2966. MEASUREMENTS ON LIGHTNING-CONDUCTOR EARTHS: I.—V. Fritsch. (*Arch. f. Tech. Messen*, April 1942, Part 130, V 35192-5, Sheets T34-35.) For previous work *see*, for example, 41 & 42 of 1941.

2967. THE ENERGY EQUATION FOR A VISCOUS COMPRESSIBLE FLUID [involved in Calculation of Atmospheric Motions: Recent Treatments are Incorrect through Neglect of Terms involving Viscous Stresses].—H. J. Stewart. (*Proc. Nat. Acad. Sci.*, May 1942, Vol. 28, No. 5, pp. 161–164.)

PROPERTIES OF CIRCUITS

2968. CONCENTRIC-TUBE "TIE-LINE" COMBINATIONS AS IMPEDANCE-TRANSFORMING SECTIONS FOR MATCHING PURPOSES AT ULTRA-HIGH FREQUENCIES.—Meinke. (In paper dealt with in 3048, below.)

2969. A SPECIAL TYPE OF CONCENTRIC LINE AS ULTRA-SHORT-WAVE RESONATOR [Two Short Concentric Cylindrical Rings, Open at Both Ends, & connected at One Point either Galvanically or Capacitively (*e.g.* by a Radial Fin from Inner Cylinder, along Its Whole Length, to Outer Cylinder)].—H. Steyskal. (*Zeitschr. f. tech. Phys.*, No. 4, Vol. 23, 1942, pp. 103–107.)

Calculation of the behaviour of a type of resonator suggested by K. Meyer and successfully used as an oscillatory circuit for transmission and reception. The analysis given forms an extension of Borgnis's treatment of the oscillation modes of concentric lines (3874 of 1939 and 50 of 1941.) In the course of the investigation the writer found that a similar design of resonant circuit had been worked out by Kalähne (*Ann. der Physik*, Vol. 18, 1905, p. 92) but the present results are extended at some points and are presented in a more convenient form. The mathematical expression for the field components and the exact equation for the calculation of the natural frequencies are derived. Comparison with Borgnis's results shows that the introduction of the reflecting plane provided by the short-circuiting radial fin has the effect of doubling the limiting wavelength, which without the reflecting plane was about equal to πd and is now about $2\pi d$: this result is easy to understand when it is remembered that in all H-type oscillations not only radial waves but also waves along the perimeter play a rôle in building up the oscillation mode. It is concluded that as regards the fundamental ($H_{m,n=1}$ type) oscillation the system with radial reflecting plane acts as a Lecher system, short-circuited at both ends, of length $l = (r_1 + r_2)\pi$, so that a satisfactory approximate formula for such waves is given by $\lambda = (r_1 + r_2)\pi/m$, where $m = \frac{1}{2}$, 1, 3/2, etc. The possible use of more than one radial fin is mentioned but not discussed.

2970. A New Type of Electrical Analogy: Part I.—A. M. Efros. (*Journ. of Tech. Phys.* [in Russian], No. 14, Vol. 10, 1940, pp. 1189–1196.)

In this part of the paper general considerations are presented regarding the derivation of a two-terminal electrical circuit equivalent to a given mechanical or electro-mechanical system. An electrical circuit is called equivalent if the current through the terminals varies in the same manner as the velocity of the point of application of the disturbing force (driving point) to the system under consideration. In other words, the impedance of the equivalent circuit must be equal to the driving-point impedance of the system, multiplied by a constant conversion factor. Formula (3) is derived for determining the driving-point impedance, neglecting the initial conditions of the system, and a corresponding formula (4) in which these conditions are taken into account. The determination of the conversion factor is discussed, and methods are indicated for deriving the simplest circuits consisting of R, L, and C elements and corresponding to the given impedance conditions.

2971. Theory of the Voltage Transformer: the Möllinger-Gewecke Diagram.—H. Woelken. (*Arch. f. Tech. Messen*, June 1942, Part 132, Z 31-1, Sheet T61.)

2972. Remark on the Mutual Inductance of Coaxial Circular Rings.—W. Rogowski. (*Arch. f. Elektrot.*, 31st Dec. 1941, Vol. 35, No. 12, pp. 752–755.)

This calculation is generally carried out with the help of elliptic integrals (eqns. 4–8). For many practical purposes this method is undesirable, and it gives no clear picture of the dependence of the mutual inductance on diameters and spacings. A new approximate formula (eqn. 18) was therefore developed, primarily for use in some special work to be reported later.

2973. The Vibrating Quartz in Communications Technique: Part I—The Mechanical and Electrical Properties of the Vibrating Quartz [Survey].—H. von Beckerath. (*E.N.T.*, March/April 1942, Vol. 19, No. 3/4, pp. 45–62.)

In spite of the thorough treatment of the subject in text-books and specialised journals, it is not easy for the communications engineer to obtain a definite and clear picture of the points which are important to him. The present work is intended to give, in the clearest possible form, a comprehensive survey of the most important developments and their technical significance. The physical bases are only considered to the extent necessary for the understanding of the technical results. Practical points are thus given greater prominence, and calculations are carried through to numerical results. The later sections deal with the quartz oscillator as a transducer, the question of permissible loading and amplitude of vibration, temperature coefficients, practical design of holders, etc., and finally the frequency-constancy attainable. Literature references go up to 1942.

2974. Connection for the Neutralisation of the Parallel Capacitance of an Oscillating Crystal connected in Series between Two Oscillatory Circuits.—W. Herzog. (*Hochf:tech. u. Elek:akus.*, Feb. 1942, Vol. 59, No. 2, p. 63.) Telefunken Patent, No. 708 073. A differential condenser is used.

2975. Applications of Junction Line Filters, *and* The Junction Line Filter [for Carrier Systems].—F. A. Hinshaw: J. O. Israel. (*Bell Lab. Record*, May 1942, Vol. 20, No. 9, pp. 214–217: pp. 218–221.)

2976. Negative Resistances: II—Theory of the Negative Resistance [Resistance with Spatially Constant Temperature: with Spatially Varying Temperature (Frontal & Radial Cooling): Stability Considerations (including Application of Formula to Uranium-Dioxide Cylinder)]—W. Amrein. (*Schweizer Arch. f. angew. Wiss. u. Tech.*, April 1942, Vol. 8, No. 4, pp. 109–122.) For first and final parts *see* March & May issues, Nos. 3 & 5.

2977. Comments on T. E. W. Schumann's Paper, "An Investigation concerning G. I. Taylor's Correlation Coefficient of Turbulence" [Rejection of S.'s Implication that after Periodic Terms have been Eliminated, Natural Phenomena are Markoffian: Thermal Agitation as Example: Value of T.'s Work].—C. L. Pekeris. (*Phil. Mag.*, July 1942, Vol. 33, No. 222, pp. 541–543.)

2978. The Reduction of the Spontaneous Fluctuations in the Amplification of Very Small Photocurrents.—Strutt & van der Ziel. (*See* 3041.)

2979. Radio-Frequency Instability: Data on the Effect of Stray Wiring Capacities [with Formula & Curves for Capacitance between Two Parallel Rods, & Application to Formula for Max. Amplification without Instability].—S. W. Amos. (*Wireless World*, July 1942, Vol. 48, No. 7, p. 157.)

2980. Cathode Follower Again: Simple Calculations of Output Impedance and Voltage Gain.—E. A. Hanney. (*Wireless World*, July 1942, Vol. 48, No. 7, p. 164.) Following on Williams's paper (2379 of 1941): *see* also 2442 of August and back references.

2981. Diminution of Variations of Amplification by Negative Feedback, referred to the Same Amplification Factor.—J. Peters. (*Hochf:tech. u. Elek:akus.*, Feb. 1942, Vol. 59, No. 2, pp. 46–50.)

By the use of negative feedback all kinds of electrical faults of amplifiers can be improved by a factor which depends on the strength of the feedback coupling. But since, simultaneously, the amplification factor decreases by the same factor, it has hitherto been impossible to judge the improvement of the properties, as referred to the same amplification factor. And since part of the deficiency to be corrected depends, among other things, on the amplification factor itself, no clear idea could be formed as to the success attained by the negative feedback: it might even be doubted whether any improvement at all had occurred. For such a comparison it is really necessary either to base one's deductions in each individual case on the same amplification factor, or else in a more general way to calculate the error or deficiency as a function of the amplification factor, for amplifiers without negative feedback as well as for those with it, and to take the ratio of these two values as a measure of the achieved improvement.

In the present paper "the solution of this problem is obtained with respect to one of the various electrical faults, the variations of the amplification factor caused by departures of the valve data from their nominal values. There is no need to define these discrepancies; it is sufficient, for a comparison, to assume a constant original error whose absolute value is of no importance, since ultimately it will be eliminated. A distinction must be made between those discrepancies which are of an individual type and in different valves appear independently of each other, and those which depend on a common external cause, such as alteration of amplification factor by changes in the common supply voltage. In the latter case the amplification factors of the individual stages naturally change simultaneously by the same amount if they were originally equal."

The over-all amplification factor V of n stages in series, with amplification factors $v_1, v_2 \ldots v_n$, is given by $V = v_1 . v_2 \ldots v_n$. By logarithmic differentiation the equation for variation is obtained as $dV/V = dv_1/v_1 + dv_2/v_2 + \ldots dv_n/v_n$; that is to say, the departures of the amplification factors of the individaul stages, referred to their own amplification, add together to give the resultant over-all variation referred to its original amplification. It is only this "relative" variation that is a serviceable measure for the error of the amplifier: for even if attenuating or amplifying quadripoles are interposed between the defective amplifier and the test point, the error so expressed will remain. No assumptions are made as to the internal construction of the stages: it must be postulated only that no attenuating quadripoles are contained in or between the separate stages: these would leave the "relative" variation at the end point untouched, but would alter the amplification over the whole path.

Applied to an amplifier without negative feedback, of n similar stages, the above equation gives $dV/V = n . dv/v$ and $\log V = n \log v$. The numerical factor in both expressions is equal to the number of stages. The same units can be applied to the variations and amplification of a negative-feedback amplifier: if the numerical factor for the variations referred to the amplification is represented by $a = dV/V : dv/v$, and that for the amplification by $b = \log V : \log v$, then the ratio of the two numerical factors, b/a, is defined as the "factor of merit" G. Since with an amplifier without negative feedback the amplification is always accompanied by a corresponding amplification-variation, so that $a = b = n$, with such an amplifier G is always unity. Thus when, in a negative-feedback amplifier, a higher value than 1 is found for G, it represents the factor by which the variations of this amplifier are reduced, in otherwise similar conditions, with respect to those of an equivalent amplifier with its amplification at its fullest (*i.e.*, with zero negative feedback). *Thus G represents the minimum attainable "improvement."* The higher the amplification before the introduction of negative feedback, the greater the attainable improvement. The latter depends also on the amplification which remains when the negative feedback has been applied. With the decrease of this amplification the attainable improvement increases until an amplification factor is reached equal to the basis of natural logarithms (= 1 neper): *see* eqn. 24 and subsequent text. Consequently, in the variation of the amplification V' of a negative-feedback amplifier group (eqn. 11), that is, in the corresponding variation of the negative feedback, there exists a maximum value for G when $V' = e$, independent of the value of the original amplification μ. This fixes the value of the attainable maximum. "Theoretically, the original amplification could be increased at will by a corresponding increase in the number of stages, but in practice a limit is set by the increasing difficulties in avoiding oscillation. Owing to the existence of this maximum number of stages for the circuit within the negative-feedback path, it is impossible to construct amplifiers with strong negative feedback to give amplifications still higher. It follows strictly that subdivision into several negative-feedback amplifiers would bring a further increase in the improvement. For all those faults which add throughout the whole connection, as the variations in question do (for example, small variations of transmission equivalent as a function of frequency) an optimum is reached at one neper's amplification for each component amplifier. This forms the ultimate limit."

Finally, the above considerations lead in section V to the derivation of a basis for comparison between various valves and valve-circuits. Thus for an amplifier without negative feedback those valves or circuits are of equal merit in which a given external action produces the same change $d \log v/\log v$, where v is the amplification factor of the valve in the given circuit. Eqns. 29 & 30 give the relations for comparison when negative feedback is used.

2982. A Push-Pull Circuit for D.C. Voltage Amplification [and for Frequencies up to 20 c/s].—F. Kerkhof. (*Zeitschr. f. Phys.*, 31st March 1942, Vol. 119, No. 1/2, pp. 43–48.)

To avoid the disadvantages of the usual resistance-coupled amplifier (high supply voltage, etc.) it was decided to convert the d.c. or l.f. a.c. voltage into an easily amplifiable a.c. voltage (actually 310 c/s) by a push-pull mixing stage consisting of two hexode systems in push-pull with a symmetrically connected oscillator. Two multiple valves, type CCH 1, were employed: the hexode systems of these formed the push-pull arrangement, while their triode systems were combined to form the 310 c/s oscillator. A type T 113 electrometer valve acted as input stage: its anode was connected to the control grid *A* of one hexode system, its space-charge grid to the control grid *B* of the other. The push-pull transformer was tuned to resonance with the 310 c/s frequency by a variable condenser, which thus served as an amplification adjustment. The output stage was a pentode leading to a resonance transformer with its output tuned to resonance by an auxiliary capacitance: this transformer was of a special design (not specified), since with an ordinary l.f. design, in spite of the tuning, large uncompensatable harmonics of the oscillator frequency would emerge, caused by the inequality of the two CCH 1 characteristics (in spite of special selection) and the high amplification in the push-pull and following stages (over 2×10^4). As it was, the filtering action of the special transformer reduced the 1st harmonic to 1% of the fundamental.

2983. A Design Form for New Technical Amplifiers [for Panel Mounting].—Schlechtweg. (*See* 3022.)

2984. A Frequency-Dividing Process using a Cathode-Ray Tube.—Brückersteinkuhl. (*See* 3037.)

TRANSMISSION

2985. A New Method for the Excitation of Rarefied Gases by Ultra-Short Electromagnetic Waves [Electrodeless Discharge at 154 Mc/s excited by 10 μs Pulses, 400 per Second (from Mesny Oscillator), yielding Peak Voltages of 12 kV, Peak Powers of order of 10 kW].—G. Goudet, P. Herreng, & G. Nief. (*Génie Civil*, 31st Jan./7th Feb. 1942, Vol. 119, No. 5/6, p. 65: summary of *Comptes Rendus* note.)

2986. Transversely-Controlled Valves with Longitudinal Work Fields.—H. E. Hollmann. (*Hochf:tech. u. Elek:akus.*, Feb. 1942, Vol. 59, No. 2, pp. 33–38.)

"Following on the exhaustive treatment of induction-current excitation by the passage of a transversely-controlled electron beam through a 'work' condenser, and of the transit-time compression occurring in such a transversely-modulated beam [*see* long abstract, 1859 of 1941], the present paper investigates the induction-current excitation in one or several longitudinal fields or double-layers traversed by a transversely-modulated beam. It is true that the problem is closely related to the 'transverse energy take-up' there discussed, in so far that in that case the energy exchange did not occur in the actual cross field itself but in the leakage fields which shut this off on both sides from the outer space, and which acted longitudinally. Nevertheless it is possible, by a particular construction of the 'work' system, to make a new type of transverse-modulation valve, whose working surpasses that of the 'transverse take-up' valve."

The writer then goes on to consider the simplest type of "energy take-up" from a transversely modulated beam: this, on the klystron analogy, consists in sending the beam through a double-layer field generated by the alternating voltage of the load circuit *S* (Fig. 1) between the two ideally transparent grids *G* and *G′*, perpendicular to the beam-system axis. Under the best conditions (fully modulated beam, the compression factor being then $P = 1.84$: load-circuit modulation at its maximum of unity: and phase conditions correct) the max. efficiency according to eqn. 3 is – 58%. "Thus this valve gives a frequency-doubling at a better efficiency than the klystron, for which it is known that 49% at most of the ray power can be converted into h.f. oscillations of the doubled frequency." The optimum dimensions of such a "transverse-modulation klystron with frequency-doubling" are found at the end of section 1.

Section 11 discusses such a valve modified to act as an amplifier or generator. If the work field is made concave (as in Fig. 2a) with the centre of curvature at the electrical centre of gravity of the modulating condenser, all electrons with equal velocities will have traversed equally long paths by the time they reach the double layer, and there will be no path-time compression. If, on the other hand, the grids are made convex (Fig. 2b) it is obviously possible to influence the path-time compression so as to emphasise, for example, the higher harmonics. "Since the general theoretical treatment of an arbitrarily curved work layer is rather complicated, we will confine ourselves to the particularly instructive example of a plane system which is inclined, as in Fig. 3, at an angle β to the valve axis." Here the path-lengths to the double-layer are no longer the same for all the electrons, but vary with the deflection: an additional compression factor *Q* is thus introduced. For the grid angle of 65° shown in the figure, and the new optimum conditions (the phase relations are different now), the efficiency according to the new eqn. 5 comes out at 58% again: "since, however, in the present case a take-up occurs of energy at the fundamental frequency [the additional compression factor *Q*, unlike *P*, involves the amplitude of the fundamental wave in the beam, so that if *Q* is made sufficiently large the load circuit can be tuned to the modulation frequency], this form of transverse-modulation klystron can be used as amplifier and regenerative generator." Further consideration of the various diagrams leads to the general conclusion that work fields symmetrical to the valve axis emphasise the even harmonics, while those lying asymmetrically to the axis bring up the odd harmonics.

The push-pull transversely-modulated valve is next considered: "an improvement of energy transfer is obtained by dividing the work-field system into two fields, one on either side of the valve axis, in phase opposition as in Fig. 5: in other words, by push-pull induction-current excitation." Unlike the previously described transverse-modulation valves, whose action is based exclusively on path-time compression, the push-pull type can work without any path-time compression in the beam-lever: if it occurs at all, it is merely as a factor helping in the transfer of energy. The efficiency in the optimum conditions is found to be

— 64%. If however the valve is so dimensioned that the beam, at its arrival at the push-pull system, is fully modulated through path-time compression, a max. efficiency of —89% is calculated, the path-time compression thus adding 25%. In spite of the high efficiency of the push-pull double-layer, its excitation-threshold conditions are less favourable than those of the continuous double-layer, because only half of the full oscillatory voltage of the load circuit comes into action. This results in a rather high internal dynamic resistance between the two grids. The arrangement shown in Fig. 6 avoids this disadvantage: it has two push-pull layers in series, and the calculated max. efficiency is 71%, while the internal resistance is only slightly more than half that of the single push-pull arrangement. With the addition of path-time compression the max. efficiency becomes — 86%. The use of more than two push-pull systems in series (curves of Fig. 7) promises little increase in efficiency, though it does reduce the internal resistance still further.

Finally, the theoretical conclusions regarding a valve with the two push-pull layers of Fig. 6 were tested by the electron-spectroscopic method described in the earlier paper (*loc. cit.*). The experimental valve took the form shown in Fig. 8: it had gas-concentration for the beam, and the two push-pull double layers were represented by a slotted screen at a short distance from the edges of two metal strips, each bent into a U and combined to form a flattened open cylinder (of section similar to, but larger than, the slit in the screen) split at its centre and followed by another slotted screen. The spectrograms of Fig. 10 confirmed the theoretical results (calculated spectrogram Fig. 9) except for the result of anode retroaction, due to the stray fields between the U-shaped plates, which was neglected in the theory.

2987. The Applications of Centimetric Electromagnetic Waves [Survey, including Waves below 1 cm generated at L.M.T. Laboratories by Magnetrons with Wave-Guides: Their Measurement: etc.].—Adam. (*See* 2935.)

2988. Modulation Circuit for Magnetrons [for Frequency Modulation].—K. Fritz. (*Hochf:tech. u. Elek:akus.*, Feb. 1942, Vol. 59, No. 2, p. 61.)

Telefunken Patent, No. 708 945. The current distribution between the anodes and the positively biased auxiliary electrodes (end plates) is modulated through a transformer connected to the latter, and this current-distribution modulation is converted to an anode-voltage modulation by a resistance or choke in the anode-current circuit.

2989. Experiments with Amplitude- and Frequency-Modulation [on a 3000 m Wave].—G. Cudell. (*Hochf:tech. u. Elek:akus.*, March 1942, Vol. 59, No. 3, pp. 66–70.)

The 100 kc/s wave was frequency-modulated with the help of the single-valve modulatable inductance circuit (L_z in Fig. 1: this circuit was taken from Weitzenmiller's paper, 2227 of 1940, and was very satisfactory): the f.m. calibration curve, Fig. 2, shows an excursion of nearly 5 kc/s on either side of the 100 kc/s. By applying the modulating voltages to the terminals B instead of to terminals A, the transmitter was amplitude-modulated. The required frequency analysis was carried out by a Rohde & Schwartz filter with a fixed frequency of 100 kc/s and a sharpness of resonance $\rho = 8500$: a cathode-ray oscillograph acted as indicator. By slowly adjusting the transmitter tuning condenser C_0 the modulated h.f. was swept across the quartz-filter frequency: whenever carrier frequency (f_h) or sideband frequency coincided with that of the filter, the spot was deflected by an amount representing the strength at that particular frequency. The frequency sweep could also have been produced by varying a voltage on the type AH1 valve in the L_z circuit. Among results thus obtained, f.m. with sinusoidal modulation gave measured spectra whose sideband heights exactly corresponded to the theoretical heights obtained from Fig. 4, curves of Bessel functions of fixed order and variable argument $\Delta\phi_h$ (where $\Delta\phi_h = \Delta f_h/f_m$). An a.m. of 20% modulation and a f.m. of $\Delta\phi_h$ about 0.2 gave two identical spectra (carrier, with 2 sidebands each about 10% of the unmodulated carrier) except that one f.m. sideband was in opposite phase to the carrier. This could be shown by simultaneous a.m. and f.m. (terminals A and B used at once), when one sideband disappeared and the other was doubled in height. With a modified circuit (no quartz filter, time-base for oscillograph) the conversion of f.m. into a.m. by a resonant circuit was shown (Fig. 6) and experiments carried out on measuring the f.m. frequency excursion.

Finally, Lissajous' figures were obtained for f.m. voltages of different wave-forms. Owing to the fact that a sinusoidal f.m. gives a cosine phase-angle characteristic, while a triangular f.m. gives a curve built up of parabolic parts and resembling a sine wave, the eye cannot distinguish between the Lissajous' figures given by f.m. of the two different types. This is of some importance, in view of the possibility that Lissajous' figures might be thought useful for testing for distortion in f.m. transmitters. The last experiment deals with a f.m. by a short pulse, producing a rectangular phase modulation.

2990. Modulation Circuit.—W. Rademacher. (*Hochf:tech. u. Elek:akus.*, Feb. 1942, Vol. 59, No. 2, p. 61.)

Patent No. 708 944. Two h.f. power-amplifier valves are fully grid-modulated. Their power-output to the aerial is varied by two complex h.f. resistances (*e.g.* h.f. transformers) one in each anode circuit: these are controlled, through auxiliary valves, by the positive and negative half-waves of the modulating voltage.

2991. Circuit for the Modulation of a H.F. Oscillation with Separate Generation of Carrier and Sideband Power, *and* A Modulated H.F. Transmitter [with Distortion-Correcting Negative-Feedback Voltage derived from Rectifier fed by the Unmodulated Carrier as well as by Modulated Component, so as to function Linearly even for Large Modulations].—W. Buschbeck. (*Hochf:tech. u. Elek:akus.*, Feb. 1942, Vol. 59, No. 2, p. 61.) Telefunken Patents, Nos. 708 468/9.

2992. Screening Arrangement for Lines carrying High-Frequency Currents.—Huber. (*See* 3002.)

RECEPTION

2993. Super-Regenerative Receiver [with Sharp-Pointed Quenching Impulses obtained by Opposing the Quench-Frequency Voltage (rectified in Full-Wave Rectifier) to the Anode D.C. Voltage].—E. Gerhard. (*Hochf:tech. u. Elek:akus.*, Feb. 1942, Vol. 59, No. 2, p. 62.) Telefunken Patent, No. 707 651.

2994. Method of Coupling for Two Amplifier Valves, particularly for Ultra-Short Waves, giving a Voltage-Division Ratio which is Independent of Frequency.—E. Heinicke. (*Hochf:tech. u. Elek:akus.*, Feb. 1942, Vol. 59, No. 2, p. 62.) Lorenz Patent, No. 707 652.

2995. Crystal Detector for Ultra-Short Waves [Detector Combination coated with Material which is Plastic at Room Temperature & has a High Coefficient of Internal Friction (Phenolic Resin)].—H. Klumb. (*Hochf:tech. u. Elek:akus.*, Feb. 1942, Vol. 59, No. 2, p. 62.) DVL Patent, No. 707 542.

2996. Circuit for the Differential Automatic-Amplification-Control of Two or More Different Frequency Bands.—H. Boucke. (*Hochf:tech. u. Elek:akus.*, Feb. 1942, Vol. 59, No. 2, p. 63.) Patent No. 707 760.

2997. The Variation of Flash-Over Voltage of High-Tension Insulators in the Normal Range of Atmospheric Humidity.—G. Pfestorf & K. H. Strauss. (*Arch. f. Elektrot.*, 31st Dec. 1941, Vol. 35, No. 12, pp. 740–751.)

2998. Registration with F.C.C. of All Diathermy Machines.—F.C.C. (*Sci. News Letter*, 30th May 1942, Vol. 41, No. 22, p. 344.)

2999. Improvement of the Reproduction of Loudspeakers following Multi-Grid Valves, by the Use of the Boucherot Connection.—A. von Lüpke. (*Zeitschr. f. tech. Phys.*, No. 4, Vol. 23, 1942, pp. 119–123.)

The well-known habit of the broadcast listener, of cutting down the higher frequencies with his tone control in spite of the fact that the makers of his receiver have spent much care in providing it with a wide frequency-band, is usually attributed to the listener's debased preference for a velvety, boomy tone. The writer, however, maintains that the listener is perfectly justified in finding a pleasanter reproduction when the tone control is used to cut off the higher frequencies, for the simple reason that with the usual pentode or tetrode output stages it is just these high frequencies that suffer from non-linear distortion. For the impedance of a loudspeaker (with its transformer) rises most steeply towards the higher frequencies (curve "a," Fig. 2), while the curve of non-linear distortion of multi-grid valves, as a function of terminating resistance, shows a marked minimum with a rise especially steep on the side of increased resistance [Fig. 1: the specially steep rise on the side of increased resistance is not obvious in the "klirr"-factor curve here, but is very marked in the modulation-factor curve "m," and the writer explains that this curve is of more importance than the "klirr"-factor characteristic, since the harmonics with which the latter is concerned, if they come through at all, affect only the tone colour and are not seriously objectionable].

Although the three- to ten-fold rise in loudspeaker impedance (compared with its values in the flattish part of the curve) which is found at 10 kc/s, and which would so seriously affect the modulation factor, is not often encountered even in local-station reception, it must be remembered that even at 5 kc/s the rise may be as much as four-fold, and also that in the latest forms of wire broadcasting or magnetophone technique the full 10 kc/s limit can now be reached: and, further, that the distortion curves of Fig. 1 were plotted for a real load, and that for complex loads the distortions would be still higher. Negative feedback in its simple form is not a solution for them, as it leaves untouched the real cause—faulty matching: "the value of the optimum external resistance is given in general by the ratio of the d.c. voltage to the d.c. current, and is thus not influenced by the internal resistance which is changed by the negative feedback." A frequency-dependent feedback has often been employed: it merely suppresses the frequencies whose reproduction is distorted by the imperfect matching. The practice which has unfortunately become prevalent in the industry, of putting a condenser in parallel with the loudspeaker, has chiefly the same effect of suppression: the impedance still remains strongly dependent on frequency (curve "b," Fig. 2) and rises sharply at the important region around 2000 c/s.

The Boucherot circuit, on the other hand, provides a simple way of making the loudspeaker impedance practically independent of frequency, and real: "it is based on the law that for every dipole with the impedance $R + jP$ there exists a corresponding dipole $R + i/jQ$, so that the parallel combination will be independent of frequency: its impedance is real and has the value R. The necessary condition is that $R^2 = P/Q$, where R represents the ohmic resistance contained in each of the two branches. Since in the present case $P = \omega L$, the admittance $Q = \omega L/R^2$, which can be realised by a condenser with the capacitance $C = L/R^2$." A footnote "5" mentions that the parallel connection of an RC element to the loudspeaker is of course already known, "but nowhere are quantitative data given which correspond to the Boucherot connection": the writer quotes various references illustrating this point.

"Thus the output transformer must be designed so that the ohmic resistance of the moving coil, transferred to the primary side, is equal to the optimum matching resistance of the valve: then a dissipative resistance of the same value, in series with a condenser of value $C = L/R^2$, must be connected in parallel to the primary winding. The actual impedance characteristic of such a circuit realised in practice is seen in curve "c" of Fig. 2 [where the values are 10 000 pF and 7 kilohms in series]:

the impedance between 100 c/s and 10 kc/s remains between 6 and 7.5 kilohms, whereas without the Boucherot circuit it rose to 34 kilohms. That the distortions have been correspondingly diminished is confirmed by measurements given later [modulation-factor curves of Fig. 4]. Subjectively, the difference in quality is readily heard: with the Boucherot circuit, reproduction resembles that given by a triode, though the proportion of individual harmonics is different. Particularly noticeable is the absence of distorted reproduction of the higher frequencies."

Fig. 6 compares the frequency curves of the power to loudspeaker: above 1000 c/s the Boucherot curve "c" falls below that of the parallel-condenser curve "b" but cuts it at about 6000 c/s and thereafter falls more slowly. Since the rise of non-linear distortion at high frequencies has been removed, it is now possible to fulfil higher requirements regarding freedom from linear distortion, by a correcting element in front of the output stage to emphasise the high frequencies. The straight gentle slope of the curve "c", compared with the initial rise and subsequent steep fall of curve "b," makes it much easier to correct. Suitable circuits for the purpose are shown in Fig. 7 (combination of frequency-dependent and -independent negative feedbacks) and Fig. 8 (parallel-resonance circuit in anode circuit of the preceding valve). Correcting circuits of the latter type can simultaneously behave as tone-control, correctors for the frequency curves of output transformer and loudspeaker, etc.

AERIALS AND AERIAL SYSTEMS

3000. THE USE OF THE PHILIPS CAPACITANCE-CHANGE PRESSURE METER FOR MEASURING THE EQUIVALENT CAPACITANCES OF A SMALL AERIAL OVER VARIOUS GROUNDS.—Fritsch & Forejt. (*See* paper dealt with in 3167, below.)

3001. THE MEASUREMENT OF THE ELECTRIC ROTATING FIELD IN THE NEAR FIELD OF A TRANSMITTER.—J. Grosskopf & K. Vogt. (*Hochf:tech. u. Elek:akus.*, March 1942, Vol. 59, No. 3, pp. 70–72.)

"In two previous papers (1833 of 1941 and 376 of February) we have shown that the parameters of the Zenneck rotating-field ellipse can be applied to the determination of the electrical constants of the ground. In the first paper these investigations were carried out on some fixed frequencies, those of neighbouring broadcast stations: from them a value was deduced which we named 'effective conductivity,' since the measured values could almost always be interpreted only on the assumption of a stratified ground.

"For the more accurate investigation of the electrical constants of stratified ground the measurement of the frequency-dependence of the rotating-field ellipse is necessary. Such an investigation was reported on in the second paper and showed substantial agreement with the theory. For this investigation a 1 kw transmitter was available, and this was erected at a distance of 5 km from the receiving point. A comparison of the measurements carried out with this transmitter and those with the broadcast stations on the same frequencies but at great distances showed agreement within the limits of error of the measurements. Now for such ground investigations it is naturally desirable to use as small a transmitter as possible: the question therefore arises, what is the shortest distance from the transmitter at which the receiving dipole can be situated in order to obtain measurements of a prescribed accuracy. Apart from this requirement for measuring purposes, the investigation has, of course, an importance for the further confirmation of the theory."

Starting from eqns. 55 and 70 (for the vertical and horizontal components of the electrical field) in Norton's theoretical paper (33 of 1938), simplified by the assumption that both transmitter and receiver are on the ground: and making, for a preliminary qualitative estimation, other simplifications (k_0^2/k^2 taken as negligible compared with unity: Sommerfeld attenuation factor F put equal to unity, as is allowable for the short distances involved), the writers obtain simple expressions for the vertical and horizontal components: $E_y = 1 - (1/k_0 r)^2 + j \, . \, 1/k_0 r$ and $E_x = k_0/k$. Thus for large values of r the ratio $\rho = E_x/E_y$ becomes the Zenneck value k_0/k. "As might be expected, the above expression for E_y is identical with the Hertzian formula for propagation over a perfectly conducting plane. It is of interest to see that the horizontal component, unlike the vertical, has no near field."

Remembering that in the actual measurements what are measured are the ratio a/b of the major to the minor axis and the inclination γ of the minor axis to the horizontal, the writers give the relations $a/b = 1/|\rho| \, . \sin \phi$ and $\gamma = |\rho| \, . \cos \phi$. For $\epsilon = 13$ and $\sigma = 1.4 \times 10^7$ the calculated values of a/b and γ are given in Fig. 1 as functions of distance r over the range $r/\lambda = 0.05 - 2$ (Fig. 1). Both curves tend asymptotically towards the Zenneck limiting value for plane waves as r/λ becomes large: for $r/\lambda = 5$ (beyond the diagram) a/b is 9.86 and γ is 8.5°. For small values of r/λ the value of γ decreases: the ellipse straightens itself up, becomes vertical when r/λ is about 0.2, and for still smaller values slopes in the opposite direction, *i.e.* towards the transmitter. The axes ratio a/b goes through a minimum at $r/\lambda = 0.2$ and increases without limit as r/λ diminishes further: in the immediate neighbourhood of the transmitter the field is, as it must be, linearly and vertically polarised.

The experimental confirmation was carried out over the same ground as that previously involved in the establishment of the existence of stratification by the frequency-dependence of the ellipse (second paper cited above), where a 10 metre-thick overlayer was found with a conductivity one-ninth of that of the lower layer. The constants of the upper layer are employed in the above calculations of a/b and γ. The receiving dipole was kept fixed and the transmitter (on 1 Mc/s) was moved away in a straight line (to avoid any directional effect), its vertical aerial being lengthened in stages as the distance passed the values $\lambda/3$ and $\lambda/2$. The measuring technique for a/b was a simplified version of that described in the first paper; it is described in the *T.F.T.* paper dealt with in 2955, above. The

measured values of a/b and γ are shown in Fig. 2 for r/λ up to 1.5. Qualitative agreement with Fig. 1 is seen: the sharp minimum of a/b occurs for r/λ at about 0.17 instead of 0.2, while the γ curve passes through zero at 0.25 instead of at 0.20, and reaches very large negative values at shorter distances. The quantitative discrepancies are attributed partly to the stratification, neglected in the calculated curves, and partly to the finite height of the receiving dipole: a theoretical allowance for stratification presents serious difficulties and no solution of this problem has yet been given. The experimental results shown in Fig. 2 are set out in another form in Fig. 3, where the ellipses are drawn, true to shape and inclination, at different points along the line of test.

As regards the original question as to the minimum distance between transmitter and receiver for accurate results, it is deduced from the calculated curves of Fig. 1 that "at a distance of about 5λ an accuracy within 4% could be expected. The measured curves of Fig. 2 still show a slight rise at $r/\lambda = 1.5$, but here again it may be assumed that the limiting value is reached at about $r/\lambda = 5$" [in the Grosskopf paper dealt with in 2954, above, these results are referred to as showing that the transition to the Zenneck field is practically complete at $r = 3\lambda$].

Finally, "it is interesting to note that the measurement of the distance-dependence of phase-velocity in the near-field of a transmitter in the same wave-band (Al'pert & others, 1885 of July) has led to a curve shape similar to those of Figs. 1 and 2."

3002. Screening Arrangement for Lines carrying High-Frequency Currents [Metallic Screening made Non-Reflecting by coating Surface next to H.F. Conductor with a Semiconducting Layer (Se, AgI, Cu_2O, Graphite, or Asbestos Cement mixed with Metallic Powder)].—E. Huber. (*Hochf: tech. u. Elek:akus.*, Feb. 1942, Vol. 59, No. 2, p. 61.) Patent No. 707 159.

3003. On the Burying-Depth of Wood Telephone Poles [for Various Soils: German & Foreign Practice: Theoretical & Experimental Investigations]. — K. Machens. (*T.F.T.*, Jan. 1942, Vol. 31, No. 1, pp. 1–11.)

VALVES AND THERMIONICS

3004. Transversely-Controlled Valves with Longitudinal Work Fields [the "Transverse-Modulation Klystron", including Push-Pull Designs].—Hollmann. (*See* 2986.)

3005. Total Secondary Emission from Thin Films of Sodium on Tungsten [Systematic Increase in Yield as Work Function of Surface was Decreased by Addition of Sodium (in accordance with Wooldridge's Theory, 147 of 1940): Decrease as Clean-Tungsten Work Function was Increased by Formation of Air Film: Yield from Clean Tungsten is Independent of Target-Temperature up to 1000° K].—K. G. McKay. (*Phys. Review*, 1st/15th June 1942, Vol. 61, No. 11/12, pp. 708–713.)

3006. The Effect of Temperature on Secondary-Electron Emission.—P. M. Morozov. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 4, Vol. 11, 1941, pp. 402–409.)

In view of the considerable divergence of the results obtained by various investigators regarding the effect of temperature on secondary-electron emission from pure metals, experiments were conducted by the author in which this effect was investigated in the cases of nickel and molybdenum. It was found that with nickel a slight decrease in the coefficient of secondary-electron emission σ takes place when the temperature is raised; for high primary-electron velocities the absolute value of this decrease is of the order of 0.010–0.018 for a temperature rise from 20° to 840°C. In the case of molybdenum, σ remains constant within 0.3% when the temperature is varied from 20° to 1100°C. Curves are plotted showing the energy distribution of secondary electrons for various energies of the primary electrons and various temperatures of the target.

3007. Secondary-Electron Emission from Solid and Liquid Lead, Tin, and Bismuth.—P. M. Morozov. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 4, Vol. 11, 1941, pp. 410–420.)

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The experimental confirmation was carried out over the same ground as that previously involved in the establishment of the existence of stratification by the frequency-dependence of the ellipse (second paper cited above), where a 10 metre-thick overlayer was found with a conductivity one-ninth of that of the lower layer. The constants of the upper layer are employed in the above calculations of a/b and γ. The receiving dipole was kept fixed and the transmitter (on 1 Mc/s) was moved away in a straight line (to avoid any directional effect), its vertical aerial being lengthened in stages as the distance passed the values $\lambda/3$ and $\lambda/2$. The measuring technique for a/b was a simplified version of that described in the first paper; it is described in the *T.F.T.* paper dealt with in 2955, above. The

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ejection from ThW increases rapidly with a decrease in the work function. A method is also proposed for investigating the effect of the velocity of the ion or of the excited atom on the " potential " ejection.

3009. The Measurement of the Evaporation Heat of Electrons from Thoriated Tungsten in an Electric Field [by Observations of the Cooling of the Filament].—L. N. Dobretsov. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 5, Vol. 11, 1941, pp. 503–514.)

The theory of the method and the apparatus required are discussed in detail, and experiments are described in which this method was used for investigating the effect of an electric field on the evaporation heat of electrons, within the region of the Schottky effect, from thoriated tungsten. The results of these experiments seem to confirm, within the accuracy of the method, the formula $\log i_1/i_2 = (\epsilon/kT) . (\phi_2 - \phi_1)$, based on the assumption that the Schottky effect is determined by the change in the evaporation heat due to the electric field. *Cf.* 409, 2139, & 2715 of 1941.

DIRECTIONAL WIRELESS

3010. The Limits of Usefulness of the Adcock Direction-Finder with *n* Masts.—H. W. Breuninger. (*Hochf:tech. u. Elek:akus.*, Feb. 1942, Vol. 59, No. 2, pp. 50–57.)

" It is shown that an Adcock-aerial system consisting of n aerials possesses a limiting frequency ω_{lim} above which no d.f. working is possible, which is independent of n, and which is governed only by the diameter of the whole system. How far below ω_{lim} bearings can be taken depends on n. The theoretical bearing error ϵ and the theoretical blurring of minimum T are expressed in approximate formulae, and are discusssed."

On the simplifying assumptions that the incident wave, of unit field strength, comes in horizontally ($\alpha=0$), and that the phase constant is so chosen that the wave oscillates as $\sin \omega t$ at the mid-point of the system, eqn. 7 is obtained for $\mathfrak{H}$, the vector quantity which is shown to represent the horizontal magnetic field inside a completely symmetrical goniometer even when (as was assumed at first not to be the case) a direct coupling exists between the field coils. By the purely mathematical transformation of Appendix 1, eqn. 7 is brought into the form $\mathfrak{H}=h . (\mathfrak{R} \cos \omega t + \mathfrak{A} \cos \omega t + \mathfrak{B} \sin \omega t)$, where $\mathfrak{R} = R.\mathfrak{s}_1$ and $R = n . J_1(s)$, $\mathfrak{s}_1$ being the unit vector representing the azimuth of the incoming wave, and s being $2\pi/\lambda$ times the radius of the system. For small values of s, and n not less than 3 (so as to define a plane), this reduces to $\mathfrak{H}=h.R \cos \omega t.\mathfrak{s}_1$. This shows that $\mathfrak{H}$ is in the same direction as $\mathfrak{s}_1$; that is, the direction of the magnetic field corresponds to the azimuth of the wave, so that a bearing determination is possible. Combining this with the above relation $R=n . J_1(s)$, it follows that R is a measure of the sensitivity so far as this depends on s. It is thus seen that at the null points of the Bessel function $J_1(s)$ a bearing is impossible. It is known that for very long wavelengths the sensitivity decreases with increasing wavelength, *i.e.* with decreasing s. As s is increased from a small value, the sensitivity R first increases, till $J_1(s)$ reaches its first maximum: it then decreases again and vanishes for $s = s_{lim} = 3.8317$: or if α is not (as assumed) zero, for $s . \cos\alpha = s_{lim} = 3.8317$. Thus for every value of s greater than s_{lim} there must be some angle α for which this vanishing condition is fulfilled. But for d.f. purposes waves of various unknown values of α must be dealt with, so that an absolute limit of usefulness is reached when $\lambda = 2\pi r/s_{lim} = 1.6398\ r$.

But in general the vectors $\mathfrak{A}$ and $\mathfrak{B}$ cannot be neglected as they were above, so that the limiting wavelength, down to which d.f. is possible, is longer than that just given: for these vectors, whose effect on $\mathfrak{H}$ in comparison with $\mathfrak{R}$ increases as s increases, produce bearing errors ϵ and blurring T, and if these exceed certain limits a bearing is no longer obtainable. The investigation of $\mathfrak{A}$ and $\mathfrak{B}$ (pp. 51–55) shows that for Adcock systems with an odd number of aerials the limit of usefulness in the direction of short waves is set chiefly by the blurring: for systems with an even number of aerials it is set entirely by the bearing error. In both cases these limits move towards shorter wavelengths as the number of aerials is increased, and approach the absolute limit given above ($\lambda = 1.6398\ r$). This limit is reached practically with 10 to 12 separate aerials. Since, however, as this limit is approached, the sensitivity for waves coming in at small values of α (*i.e.* nearly horizontally) decreases, the practical usefulness of Adcock systems with many aerials is limited by this loss of sensitivity and not by blurring or bearing error. Since, also, this sensitivity (so far as it depends on s and thus on the diameter of the system) already reaches, at $s=3.4$, a value only about one-third of its greatest value (at $s=1.84$—maximum of $J_1(s)$), it is of little advantage in practice to increase the number of aerials above 7 or 8. These results apply to the ideal Adcock system: the limits are generally rather less favourable for an actual system, owing to unavoidable imperfections in this.

3011. Method of Improving the Sharpness of Indication of a Equi-Signal Guiding Beam.—L. T. Wen. (*Hochf:tech. u. Elek:akus.*, Feb. 1942, Vol. 59, No. 2, pp. 63–64.)

Patent No. 708 473. The beam is made to swing, slowly by comparison with the complementary keying frequency, through an angle less than the sector angle within which, if the beam were stationary, the long-dash composite signal would be receivable. In this way the long-dash zone may be made as narrow as desired, since in the remainder of the sector the long-dash signal is broken up, in rhythm with the swing, by the complementary signals.

3012. Arrangement for the Transmission of Short-Time High-Frequency Pulses [to avoid Distortion of Pulse Form].—P. Kotowski. (*Hochf:tech. u. Elek:akus.*, Feb. 1942, Vol. 59, No. 2, p. 61.)

Telefunken Patent, No. 708 475. To avoid distortion, the whole h.f. path from transmitter to receiver must be so designed that the over-all phase-rotation time $d\phi/d\omega$ is less than one-third the pulse period, where ϕ is the phase angle between the voltages at the keying-point and the demodulat-

merge into a lengthening of reverberation and the term flutter echo no longer applies: the writer calls the special frequencies at which the phenomena occur "singular natural frequencies." These singular frequencies are shown up in reverberation measurements (Fig. 12): they can also be detected, even when corrective measures have rendered them subjectively unnoticeable, by the fact that they change the Gaussian distribution mentioned above (*see* Zurich studio 1, Fig. 13). Such a treatment of reverberation-time values for different points therefore provides a new criterion for the acoustics of a studio, taking into account the form of the room and the spatial distribution of the sound absorption. "This is the more important because simple reverberation theory cannot consider these factors."

3027. THE ACOUSTICS OF LARGE BUILDINGS [Description of W. Oelsner's (1935) Observations & Conclusions, "Not Sufficiently attended to by Acousticians": Successful Application to a New Church in Copenhagen].—K. W. Wagner: Oelsner. (*Génie Civil*, 31st Jan./7th Feb. 1942, Vol. 119, No. 5/6, p. 66: summary only.) For an Oelsner patent *see* 189 of 1940.

3028. THE "O.M. CORBINO" NATIONAL ELECTRO-ACOUSTICAL INSTITUTE [including Illustrated Description of the Large "Absorbing Chamber" & Its Construction].—A. Giacomini. (*La Ricerca Scient.*, June/July 1942, Vol. 13, No. 6/7, pp. 249–266.) *See* also 2729 of September.

3029. EXPERIMENTS WITH HELMHOLTZ RESONATORS [Cylindrical Type, with Neck of Constant Length but Varying Diameter: Empirical Formula Frequency $\propto 1/V^n$ (V = Volume of Body), where n varies between 0.5 and 0.8, approaching 0.5 (Helmholtz's Value) for High Frequencies & Small Neck-Diameters: etc.].—H. Mary Browning. (*Phil. Mag.*, July 1942, Vol. 33, No. 222, pp. 551–556.)

3030. THE FINE STRUCTURE OF THE RESONANCE CURVES OF ACOUSTIC RESONATORS [of Various Forms: by Use of Sensitive Flames].—H. Zickendraht. (*Sci. Abstracts*, Sec. A, June 1942, Vol. 45, No. 534, p. 158.) For his paper on the use of such flames *see* 1721 of June.

3031. A NEW TYPE OF ELECTRICAL ANALOGY: PART I.—Efros. (*See* 2970.)

3032. THE PROPAGATION OF SOUND IN A CRYSTAL POSSESSING PIEZOELECTRIC PROPERTIES.—I. G. Shaposhnikov. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 2/3, Vol. 11, 1941, pp. 332–339.)

The absorption and dispension of sound in a piezoelectric crystal are considered. Formulae 13 and 14 are derived for the case of a longitudinal plane wave, giving the sound velocity V and coefficient of absorption α per unit length.

3033. ON THE ABSORPTION OF SOUND IN DIELECTRICS.—I. Pomeranchuk. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 4, Vol. 11, 1941, pp. 455–462.)

It is pointed out that the absorption of sound in dielectrics is greatly affected by the dispersion and velocity anisotropy of thermal oscillations. From a previous paper (in No. 1 of same journal: *see* also 1802 of June) on the thermal conductivity of dielectrics at temperatures higher than the Debye temperatures, condition I is quoted and sound absorption in crystals satisfying as well as not satisfying this condition is discussed theoretically.

3034. THE USE OF SUPERSONIC WAVES FOR THE OUTGASSING OF THE LIGHT METALS [Good Results: Difficulties with Magnesium-Aluminium Alloys, and Methods of Overcoming Them].—(*Génie Civil*, 31st Jan./7th Feb. 1942, Vol. 119, No. 5/6, p. 67: short summary, from *Schiffbau.*) *Cf.* 1975 of 1939, 2307 of 1940, & 3079 of 1941.

3035. THE USE OF SOUND WAVES TO IMPROVE SULFA DRUG TREATMENT OF WOUNDS, ETC.—L. A. Chambers & others. (*Science*, 5th June 1942, Vol. 95, Supp. p. 11.)

PHOTOTELEGRAPHY AND TELEVISION

3036. THE TRANSMISSION OF MESSAGES AND PHOTOGRAPHS BY RADIOELECTRIC PATHS [including the Preference (since 1939) for Frequency Modulation rather than Time Modulation].—G. Masson. (*Génie Civil*, 3rd/10th Jan. 1942, Vol. 119, No. 1/2, p. 19: summary of *Soc. franç. des Élec.* paper.) From the Belin laboratories.

3037. A FREQUENCY-DIVIDING PROCESS USING A CATHODE-RAY TUBE [Ray, describing a Spiral Path under Influence of Rotating Field (produced by the Frequency to be Divided) and also of a Radial Field, makes Contact with Electrodes after More than One Complete Revolution].—K. Brückersteinkuhl. (*Hochf:tech. u. Elek:akus.*, Feb. 1942, Vol. 59, No. 2, p. 61.) Fernseh Company Patent, No. 707 650.

3038. ARRANGEMENT FOR THE TRANSMISSION OF SHORT-TIME HIGH-FREQUENCY PULSES [to avoid Distortion of Pulse Form].—Kotowski. (*See* 3012.)

3039. ON THE ENERGY DISTRIBUTION OF PHOTO-ELECTRONS: PART II—ANTIMONY-CAESIUM AND OXYGEN-SENSITISED ANTIMONY-CAESIUM CATHODES.—Yu. M. Kushnir, E. A. Vaynrib, & V. P. Goncharov. (*Journ. of Tech. Phys.* [in Russian], No. 14, Vol. 10, 1940, pp. 1197–1200.)

For Part I *see* 3103 of 1940. The preparation of the cathodes is described and the results obtained by the same electro-optical method (Fig. 1) as used in the previous investigation are shown in a number of curves. The main conclusions reached are:—(1) As regards the energy distribution of photo-electrons there is no great difference between the two types of cathodes, and (2) unlike the oxygen-sensitised silver–caesium cathodes, the saturation potential of the plain and oxygen-sensitised antimony–caesium types is independent of the wavelength.

3040. ON THE ALTERATION OF THE THERMIONIC AND PHOTOELECTRIC EMISSION CONSTANTS OF SILVER-OXIDE–CAESIUM CATHODES DURING THEIR ACTIVATION.—R. Suhrmann & F. W. Dehmelt. (*Zeitschr. f. Phys.*, 25th Feb. 1942, Vol. 118, No. 11/12, pp. 677–694.)

"Among the 'composite' photocathodes the silver-oxide–caesium cathodes are of special technical and scientific interest, since on irradiation with long-wave light they display a high electron-emitting power and give out 'thermo-electrons' even at temperatures little above room temperature. Such cathodes are prepared by covering a silver surface with a thin oxide skin by means of a glow discharge in oxygen, and then activating this with caesium vapour in a vacuum, at a temperature between 100° and 200° C. By this means the silver oxide is reduced, so that the silver cathode is now covered with a thin film of caesium oxide, in and on which reduced silver and caesium are atomically distributed. The object of the present investigation is to determine in what manner the thermionic and photoelectric emission constants of such cathodes change during heating, in order to obtain evidence as to the physico-chemical processes occurring during the activation of the cathode. The question will also be examined whether the large differences found by Campbell (1931 Abstracts, p. 508) for such cathodes, between the work functions of the thermo-electrons and the photo-electrons, appear in all activation conditions, and how these differences may be interpreted."

The thermionic constants ψ and A (eqn. 1) and the photoelectric constants ϕ and M (eqn. 2) were measured in two series of experiments, the first three days after the vaporisation of the caesium over the silver-oxide-coated silver cathode, the second after the caesium had been in contact with the cathode surface for about 14 days. The comparison between the results of these two series is a complicated business which would require a very long abstract to cover adequately, but it may be mentioned that in both cases ψ was found to be a few tenths of a volt smaller than ϕ, in agreement with Campbell's result (Görlich's finding, with Cs-Cs_2O-[Ag] cathodes, that ψ and ϕ coincided—*see* 1703 of 1941—is attributed to his faulty method of measuring ϕ, which would lead to too small values and thus bring ϕ nearer to the really smaller ψ values: *see* footnote on p. 685): and that while, in the first series of experiments, ϕ and ψ decreased similarly with increasing activation (Fig. 5a), in the second series ϕ showed a very deep and pronounced minimum (Fig. 6a) whereas ψ displayed a less pronounced maximum (Fig. 6c). Similarly the curves for log A are completely different in the two series, following in both cases the behaviour of the corresponding ψ curve. Among the tentative conclusions reached from these and other results is the possibility (particularly supported by the second series of experiments) that "the change in the thermionic emission constants during activation can be traced to the behaviour of the photoelectric constants, so that the variation of both types of emission during activation can be explained by the same change of the physico-chemical nature of the cathode surface." This explanation requires the assumption (supported by experiment) of a positive temperature coefficient for the extraction potential.

3041. THE REDUCTION OF THE SPONTANEOUS FLUCTUATIONS IN THE AMPLIFICATION OF VERY SMALL PHOTOCURRENTS.—M. J. O. Strutt & A. van der Ziel. (*E.T.Z.*, 4th June 1942, Vol. 63, No. 21/22, pp. 263–264: summary only.)

Summary of the paper referred to in 484 of February. The lower limit of amplifiable current-changes in the photocell circuit is set by the spontaneous electron motions in the amplifier. "Hitherto, the secondary-electron multiplier has offered the only means of amplifying the smallest photocurrents at the higher frequencies." In the expression for the ratio of the useful-current-amplitude to fluctuation-amplitude, given for such a multiplier near the top of p. 263, the second and third terms of the denominator are seen to be negligible compared with the first for values of the input resistance R_1 which are the smaller, the higher the multiplying factor of the multiplier. The value of R_1 need not, therefore, be made so high as in an ordinary amplifier, in order to keep the fluctuation noise low compared with the useful modulation. Since, however, the first term of the denominator increases with the inhomogeneity of the secondary effect, the use of the secondary-electron multiplier, although a very practical method of reducing the spontaneous fluctuations, is by no means the ideal solution.

Fig. 6 shows the circuit suggested by the present writers: its chief difference from the usual circuits is that the anode circuit is joined to the control grid through a resistance R_{ag}: this, and the grid-leak resistance R_g, are regarded as sources of spontaneous fluctuations. The ratio of the squares of the signal voltage U_a and fluctuation voltage u_a is given in the long equation at the top of p. 264: when R_{ag} is made to tend towards infinity this reduces to the short expression given on the next line. To compare the two expressions, circuits must be chosen which are similar as regards capacitances and input resistances. "For $R_e = R_g$ we must so select R_{ag} and R_a [the load] that the second and third terms in the denominator of the equation of the new circuit are considerably smaller than in the case where R_{ag} approaches infinity. This condition is fulfilled if SR_a is made much greater than unity and R_a much less than R_{ag}. The complete arrangements necessary for the carrying out of this plan may be summarised as follows:—the grid-leak resistance R_g of the amplifier is given a much larger value than that corresponding to the necessary width of frequency band, and then the input impedance desired, in consideration of the necessary band width, is obtained by coupling the output circuit to the input circuit through the resistance R_{ag}."

3042. CONTRIBUTION TO KNOWLEDGE OF THE SELENIUM PHOTOELEMENT: V—EFFECT OF ALPHA RAYS.—A. Becker. (*Zeitschr. f.*

Phys., 25th Feb. 1942, Vol. 118, No. 11/12, pp. 695–705.)

To obtain a satisfactory idea of the elementary processes in photoelements and rectifier cells it is particularly important to extend our present knowledge to yield a clear picture of that boundary zone between covering electrode and semiconductor which physical and chemical considerations have shown to be a determining factor in the cell mechanism. The writer's earlier experiments with cathode-ray irradiation (631 of 1938) have shown directly that electron excitation in this zone plays a part in this mechanism. The present investigation brings out the fact that other special processes and layer properties are also involved : it makes use of a form of radiation whose direct action, owing to its slight depth of penetration, is practically limited to the zone under consideration and leads to an important modification of the electron concentration there, with the new effect of a marked reduction in the photoelectric efficiency of the cell. This effect is found whenever the alpha radiation is allowed to penetrate the covering layer : that is, when unvarnished cells are used and the gold covering-layer is thin enough to present practically no obstacle to the radiation. It does not seem to depend on the wavelength of the light, so that the changes are apparently not in the optical properties of the active layer : nor, it is deduced from the curves, can they be explained merely by changes in the electron distribution.

The detailed results differ if the cells are of markedly different types. Thus with cells of comparatively low resistance and little rectifying action the effect of the radiation is to decrease the "dark" resistance and practically to eliminate all those special properties of the conductor/semiconductor system which point to the presence of a definite boundary layer. With other cells, having marked rectifying properties and high resistance, the "dark" resistance increases with the action of the alpha rays, though in both cases the photoelectric efficiency is reduced. Subsidiary tests with gamma radiation showed no such effect. The search for the cause of the alpha-ray effect included tests which proved that it was not due to any change in the optical properties of the gold covering-layer, and further tests on the action of alpha rays on the spectral transparency of a layer of red selenium, which did give a certain positive result but not one which could explain the observed phenomena. Further investigations on this point will be reported later : meanwhile no definite conclusions can be drawn from the present experiments. For previous parts of the writer's investigations *see* 1115 of 1940.

3043. The Repairing of Selenium Barrier-Layer Photocells by an Electric Current.—T. I. Moldaver. (*Journ. of Tech. Phys.* [in Russian], No. 15, Vol. 10, 1940, pp. 1306–1307.)

The photocurrent output into the external circuit depends to a great extent on the resistance offered to photoelectrons leaking from the semi-transparent electrode to the selenium covered by the barrier layer. The value of this resistance may become greatly reduced owing to the existence of short-circuits ("bridges") between the semi-transparent electrode and the selenium. It was suggested that by passing an electric current of sufficient strength through the cell these bridges could be burned out. Experiments were carried out to test this suggestion, and great improvement was observed in 20% of the cells experimented with, when an alternating current at 12 v was passed through the cell for two periods of 30–40 seconds each.

3044. Electro-Optical Properties of Colloids [Experimental Investigation of Anomalous E-O Effects in Bentonite Solutions, Frequencies 50 c/s to 10 Mc/s : Previous Workers have Erroneously assumed that an A.C. Field always creates a Steady Optical Shift : Development of Photoelectric Method alternating with Compensator Method].—H. Mueller & B. W. Sakmann. (*Journ. Opt. Soc. Am.*, June 1942, Vol. 32, No. 6, pp. 309–317.) Measurements and their interpretation will be reported later.

3045. The Light Scattering and Kerr Constants of Spherically Symmetrical Molecules [by Quantum Mechanics].—Neugebauer. (*See* 2958.)

3046. A Water-Cooled Mercury-Vapour Lamp of High Luminous Density [Type HBF-1000, taking 1 kW and giving a Density of 30 000 Stilb].—J. Kern. (*Zeitschr. f. tech. Phys.*, No. 4, Vol. 23, 1942, pp. 108–113.) A "stilb" is Blondel's unit for television work : it is the density of 1 cm² of surface radiating 1 Hefner candle in the direction normal to the surface.

MEASUREMENTS AND STANDARDS

3047. Measurements of [Ultra-Short] Electromagnetic-Wave Absorption in Liquid Dielectrics by the Malsch Thermometric Method.—A. L. Khodakov. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 4, Vol. 11, 1941, pp. 467–474.)

The theory of the Malsch method (1932 Abstracts, p. 474) is briefly discussed, and a report is given of an experimental investigation in which a similar method was used on waves from 10 to 3 m. Within this range the dipole conductivity of water, amyl alcohol, and nitrobenzol was measured. For each of these liquids the "jump wavelength" λ_s (eqn. 6) and the thermal coefficient of λ_s were calculated. The apparatus developed for these experiments is described and a number of experimental curves and tables are shown.

3048. The Bolometer as a Power Meter at Ultra-Short Waves [down to 20 cm : Powers down to 2×10^{-8} Watt detectable].—H. Meinke. (*E.N.T.*, March/April 1942, Vol. 19, No. 3/4, pp. 27–40.)

From the Telefunken laboratories. "The exact measurement of the absolute values of current and voltage at very short wavelengths presents considerable difficulty, particularly when the amounts to be measured are very small. On the other hand it is shown below that a measurement of the absolute values of small *powers* can be carried out with really good accuracy. Further, by exploring the standing waves along a line the terminal impedance of this line is obtained (Schmidt, 1933 Abstracts, p. 222), so that an exact measuring method for resistances is also available. It is applicable to test objects which carry only small voltages, provided a highly sensitive heterodyne receiver is used for exploring the line. By way of the power and the resistance, the voltages and currents can then be obtained. The power measurement takes place with a bolometer, by the substitution method, which always gives the most accurate results. To measure the power delivered by a given voltage source to a given resistance, this load resistance is replaced by a bolometer arrangement whose input resistance is brought, with the help of loss-free transformation circuits (quadripoles), to the complex value of the resistance which it replaces. Section II therefore deals with the computation of the input resistance of a bolometer at ultra-short wavelengths, while section III discusses the fundamental possibilities as to what loss-free quadripoles can be used to transform this bolometer resistance to the desired resistance value.

"Apparatus and devices which have already been developed into satisfactory practical shape work quite generally with cable connections, so that the input resistance of such apparatus have to be matched with the characteristic impedance of the cable. These cables, even at ultra-high frequencies, display no marked departures from the form well-known in wide-band-cable technique (Kaden, 596 of 1937), so that their characteristic impedance may be taken as in the neighbourhood of 70 ohms. Thus the transformation of the bolometer resistance to a pure ohmic resistance of the order of 70 ohms is dealt with as a specially important case of the resistance transformation.

"Among the various applications of the power measurement one of the most prominent (in the present investigations) was the calibration of the voltage-divider at the output of a sensitivity-measuring signal generator for receiver testing (Fränz, *Hochf:tech. u. Elek:akus.*, April 1942, Vol. 59, No. 4, p. 105 onwards). Consequently the bolometers described as examples are designed specially for the measurement of as small powers as possible: nevertheless all the considerations hold good for bolometers of greater power. For the quantitative design of the quadripoles, graphical methods are used which allow in particular those quadripoles to be calculated which take advantage of the transforming properties of lines. A line of variable length, short-circuited at one end and connected as a paralleled adjustable impedance (Mason & Sykes, 3671 of 1937) is the best of all designs of transforming section for ultra-short waves. The transforming properties of an arrangement comprising two such lines of variable length are investigated thoroughly ["double tie-line", Fig. 11: the example described (table 1), with its 10 cm of linking line, transforms the bolometer input resistance to an ohmic resistance of 70 ohms over the wavelength range 22 to 330 cm. For longer waves the 10 cm link is too short and its transforming action disappears: for shorter waves (20 cm) its length becomes equal to a half wavelength and at this point, and in its neighbourhood, losses become heavy: such a double tie-line must never be used at a wavelength about double the length of the linking line].

"Special attention must be given to the losses in the matching quadripole [section VI: these are due, in the tie-lines, to skin effect and imperfect short-circuiting at the end, and in the linking line to skin effect: they are all current losses, dielectric losses being avoided in a good design], since the power thus lost does not reach the bolometer, and the measurement is therefore falsified [the following guiding rules are given (bottom of p. 37): none of the lines involved should approach nearer to the length 0 or $\lambda/2$ than $\lambda/50$, lengths over $\lambda/2$ are to be avoided, no current antinode should be formed on the linking line even when the matching is imperfect, line lengths of $\lambda/4$ (particularly loss-free) should be striven for]. Some specially low-loss quadripoles are described. Finally, the practical working of the method is discussed. The treatment of the transforming quadripoles is kept so general that it can be applied in many other fields".

Among the special quadripoles mentioned is the "triple tie-line", consisting of the double type with the addition of a second linking line and a third adjustable tie-line. As regards this, reference is again made to Fränz's paper (*loc. cit.*). For specially accurate measurements the double tie-line is abandoned in favour of the single tie-line combined with an adjustable, practically loss-free series air-condenser, as seen in Fig. 14. Objections to this are the small transformation range and the rather difficult construction. The stray capacitances of the condenser plates to the screening tube must also be taken into account (equivalent circuit Fig. 15). Section VII deals with the concentric cable (characteristic impedance 70 ohms) connecting the bolometer: the high-sensitivity receiver and its screening from stray fields: the choice of the length and resistance of the bolometer filament (a final conclusion is in favour of a length of about 30 mm, rather shorter for $\lambda = 20$ cm, rather longer for $\lambda = 1$ m): the d.c. bridge circuit for the bolometer and the variation of sensitivity with the permanent biasing load. The bolometer itself (Fig. 1) is fully screened: this avoids "electrical energy loss through radiation" and stabilises the temperature conditions of the filament. Calibration and all questions regarding the bridge circuit are dealt with in Wallauschek's paper, 1745 of June.

3049. Impedance Measurements over a Wide Frequency Range [from "Infra-Low" to "Ultra-High", with Particular Reference to Measurements on Dielectrics: Description of Equipment & Components (Twin-T Network, Series-Substitution Schering Bridge, etc.)].—L. E. Packard. (*Proc. Radio Club of Am.*, April 1942, Vol. 19, No. 1, pp. 1–13.) A summary was dealt with 1115 of April. The literature references include two or three (from *General Radio Experimenter*) not dealt with in these "Abstracts & References".

3050. The Application of Drude's Second Method of determining Dielectric Constants to the Measurement of Small

INDUCTANCES AND RESISTANCES.—Maibaum. (In paper dealt with in 3051, below.)

3051. ON CERTAIN PHENOMENA IN A NON-UNIFORM LECHER SYSTEM.—B. K. Maybaum [Maibaum]. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 5, Vol. 11, 1941, pp. 544–553.)

For previous work *see* 471 of 1941. It has been pointed out in several recent publications that Morton's formula (*Phil. Mag.*, 1897), which is used in Drude's second method for calculating the dielectric constant of a liquid, does not take into account the fact that the value of the constant depends on the position of the condenser on the line; it decreases when the condenser approaches one of the bridges. In some cases with condensers containing non-conducting dielectrics, even small negative displacements were observed. Romanov (2744 of 1936) and Slätis (4525 of 1938) offered two different explanations of this phenomenon, but in each of these it is assumed that the phase-velocity of the propagation of electromagnetic waves along the line exceeds the velocity of light. In this paper a theoretical discussion is presented which shows that negative displacements can be explained without the above assumption. Experiments were conducted which confirmed the theoretical conclusions reached, and in particular showed that if the element disturbing the uniformity of the line is moved along the line, a kind of "pulsation" of the dimensions of the system takes place. The effect of the inductance of the condenser leads was also examined, both theoretically and experimentally, and it was found that, contrary to Slätis, this inductance shortens, not lengthens, the system.

On the basis of this investigation, certain modifications of Morton's formula are suggested, in particular for the case when the condenser is enclosed in a thermostatically controlled oven. The application of Drude's second method to measurements of small inductances and resistances at high frequencies is also briefly discussed. For a correction to the formula on p. 552 *see* inset slip at end of journal.

3052. CORRESPONDENCE ON THE PAPER BY V. I. KALININ & Z. M. POSADSKOVA ENTITLED "ON THE SLÄTIS EFFECT" [*see* 472 of 1941]. —E. M. Fradkina & I. A. El'tsin. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 2/3, Vol. 11, 1941, pp. 373–375.)

In a letter to the editor the writers point out a number of mistakes and inaccuracies in the paper by K. & P., and state that their investigation cannot therefore be considered as a verification of the Slätis theory. In a reply by K. & P. additional explanations are given, and it is also stated that their original paper should only be regarded as a preliminary communication on the work, which has not yet been completed. In a concluding letter, however, F. & E. point out that K. & P. are still using an incorrect equation (4) (p. 373) in which constant and variable values are equated.

3053. THERMIONIC WATTMETERS [Short Survey based on Work of Lange (1932 Abstracts, p. 650), Rosenzweig (*Electrical Review*, 1939, p. 192), Mohr (3829 of 1937), & Pierce (2756 of 1936)].—O. Schäfer. (*Arch. f. Tech. Messen*, June 1942, Part 132, J 8336-1, Sheet T62.) The literature reference for the two-hexode circuit of Fig. 3 should be "4," not "1."

3054. OUTPUT POWER METER [Type 783-A: up to 100 Watts].—General Radio. (*Review Scient. Instr.*, June 1942, Vol. 13, No. 6, pp. 271–272.)

3055. ON THE MEASUREMENT OF GROUND CONDUCTIVITY [Simplified "Rotating Dipole" Technique, applicable also to Field-Strength Measuring Apparatus in general], *and* A NEW CONDUCTIVITY METER.—Grosskopf, Vogt, Pützer. (*See* 2955 & 2956.)

3056. REMARK ON THE MUTUAL INDUCTANCE OF COAXIAL CIRCULAR RINGS.—Rogowski. (*See* 2972.)

3057. THE VIBRATING QUARTZ IN COMMUNICATIONS TECHNIQUE: PART I.—von Beckerath. (*See* 2973.)

3058. THE USE OF X-RAYS IN THE PRODUCTION OF PIEZO-QUARTZ CRYSTALS.—V. I. Arkharov. (*Journ. of Tech. Phys.* [in Russian], No. 15, Vol. 10, 1940, pp. 1268–1275.)

The various stages of the manufacture of a crystal, and errors occurring in the process, are briefly discussed. Methods making use of X-rays are then proposed to facilitate the following operations:—(1) the orientation of the crystal for cutting into layers perpendicular to the optical axis; (2) marking off the electrical axes on the surface of the layer (prior to cutting into blocks), and (3) checking the quality of the plates and detecting the distortion which may have occurred in the plate in cutting it off from the block. Further possible uses of the X-ray technique in the production of crystals are also indicated.

3059. THE X-RAY GONIOMETRIC APPARATUS FOR CORRECTING THE CUTTING OF QUARTZ CRYSTALS INTO LAYERS.—V. I. Arkharov & V. S. Averkiev. (*Journ. of Tech. Phys.* [in Russian], No. 15, Vol. 10, 1940, pp. 1276–1280.)

Continuing the above work, a description is given of the apparatus developed by the authors for increasing the accuracy of crystal orientation when the crystal is cut into layers perpendicular to the optical axis. The crystal is oriented to a first approximation by one of the usual methods, and clamped in the special goniometric clamp (Fig. 1) of the sawing table. The clamp is then transferred to an X-ray installation (Figs. 2 & 3) and further orientation is effected by finding the reflection of monochromatic X-rays from the base plane of the crystal. To obtain this reflection, the clamp frame can be rotated about two perpendicular axes. The frame is then fixed in the desired position and the clamp transferred back to the sawing table. It is claimed that when this method is used the maximum deviation in the orientation of the crystal from an average value does not exceed 10–12 min. The quadratic error of several orientations does not exceed 5 min.

3060. High-Speed Limit Bridge [for Production Testing of Condensers & Resistances: High/Low Dials set for Desired Plus/Minus Limits, Instantaneous "Magic Eye" Indication].—Industrial Instruments. (*Review Scient. Instr.*, May 1942, Vol. 13, No. 5, p. 237.)

3061. Kelvin-Wheatstone Bridge [Range 0.00001 Ohm to 11 Megohms].—Shallcross Company. (*Gen. Elec. Review*, May 1942, Vol. 45, No. 5, p. 304.)

3062. Direct Pen Recording of Galvanometer Deflections [Pen-on-Paper Records by Moving-Photocell Device].—Pompeo & Penther. (*See* 3179.)

3063. Modern Testing Equipment for Individual Coils [Rapid Methods of detecting Short-Circuited Turns, counting Number of Turns, testing Correct Sequence of Winding & Insulating Layers].—H. Poleck. (*Arch. f. Tech. Messen*, July 1942, Part 133, V 3526-2, Sheets T65–66.)

3064. Transient Peak Voltmeter [a "Unique" Instrument indicating (for about 30 Seconds after Its Occurrence) the Peak Value of a Transient or Recurrent Voltage, with the Ease of a Recurrent-Voltage Indicator and without Necessity of recording & developing Film Traces: Use of Condenser holding Charge for Necessary Time by Isolation through Valve Blocking Circuits].—J. E. Hancock & B. R. Shepard. (*Gen. Elec. Review*, June 1942, Vol. 45, No. 6, pp. 331–333.)

3065. Vacuum-Tube Voltmeter [Type 400A: Wide Frequency Range].—Hewlett-Packard. (*Review Scient. Instr.*, June 1942, Vol. 13, No. 6, p. 270.)

3066. A Substandard D.C. Voltmeter to read 300 Kilovolts [to replace Sphere-Gap: M.C. Milliammeter with Special 160 Megohm Resistance].—F. W. Waterton. (*Journ. of Scient. Instr.*, July 1942, Vol. 19, No. 7, pp. 105–107.)

3067. High-Voltage Measurement with the Rotating Voltmeter: II [Developments from Schwenkhagen's Original (1926) Use for Atmospheric-Discharge Field-Strength Measurement to Present Time].—H. Prinz. (*Arch. f. Tech. Messen*, July 1942, Part 133, J 763-4, Sheets T72–73.) An improved design will be reported in a later paper (J 763-5).

3068. Measurement of Phase Difference with a Single Ammeter.—H. Weber. (*E.T.Z.*, 21st May 1942, Vol. 63, No. 19/20, p. 243.) For a correction to a formula *see* issue for 2nd July, No. 25/26, p. 316.

3069. The Ballistic Galvanometer: Calibration [by Determination of Its Characteristic Values: with the Help of a Standard of Mutual Inductance: of a Standard Condenser].—J. Bubert. (*Arch. f. Tech. Messen*, June 1942, Part 132, J 727-4, Sheets T57–58.)

3070. Units and Dimensions [Controversial Matter can be almost eliminated by Carefully Chosen Terminology & Notation].—E. A. Guggenheim. (*Phil. Mag.*, July 1942, Vol. 33, No. 222, pp. 479–496.) *Cf.*, for example, 1474 of May and 2541/2 of August.

SUBSIDIARY APPARATUS AND MATERIALS

3071. A Recording Paper for Field and General Use [Speeds of 300 Inches per Second & probably over: Unspoilt by Rain: Other Advantages].—Tarrant. (*Engineering*, 17th July 1942, Vol. 154, p. 54: *Nature*, 1st Aug. 1942, Vol. 150, pp. 153–154.)

3072. Ultra-Fast Cathode-Ray Oscillograph for Lightning-Arrester Research [Recording Speed of 18 000 Miles/Second].—Wade & others. (*Sci. News Letter*, 4th July 1942, Vol. 42, No. 1, p. 3.) From the General Electric Company.

3073. Apparatus for the Demonstration of Surges along Lines [Multivibrator generates 5×10^{-7} s Pulses which are Amplified and passed to Twisted Double Line, the Course of the Potential at Beginning or End of This being shown on Cathode-Ray Screen: Periodic Time Base given by Valve Oscillator which also controls the Pulse Series from Multivibrator].—Goubau. (*Hochf:tech. u. Elek:akus.*, Feb. 1942, Vol. 59, No. 2, pp. 39–40.)

3074. Methods of generating Linear Time-Base Potentials for Cathode-Ray Oscillographs: I—Fundamentals of Potential Generation [Exponential & Sinusoidal Bases]: II—Subsequent Distortion-Correction by Circuit Elements [and the Linearisation Functions for Exponential & Sinusoidal Charging].—Pieplow. (*Arch. f. Tech. Messen*, June & July 1942, Parts 132 & 133, J 834-7 & -8, Sheets T59–60 & T74.)

3075. The Effect of Crystal-Lattice Interference on the Image Formation in the Electron Microscope [Lines of Blackening in Images of Crystalline Lamellae (*e.g.* von Ardenne, 1738 of 1941) are Not an "Unknown Effect" but the Result of Primary-Ray Weakening through Lattice Interference, pointed out by Writer (4194 of 1936): Proof by Shadow-Microscopic Photographs: Connection between the Lines and Distortion of the Crystal].—Boersch. (*Zeitschr. f. Phys.*, 25th Feb. 1942, Vol. 118, No. 11/12, pp. 706–713.) *Cf.* 3076, below.

3076. The Observation of Crystalline Reflections in Electron-Microscope Images [explaining von Ardenne's "Dark Bands" as due to Bragg Reflections from Properly Oriented Crystalline Planes: Final Check by Special Experiment].—Hillier & Baker. (*Phys. Review*, 1st/15th June 1942, Vol. 61, No. 11/12, pp. 722–723.) *Cf.* Boersch, 3075, above.

3077. An Experiment in Emission Microscopy with Electrostatic Lenses.—Mahl. (*Zeitschr. f. tech. Phys.*, No. 4, Vol. 23, 1942, pp. 117–119.)

From the AEG Laboratories. The emission microscope has been neglected recently in favour of the transmission type: the writer has therefore made some exploratory tests to see the effect of the application of the high voltages, internal photography, magnetic screening, and vertical design employed for the latter instruments (and all tending to give higher resolving power) to the emission type which in the hands of Brüche & Knecht reached a resolving power of 2–3 μ. Using his electrostatic supermicroscope (3717 of 1939 [and 1570 of 1940]: *see* also reference "6") with simple changes to convert it to emission instead of transmission, he obtained resolving powers around 0.2 μ, about equal to those of an optical microscope with visible light: he has no doubt that this result could be improved on considerably by better adjustment and design. At the same time Mecklenburg, with a specially constructed emission-type instrument, has obtained a resolving power of 100 mμ (as described in Ramsauer's newly published book, reference "7"). A footnote acknowledges the recently published letter from Boersch (1773 of June) announcing a resolving power of 70 mμ with the use of an immersion objective as employed by the present writer: and mentions that with a magnetic-type emission microscope Kinder has obtained 140 mμ (letter to appear in *Naturwissenschaften*).

3078. Ultimate Resolving Power of the Electron Microscope [prompted by Recent Attainment of Powers approaching 30 A.U: Theoretical Limit due to Diffraction Only found to be about ½ to 2 A.U. for Most Atoms: More Serious Restriction is Necessity for Contrast sufficient to register on Photographic Plate (Minimum Atomic Number for 60 keV found to be about 7: *cf.* Hillier, 797 of March): Contrast Limitation disappears if Dark-Field Illumination is used].—Schiff. (*Phys. Review*, 1st/15th June 1942, Vol. 61, No. 11/12, pp. 721–722.) *Cf.* 2064 of July.

3079. On the Intensity Relations in the Electron Microscope: Part I—The Blackening of Photographic Plates by Electron Rays.—von Borries. (*Physik. Zeitschr.*, 20th June 1942, Vol. 43, No. 11/12, pp. 190–204 and Plate.)

Author's summary:—"For 11 different emulsions and for volt-velocities from 12.8 to 220 kv, the blackening as a function of the incident electron density is measured and expressed in tables of curves. Similar investigations were made later on 5 other emulsions at 18 kv and 70 kv. The electronic blackening curves thus obtained are compared with those given by the same emulsions on exposure to light. From the measurements, the working density of the incident electrons necessary for the production of a given blackening is derived: these densities are given in further curve-families, as a function of ray voltage, for the particular degree of blackening $S=0.2$ and $S=1$ [it is pointed out on p. 199 that the range between 0.2 and 1 is of special importance for electron microscopy at high resolving powers, as was found by measurements on the blackening in a number of good photographs]. A pronounced minimum is shown in these curves (Figs. 12–17) at voltages between 30 and 80 kv. These optimum voltages are found in a first approximation to be dependent on the weight per cm² of the sensitive layer [obtained by weighing the plate with and without the layer], and lie in the region where the practical penetration depth, g/cm^2, of the electrons is equal to the layer weight [Fig. 18, where both quantities are shown as a function of the ray voltage: "thus to a first approximation the optimum voltage for an emulsion is that at which the practical electron penetration depth is equal to the layer thickness of the emulsion"]. It is also found that the X-rays set up in the layer itself do not contribute noticeably to the blackening, and that at high ray voltages the blackening action of the electrons can be increased by the introduction, in front of the layer, of a thin foil." The use of such foils may attain practical importance: to avoid loss of resolving power the foil must be carefully placed in full contact with the layer, and the material must be of high specific gravity so that the transverse paths of the electrons may be short. They can serve simultaneously to make the plates insensitive to light. *Cf.* 3080, below.

3080. The Photographic Action of Electrons in the Range between 40 and 212 Kilovolts [Measurements on Eastman Medium Lantern-Slide Plates (and Comparison with German Results): Sensitivity Peak near 100 kV followed by Rapid Drop, so that Effective Sensitivity at Higher Voltages can be Increased by (*e.g.*) Gold or Silver "Intensifying Screen"].—Baker, Ramberg, & Hillier. (*Journ. Applied Phys.*, July 1942, Vol. 13, No. 7, pp. 450–456.) *Cf.* von Borries, 3079, above.

3081. The Marking of Preparation-Carriers for the Electron Microscope [Defect of the Circular-Aperture Carrier (otherwise the Best) is Absence of Sign for Orienting: Provision of a Chip at Edge of Aperture, projecting into Image Field].—Frey. (*Zeitschr. f. tech. Phys.*, No. 3, Vol. 23, 1942, p. 82.)

3082. On the Spatial Measurement of Objects with the Electron Microscope [Derivation of Formulae for Determination of Space Coordinates of Object Points from Stereophotographic Images: Estimate of Reliability by Application to Siemens Chromium-Smoke Photographs].—Gotthardt. (*Zeitschr. f. Phys.*, 25th Feb. 1942, Vol. 118, No. 11/12, pp. 714–717.)

An earlier letter (Eitel & Gotthardt, *Naturwiss.*, Vol. 28, 1940, p. 367 onwards) is referred to: also a paper by H. O. Müller, "Measurement of the Depth of Supermicroscopic Objects," to appear in *Kolloid-Zeitschrift*.

3083. Auxiliary Apparatus for counting Particles in the Slit-Ultramicroscope.—Spengler & Hirschmüller. (*Sci. Abstracts*, Sec. A, April 1942, Vol. 45, No. 532, p. 126.)

3084. NEW ELECTRON SPECTROMETER MAY IDENTIFY MOLECULES [Composition & Properties of Electron-Microscopic Objects examined].—Prebus. (*Sci. News Letter*, 27th June 1942, Vol. 41, No. 26, p. 403: *Science*, 26th June 1942, Vol. 95, Supp. p. 8.)

3085. THE FATIGUE EFFECT IN LUMINESCENT MATERIALS [under Ultra-Violet Irradiation: Distinction between Fatigue & Phosphorescence Decay: Comparison with Fatigue in Selenium Photoelements (Lange, Bergman): Experimental Investigation of Fatigue & Recovery in Solids (including Zinc Silicate) & Liquids: Sulphides alone show No Fatigue: Tests on Zinc Silicate with Cathode Rays: etc.].—Beese & Marden. (*Journ. Opt. Soc. Am.*, June 1942, Vol. 32, No. 6, pp. 317–323.)

3086. ON THE LAW OF LUMINESCENCE DECAY OF COMPLEX MOLECULES.—Tumerman. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 5, Vol. 11, 1941, pp. 515–529.)

An experimental investigation was carried out to determine the law of the decay of luminescence for solutions of complex organic substances at temperatures from +20° to −107°C. The theory of fluorometric methods (*see*, for example, 4097 of 1938) is discussed, and a detailed description of the apparatus used is given. Experiments have shown that at comparatively high (room) temperatures the law of decay can be represented with sufficient accuracy by an exponential function (23). With a fall of temperature a considerable prolongation of the excitation state of the molecules was observed. It was also found that the exponential decay was preceded by a "dark pause" during which the reconstruction of molecules after the absorption of light was presumably taking place. The addition of extinguishers such as KI or aniline, in very weak concentrations, sharply decreases the duration of the dark pause and makes the law of decay, as well as the duration of the excitation state of the molecules, almost independent of temperature.

3087. THE DECAY OF ULTRA-VIOLET PHOSPHORESCENCE OF NaCl CRYSTALS WITH COLOURED SUBSTRUCTURE.—D'yachenko & Selegenev. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 5, Vol. 11, 1941, pp. 530–535.)

It is known that the decay of ultra-violet phosphorescence of NaCl crystals, which have been subjected to the action of X-rays or ultra-violet rays, has two components, one of which decays quickly and the other slowly. An account is given of experiments in which processes relating to the first component were investigated.

3088. THE USE OF ELKONITE [Mallory Long-Life Electrode Material, Tungsten-Copper] FOR CYCLOTRON ION SOURCES.—Curtis & Bender. (*Review Scient. Instr.*, June 1942, Vol. 13, No. 6, p. 266.) When the arc capillary was made of copper, the latter soon melted or sputtered under the intense ion bombardment.

3089. EMISSION-REGULATING CIRCUIT FOR AN IONISATION GAUGE [using Principle of Control employed by Ridenour & Lampson (3132 of 1937) but utilising "Valuable Control Characteristics" of Small Gas-Filled Tetrode, RCA-2050 (4279 of 1940)].—Nelson & Wing. (*Review Scient. Instr.*, May 1942, Vol. 13, No. 5, pp. 215–217.)

3090. A [Commercial] FLUORESCENT LAMP AS A VOLTAGE STABILISER [successfully used for Supply to Filaments of Ionisation Gauge & of Magnetron Valve].—Parratt & Stephenson. (*Review Scient. Instr.*, May 1942, Vol. 13, No. 5, pp. 233–234.)

3091. METHOD FOR THE STABILISATION OF HIGH VOLTAGES [particularly for Atmospheric-Pressure Geiger Counters requiring Voltages above 7000 Volts, where it is preferable to Stabilise on the L.T. Side: Battery-Driven Alternator as the Ideal Solution: Successful Prolonged Use of Lightly Loaded Asynchronous Induction Motor instead of Batteries or Synchronous Motor: Calculation of Voltage Fluctuations].—Occhialini. (*La Ricerca Scient.*, June/July 1942, Vol. 13, No. 6/7, pp. 319–321.)

3092. A VOLTAGE REGULATOR [D.C. Regulating Circuit using Stabilovolt Tube in Special Circuit including Small Rectifier, enabling Much Greater Loads to be handled than with Normal Arrangement].—Berg. (*Journ. of Scient. Instr.*, July 1942, Vol. 19, No. 7, pp. 108–109.)

3093. SEALING MICA TO GLASS OR METAL TO FORM A VACUUM-TIGHT JOINT.—Donal. (*Review Scient. Instr.*, June 1942, Vol. 13, No. 6, pp. 266–267.)

3094. SEALING QUARTZ WINDOWS ON PYREX TUBES.—Benson. (*Review Scient. Instr.*, June 1942, Vol. 13, No. 6, pp. 267–269.)

3095. DUO-SEAL VACUUM PUMPS [using Little Oil].—Welch Scientific. (*Review Scient. Instr.*, May 1942, Vol. 13, No. 5, pp. 235–236.)

3096. ON THE SERVICEABILITY OF BUNA RUBBER [and Perbunan] FOR HIGH-VACUUM WASHERS.—Jaeckel & Kammerer. (*Zeitschr. f. tech. Phys.*, No. 4, Vol. 23, 1942, pp. 85–88.)

It is thought in many quarters that buna rubbers are unsuitable for such use, chiefly because they sometimes smell strongly and are thus considered likely to give out gases into the vacuum. The present tests, however, show that it is possible to prepare qualities of buna which are just as good in this respect as natural rubber. And since perbunan, in particular, stands up to time, temperature, and oil better than natural rubber, it should be considered not merely as equal, but as superior, to the latter material.

3097. STATISTICAL THEORY OF RUBBER.—Wall. (*Journ. Applied Phys.*, May 1942, Vol. 13, No. 5, p. 304: summary only.)

3098. THE STUDY OF POLYMERS: PART V [Survey on the Crystallisation of Rubber].—Lysenko. (*Journ. of Tech. Phys.* [in Russian], No. 14, Vol. 10, 1940, pp. 1151–1166.) With 57 literature references: to be continued.

3099. NEW HIGH-TEMPERATURE "S-110" INSULATING VARNISH [standing Operating Temperatures of 250° C and Higher].—Sterling Varnish. (*Gen. Elec. Review*, June 1942, Vol. 45, No. 6, pp. 363–364.)

3100. INFRA-RED HEATING: CANADIAN DEVELOPMENTS AND NEW APPLICATIONS REVIEWED, *and* INFRA-RED BAKING.—Ackland: Seymour. (*Electrician*, 31st July 1942, Vol. 129, pp. 108–109: summary only: 21st Aug. 1942, pp. 200–204.) *Cf.* 1200 of 1941 and 1789 of June.

3101. PROPERTIES AND CHARACTERISTICS OF FORMEX WIRE [for Magnets: insulated with Film of Synthetic Resin of Polyvinyl Acetal Type].—Curtin. (*Gen. Elec. Review*, May 1942, Vol. 45, No. 5, pp. 285–292.) *See* also *Electrician*, 7th Aug. 1942, Vol. 129, pp. 147–151.

3102. THERMAL BREAKDOWN IN SUPER-TENSION CABLES [including the Importance of the Dielectric-Loss Temperature Coefficient].—Beavis. (*Nature*, 27th June 1942, Vol. 149, p. 737: summary only.)

3103. FRICTIONAL PHENOMENA: IX—APPLICATIONS OF LIQUID VISCOSITY TO ELECTRICAL INSULATING LIQUIDS, PARTICULARLY IN HIGH-VOLTAGE CABLES.—Gemant. (*Journ. Applied Phys.*, May 1942, Vol. 13, No. 5, pp. 290–299.) For previous reference to these researches *see* 3510 of 1941 and 1503 of May.

3104. SYMPOSIUM ON INSULATING OILS.—I.E.E. (*Nature*, 20th June 1942, Vol. 149, pp. 703–704: summaries of five papers.)

3105. HIGH-VOLTAGE OIL CAPACITORS [Heavy Duty, Type '20].—Aerovox. (*Review Scient. Instr.*, June 1942, Vol. 13, No. 6, p. 270.)

3106. DECADE CAPACITOR [Any Value from 0.01 to 11.1 μF in 0.01 μF Steps (or Other Ranges) by twisting Three Knobs].—Industrial Instruments. (*Gen. Elec. Review*, Jan. 1942, Vol. 45, No. 1, p. 65.)

3107. THE THEORY OF ABSOLUTE REACTION RATES AND THE CONDUCTIVITY OF HYDROCARBONS AT HIGH FIELD STRENGTHS [in connection with Plumley's Suggestion (3508 of 1941) that Conductivity of Heptane is due to Field-Facilitated Ionisation].—Davidson. (*Phys. Review*, 1st/15th June 1942, Vol. 61, No. 11/12, p. 721.)

3108. THE ORDERED STATE OF THE IONS IN LIQUID ELECTROLYTIC SOLUTIONS [Survey bringing Recent Results in Electrolyte Research into Relation with Interionic Theory: including H.F. Conductivity, Frequency-Dependence of Dielectric Constant, etc.].—Falkenhagen. (*Physik. Zeitschr.*, 20th June 1942, Vol. 43, No. 11/12, pp. 170–190.) With a very large number of literature references.

3109. ON THE MEASUREMENT OF GALVANO-MAGNETIC EFFECTS IN DIELECTRICS.—Davidenko & Shmushkevich. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 5, Vol. 11, 1941, pp. 486–488.)

With reference to a paper by Pruzhinina-Granovskaya on the variation in the resistance of a dielectric (mica) in a magnetic field (1770 [and 1209] of 1941), it is pointed out that in investigating the Hall effect it is necessary to use mica samples whose over-all dimensions satisfy certain conditions. A number of other critical remarks are also made.

3110. ON THE NATURE OF ADDITIONAL CONDUCTIVITY OF DIELECTRICS IN STRONG FIELDS.—Venderovich, Kolomoytsev, & Sinyakov. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 4, Vol. 11, 1941, pp. 448–454.)

Various theories have been proposed in connection with the phenomenon first observed by Poole in 1916 [*see* for example 1209 of 1941], that the conductivity of dielectrics increases with the increase in the field strength. Some of these theories have been tested experimentally by the authors and the following main conclusions were reached: (a) Neglect of the polarisation e.m.f. in calculations of the conductivity may lead to serious mistakes, but does not account completely for the Poole effect. (b) The condition that the total conductivity of a dielectric should be equal to the sum of ion and electron conductivities is satisfied by Frenkel's formula (1711 of 1939) for the electron-current component more adequately than by the one proposed by Poole. (c) Measurements of transverse conductivity in a NaCl crystal have shown that its value is not affected when a strong longitudinal field is applied to the crystal. This means that Poole's effect cannot be explained by the concentration of electrons in the conductivity zone.

3111. THE ELECTRICAL BREAKDOWN OF INSULATING CRYSTALS.—Vorobjev. (*Journ. of Tech. Phys.* [in Russian], No. 14, Vol. 10, 1940, pp. 1183–1188.) A German version was dealt with in 852 of March.

3112. THERMAL CONDUCTIVITY OF PARAMAGNETIC DIELECTRICS AT LOW TEMPERATURES, *and* THERMAL CONDUCTIVITY OF DIELECTRICS AT TEMPERATURES ABOVE THE DEBYE TEMPERATURE.—Pomeranchuk. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 2/3, Vol. 11, 1941, pp. 226–245: pp. 246–254.) *Cf.* 1802 of June.

3113. THE ELECTRICAL CONDUCTIVITY OF ALUMINA AT HIGH TEMPERATURES.—Shul'man. (*Journ. of Tech. Phys.* [in Russian], No. 14, Vol. 10, 1940, pp. 1173–1182.)

Experiments were conducted with Al_2O_3 at temperatures from 700°K to 2200°K. A number of experimental curves and Debye spectrograms are shown, and a theoretical interpretation of the results obtained is given: a comparison is made with conclusions reached by other investigators.

3114. Researches on Native Siliciferous Materials capable of Application in the Manufacture of Refractories.—Giannone & others. (*La Ricerca Scient.*, June/July 1942, Vol. 13, No. 6/7, pp. 294–307.)

3115. Kyanite from Home and Abroad [for Refractories & Electrical Porcelain Industries].—(*Review Scient. Instr.*, June 1942, Vol. 13, No. 6, p. 274.)

3116. Limits of Performance of Hot-Cathode Converter Tubes [Survey]. — Kluge. (*E.T.Z.*, 7th May 1942, Vol. 63, No. 17/18, pp. 201–207.)

Author's summary :—" The introduction contains a compressed survey of modern ideas on the surface structure and emission mechanism of three typical types of hot cathode, the solid (tungsten) cathode and the thoriated and barium-oxide cathodes. The highest working-current densities for prolonged service are attainable with the thoriated type, if a sufficiently high pressure of inert-gas filling is provided. The explanation of the mode of action of the barium-oxide cathode is based on the semiconducting nature of the formed oxide layer : the neutral barium atoms anchored in the ionic lattice of the barium-oxide layer are just as important for the emission mechanism as the atoms adsorbed at the surface. The practical limit of current output lies today, for single-anode tubes, at about 200 A peak current [though tubes have been constructed to carry 1000 A : reference " 6 "] for conditions where resistance to arc-back plays a subordinate part.

" When voltage rectification is the predominant interest, alternating voltages up to 30 kV peak values can be rectified by mercury-vapour tubes over a limited range of external temperature. Extremely high values of blocking voltage are attained with cascade tubes. With the new designs of these (Fig. 5), voltages of 150–200 kV can be reached if the current loading can be kept down (0.01–0.1 A). With the so-called ' high-current ' tubes in the new iron containers particularly low internal losses have been achieved : low-voltage arcs burning at 5–6 V are obtained here [§5]. In the field of tubes with control grids, a new design of high-power thyratron is described, having a peak blocking voltage of 15 kV and a peak current of 150 A. In considering the power necessary for control (§9) the growing importance of the screen-grid thyratron and of the magnetically controlled tubes is pointed out. Finally it is estimated that the life of the tubes described can be increased, if the design is sufficiently spacious, by the adoption of multiple cathodes : an example of such a dual-cathode tube [in which the spare cathode is shielded from ion bombardment by a rotatable cover : Fig. 8] is illustrated and described." Hull's " dispenser " cathode (3961 of 1939) is mentioned as another method of obtaining long life.

3117. Anisotropy of a Free Path of Electrons in Plasma, disturbed by a Low Magnetic Field.—Fataliev. (*Journn. of Exp. & Theoret. Phys.* [in Russian], No. 2/3, Vol. 11, 1941, pp. 290–299.)

3118. A New Method for the Excitation of Rarefied Gases by Ultra-Short Electromagnetic Waves.—Goudet & others. (*See* 2985.)

3119. Current Density at the Cathode of a Glow Discharge through Gases [Results by New Methods : Aston's Relation holds good also at Low Pressures : etc.].—Chaudhuri & Baaqui. (*Current Science* [Bangalore], May 1942, Vol. 11, No. 5, pp. 188–189.)

3120. The Flash-Over Voltage of Insulators in Air at Increased Pressures [up to 4 Atmospheres].—Weber. (*Arch. f. Elektrot.*, 31st Dec. 1941, Vol. 35, No. 12, pp. 756–758.)

3121. The Variation of Flash-Over Voltage of High-Tension Insulators in the Normal Range of Atmospheric Humidity.—Pfestorf & Strauss. (*Arch. f. Elektrot.*, 31st Dec. 1941, Vol. 35, No. 12, pp. 740–751.)

3122. The Change of Sign of the Rectification Coefficient of Copper-Oxide Rectifiers at High Temperatures.—Dunaev. (*Journ. of Tech. Phys.* [in Russian], No. 15, Vol. 10, 1940, p. 1305.)

It has been observed by the author that at temperatures from 320°C to 360°C the reverse current, increasing with temperature, actually exceeds the forward current, as can be seen from the curves of Fig. 1. It is suggested that this effect is due to the change of sign of the conductivity of Cu_2O.

3123. The Inward Migration of Electrons in Alkali-Halide Crystals [with Application to Hilsch & Pohl's Model of a Barrier-Layer Rectifier].—Karabascheff. (*Zeitschr. f. Phys.*, 25th Feb. 1942, Vol. 118, No. 11/12, pp. 718–726.)

See Hilsch & Pohl's paper on the control of electron currents with a " three-electrode " crystal, 1683 of 1939. Author's summary :—" In the first part, two facts are found experimentally : (1) the subsidiary current linked with the inward migration of the electrons increases in proportion to time, and (2) the rate of current increase, di/dt, increases with the square of the potential. In the second part both these facts are interpreted on the basis of the mechanism of electron diffusion in electric fields, and represented quantitatively by equations 6′ and 7."

3124. Selenium Rectifiers for Repeater Stations [in Swiss Telephone System].—Jacot. (*E.T.Z.*, 7th May 1942, Vol. 63, No. 17/18, pp. 214–215 : summary only, including comparison with the rectifiers used by the German P.O.)

3125. On the Electrical Properties of Lead Sulphide [and its Position in the Classification of Semiconductors]. — Hintenberger. (*Zeitschr. f. Phys.*, 31st March 1942, Vol. 119, No. 1/2, pp. 1–21.) Full report on the work dealt with in 1761 of 1941.

3126. ON THE TEMPERATURE-DEPENDENCE OF THE RESISTANCE OF SOME ELECTRICAL CONDUCTORS AND SEMICONDUCTORS [Derivation of Equations for Tungsten Filaments & Carbon Filaments, from Experimental Curves].—Voelkner. (*Zeitschr. f. tech. Phys.*, No. 4, Vol. 23, 1942, pp. 100–103.) Presumably to be continued, since the introduction mentions similar treatment of chemically pure iron, "Silundum," and a sulphide of copper.

3127. NEGATIVE RESISTANCES: II—THEORY [including Application of Formula to Uranium Dioxide Cylinder].—Amrein. (*See* 2976.)

3128. A PULSE GENERATOR FOR CIRCUIT TESTING [for Circuits used with Geiger Counters, Ionisation Chambers, etc: Independent Variation of Duration (40 μs to 3 ms), Voltage (0 to 150 V), & Pulses per Second (0.8 to 30 000)].—Manning & Young. (*Review Scient. Instr.*, May 1942, Vol. 13, No. 5, p. 234.)

3129. THYRATRON CONTROL OF ALTERNATING-CURRENT SWITCHING [at Any Desired Point in the Voltage Wave].—Knight. (*Journ. Inst. Eng. Australia*, April 1942, Vol. 14, No. 4, pp. 94–100.)

3130. SPECIAL CIRCUIT FOR VIBRATING D.C./A.C. CONVERTERS.—Schmidt & Widakovitch. (*Génie Civil*, 1st July 1942, Vol. 119, No. 16, p. 204.) French Patent 842 433.

3131. ELECTRICAL CONTACTS FOR INSTRUMENTS [the Question of Silver Contacts near Vulcanised Rubber].—Bayley: Chaston. (*Journ. of Scient. Instr.*, July 1942, Vol. 19, No. 7, p. 111.) Letter prompted by 2133 of July. For another letter, on the question of sulphur in some neoprene mixings, *see* issue for August, No. 8, p. 124 (Dawson).

3132. THE TESTING OF CONTACT PRESSURES.—Werner. (*E.T.Z.*, 7th May 1942, Vol. 63, No. 17/18, p. 217.) Summary of the paper dealt with in 861 of March.

3133. THE MANUFACTURE OF PERMANENT MAGNETS MADE OF HEAT-AGGLOMERATED POWDER OF IRON-NICKEL-ALUMINIUM ALLOYS [and Their Advantages over Solid Mishima-Honda Magnets].—Holop. (*Génie Civil*, 3rd/10th Jan. 1942, Vol. 119, No. 1/2, p. 18: summary from *Stahl u. Eisen.*)

3134. PROPERTIES OF HIGH PURITY IRON [Total Impurities 0.01% or Less: Max. Permeabilities up to 88 400].—Cleaves & Hiegel. (*Journ. of Res. of Nat. Bur. of Stds.*, May 1942, Vol. 28, No. 5, pp. 643–667.) The results confirm the belief that such magnetic properties as permeability and coercivity are influenced by factors other than purity, and hence are not satisfactory criteria of purity in iron.

3135. PERMANENT MAGNETS OF GREAT PULLING POWER.—Snoek. (*E.T.Z.*, 7th May 1942, Vol. 63, No. 17/18, p. 215: summary, from *Philips tech. Rundschau*, Vol. 5, 1940, p. 196 onwards.)

For a given induction $\mathfrak{B}$ the pull K of a magnet is proportional to the pulling-surface area O: $K = \mathfrak{B}^2 O/8\pi = \phi/8\pi O$, when ϕ is the flux through the armature. Since the induction remains constant with a true-to-scale enlargement or reduction of the magnet, the pull will alter in proportion to the square of the dimensions while the weight varies with the cube: the pull/weight ratio will therefore improve as the dimensions decrease, subject to the limitations of precision of workmanship. In practice the ratio reaches a max. value at certain dimensions, and this maximum is approximately determined by the material, and forms a measure of the latter's quality. By the use of modern permanent-magnet alloys with high coercive force and remanence (of the order of 550 oersteds and 12 000 gauss respectively) and of a 50/50 iron-copper alloy with high saturation for the pole-pieces, together with a skilful design of the magnet system (particularly to give a concentration of the lines of force at the surface of contact), very high values for this ratio have been attained. With a magnet-steel cube of 4 mm edge and 0.47 gm weight a pull of 1.65 kg was found, giving a ratio of 3500. By a change in design and size this was increased to 5000, the pull being 65 kg and the weight of the magnet steel 13 gm. The construction of such magnet systems, including the determination of the optimium air-gap by gradual grinding-away, is described in the original paper. For another Philips paper, on new steels, *see* 2138 of July.

STATIONS, DESIGN AND OPERATION

3136. ARRANGEMENT FOR COMMUNICATION BETWEEN A TRAILING AIRCRAFT AND A TRAILED AIRCRAFT [Transmitting & Receiving Sets in Each are connected to Metal Fuselage & to the (Insulated) Towing Cable].—Bergtold. (*Hochf:tech. u. Elek:akus.*, Feb. 1942, Vol. 59, No. 2, p. 61.) Telefunken Patent, No. 708 946.

3137. THE LAW [of 1st October 1941] REORGANISING FRENCH NATIONAL BROADCASTING.—(*Génie Civil*, 3rd/10th Jan. 1942, Vol. 119, No. 1/2, pp. 13–14.)

GENERAL PHYSICAL ARTICLES

3138. ON THE DISTRIBUTION OF ELECTRICAL CHARGES ON THE SURFACE OF A THIN OPEN CONDUCTOR.—Grünberg. (*See* 2957.)

3139. A RELATIVITY QUERY [Einstein's Light Paths given Very Simply by Fermat's & Least-Action Principles, respectively, by assuming Medium to be Very Slightly Aelotropic: Previous Publication ?].—Houstoun. (*Nature*, 4th July 1942, Vol. 150, p. 25.)

3140. ON THE CENTRIFUGING OF ELECTRONS [Remarks on Work of Wolf (2896 of 1941 and back reference) & others: the Dry-Plate Rectifier as Another Possible Object for

Test: Experiments with Accelerations up to 450*g* give Negative Results].—Klarmann. (*Naturwiss.*, 3rd July 1942, Vol. 30, No. 27, p. 424.) "Anyhow, in practice there is no need to fear an effect of centrifugal force on the characteristic curves of dry-plate rectifiers."

3141. EIGENFUNCTIONS IN HEISENBERG APPROXIMATION OF THE TWO-ELECTRONS PROBLEM [and Application to the Helium States].—Pincherle. (*Phil. Mag.*, June 1942, Vol. 33, No. 221, pp. 462–466.)

3142. THE FARADAY EFFECT IN ELECTRON GAS [Quantum-Mechanical Calculation of Rotation of Polarisation Plane in Metals].—Kovadlo. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 2/3, Vol. 11, 1941, pp. 312–317.)

3143. ON THE CALCULATION OF THE DISTRIBUTION FUNCTION [for Particles confined to a Large Circle, for Repulsive Potential of Long Range: Calculation from Boltzmann-Gibbs Equation, & Comparison with Debye-Hückel (Electrolyte) Equation].—Ufford & Wigner. (*Phys. Review*, 1st/15th April 1942, Vol. 61, No. 7/8, pp. 524–527.)

3144. STRUCTURE AND CAPACITY OF ELECTRICAL DOUBLE LAYER [Theory of Structure of Diffuse Double Layer, based on Dipole Properties or Dielectric Constants of Ions & Solvent: Application to Capacity of Mercury-Solution Interfaces].—Bikerman. (*Phil. Mag.*, May 1942, Vol. 33, No. 220, pp. 384–397.)

3145. ELECTROMAGNETIC DIMENSIONS AND UNITS [and the Influence of the Medium on the Magnetic Moment].—Palacios y Martinez: Sommerfeld. (*Physik. Zeitschr.*, Jan. 1942, Vol. 43, No. 1/2, pp. 22–24.)

3146. ON THE DEFINITION OF PERMEABILITY VALUES AND THE MAGNETIC UNITS: REMARKS ON EQUATION TECHNIQUE.—Fischer. (*Physik. Zeitschr.*, Jan. 1942, Vol. 43, No. 1/2, pp. 24–28.)

3147. UNITS AND DIMENSIONS [Controversial Matter can be almost eliminated].—Guggenheim. (*See* 3070.)

MISCELLANEOUS

3148. "THE LAPLACE TRANSFORM" [Book Review].—Widder. (*Science*, 22nd May 1942, Vol. 95, pp. 531–532.) "Contains no applications outside pure mathematics," but "could serve as a useful source in which applied mathematicians might look for the properties which they need to use."

3149. DIFFERENTIALLY CYCLICAL SETS OF FUNCTIONS: AN EXTENSION OF THE CONCEPT OF HYPERBOLIC FUNCTIONS.—Silberstein. (*Phil. Mag.*, June 1942, Vol. 33, No. 221, pp. 457–461.)

3150. ON THE DIRICHLET PROBLEM FOR THE HYPERBOLIC CASE.—Hadamard. (*Proc. Nat. Acad. Sci.*, June 1942, Vol. 28, No. 6, pp. 258–263.)

3151. THE GEOMETRY OF MATRICES.—Turnbull. (*Phil. Trans. of Roy. Soc.*, Ser. A, 30th June 1942, Vol. 239, No. 805, pp. 233–267.)

3152. HARMONIC ANALYSERS [Survey], *and* ANALYSIS OF PERIODIC FUNCTIONS BY MEANS OF EQUALLY SPACED ORDINATES [Survey, including Lübcke, Michelson-Stratton, & Vercelli Analysers].—Willers. (*Arch. f. Tech. Messen*, June & July 1942, Parts 132 & 133, V 3620-6 & 7, Sheets T53–54 & T67.)

3153. ON THE CALCULATION OF ORDINARY CORRELATION EQUATIONS.—Mitropol'ski. (*Journ. of Tech. Phys.* [in Russian], No. 15, Vol. 10, 1940, pp. 1227–1241.)

Methods are indicated for deriving and solving a correlation equation of the *h*th order (1) determining the relationship between statistical values X_2 and X_1. The discussion is illustrated by a concrete example (the relationship between the resistance to fracture by tension, and the malleability, of steel for axles).

3154. COMMENTS ON SCHUMANN'S PAPER "AN INVESTIGATION CONCERNING G.I. TAYLOR'S CORRELATION COEFFICIENT OF TURBULENCE."—Pekeris. (*See* 2977.)

3155. MODEL QUALITY CONTROL CHARTS.—Rissik. (*Engineer*, 24th & 31st July and 7th Aug. 1942, Vol. 174, pp. 65–65, 86–89, & 106–108.)

3156. SCIENCE AND THE WAR ["Committee" Decisions and the Need for Statistical Technique].—Nicol. (*Sunday Times*, 9th Aug. 1942, p. 4.) *See* also 2166 of July.

3157. SCIENTIFIC MEN IN WAR-TIME [Strategy & Tactics in the Application of Scientific Developments: Leading Article].—(*Nature*, 18th July 1942, Vol. 150, pp. 65–67.) *See* also issue of 25th July, pp. 116–117.

3158. FIRST REPORT OF WAR POLICY COMMITTEE, AMERICAN INSTITUTE OF PHYSICS: MAY 1st, 1942.—(*Review Scient. Instr.*, June 1942, Vol. 13, No. 6, pp. 245–247.)

3159. LEADING ARTICLE ON WAR-TIME NEED FOR COUNCIL OF MECHANICAL ENGINEERS, *and* AN ENGINEERS' WAR.—Anon: Hallett. (*Engineer*, 17th July 1942, Vol. 174, pp. 52–53: pp. 53–54.) For further correspondence prompted by Hallett's letter *see* issues for 24th & 31st July, pp. 74 & 96.

3160. MEMORANDUM ON ENGINEERING EDUCATION [Extracts from].—Institution of Civil Engineers. (*Engineer*, 17th July 1942, Vol. 174, pp. 57–59.)

3161. WARTIME ELECTRICAL RESEARCH [and the Differences between World Wars I and II in This Respect: etc.].—Hawkins. (*Gen. Elec. Review*, June 1942, Vol. 45, No. 6, pp. 323–325.)

3162. POST-WAR PLANNING IN RADIO TELECOMMUNICATION [Summary of I.E.E. Discussion]. —(*Nature*, 30th May 1942, Vol. 149, pp. 614–615.)

3163. ANNUAL REVIEW: ELECTRICAL DEVELOPMENTS OF 1941 [including Radio & Television].—Bartlett. (*Gen. Elec. Review*, Jan. 1942, Vol. 45, No. 1, pp. 7–58.)

3164. A BRIEF REVIEW OF THE TECHNICAL WORK OF THE BOARD OF SCIENTIFIC AND INDUSTRIAL RESEARCH.—Bhatnagar & Parthasarathy. (*Current Science* [Bangalore], April 1942, Vol. 11, No. 4, Supp. pp. 172–176.)

3165. RADIOACTIVE EXPLORATION [Analysis of Detection Methods as applied to Geophysics].—Rose. (*Sci. Abstracts*, Sec. A, May 1942, Vol. 45, No. 533, p. 152.)

"Ionisation-counting instruments form the commonest means of detection. One is described which is sensitive to 10^{-12} g Ra at a distance of several feet."

3166. PAPERS ON THE ELECTRIC ROTATING FIELD IN THE NEAR FIELD OF A TRANSMITTER [in connection with Method of Measuring the Electrical Constants of the Ground].—Grosskopf, Vogt, Pützer. (*See* 2954/6 & 3001.)

3167. DETECTION OF STEEPLY INCIDENT ELECTRICAL DISCONTINUITY SURFACES IN THE SUBSOIL, BY RADIO PROSPECTING [by the Equivalent Capacitance Process].—Fritsch & Forejt. (*Hochf:tech. u. Elek:akus.*, Feb. 1942, Vol. 59, No. 2, pp. 41–45.)

The writer begins with a short outline of the equivalent-capacitance method, already described at length (*see* 3017 of 1939 and reference "2"). The determination of the equivalent capacitance is generally carried out by the "break-off" procedure described by Schmidt (1933 Abstracts, p. 337) or by a bridge method. Recently the latter method has been used successfully, the circuit of Fig. 7 being employed. The actual apparatus takes the form of the Philips pressure-indicator Type GM 3154 (Fig. 9) with cathode-ray-tube indicator. The test aerial is an aluminium cylinder 2 m long which is mounted horizontally on a vertical wooden lath so as to be adjustable to different heights above the ground, ranging from 36 to 140 cm. A lead about 10 m long is connected to the aerial through a slide-wire stretched along the lath and clamped into contact with the aerial rod in its different positions: altering the height of the aerial, therefore, does not alter that of the lead. The other end of the latter goes to the condenser-variation pick-up of the Philips apparatus, clamped to a table, from which runs the special cable to the instrument, about 15 m away. The other pole of the condenser pick-up is earthed beneath the table, so that the condenser lies in parallel with the test aerial.

If the equivalent capacitance of the aerial is C_a, that of the connecting lines C_l, and that of a fixed known condenser C_n, the measurements made are $C_1 = C_a + C_l$, $C_2 = C_n + C_l$, and $C_3 = C_l$. Each value is measured several times, and C_a thus determined. By this procedure, the unavoidable zero-point wandering is allowed for. On the average, results are reproducible within 1%: in the most unfavourable conditions the accuracy is within 5%. Precautions as to changes in the surface layer through sunshine are mentioned. The successful tracing of the contact between Permian and Carboniferous sandstone is described.

3168. A SCIENTIFIC INVESTIGATION OF THE CLAIMS OF THE WATER-DIVINER OR "DOWSER" [Experiments with Ionisation Indicators].—(*Sci. Abstracts*, Sec. A, June 1942, Vol. 45, No. 534, p. 166.)

3169. THE USE OF X-RAYS IN THE PRODUCTION OF PIEZO-QUARTZ CRYSTALS. — Arkharov, Averkiev. (*See* 3058 & 3059.)

3170. A PUSH-PULL CIRCUIT FOR D.C. VOLTAGE AMPLIFICATION.—Kerkhof. (*See* 2982.)

3171. APPLICATIONS OF THE CATHODE-RAY OSCILLOGRAPH IN INDUSTRY: PART V—TESTS INVOLVING INDEPENDENT BASES OTHER THAN TIME.—Wilson. (*BEAMA Journal*, July 1942, Vol. 49, No. 61, pp. 182–188.) The first of this series was referred to in 1248 of April.

3172. SOME OPERATING CHARACTERISTICS OF THE WILSON CLOUD CHAMBER.—Hazen. (*Review Scient. Instr.*, June 1942, Vol. 13, No. 6, pp. 247–257.)

3173. A NEW TYPE OF ELECTRICAL ANALOGY: PART I.—Efros. (*See* 2970.)

3174. THE MEASUREMENT OF SMALL MOVEMENTS [Survey].—Staiger. (*Arch. f. Tech. Messen*, June 1942, Part 132, V 1121-1, Sheets T51–52.)

3175. KNOCK-MEASURING METHODS BASED ON PRESSURE-ACCELERATION [Recent DVL Technique].—Lichtenberger & Seeber. (*Arch. f. Tech. Messen*, July 1942, Part 133, V 8234-4, Sheet T68.)

3176. A WATER-COOLED MERCURY-VAPOUR LAMP OF HIGH LUMINOUS DENSITY.—Kern. (*See* 3046.)

3177. ELECTRO-OPTICAL PROPERTIES OF COLLOIDS [Experimental Investigation of Anomalous Effects].—Mueller & Sakmann. (*See* 3044.)

3178. APPARATUS FOR TECHNICAL STROBOSCOPY [including Use of Cathode-Ray Tubes as Light Sources for Frequencies above 5000 c/s, where Other Methods fail].—Drewell. (*Arch. f. Tech. Messen*, July 1942, Part 133, V 145-2, Sheets T63–64.)

3179. DIRECT PEN RECORDING OF GALVANOMETER DEFLECTIONS [Pen-on-Paper Records (7 cm/s) by Moving-Photocell Device: Use of Gas-Filled Tetrode, RCA-2051 (4279 of 1940)].—Pompeo & Penther. (*Review Scient. Instr.*, May 1942, Vol. 13, No. 5, pp. 218–222.) Already dealt with in 3188 of 1941.

3180. THE REPAIRING OF SELENIUM BARRIER-LAYER PHOTOCELLS BY AN ELECTRIC CURRENT.—Moldaver. (*See* 3043.)