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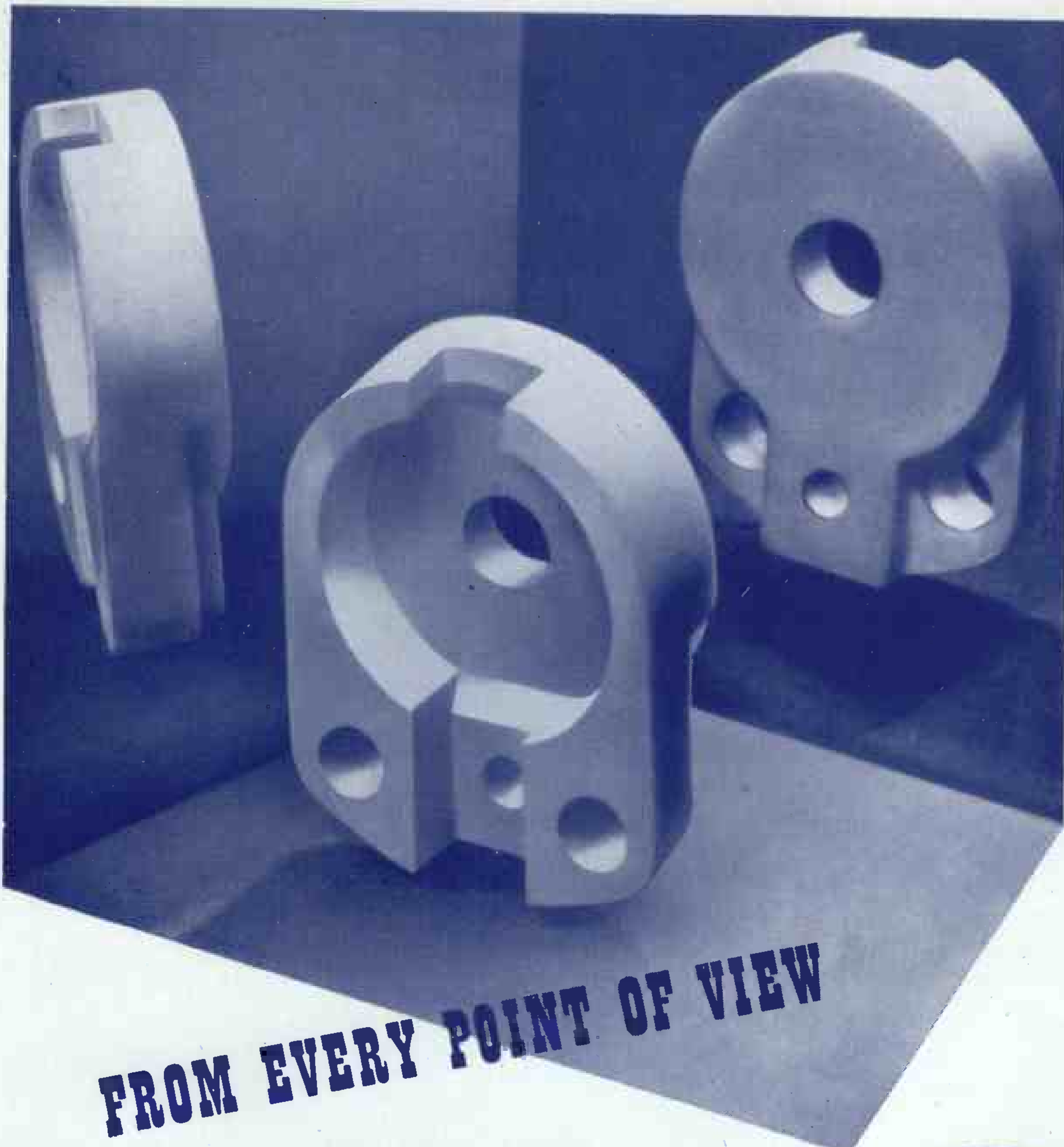

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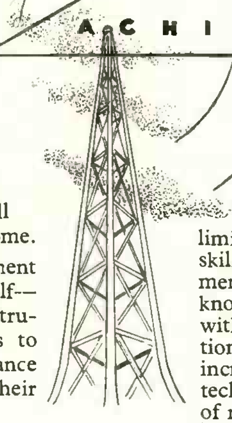

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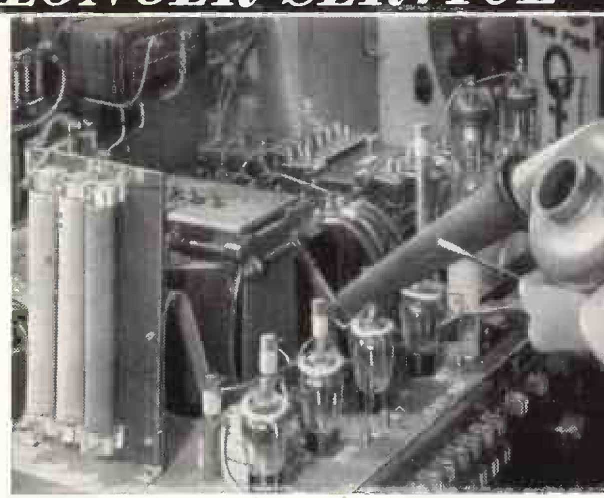

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WIRELESS ENGINEER

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

VOL. XX NOVEMBER, 1943 No. 242

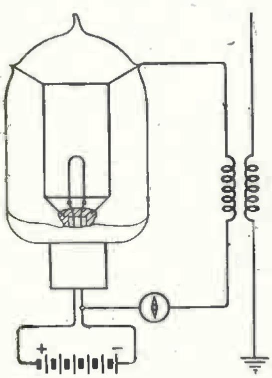
Early Radio Inventions

AT a special session of the American Institute of Electrical Engineers on January 27th, the 1942 Edison Medal, the highest award of the Institute, was presented to Edwin H. Armstrong, professor of electrical engineering at Columbia University, New York. The presentation address was made by Professor Alan Hazeltine; this address and Professor Armstrong's reply are published in the April number of *Electrical Engineering*. No one with a knowledge of the history of the development of radio science would question for a moment the outstanding achievements of Armstrong which amply qualify him for the distinction thus conferred upon him. In making the presentation address on such an occasion the speaker would naturally concentrate on the achievements of the recipient, but the following extract from the address surely shows a lack of generosity to those workers who filled in the gap between Edison and Armstrong.

"If we review," says Hazeltine, "the advances in electrical technology in the past 25 years, one development stands out from all others, electronics, and specifically the application of the three-electrode vacuum tube. It is appropriate to recall here that the original electronic tube was the two-electrode tube of Edison, in whose honour the Edison Medal was established. Others subsequently applied this "Edison effect" in radio detection and introduced the control electrode, but the action was viewed as that of a trigger, as in the modern thyratron, which is of limited application. The real foundation for the unlimited development which we have witnessed was laid by Doctor Edwin Howard Armstrong in an article published in the *Electrical World* in December, 1914. Here the common engineering tool, the characteristic curve, was employed for the first time to show how the tube amplifies, and the theory was substantiated by oscillograms which Armstrong had taken. The previously mysterious action of the tube as a rectifying detector with a grid capacitor was elucidated in the same way. . . . I also remember the excitement produced a few months later by Armstrong's first paper before the Institute of Radio Engineers on his feed-back circuit, which employed this theory to give undreamed-of amplification of weak radio signals and permitted the general use of heterodyne reception by providing for the first time a source of continuous oscillations of frequencies as high as any then used for radio transmision." The way in which Prof. Hazeltine skates lightly over the work of others previous to Armstrong is probably explained when he says: "These publications of Armstrong started my own work in radio, and profoundly affected my subsequent career, as they have affected the careers of many others. It is rather hard now to take ourselves back to conditions in radio prior to Armstrong." This is undoubtedly so in the case of the vast majority of those now interested in radio; they will find it difficult to imagine a world in which a three-electrode valve was unknown, and equally difficult to say who laid "the real foundation for the unlimited development which we have witnessed," an achievement the credit for which is given by Hazeltine to Armstrong.

Edison discovered—to quote his own words

—"that if a conducting substance is interposed anywhere in the vacuous space within the globe of an incandescent electric lamp, and said conducting substance is connected outside of the lamp with one terminal, preferably the positive one, of the incandescent conductor, a portion of the current will, when the lamp is in operation, pass through the shunt circuit thus formed, which shunt includes a portion of the vacuous space within the lamp. The current I have found to be proportional to the degree of incandescence of the conductor, or candle-power, of the lamp." Except for the words "preferably the positive one" there is no reference in this 1883 patent to the unidirectional property of the lamp; it was merely a device to connect across the d.c. mains and give a small shunt current which varied considerably when the voltage of the mains varied, and it thus provided a sensitive indicator of the mains voltage. During the following twenty-one years several physicists, notably Elster and Geitel, and also Fleming, investigated the properties of the Edison device, but it was not until 1904 that anyone suggested making use of its unidirectional property; in that year Fleming had the brain-wave to use it as a rectifier of alternating currents and specially as a detector of radio signals. Although he claimed to have discovered the unilateral conductivity, and subsequently had to amend the specification by disclaimer, and although there is no suggestion of an anode battery, and Fleming admitted that the device was not so sensitive as a coherer or magnetic detector, this patent of Fleming is undoubtedly one of the great landmarks of radio history; it was the first suggestion that thermionics could be applied to radio.

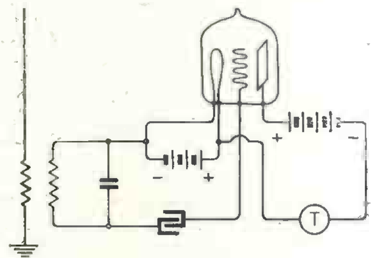


Fleming, 1905

de Forest's Great Invention

In 1906 de Forest read a paper before the American Institute of Electrical Engineers in which he described the use of a diode with a battery in the anode-filament circuit, and said: "When an independent external source of electromotive force is applied in the manner I have described, the action becomes quite different. It then operates as a relay to the Hertzian energy instead of merely rectifying this energy."

This paper of de Forest's also contains the germs of other improvements in the construction and use of thermionic valves. He refers



de Forest, 1906

to the superiority of tantalum and other of the new filament materials over carbon, and states that, although he had not been able to use the tungsten filament, he thought that it might give even better results. Further, he showed that it was not necessary to connect the oscillatory circuit to the anode, but that it might be connected to a separate electrode, a third electrode, surrounding the glass vessel, so arranged that its variation of potential controlled the current passing through the valve.

Probably the greatest single invention in the whole history of the subject was made by Lee de Forest in 1906, when he inserted the third electrode in the form of a grid between the cathode and anode. To appreciate the importance of de Forest's contribution one has only to compare the two diagrams reproduced here from the patent specifications of Fleming and de Forest. Except for the absence of a grid-leak, de Forest's diagram might almost be dated 1943. The third claim of the patent specification is for "an oscillation detector comprising an evacuated vessel, two electrodes enclosed within such vessel, means for heating one of said electrodes, and a grid-shaped member of conducting material enclosed within said vessel and interposed between said electrodes." This will surely rank for all time as one of the greatest inventions of radio telegraphy.

It will be noticed that this invention relates to an oscillation detector and not to an amplifier, but ten weeks before this de Forest had applied for a patent for a three-electrode amplifier, the fourth claim of which reads as follows: "In a device for amplifying electrical currents, an evacuated vessel, three electrodes sealed within such vessel, means for heating one of said electrodes, a local receiving-current including two of said electrodes, and means for passing the current to be amplified between one of the electrodes which is included in the receiving circuit and the third electrode." The sixth claim is somewhat more precise: "In a device for amplifying electric currents, an evacuated vessel, a heated electrode and two non-heated electrodes sealed within said vessel, the non-heated electrodes being unequally spaced with respect to said heated electrode, a local receiving circuit including said heated electrode and that one of the non-heated electrodes which has the greater separation from the heated electrode, and means for passing the current to be amplified between the heated electrode and the other non-heated electrode."

Within the space of a few months de Forest had thus invented the triode amplifier and the triode detector, and, starting from the idea of a diode with a band of metal foil around the waist of the bulb to act as a control electrode, had put the third electrode inside the bulb and then given it the form of a grid interposed between the anode and cathode. All this happened within the latter half of the year 1906. Although we doubt whether it is true, as Dr. Hazeltine suggests, that the action was viewed as that of a trigger, there is no doubt that de Forest had some very strange ideas as to what was happening in the bulb. The following extract from his amplifier patent is almost incredible. "The current to be amplified may be impressed upon the medium intervening between the electrodes *D′* and *E*, and thereby alter, by electrostatic attraction, the separation between the electrodes. In this case *D′* may be a strip of platinum-foil, and the slightest approach thereof toward the filament will act to slightly cool the gaseous medium, and thereby alter the current in the local circuit, or, if *D′* is rigid, the increase in electrostatic attraction between *D′* and *E* will cause *E* [i.e., the filament] to recede from *D*, and thereby alter the current in the local circuit." In extenuation we would point out that this was written in 1906. It was eight years later in 1914 that Armstrong published his paper showing clearly with the aid of characteristic curves how de Forest's audion really functioned.

The Invention of the Valve Oscillator

In 1917 Armstrong was awarded the first Medal of Honour of the Institute of Radio Engineers for his work on regeneration and the generation of oscillations by means of thermionic valves, but the credit for this invention was the subject of a lengthy lawsuit between Armstrong and de Forest. The Commissioner of Patents awarded priority to Armstrong, but this was reversed on appeal and the Supreme Court decided in favour of de Forest. Armstrong then returned the Medal to the Institute in 1934, but they very properly declined to take it back and reaffirmed the award. It is noteworthy that the judgment of the Court of Appeals says: "Especially are we impressed by the party Armstrong and his witnesses. We have no doubt but what he produced the invention at the time alleged, and did all the things attributed to him by the testimony, as set forth in this record. His earliest claim to a conception of this invention is October, 1912, followed by a witnessed sketch on January 31st, 1913. . . . Coming, therefore, to de Forest's case, the Examiner of Interferences found that in the experiment of August 6th, 1912, the repeating circuit used as an amplifier of telephonic currents was modified by a connection between the plate-filament circuit and the grid-filament circuit. This resulted in the production of a beautiful clear tone. This, the witnesses have testified, was due to the audion generating oscillations or alternating current due to the feed-back action and was understood by them at the time of the experiment." This was the view taken by the Supreme Court, and so, in the invention of the valve oscillator, de Forest beat Armstrong by a few months.

In conclusion, we would quote from A. H. Morse's comment on this judgment in his "Radio: Beam and Broadcast," published in 1925. "Armstrong's work in radio is such that, had he no patented or patentable inventions—and he has many—he would still rank as one of the foremost exponents of the art."

G. W. O. H.

Direct Reading of the Frequency of Resonant Circuits*

By W. H. F. Griffiths, F.Inst.P., M.I.E.E.

SUMMARY.—Direct reading frequency scales of 0.01 per cent. accuracy and covering a range of 100 kc/s to 15 Mc/s are described together with the work involved in designing a resonant circuit in which they can be incorporated with efficacy. Formulae are developed in detail for the design of a variable condenser to conform to the required linear law of frequency and of the capacitance range appropriate to any required accuracy.

The extent to which the linearity of the design-law is affected by the "edge capacitance" of the plate system of the variable condenser is discussed quantitatively and formulae developed for both departure from linearity and the errors introduced by such departure. A formula for edge capacitance correction is then developed. Experimental verification of the formulae for both law error and its correction is provided by a typical example.

The effect of using range coils of different distributed capacitances is investigated and formulae are developed for imperfection of law and interpolation errors due to this cause.

The effect of constructional imperfections of a variable condenser upon the linearity of law is discussed. That due to plate "wobble" and inequality of dielectric gap distances is dealt with together with its elimination in a design of variable condenser in which adjacent dielectric gaps are arranged to be in series electrically and complementary geometrically.

At the highest frequency ranges of a wavemeter the linearity of law is usually affected by the self-inductance of the variable condenser. This effect is discussed quantitatively and formulae are developed for the errors of frequency which may be introduced by such effect.

The effect upon the law of using an independent condenser of fixed value to augment the residual capacitance of the variable condenser is touched upon with the help of an example. It is suggested that this effect may be used to provide some measure of compensation for the effect of the variation of the self-inductance of the variable condenser.

Finally, the possibility of a further source of law imperfection at the highest frequencies is suggested—that of eddy current effects in range coils of low inductance value.

WHEN using a wavemeter or calibrated oscillator one is too often conscious of the fact that the nature of the scale is the limiting factor in the accuracy of the measurement of frequency. Moreover, if the scale is graduated merely in degrees of arc, or by some arbitrary linear subdivision, the translation of the scale reading into actual frequency is, almost invariably, a still more serious limitation to accuracy.

For these reasons the author has devoted much thought to the provision of direct reading frequency scales for the resonant circuits of wavemeters and oscillators of all accuracies, and the purpose of this article is to point out the many design features which need careful attention before such scales may be applied with efficacy.

Most of the design formulae and general conclusions may be applied to circuits of all accuracies but, naturally, they are of greater use in the design of those of high accuracy.

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

Direct reading frequency scales of, say, 1 per cent. accuracy demand of the instrument maker no more than ordinary skill, whereas it will be appreciated that the provision of direct reading frequency scales covering a wide range of frequency to an accuracy of 0.01 per cent. is a task which will tax the designer's skill and ingenuity to the utmost. This applies not only to the variable condenser, however, but also to the actual scale and scale reading device. Moreover, good design alone will not suffice to produce a scale of this accuracy; the instrument maker's skill and the engraver's care are also required to be of the highest order.

The direct reading frequency scale arrangement of the author's 0.01 per cent. wavemeter-oscillator is shown in the illustration of Fig. 1. This scale, which covers the range 100 kc/s to 15 Mc/s,† comprises a number of ranges of frequency engraved concentrically on a thick disc of

† It is used for frequencies up to 60 Mc/s or so by simply multiplying by 2, 3, 4, etc.

nickel silver which is rotated with the moving plate system of the variable condenser of the wavemeter. A robust cast saddle, under which the scale disc rotates, carries a magnifier of wide view in a circumferential direction but masked narrowly in a radial direction so that only the scale appropriate to the range in use may be viewed. This viewing device is set to the appropriate scale by sliding radially in the guides which are to be seen in the opening of the saddle casting—the engraved metal plate attached to the left hand guide indicating not only the range designation and correct range coil appropriate to it, but also the frequency range and the potential setting of the control electrode which governs the value of the negative resistance of the oscillating valve—be it dynatron or transitron.

A radial strip of the engraved scale disc is shown in Fig. 2. This illustration, although a full size reproduction, gives no idea of the fineness of the scale dividing. The delicacy of the dividing and numerals is such that the scale could not be read without eye strain were it not for the illumination provided at the base of the sliding viewing device. This illumination has to be arranged so that no shadows are cast by the index lines, two of which are provided, one on either surface of a transparent scale covering, in order to avoid errors of reading due to parallax.

The delicate engraving, correctly proportioned and with simple wide-view magnification and perfect illumination ensures comfort in reading provided that the finish of the surface of the scale disc is suitable both in colour and grain.

On the peripheral edge of the scale disc will be seen a degree scale which is read against the carefully matched vernier to be seen in the aperture in the saddle. This scale permits reading to 0.002 per cent. and is used for the initial frequency calibration which is then transferred to the direct reading scales.

The author feels that this brief description is inadequate to command the admiration that is invariably expressed by those inspecting the actual apparatus—admiration which is undoubtedly earned by the instrument maker, calibrater and engraver, and is tribute to which the author would also subscribe. From the design point of view,

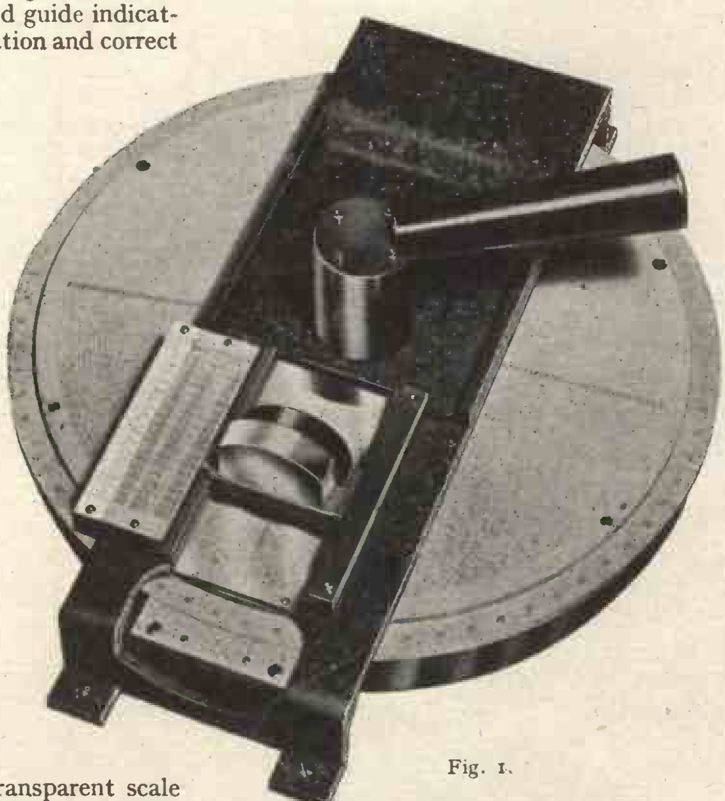


Fig. 1.

however, the association of such scales with the variable condenser is often thought to be a simple matter—being *merely* the design of the variable condenser so that it has a truly inverse square law of capacitance! This, however, is not by any means as simple as it appears owing to a variety of complications which spoil the linearity of the frequency law which would otherwise be obtained due to the shaping of the moving plates of the condenser. Some of these complications are enumerated below :

(*a*) The " edge capacitance " of the peripheral edges of the moving plates—this

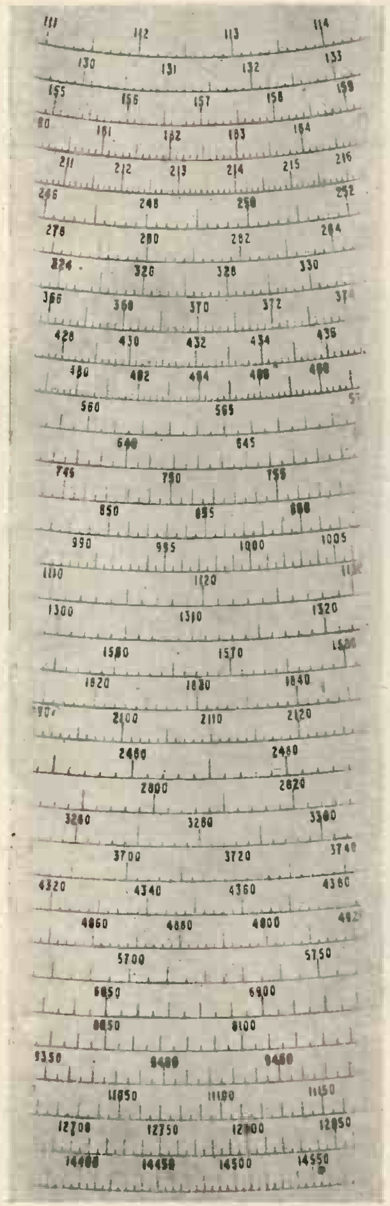


Fig. 2.

changes the general law throughout the whole scale.

(*b*) The edge effects of the radial leading and trailing edges of the moving plates—these give rise to rapid and large law changes at the scale ends which limit the scale length appreciably where great accuracy is required.

(*c*) The effect of associating with the condenser a plurality of " range coils " some of which have values of self-capacitance different from that for which the design provides.

(*d*) The effect of plate " wobble " on trueness of " law " and its accompanying defect —inequality of dielectric gaps.

(*e*) The effect of the variation of self-inductance upon the law—an effect which becomes increasingly appreciable as the frequency is raised.

In order that a variable condenser scale may be directly engraved with frequency, a number of actual frequency calibrations must be imparted to it preferably at cardinal frequencies. The angular distances between these cardinal frequencies are then subdivided by *linear* interpolation. This is, of course, the reason for the necessity for a linear law of frequency and for the strict conformity to such law where great accuracy is required of the direct reading frequency scales.

If C_R is the resultant capacitance of a resonant circuit for any variable condenser setting θ, then

$$f = \frac{1}{2\pi\sqrt{LC_R}}$$

Therefore $f \propto \frac{1}{\sqrt{C_R}}$

For f to be linear with θ therefore

$$C_R = \frac{1}{(a\theta + b)^2} \quad \ldots \quad \ldots \quad (1)$$

The diagram of Fig. 3 shows the general case of resultant capacitance of a resonant circuit. It is that of a variable condenser with a certain amount of constant capacitance in parallel and a fixed capacitance, C_f, in series with the combination. Across the whole of this another constant capacitance, C_A (such as that of a valve or the self-capacitance of a coil) may be connected. The resultant capacitance of such a circuit is

$$C_R = \frac{CC_f}{C + C_f} + C_A$$

Therefore

$$C = \frac{C_f(C_A - C_R)}{C_R - C_A - C_f} \quad \ldots \quad \ldots \quad (2)$$

$$C = \frac{1/(a\theta + b)^2 - C_A}{1 + C_A/C_f - 1/\{C_f(a\theta + b)^2\}} \qquad (3)$$

This is the value of capacitance which must govern the design of the plate-shape of the variable condenser in such a case, but for all other computations such as those dealing with the accuracy and law of the actual scale the value

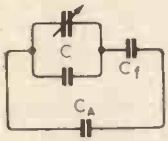


Fig. 3.

$$C_R = \frac{1}{(a\theta + b)^2}$$

must be used. The resonant circuits of accurate wavemeters and oscillators of variable frequency are so rarely complicated by a series capacitance, C_f, that it is hardly worth while complicating the formulae which follow by its inclusion. When $C_f = \infty$ expression (3) reduces to

$$C = 1/(a\theta + b)^2 - C_A$$

but in this case without the complication of C_f the capacitance C_A would be included in the residual capacitance, C_{min}, and the expression then assumes its simplest form

$$C = 1/(a\theta + b)^2 \qquad .. \qquad .. \qquad (3a)$$

which is the same as that for C_R of the general case since all stray and constant capacitances, being simply in parallel, are included in C_{min}.

The value of C_{min} must, of course, include the value of the self-capacitance, c_s, of the inductance L of the resonant circuit. If the value of L is to be changed in order to provide a plurality of frequency ranges it is probable that the value of c_s will change also from range to range. The effect of a change in value of c_s on the frequency law of the various ranges will be discussed later in the article, and at this stage a mean value must be estimated for inclusion in C_{min}.

Although the total angular extent of the moving plates of the conventional plate system of a variable condenser is 180 degrees the actual scale must be limited to 160 degrees in order to minimise the edge effects (*b*) to which reference was made at the commencement of the article. Therefore C_{min} must represent the resultant capacitance of the circuit when the variable condenser is set to the high frequency end of the limited scale (i.e. when $\theta = 160$, see Fig. 5).

For a given quality of variable condenser and its auxiliaries, it is the value of C_{min} that largely determines the calibration permanence of the resonant circuit, for upon this value depends the relative importance of the permanence of the various stray capacitances some of which are extremely variable with temperature, humidity and age.

For a given accuracy of frequency of a resonant circuit the value of C_{min} is fixed according to the experience of the designer. In the author's opinion this is always the first step in the quantitative design of a wavemeter or accurate oscillator. The curve of Fig. 4 is given by the author as a suggestion only, and the designer should not have implicit faith in this until he has satisfied himself that all possible precautions have been taken to ensure the permanence of the component self-capacitances, intentional and incidental.

Next, from the dimensions available for the scale, the capacitance range of the variable condenser is found in the following manner.

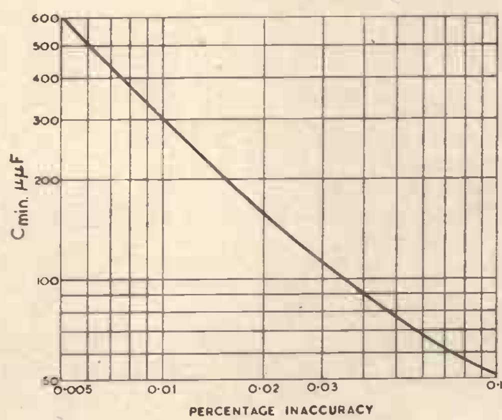


Fig. 4.

The scale inaccuracy may be expressed as the smallest circumferential distance to which consistent readings may be made. If this distance is, say, 0.01 cm for the reading of an accurate degree scale with the assistance of an accurately matched vernier it is only safe to allow, say, one-third of this reading accuracy in the case of direct reading frequency scales because no assistance is available from a vernier, and there are inaccuracies introduced by the transference of the degree scale calibration to the direct reading scales. If, therefore, we express this circumferential distance of 0.03 cm as an angle $\delta\theta$,

$$\delta\theta = \frac{0.03 \text{ Radian}}{R_s} = \frac{0.03 \times 180}{\pi R_s} = \frac{1.72}{R_s}$$

where R_s is the radius of the scale.

The scale inaccuracy $\phi = \delta\theta \, . \, \frac{df}{d\theta}\Big| mf$

where m is the degree (diameters) of any optical magnification provided to facilitate scale reading.

Therefore $\phi = \delta\theta \, . \, \frac{dC_R}{d\theta}\Big| 2mC_R$

Expressed as a percentage this becomes

$$\phi = \frac{172}{2mR_s} \cdot \frac{1}{C_R} \cdot \frac{dC_R}{d\theta} \qquad \ldots \quad \ldots \quad (4)$$

where $C_R = C$ in the simple case at present under consideration.

From (3a)

$$\frac{dC}{d\theta} = -\frac{2a}{(a\theta + b)^3} \qquad \ldots \quad \ldots \quad (5)$$

and

$$\phi = \frac{172 \times 2a}{2mR_s(a\theta + b)^{-2}(a\theta + b)^3}$$

$$= \frac{172a}{mR_s(a\theta + b)} \qquad \ldots \quad \ldots \quad (6)$$

Having fixed the permissible value of ϕ* it is now possible to proceed to determine the constants a and b for, from (6),

$$a\theta + b = \frac{172a}{\phi m R_s}$$

and since $df/d\theta$ is constant with θ it follows that ϕ is greatest when f is least, i.e. when $\theta = 0$.

Then

$$b = \frac{172}{\phi m R_s} \, . \, a$$

Therefore

$$a = \frac{1/(160\sqrt{C_{min}})}{1 + 172/(160\phi m R_s)} \qquad \ldots \quad \ldots \quad (7)$$

* This should be at least three times the *inaccuracy* of reading the degree scale of the condenser which latter should not be greater than one-third the inaccuracy of the circuit from all causes including temperature and humidity changes and all forms of ageing.

and

$$b = \frac{172}{\phi m R_s} \cdot \frac{1/(160\sqrt{C_{min}})}{1 + 172/(160\phi m R_s)} \qquad \ldots \quad (8)$$

Now even before finding the capacitance of the condenser the frequency slope of the scale may be determined, for,

$$f = \frac{1}{2\pi\sqrt{LC}}$$

or rather, if the same values of the constants a and b are employed and L is in henries,

$$f = \frac{1}{2 \times 10^{-6}\pi\sqrt{LC}}$$

Therefore from (3a)

$$f = \frac{a\theta + b}{2 \times 10^{-6}\pi\sqrt{L}}$$

and

$$\frac{df}{d\theta} = \frac{a}{2 \times 10^{-6}\pi\sqrt{L}} \qquad \ldots \quad \ldots \quad (9)$$

which is, of course, constant.

The maximum capacitance C_{max} may now be found, for this must be the value of C when $\theta = 0$ and then $C = 1/b^2$

Therefore

$$C_{max} = 1 \Big/ \left(\frac{172}{\phi m R_s} \cdot \frac{1/(160\sqrt{C_{min}})}{1 + 172/(160\,\phi\, mR_s)} \right)^2 \qquad \ldots \quad \ldots \quad (10)$$

Having determined the values of the constants a and b the frequency law of the resonant circuit is known completely and the range of the variable condenser is also known. The design of the plate shape may now be proceeded with.

That part of C which must be provided by actual plate area equals $C - C_{min}$ and the plate area in operation at any angle, θ, must therefore be proportional to this value.

Therefore

$$A = k\left\{\frac{1}{(a\theta + b)^2} - C_{min}\right\}$$

where k is a constant.

The inoperative area of the central clearance of the fixed plates around the spindle of the moving plates is always the sector of a circle of radius, r, and is $\frac{\theta}{2 \times 57.3} \, . \, r^2$ and may be written $K(160 - \theta)$ where K is another constant $r^2/114.6$.

Therefore

$$A = k\left\{\frac{1}{(a\theta+b)^2} - C_{min}\right\} + K(160 - \theta) \quad \ldots \quad \ldots \quad (11)$$

There are three ways of determining the value of the constant k, the choice of one of which will be determined by the conditions governing the design of the condenser.

1. In terms of the number "n" of dielectric gaps and the dielectric gap distance "g".

2. In terms of the maximum radius permissible for the moving plates.

3. In terms of the total area of a moving plate.

1. $$C_{max} - C_{min} = \frac{nA}{0.9 \times 4\pi g}$$

from which

$$k = \frac{0.9 \times 4\pi g(C_{max} - C_{min}) - 160nK}{n(C_{max} - C_{min})}$$

$$= \frac{3.6\pi g}{n} - \frac{160 \cdot K}{C_{max} - C_{min}} \quad \ldots \quad (12)$$

2. $$R_0^2 = 114.6\left\{\frac{2ka}{b^3} + K\right\}$$ from the formula for plate radius R developed hereinafter.

from which

$$k = \frac{b^3(R_0^2 - 114.6\,K)}{229.2\,a} \quad \ldots \quad (13)$$

3. Total plate area (at $\theta = 0$)

$$= k\,\{C_{max} - C_{min}\} + 160\,K$$

from which

$$k = \frac{\text{Total area of a single plate} - 160\,K}{C_{max} - C_{min}} \quad \ldots \quad \ldots \quad (14)$$

Now the area of a sector of a circle of angle β is:

$$\frac{\beta}{2 \times 57.3} \cdot R^2$$

and a small incremental area

$$\delta A = \frac{\delta\theta}{2 \times 57.3} \cdot R^2$$

Therefore $$R = 10.7\sqrt{\frac{dA}{d\theta}}$$

$$\frac{dA}{d\theta} = -\left[\frac{2ka}{(a\theta + b)^3} + K\right] \quad \ldots \quad (15)$$

Therefore the plate radius at any angle θ is given by

$$R = 10.7\sqrt{\frac{2ka}{(a\theta + b)^3} + K} \quad \ldots \quad (16)$$

If a condenser of fixed value is included in the resonant circuit in series with the variable condenser, the following expressions and their constants have to be substituted for those already given. They are derived in the same manner.

$$A_3 = k\left\{\frac{C_f}{C_f(a_3\theta + b_3)^2 - 1} - C_{min}\right\}$$
$$+ K(160 - \theta) \quad \ldots \quad \ldots \quad (17)$$

$$\frac{dA_3}{d\theta} = -\left[\frac{2a_3kC_f^2(a_3\theta + b_3)}{\{C_f(a_3\theta + b_3)^2 - 1\}^2} + K\right] \quad \ldots \quad \ldots \quad (18)$$

$$R_3 = 10.7\sqrt{\frac{2a_3kC_f^2(a_3\theta + b_3)}{\{C_f(a_3\theta + b_3)^2 - 1\}^2} + K} \quad \ldots \quad \ldots \quad (19)$$

where

$$a_3 = \frac{1}{160}\left\{\left(\frac{1}{C_{min}} + \frac{1}{C_f}\right)^{\frac{1}{2}} - b_3\right\}$$

and $$b_3 = \left\{\frac{1}{C_{max}} + \frac{1}{C_f}\right\}^{\frac{1}{2}}$$

Expression (16) determines that part of the moving plate which is drawn in heavy line in Fig. 5. The plate shape beyond these

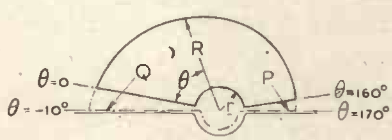


Fig. 5.

boundaries, i.e., from 0° to − 10° and from 160° to 170°, can be completed only after a trial test of the law with moving plates extended to − 10° and 170° by values of R extrapolated approximately from the same law. For condensers of resonant circuits of great accuracy it may even be necessary to modify the values of R for a few degrees at the extreme limits of the heavily lined portion of the plate. The angular limitations of the plate shape and the subsequent end modifications are, of course, rendered necessary by the deviation from law linearity which would otherwise occur at the ends of the frequency scale due to the "edge capacitance" of the leading and trailing edges P and Q respectively. The extent to which the fringing of the electrostatic field at these edges disturbs the law, together with the plate shape modifications necessary to correct this disturbance, will be shown later in the article by means of an example.

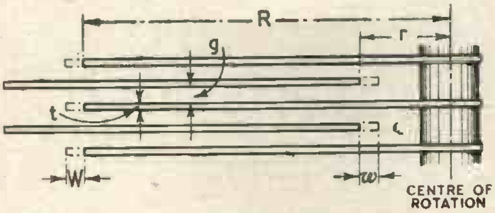


Fig. 6.

The frequency scale also suffers, however, by a gradual deviation from linearity throughout its entire length due to the fringing of the electric field round the peripheries of the moving plates and round the semicircular edges of the central clearances in the fixed plates. The augmentation of capacitance due to this edge capacitance may be said to be equivalent to an extension of R by an amount W and to a diminution of r by an amount w, as shown in Fig. 6 which is a radial section through a part of a system of fixed and moving plates. In order to arrive at a value for W, use may be made of Thomson's formula* for the quantity of electricity on a strip of a semi-infinite plate placed midway between two infinite plates.

$$\frac{V}{4\pi(H-h)}\left\{x + \frac{H}{\pi}\log.\frac{2H-h}{h} + \frac{H-h}{\pi}\log.\frac{h(2H-h)}{(H-h)^2}\right\}$$

where $2h$ = the thickness of the semi-infinite plate,

and $2H$ = the distance between the infinite plates.

From this expression it is obvious that W in this case is given by

$$\frac{H}{\pi}\log\frac{2H-h}{h} + \frac{H-h}{\pi}\log\frac{h(2H-h)}{(H-h)^2}$$

which, if the central plate is very thin, reduces to

$$\frac{2H}{\pi}\log 2$$

In terms of the dielectric gap distance and moving plate thickness:

$$W = \frac{g+\frac{1}{2}t}{\pi}\log\frac{2g+\frac{1}{2}t}{\frac{1}{2}t} + \frac{g}{\pi}\log\frac{t(g+\frac{1}{4}t)}{g^2} \quad \text{.. .. (20)}$$

The value of W found from expression (20) may be slightly inaccurate because the actual value may be affected somewhat by a variety of causes. Among these is the limitation of the edge capacitance due to the rounding of the peripheral edges of the moving plates and to the finite radii of the plates. But for accurate condensers of reasonably large dimensions expression (20) will be found to be of sufficient accuracy for practical purposes. It will be found also that it is sufficiently accurate to make $w = W$, especially as an error in an assumed value of w is of little importance in the expressions (24) to (29) which follow.

The curves of Figs. 7 and 8 show the nature of the variation of W with moving plate thickness, t, and with dielectric gap distance, g, respectively.

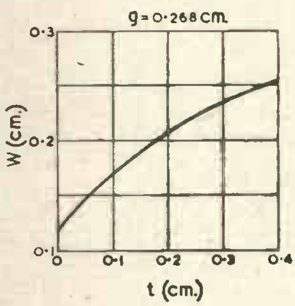
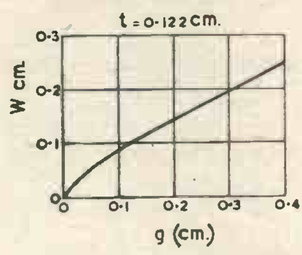


Fig. 7.



(*Left*) Fig. 8.

The departure of the frequency law from linearity caused by edge capacitance is responsible for frequency errors of interpolation. Unless the value of $df/d\theta$ is quite constant from $\theta = 0$ to $\theta = 160$ it is impossible, without the risk of interpolation error, to provide a frequency scale of linear subdivision even between two adjacent cardinal frequencies which are calibrated. If the plate shape of the variable condenser has been correctly designed the $df/d\theta$ curve will be practically straight between adjacent calibrated points whatever the

* J. J. Thomson, "Recent Researches in Electricity and Magnetism," p. 211. Oxford, Clarendon Press (1893).

cause of the imperfection of law.* Thus the two calibrated points A and B of Fig. 9, as a sufficiently close approximation, may be regarded as being joined by a portion of the $df/d\theta$ curve which is sensibly a straight line. Having by calibration determined the angular scale settings θ_A and θ_B for the adjacent cardinal frequencies at A and B respectively, the direct reading scale between them is then subdivided evenly on the assumption of a linear law having a value of $df/d\theta$ equivalent to that at the point X exactly midway between A and B. Let the number of

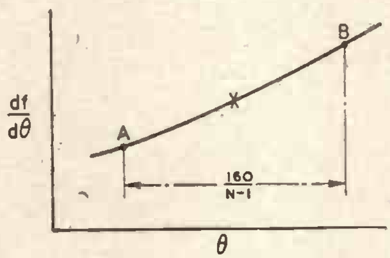


Fig. 9.

equidistant calibrated points throughout the range 0 to 160 degrees be N, then the frequency of X is read, incorrectly, as

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

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

The correct frequency at X is, however,

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

The maximum interpolation error caused by an inconstant value of $df/d\theta$ occurs at a point exactly midway between adjacent calibrated frequencies and this, as is seen above, is given by

$$+ \frac{3200}{(N-1)^2} \cdot \frac{d^2f}{d\theta^2} \quad \ldots \quad \ldots \quad (21)$$

The error is the same both in magnitude and algebraic sign if f_x is computed from f_B.

In a wavemeter or calibrated resonant circuit there are many sources of error other than that of non-linearity of frequency law. There are even several sources of non-linearity of law. Any one of these sources of error cannot be allowed to approach the total inaccuracy, α. The maximum error due to interpolation therefore should, at least, be limited to $\alpha/5$ for any one cause of law imperfection.

Then

$$\frac{3200}{(N-1)^2} \cdot \frac{d^2f}{d\theta^2}\bigg/ f \leqslant \frac{\alpha}{5}$$

from which the number, N, of equidistant calibrated frequencies required to limit the interpolation inaccuracy to $\alpha/5$ is given by

$$N \geqslant \sqrt{\frac{15600}{\alpha f} \cdot \frac{d^2f}{d\theta^2}} + 1 \quad \ldots \quad \ldots \quad (22)$$

It will be shown that the frequency from which $d^2f/d\theta^2$ is obtained is, owing to the effect of edge capacitance, quite different from the simple correct law frequency

$$f = \frac{a\theta + b}{2 \times 10^{-6}\,\pi\sqrt{L}}$$

for which $df/d\theta$ is a constant and $d^2f/d\theta^2$ therefore zero. In order to form an expression for f',† the area, A_E, of the equivalent edge capacitance strips, W and w, at any angle θ must first be found. From $\theta = 0$ to $\theta = \theta_1$, letting $w = W$, the combined areas of these strips is given sufficiently closely for the present purpose by

$$2\pi(r + \text{mean } R)\, W \frac{\theta_1}{360}$$

$$\text{mean } R = \frac{1}{\theta_1}\int_0^{\theta_1} R \,.\, d\theta$$

Therefore the areas

$$= \frac{2\pi\theta_1 W}{360\,\theta_1}\left[\int_0^{\theta_1} R d\theta + r\theta_1\right]$$

The actual area of these equivalent strips embraced within the fixed plate system of the condenser at any scale setting, θ_1,

---

* Excluding, of course, local imperfections which may be caused by irregularities in the construction of the variable condenser. Such imperfections are negligible in a condenser of the best quality, however.

† The symbol f' is used hereafter to distinguish the frequency as modified by edge capacitance from that, f, which would have been obtained for the same angle θ had there been no peripheral edge capacitance.

however, is that from 160° to θ_1 and therefore

$$A_E = A_{E(max)} - \frac{2\pi W}{360}\left[\int_0^{\theta_1} R\,.\,d\theta + r\theta_1\right]$$

$$= \frac{2\pi W}{360}\left[\left\{\int_0^{160} R.d\theta + 160r\right\} - \left\{\int_0^{\theta_1} R.d\theta + r\theta_1\right\}\right]$$

$$= \frac{2\pi W}{360}\left[\int_{\theta_1}^{160} R.d\theta + r(160 - \theta_1)\right] \quad .. \quad (24)$$

$$R = 10.7\sqrt{\frac{2ka}{(a\theta + b)^3} + K}$$

Let $B = 229\,ka$ and $U = 114.6\,K$

Then $\displaystyle\int_{\theta_1}^{160} R\,.\,d\theta = \int_{\theta_1}^{160} \sqrt{B(a\theta + b)^{-3} + U}\,.\,d\theta$

Put $a\theta + b = \left(\frac{B}{U}\right)^{\frac{1}{3}} . \frac{1}{v}$

so that $a\,.\,d\theta = \left(\frac{B}{U}\right)^{\frac{1}{3}}\left(-\frac{1}{v^2}\right).\,dv$

Substituting for θ and $d\theta$ the original integral becomes

$$\int_{\theta_1}^{160}\sqrt{B\left(\frac{U}{B}\,.\,v^3\right) + U}\,.\,\frac{1}{a}\left(\frac{B}{U}\right)^{\frac{1}{3}}\left(-\frac{1}{v^2}\right).\,dv$$

$$= \frac{B^{\frac{1}{3}}U^{\frac{1}{6}}}{a}\int_{v_2}^{v_1}\frac{\sqrt{v^3 + 1}}{v^2}\,.\,dv$$

where $v_2 = \dfrac{\left(\frac{B}{U}\right)^{\frac{1}{3}}}{160a + b}$ and $v_1 = \dfrac{\left(\frac{B}{U}\right)^{\frac{1}{3}}}{a\theta_1 + b}$

This may be re-written

$$\frac{B^{\frac{1}{3}}U^{\frac{1}{6}}}{a}\int_{v_2}^{v_1} v^{-\frac{1}{2}}\sqrt{1 + v^{-3}}\,.\,dv$$

from which it is possible to proceed with a series expansion and term-wise integration so :

$$\frac{B^{\frac{1}{3}}U^{\frac{1}{6}}}{a}\int_{v_2}^{v_1} v^{-\frac{1}{2}} + \tfrac{1}{2}v^{-\frac{7}{2}} - \tfrac{1}{8}v^{-\frac{13}{2}} + \tfrac{1}{16}v^{-\frac{19}{2}} - \tfrac{5}{128}v^{-\frac{25}{2}} \ldots$$

As the present purpose is the estimation of an error and correction, both of which are themselves small, a first approximation will be found sufficiently accurate.

Thus $\displaystyle\int_{\theta_1}^{160} R\,.\,d\theta = \frac{B^{\frac{1}{3}}U^{\frac{1}{6}}}{a}\,.\,2\left[\sqrt{v}\left(1 - \frac{1}{10v^3}\right)\right]_{v_2}^{v_1}$

$$\text{and } A_E = \frac{2\pi W}{360}\left[\frac{B^{\frac{1}{3}}U^{\frac{1}{6}}}{a}\,.\,2\left[\sqrt{v}\{1 - \tfrac{1}{10}v^{-3}\}\right]_{v_2}^{v_1} + r(160 - \theta_1)\right] \quad .. \quad (25)$$

Evaluating $\dfrac{B^{\frac{1}{3}}U^{\frac{1}{6}}}{a}\,.\,2\sqrt{v}(1 - \tfrac{1}{10}v^{-3})$ for the constant limit v_2 in order to obtain a constant, E, the value of A_E for any angle, θ, may be expressed as :

$$A_E = \frac{2\pi W}{360}\left[\frac{B^{\frac{1}{3}}U^{\frac{1}{6}}}{a}\,.\,2\sqrt{v}(1 - \tfrac{1}{10}v^{-3}) - E + r(160 - \theta)\right] \quad .. \quad .. \quad (26)$$

where $v = \dfrac{\left(\frac{B}{U}\right)^{\frac{1}{3}}}{a\theta + b}$

$$A_E = \frac{2\pi W}{360}\left[\left\{\frac{B^{\frac{1}{3}}U^{\frac{1}{6}}}{a}\,.\,2\,\frac{\left(\frac{B}{U}\right)^{\frac{1}{6}}}{(a\theta + b)^{\frac{1}{2}}}\left(1 - \frac{U(a\theta + b)^3}{10B}\right)\right\} - E + r(160 - \theta)\right]$$

$$= \frac{2\pi W}{360}\left[\left\{\frac{2B^{\frac{1}{2}}}{a(a\theta + b)^{\frac{1}{2}}}\,.\left(1 - \frac{U(a\theta + b)^3}{10B}\right)\right\} - E + r(160 - \theta)\right]$$

Letting $a\theta + b = y$, $\sqrt{B} = \sqrt{229\,ka} = q$

and $\dfrac{2\pi W}{360} = p$

$$A_E = p\left[2\,.\,\frac{q}{a}\,.\,y^{-\frac{1}{2}} - \tfrac{1}{5}\,.\,\frac{U}{aq}\,.\,y^{\frac{5}{2}} - E + r(160 - \theta)\right] \quad .. \quad .. \quad (26a)$$

The capacitance of the variable condenser is, of course, adjusted to the figures of the theoretical law neglecting the effects of edge capacitance the magnitudes of which are unknown at this stage. These figures are C_{max} and C_{min} at $\theta = 0$ and $\theta = 160$ respectively. This being so the capacitance C' at any other scale setting θ is given by :

$$C' = C_{min} + \left\{(A + A_E)\frac{C_{max} - C_{min}}{A_{max} + A_{E(max)}}\right\} \quad .. \quad .. \quad (27)$$

in which, from expression (11), $A = k\left\{(a\theta + b)^{-2} - C_{min}\right\}$ and $A_{max} = k\left\{\frac{1}{b^2} - C_{min}\right\}$

The complete expression for frequency as modified by edge capacitance is then given by:

$$f' = \frac{1}{2 \times 10^{-6}\pi\sqrt{L}\left[C_{min} + \left\{(A + A_E)\dfrac{C_{max} - C_{min}}{A_{max} + A_{E(max)}}\right\}\right]^{\frac{1}{2}}} \qquad \ldots \quad \ldots \quad (28)$$

$$= \frac{10^6}{2\pi\sqrt{L}\left[C_{min} + \left\{\left[k\{(a\theta + b)^{-2} - C_{min}\} + p\{2\dfrac{q}{a}y^{-\frac{1}{2}} - \frac{1}{5}\cdot\dfrac{U}{aq}\cdot y^{\frac{5}{2}} - E + r(160 - \theta)\right]\cdot\dfrac{C_{max} - C_{min}}{A_{max} + A_{E(max)}}\right\}\right]^{\frac{1}{2}}} \qquad \ldots \quad \ldots \quad (29)$$

Let $2\pi\sqrt{L} = \text{unity}$ and $\dfrac{C_{max} - C_{min}}{A_{max} + A_{E(max)}} = s$

$$\text{then } f' = \frac{10^6}{\left[C_{min} + s\left[k(y^{-2} - C_{min}) + p\left\{-\frac{1}{5}\cdot\dfrac{U}{aq}\cdot y^{\frac{5}{2}} + 2\dfrac{q}{a}y^{-\frac{1}{2}} - E + r(160 - \theta)\right\}\right]\right]^{\frac{1}{2}}}$$

$$= \frac{10^6}{\left[s\left\{-\frac{1}{5}\cdot\dfrac{pU}{qa}y^{\frac{5}{2}} + ky^{-2} + 2\dfrac{pq}{a}y^{-\frac{1}{2}} + pr(160 - \theta) - pE\right\} + C_{min}(1 - sk)\right]^{\frac{1}{2}}}$$

Working logarithmically to differentiate with respect to θ, remembering that $y = a\theta + b$

$$\log_e f' = 6\log_e 10 - \tfrac{1}{2}\log_e\left[s\left\{-\frac{1}{5}\cdot\frac{pU}{qa}y^{\frac{5}{2}} + ky^{-2} + 2\frac{pq}{a}y^{-\frac{1}{2}} + pr(160 - \theta) - pE\right\} + C_{min}(1 - sk)\right]$$

$$\frac{1}{f'}\frac{df'}{d\theta} = \frac{\frac{1}{2}s\left[\frac{1}{2}\cdot\dfrac{pU}{q}y^{\frac{3}{2}} + 2kay^{-3} + pqy^{-\frac{3}{2}} + pr\right]}{s\left\{-\frac{1}{5}\cdot\dfrac{pU}{qa}y^{\frac{5}{2}} + ky^{-2} + 2\dfrac{pq}{a}y^{-\frac{1}{2}} + pr(160 - \theta) - pE\right\} + C_{min}(1 - sk)}$$

$$\frac{df'}{d\theta} = \frac{\frac{1}{2}s\,.\,10^6\left\{\frac{1}{2}\dfrac{pU}{q}y^{\frac{3}{2}} + 2kay^{-3} + pqy^{-\frac{3}{2}} + pr\right\}}{\left[s\left\{-\frac{1}{5}\cdot\dfrac{pU}{qa}y^{\frac{5}{2}} + ky^{-2} + 2\dfrac{pq}{a}y^{-\frac{1}{2}} + pr(160 - \theta) - pE\right\} + C_{min}(1 - sk)\right]^{\frac{3}{2}}} \qquad \ldots \quad \ldots \quad (30)$$

which may be plotted, as in Fig. 10, to show the magnitude of the effect of edge capacitance upon the law of the condenser. This is especially useful when investigating the *causes* of law departure from linearity.

Again using the logarithmic method to differentiate $df'/d\theta$ with respect to θ,

$$\log_e\frac{df'}{d\theta} = \log_e\tfrac{1}{2}s + 6\log_e 10 + \log_e\left\{\frac{1}{2}\cdot\frac{pU}{q}y^{\frac{3}{2}} + 2kay^{-3} + pqy^{-\frac{3}{2}} + pr\right\}$$

$$- \tfrac{3}{2}\log_e\left[s\left\{-\frac{1}{5}\cdot\frac{pU}{qa}y^{\frac{5}{2}} + ky^{-2} + 2\frac{pq}{a}y^{-\frac{1}{2}} + pr(160 - \theta) - pE\right\} + C_{min}(1 - sk)\right]$$

$$\frac{1}{\frac{df'}{d\theta}} \cdot \frac{d^2f'}{d\theta^2} = \frac{a\left(\frac{3}{4} \cdot \frac{pU}{q} y^{\frac{1}{2}} - 6kay^{-4} - \frac{3}{2}pqy^{-\frac{5}{2}}\right)}{\frac{1}{2} \cdot \frac{pU}{q} y^{\frac{3}{2}} + 2kay^{-3} + pqy^{-\frac{3}{2}} + pr}$$

$$- \frac{\frac{3}{2} s \left(- \frac{1}{2} \cdot \frac{pU}{q} y^{\frac{3}{2}} - 2kay^{-3} - pqy^{-\frac{3}{2}} - pr\right)}{s\left\{- \frac{1}{5} \cdot \frac{pU}{qa} y^{\frac{5}{2}} + ky^{-2} + 2\frac{pq}{a} y^{-\frac{1}{2}} + pr(160 - \theta) - pE\right\} + C_{min} (1 - sk)}$$

$$= \frac{\frac{3}{2} ay^{\frac{1}{2}}\left(\frac{1}{2}\frac{pU}{q} - pqy^{-3} - 4kay^{-\frac{9}{2}}\right)\left[s\left\{- \frac{1}{5}\frac{pU}{qa} y^{\frac{5}{2}} + ky^{-2} + 2\frac{pq}{a} y^{-\frac{1}{2}} + pr(160 - \theta) - pE\right\} + C_{min} (1 - sk)\right] + \frac{3}{2} s\left[\frac{1}{2}\frac{pU}{q} y^{\frac{3}{2}} + 2kay^{-3} + pqy^{-\frac{3}{2}} + pr\right]^2}{\left\{\frac{1}{2} \cdot \frac{pU}{q} y^{\frac{3}{2}} + 2kay^{-3} + pqy^{-\frac{3}{2}} + pr\right\}\left[s\left\{- \frac{1}{5}\frac{pU}{qa} y^{\frac{5}{2}} + ky^{-2} + 2\frac{pq}{a} y^{-\frac{1}{2}} + pr(160 - \theta) - pE\right\} + C_{min} (1 - sk)\right]}$$

$$\frac{d^2f'}{d\theta^2} = \frac{\frac{3}{4} \times 10^6 . s\left[ay^{\frac{1}{2}}\left(\frac{1}{2}\frac{pU}{q} - pqy^{-3} - 4kay^{-\frac{9}{2}}\right)\left[s\left\{- \frac{1}{5}\frac{pU}{qa} y^{\frac{5}{2}} + ky^{-2} + 2\frac{pq}{a} y^{-\frac{1}{2}} + pr(160 - \theta) - pE\right\} + C_{min} (1 - sk)\right] + s\left[\frac{1}{2}\frac{pU}{q} y^{\frac{3}{2}} + 2kay^{-3} + pq\, y^{-\frac{3}{2}} + pr\right]^2\right]}{\left[s\left\{-\frac{1}{5}\frac{pU}{qa} y^{\frac{5}{2}} + ky^{-2} + 2\frac{pq}{a} y^{-\frac{1}{2}} + pr(160 - \theta) - pE\right\} + C_{min} (1 - sk)\right]^{\frac{5}{2}}} \quad \ldots \quad (31)$$

Having found $\frac{d^2f'}{d\theta^2}$ the maximum interpolation error at any scale setting θ for a given number of calibration frequencies may now be determined from (21) or, for a given permissible interpolation inaccuracy the appropriate number of calibration points may be determined from (22).

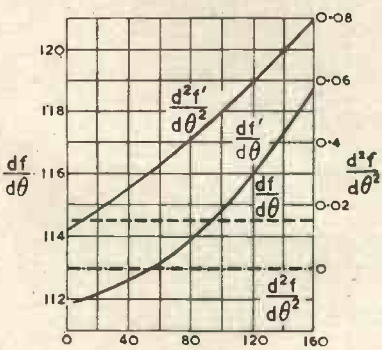


Fig. 10.

The magnitude of the effect of edge capacitance on the law and interpolation error of a 0.01 per cent. wavemeter will now be shown by way of example. The variable condenser of this wavemeter is of large dimensions and in every way representative of the best practice.

The constants of the plate design are :

$$a = 1.14415 \times 10^{-4}$$
$$b = 0.041025$$
$$k = 0.16569$$
$$K = 0.0431$$
$$r = 2.22 \text{ cm}$$

From (16) these constants give a plate radius R varying from 8.28 cm at $\theta = 0$ to 5.10 cm at $\theta = 160$.

The condenser is built up to give the values

$$C_{max} = 594.4 \ \mu\mu\text{F}$$
$$C_{min} = 284.1 \ \mu\mu\text{F}$$

by employing the following constants

$$n = 16$$
$$g = 0.268 \text{ cm}$$
$$t = 0.122 \text{ cm}$$

From (20) $W = 0.18$ cm from the latter two constants.*

A value of L was chosen such that $f = a\theta + b$ and the value of $df/d\theta$ from (9) would have been constant at 114.5 (and, of course, $d^2f/d\theta^2$ zero) had edge capacitance effects been negligible. The curves of Fig. 10 which were computed from expressions (30) and (31) show how $df/d\theta$ is changed to $df'/d\theta$ by edge capacitance and the consequent curve of $d^2f'/d\theta^2$ produced. In Fig. 11 is shown the percentage change of $df'/d\theta$ throughout the entire range of the variable condenser. This will be useful later in comparing the $df/d\theta$ curves of the different frequency ranges associated with a series of range coils used with the same variable condenser. The curve of Fig. 12 shows the maximum value of the interpolation error due to $d^2f'/d\theta^2$ at all parts of the scale—that which occurs midway between adjacent calibration points when $N = 7$. From Fig. 12 it is seen that the interpolation error is much too great for a 0.01 per cent. wavemeter at the high frequency end of the scale—the edge capacitance always affects this end of the scale most. This being so it is necessary to correct the plate shape as determined by R. The obvious correction is that of reducing the radius R by an amount approximately equal to the effective increase of that dimension by edge capacitance.

The amount of such reduction, $R - R_1$, for any angle θ, is obtained as follows. The drawing of Fig. 13 is of a very small part of the moving plate, much enlarged, in which the thick curve represents the peripheral edge and R the radius to the centre of plate rotation. The thin line curve is an arc of a circle of radius R, and W is perpendicular to a tangent of the peripheral edge of the plate. The distance δR is the extension of plate shape radius R corresponding to the effective edge capacitance width W. That

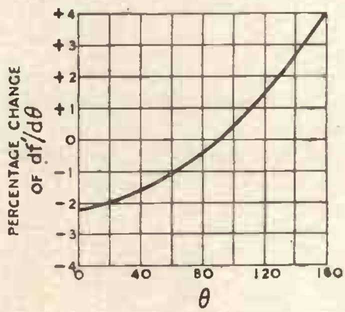


Fig. 11.

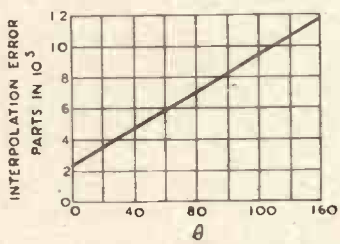


Fig. 12.

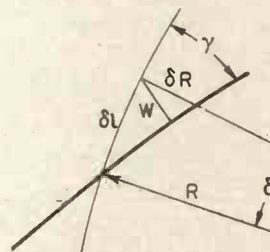


Fig. 13.

portion of the circumference of the circle of radius R subtended by the angle $\delta\theta$ is termed δl.

$$\tan . \gamma \doteq \frac{\delta R}{\delta l} = \frac{\delta R}{2\pi R \delta\theta/360} = \frac{360}{2\pi R} \cdot \frac{\delta R}{\delta\theta}$$

$$\gamma = \tan^{-1} \frac{360}{2\pi} \cdot \frac{1}{R} \cdot \frac{dR}{d\theta} \quad \cdot\cdot \quad (32)$$

Then the augmentation of R due to *peripheral* edge capacitance

$$= W \sec . \gamma$$

and the corrected radius of the plate shape which compensates the edge capacitance of both peripheral and inner edges of the plate is therefore given by

$$R_1 = R - \{W(1 + \frac{r}{R - W}) \sec \gamma\} \quad (33)$$

From (16)

$$R = \frac{[114.6 \{2ka + K(a\theta + b)^3\}]^{\frac{1}{2}}}{\{(a\theta + b)^3\}^{\frac{1}{2}}}$$

$$\log_e R = \tfrac{1}{2} \log_e [114.6\{2ka + K(a\theta + b)^3\}] - \tfrac{1}{2} \log_e (a\theta + b)^3$$

$$\frac{1}{R} \cdot \frac{dR}{d\theta} = \frac{1}{2}\left[\frac{343.8\, Ka(a\theta + b)^2}{114.6\{2ka + K(a\theta + b)^3\}}\right] - \frac{1}{2}\left[\frac{3a(a\theta + b)^2}{(a\theta + b)^3}\right]$$

$$= 1.5a\left\{\frac{K(a\theta + b)^2}{2ka + K(a\theta + b)^3} - \frac{1}{a\theta + b}\right\}$$

* The value for W found from expression (20) has been used here although, as was to be expected, the mean of several values found by careful experiment was somewhat lower, viz. 0.17 cm.

Therefore, from (32),

$$\gamma = \tan^{-1}\frac{270a}{\pi}\left\{\frac{K(a\theta+b)^2}{2ka+K(a\theta+b)^3} - \frac{1}{a\theta+b}\right\} \quad \ldots \quad (34)$$

In variable condensers for circuits of high accuracy the ratio C_{max}/C_{min} is nearly always less than 2.3 in which case the value of sec γ is sufficiently close to unity to be ignored and the corrected plate shaping radius becomes simply

$$R_1 = R - W\left(1 + \frac{r}{R-W}\right) \quad \ldots \quad (35)$$

The evaluation of expression (33) for the example under investigation and to which Figs. 10, 11 and 12 refer, is given in the tabulation in the next column.

Although the correction given by R_1 produces a strictly linear law of frequency despite the effects of edge capacitance, it

θ	R	$W(1+\frac{r}{R-W})$ sec. γ	R_1
0	8.241	0.230	8.011
10	7.932	0.232	7.700
20	7.645	0.234	7.411
30	7.377	0.236	7.141
60	6.672	0.242	6.430
90	6.091	0.248	5.843
100	5.920	0.250	5.670
120	5.605	0.254	5.351
160	5.075	0.262	4.813

may also effect too much reduction of plate area. If this is so the following procedure may be adopted.

A new plate shape of radius R' is computed from (16) having, at $\theta = 0$, a radius

$$R' = R + W\left(1 + \frac{r}{R-W}\right)\sec\gamma$$

from which a new value for the constant k is determined using expression (13). For any

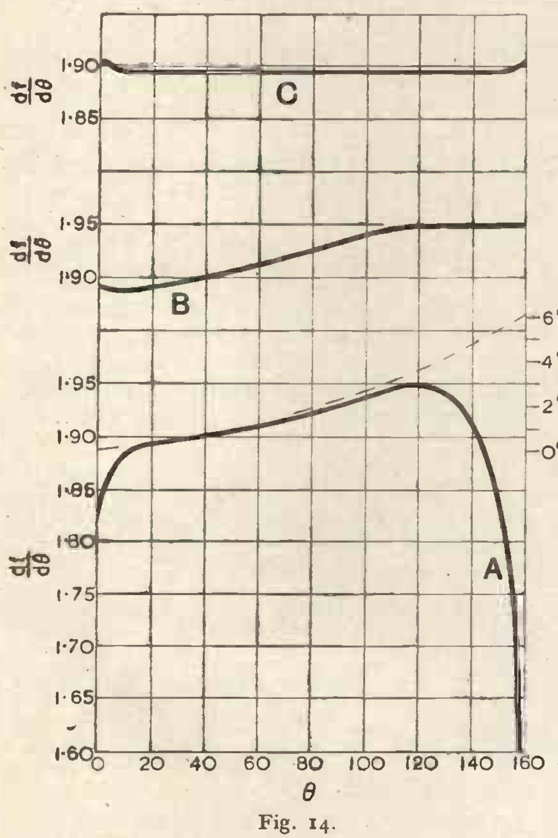


Fig. 14.

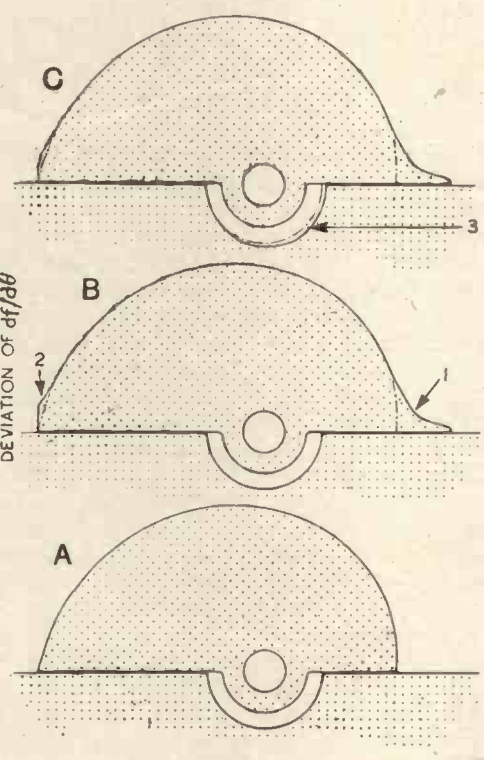


Fig. 15.

angle, θ, that portion of the equivalent edge capacitance area which does not affect the linearity of the frequency law is given by $R' - R$ and this needs no correction. The original plate radius R therefore need be reduced by only

$$W\left(1 + \frac{r}{R - W}\right) \sec\gamma - (R' - R)$$

giving the corrected radius for any angle θ as

$$R_2 = R' - W\left(1 + \frac{r}{R - W}\right) \sec\gamma \quad (36)$$

The $df/d\theta$ curves of Fig. 14 together with the plate-shape drawings of Fig. 15 show the success which attended the application of the preceding formulae for law imperfection and its correction. These curves relate to the condenser of the previous example. The heavy curve A shows the actual imperfection of law obtained with a condenser built with plates shaped as A, Fig. 15, to the formula (16). The frequency range used for this investigation and correction of law was 1.4 to 2.0 Mc/s* and these approximate figures should be associated with the curves of Fig. 14. Any experimental work in connection with the verification or correction of the capacitance law of a condenser which is to be used throughout a wide range of frequency must be performed at a frequency low enough to avoid the effects of the self-inductance of that condenser. The general shape of curve A is almost exactly accounted for by the edge capacitance expression (30) for $df'/d\theta$ as is indicated by the calculated thin broken line curve which is reproduced from Fig. 11. The deviations from this theoretical curve at the ends of the scale are accounted for by the edge effects of the leading and trailing edges of the moving plates. End corrections as shown at 1 and 2 of Fig. 15, were applied by an " estimation, trial and error " method and the $df/d\theta$ curve B resulted. This curve needed only the general law correction as given by expression (36) from $\theta = 20$ to $\theta = 110$. It was not convenient to do this but an equivalent area was cut from the inner radius r of the fixed plates as shown at 3 in Fig. 15 and the completely corrected $df/d\theta$ curve C was then obtained. The curves of Fig. 16 show the plate radius R as originally designed together with the simple correction R_1 and the minimum possible equivalent correction R_2. The area cut from the inner radius r of the fixed plates was equivalent to that corresponding to the difference between curves R and R_2 between $\theta = 20$ and $\theta = 110$.

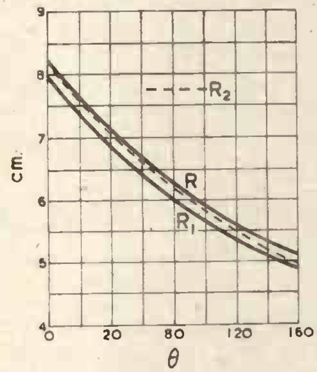


Fig. 16.

Before leaving the subject of edge effects it should be noted that the effect of edge fringing upon the calculated law of a variable condenser may be reduced in the following ways :

1. By reducing the thickness of the moving plates. This is not advised, however, because of the resulting frailty of the plates and the reduction of their resistance to shock in consequence.

2. By reducing the dielectric air gap distance *for a given area of moving plate* or, conversely, by increasing the area of moving plate for a given gap distance. This is not advised in the case of accurate condensers because of the lack of permanence of capacitance (or frequency) calibration which invariably accompanies the use of small gap distances.

In addition to the effect of edge capacitance upon the general law of the condenser there may be local irregularities in the law introduced by the disturbance of the fringing field from the peripheral edges of the moving plates by the proximity of the spacing washers of the fixed plate system. In order

* This frequency range was chosen in order to avoid the use of inductances of self-capacitance values different from that used in the estimation of the " law value " of C_{min}, the reason for the choice will be seen later. The values of $df/d\theta$ will, therefore, be different from those of Fig. 10, although the curve of Fig. 11 should agree with curve A of Fig. 14.

to avoid this the radial distance between such washers and the peripheral edge of the moving plates should be not less than $5g$ for the smallest values of g to $3g$ for the largest values of g.

The reader should be warned against the scheme sometimes resorted to in variable condensers having linear laws of capacitance—the employment of a continuous circumferential spacer for separating the fixed plates. This scheme, although excellent for eliminating the local irregularities of $dC/d\theta$ due to the more conventional spacing *washers*, cannot be employed for that purpose in condensers other than those having linear laws of capacitance. Whether the conventional spacing washers or circumferential spacers are employed, therefore, the radial clearance between these and the moving plates must be large.

(*To be concluded.*)

I.E.E. Meetings

A LECTURE commemorating the life and work of Nikola Tesla will be given by Dr. A. P. M. Fleming, C.B.E., at a meeting of the Institution of Electrical Engineers on November 25th, at 3.0 p.m.

At a meeting of the Wireless Section on November 3rd, J. Kemp will deliver a paper on "Wave Guides in Electrical Communication." "The Rôle of Ultra-High Frequencies in Post-War Broadcasting" will be discussed on November 16th. The openers will be K. I. Jones and D. A. Bell. "Enemy Airborne Radio Equipment" is the subject of a paper by C. P. Edwards to be given on November 24th. Two papers on hearing aids will be read by Dr. T. S. Littler and C. M. R. Balbi on December 1st.

Wireless Section meetings begin at 5.30 p.m.

Correspondence

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

Shot Noise and Valve Equivalent Circuits

To the Editor, "Wireless Engineer"

SIR,—The two modes of representing the voltage amplification of a valve,

$$V = \mu E_g R/(R + R_a) \qquad \text{(i)}$$

and

$$V = G_m E_g RR_a/(R + R_a) \qquad \text{(ii)}$$

(where V is the voltage developed across the anode circuit resistance R and $G_m = \mu/R_a$) are algebraically and practically equivalent so long as we are concerned with a signal voltage E_g applied to the grid; the equivalence is of the same order of identity as that between the two equivalent circuits for a transformer obtained by referring all quantities either to the primary side or to the secondary side.

But shot noise arising within the valve is not a voltage applied to the grid of the valve, so there is no obvious reason for expecting it to involve either (i) or (ii); it is, however, possible to develop two physical pictures of shot noise in terms of either voltage or current fluctuations, parallel with the dual equations (i) and (ii). According to the first of these, which was described in your Editorial as regarding the source of shot noise and the anode resistance of the valve as two valves in parallel, we have the circuit of Fig. 1; the valve has an anode to cathode capacitance C_{AC} and resistance R_a, and its physically accessible terminals are at A and C, to which is connected the external load resistance R. Shot effect then arises from the transfer at random intervals of negative charges e from plate c to plate a of the capacitance C_{AC}, and clearly R_a and R must be taken in parallel in calculating the resulting fluctuations of voltage. According to the second concept, both shot and thermal noise are expressed as fluctuations of current originating at a constant-current generator associated with the conductivity of the resistor concerned. This has been clearly explained for thermal fluctuations in metallic resistors[1,2] so that if the valve were replaced by a resistor the equivalent circuit would be Fig. 2, where X and Y are the physically accessible terminals of the resistance R_o; the generator delivers a constant current (i.e. has infinite internal impedance) the mean square magnitude of which is $\overline{I^2} = (4kT/R_o)\,df$, and the resultant voltage developed when this system is connected to a load R is once

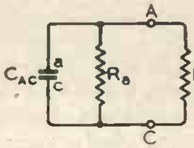


Fig. 1.

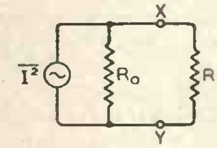


Fig. 2.

more a function of R and R_o in parallel. Although the calculation of the magnitude of the mean square fluctuation current is more difficult in a valve, there are grounds for believing that this is also a possible representation of the shot noise in a space-charge-limited valve, in which case R_o becomes R_a and the shot noise voltage in the external circuit is once more proportional to the resultant of R and R_a in parallel, through which flows a fluctuation current of determinable mean square value.

I suggest that the understanding of shot noise has progressed since Moullin wrote his book (for example, it is now firmly established that the

[1] D. A. Bell, *Journ. I.E.E.*, Vol. 82, p. 522, 1938.
[2] C. J. Bakker and G. Heller, *Physica*, Vol. 6, p. 262, 1939.

"smoothing factor" in a space-charge-limited valve is a function of cathode temperature) so that we can determine the position in the equivalent circuit of the generator of shot voltage or current, but that this does not necessarily have any bearing on the equivalent circuits used to express the amplifying properties of valves.

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

"Reactance-valve Frequency Modulator"

To the Editor, "Wireless Engineer"

SIR,—With reference to the paper "Reactance-valve Frequency Modulator," by Dr. Williams,

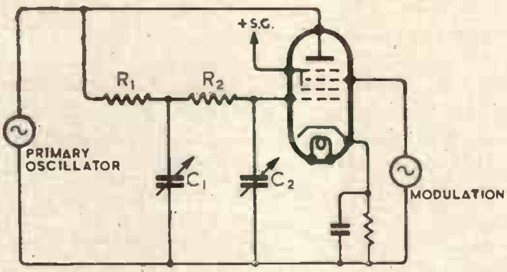


Fig. 1.

which appeared in the August issue of *Wireless Engineer*, it is of interest to draw attention to other methods of designing phase-splitting circuits producing pure reactance in the quadrature valve. One system of neutralisation of R_a is described by C. F. Sheaffer,[1] in which he shows how a grid driving voltage lagging or leading the anode voltage by more than 90° may be obtained by feeding the reactance valve anode from one side of the primary oscillator tuned circuit, and the grid circuit from the opposite end, which is of reversed phase. In this case the desired phase difference becomes less than 90°, and is easily secured in practice.

An easier method of deriving the desired driving voltage is by use of a two-stage phase-splitting circuit, such as is commonly used in phase-shift oscillators. The circuit now becomes that shown in Fig. 1.

[1] "Frequency Modulator," *Proc. I.R.E.*, Vol. 28, p. 66, 1940.

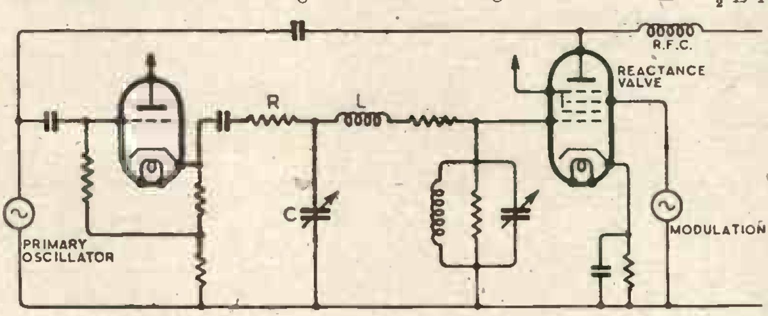


Fig. 2.

In this case, each tandem element need only produce a little more than 45° phase shift.

Dr. Williams points out that with circuits of this kind, either the resistances are so low that serious damping of the primary oscillator tuned circuit is produced, or else the condensers are reduced in value to a few micro-microfarads only. There are two easy ways of avoiding this. In the first place, low resistances are admissible provided a cathode follower is used between primary oscillator and phase-shift circuits. Secondly, a parallel-tuned circuit, operated just off resonance, can simulate a small condenser, while still using a tuning condenser large enough to swamp such indefinite elements as inter-electrode capacitance. Fig. 2 shows a circuit including both arrangements.

In this circuit R and C (say 5,000 ohms and 50 micro-microfarads) produce a phase shift of just less than 90°. The small inductance L in conjunction with the tuned circuit, operated at resonance, or a resistance in conjunction with the same circuit, slightly mistuned, give the additional phase shift required. The use of the cathode follower confers other advantages, well known in other connections.

A network of this kind is adjusted by obtaining the loudest signals from a F.M. receiver, using a given modulating voltage. Resistance neutralisation is secured when minimum amplitude modulation is produced.

Finally, the effect of a reactance-valve current lagging or leading by more than 90° can easily be shown to give zero or negative input impedance, by showing that it draws negative power from the supply.

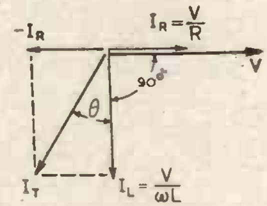


Fig. 3.

Let V = peak primary oscillator voltage.
I = peak current in reactance valve.
ϕ = phase difference = $90° + \theta$.

Then W = input power = $\frac{1}{2} E I \cos \phi$.

$$= \tfrac{1}{2} E I \cos (90° + \theta)$$

$$= -\tfrac{1}{2} E I \sin \theta.$$

A simple vector diagram (Fig. 3) illustrates the same point. If the reactance valve impedance is represented by an inductance L in parallel with a resistance R the phase-splitting network causes a lagging current to be drawn $90° + \theta$ behind the applied voltage V. If the lagging current has a component parallel to V, then provided θ is suitably chosen, the resistive part of the reactance valve impedance is neutralised.

The case of the self-oscillating valve is of course reached if $\theta = 90°$.

F. BUTLER.

Putney, S.W.15.

Impedance Transformations in Band-pass Filters*

By A. S. Gladwin, B.Sc., A.R.T.C.

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

SUMMARY.—By modifying the values of the elements of a filter, and/or by introducing new elements, band-pass filters may be made to behave like the original filter plus a perfect transformer. The conditions necessary to permit this transformation, and the limitations on the types of impedance arms, ratio of transformation and frequency range, are examined. A new equivalent circuit aids the analysis.

CONTENTS

1. Introduction

It is well known that a band-pass filter may be designed in such a way that it behaves as a symmetrical filter section plus a perfect transformer. The advantages of such an arrangement are :—

1. The filter may be used to connect two networks of different impedances, and be matched to both, without the use of an auxiliary transformer. This condition gives minimum insertion loss, or, in the case of amplifier circuits, maximum gain.

2. The circuit elements may be given values which are easier of physical realisation than those of the prototype section. It may be possible to eliminate one of the filter elements by choice of a suitable transformation ratio. With this end in view, a symmetrical filter may be built in two sections with a double transformation, e.g. a step up followed by a step down, so that the image impedances at the input and output terminals are equal.

The first factor is the one of chief interest in high-frequency filters, especially wide band filters.

The design of impedance transforming filters is usually based on the equivalent circuits of Fig. 1, which are due to Norton.[1] The proof of these equivalences is simple, but the transformations are not of the type which can easily be remembered. Two circuits are necessary because Fig. 1(b) cannot be expressed in T form and Fig. 1(d) cannot be expressed in π form.

A symmetrical equivalent circuit, which can be expressed in both T and π forms, and which can be used instead of Fig. 1, will now be described.

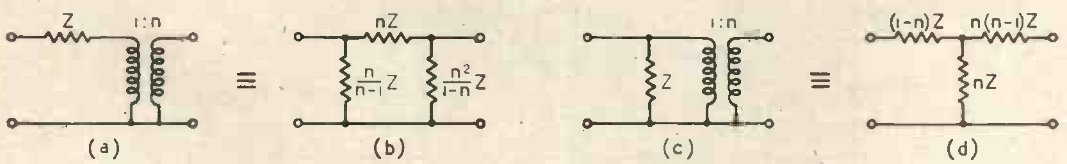


Fig. 1.

2. List of Symbols

$C_1\ C_{1a}\ ..\ C_{1x}\ C'_1$ Capacitances in filter series arms.

$C_2\ C_{2a}\ ..\ C_{2y}\ C'_2$ Capacitances in filter shunt arms.

i_1 Input current to a network.

i_2 Output current from a network.

$L_1\ L_{1a}\ ..\ L_{1x}\ L'_1$ Inductances in filter series arms.

$L_2\ L_{2a}\ ..\ L_{2y}\ L'_2$ Inductances in filter shunt arms.

$m = Z_1$ (or Z_{1a}, etc.) / Z_2 (or Z_{2a}, etc.)

n Turns ratio of a transformer.

v_1 Input voltage to a network.

v_2 Output voltage from a network.

$\omega = 2\pi \times$ frequency.

Z_i Input impedance of a network.

Z_L Terminating impedance of a network.

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

$Z_1\ Z_{1a}\ ..\ Z_{1x}$ Impedance of filter series arms.
$Z_2\ Z_{2a}\ ..\ Z_{2y}$ Impedance of filter shunt arms.
Z_T Transfer impedance.

3. Equivalent Circuits

Consider the symmetrical 4-terminal network shown in Fig. 2, which is composed of

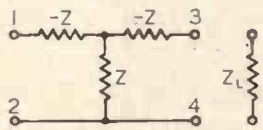


Fig. 2.

equal and opposite impedance arms Z and $-Z$. Z is any impedance whatever, and in general is a network composed of resistances, capacitances and inductances. $-Z$ is represented by the same network with the sign of each element reversed, i.e. negative resistances, capacitances and inductances. These negative elements cannot be realised *per se* in passive networks, though at any particular frequency the shunt arm may be an inductance of reactance jX, and the series arms capacitances of reactance $-jX$. In passive networks, therefore, the network of Fig. 2 must be associated with positive impedances of magnitude and nature sufficient to cancel the negative impedances. The limitations which this requirement places on the filter design will be considered later.

Let the terminals 3, 4 of Fig. 2 be closed by an impedance Z_L. Then the impedance Z_i looking in at 1.2 is

$$Z_i = -Z + \frac{Z(Z_L - Z)}{Z_L} = \frac{-Z^2}{Z_L}$$

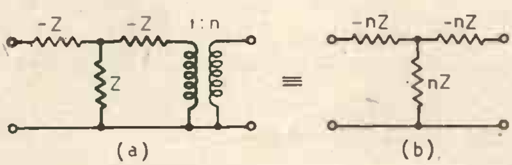


Fig. 3.

Hence the section is an impedance inverting network. If instead of terminating the section with Z_L, a perfect transformer of turns ratio n is interposed between terminals 3, 4 and Z_L, an impedance Z_L/n^2 is reflected to the primary, and the input impedance becomes

$$Z_i = \frac{-Z^2}{Z_L/n^2} = \frac{-(nZ)^2}{Z_L}$$

As far as Z_i is concerned, the effect of interposing the transformer is the same as if no transformer were in circuit, but Z were changed to nZ, and $-Z$ to $-nZ$. This suggests the equivalence of Fig. 3. That Figs. 3(a) and (b) are completely equivalent is easily proved.

The input and output open circuit impedances are in both networks zero. For Fig. 3(b) the transfer impedance Z_T (= input voltage/output short circuit current) is $-nZ$ and for Fig. 3(a)

$$Z_T = -Z/\tfrac{1}{n} = -nZ$$

Hence the networks are completely equivalent.

Figs. 4(a) and (b) show similar equivalences for π sections which are derived from Fig. 3 by applying the star-delta transformation theorem.

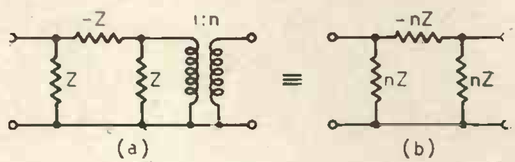


Fig. 4.

Before leaving this network an interesting property may be noted.

Let the terminals 3, 4 of Fig. 2 be closed by an impedance Z_L, and let a voltage v_1 be applied across 1.2.

The current through Z_L is i_2 and

$$v_1 = i_2(Z_L - Z) - Z(i_2 + i_2(Z_L - Z)/Z) = -i_2 Z$$

$$\therefore\ i_2 = -v_1/Z.$$

(It may be noted that this circuit is a case in which Thévenin's theorem breaks down and cannot be used to find i_2, since it gives the indeterminate result ∞/∞). The output current is independent of Z_L, and the network is therefore a constant current network.

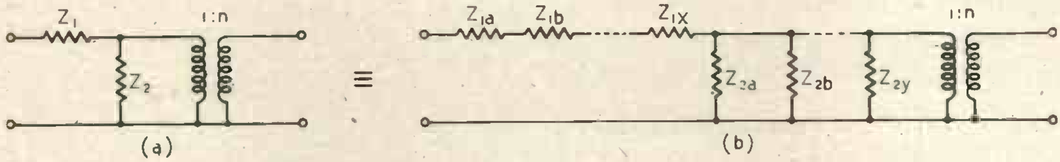
Let the voltage across Z_L be v_2 and let the input current be i_1. The voltage across Z is

$$v_2 - v_2 Z/Z_L$$

$$\therefore\ i_1 = v_2/Z_L + \frac{v_2 - v_2 Z/Z_L}{Z}$$

$$= v_2\left[\frac{Z + Z_L - Z}{ZZ_L}\right] \doteq v_2/Z.$$

Hence, if i_1 is maintained at a constant value, v_2 is constant and independent of Z_L; the network is therefore a constant voltage network.



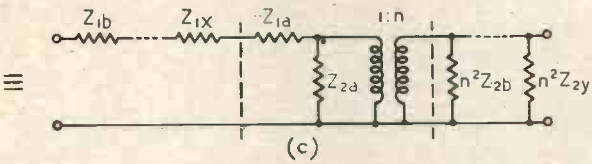


Fig. 5.

This network has the remarkable property of being both a constant current and a constant voltage network.*

Only the symmetrical network of Fig. 2 or its π equivalent Fig. 4(a) possesses these properties. For if the right-hand arm is $-Z + Z'$ instead of $-Z$, the constant current property is maintained, but the voltage across Z_L is $\frac{Z_L}{Z_L + Z'}\, i_1 Z$, which depends on the value of Z_L. Similarly, any change in the left-hand arm maintains the constant voltage property but destroys the constant current property. Changes in both arms destroy both properties.

It follows that any 4 terminal network, which possesses both constant current and constant voltage properties, must be, or must be capable of reduction to, the form of Fig. 2.

As a corollary to the foregoing remarks, any 4-terminal passive network which exhibits constant current properties in one direction of transmission, will have constant voltage properties in the opposite direction and *vice versa*. For a constant current network,

$$i_2 = av_1$$

Considering i_2 as an input current, it has a negative value,

$$\therefore \quad v_1 = \frac{-i_2}{a}$$

so that looking in at the output terminals the network has constant voltage properties.

4. Relations between Shunt and Series Arms

Fig. 5(a) shows a full section of a filter, in which an impedance transformation of n^2 is obtained by means of a perfect transformer. Suppose that the series arm Z_1 can be divided into a number of positive impedances, $Z_{1a}\, Z_{1b}\, .\ .\ Z_{1x}$ connected in series, and that the shunt arm Z_2 can be divided into a number of positive impedances

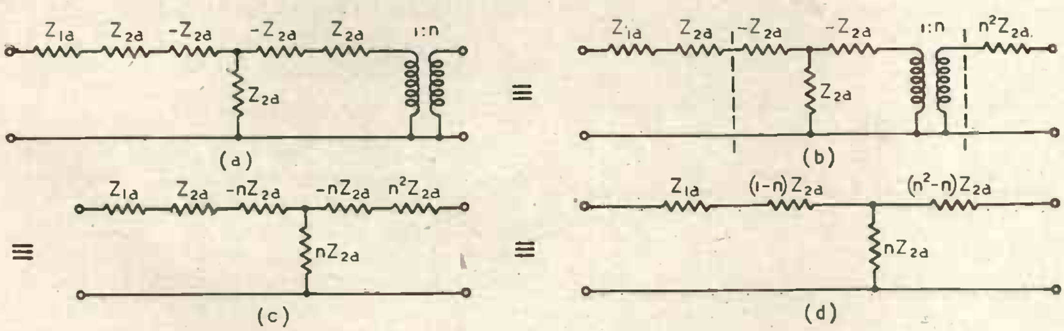


Fig. 6.

$Z_{2a}\, Z_{2b}\, .\ .\ Z_{2y}$, connected in parallel. Fig. 5(a) can then be represented as in Fig. 5(c). The portion of Fig. 5(c) between the dotted lines will now be considered. Two equivalent circuits can be derived for this portion, based on the equivalences of Figs.

* Some of the properties of this type of network have previously been described by Bartlett. See reference [2].

3 and 4, supported by the following two propositions which are axiomatic :—

(1) A network is unchanged, if any branch is interrupted, and equal and opposite impedances, connected in series, are inserted in the branch.

(2) A network is unchanged, if, between any two points in the network, equal and opposite impedances are connected in parallel.

The section of Fig. 5(c) between the dotted lines can be represented as in Fig. 6(a) by proposition 1.

In Fig. 6(b), the impedance Z_{2a} in the right-hand arm has been taken to the other side of the transformer, where it becomes n^2Z_{2a}. The portion of Fig. 6(b) between the dotted lines can then be transformed according to Fig. 3. Figs. 6(c) and (d) show the completion of the transformation.

Fig. 7 shows the second derivation using proposition 2 and the equivalences of Fig. 4.

The necessary relations between Z_1 and Z_2, if Figs. 6(d) and 7(d) are to be capable of physical realisation, will now be considered. Dealing first with Fig. 6(d) ; the right-hand arm $(n^2 - n)Z_{2a}$ stands by itself, since the remaining components n^2Z_{2b}, etc., are shunt connected. $(n^2 - n)Z_{2a}$ must therefore be a positive impedance, i.e., $n \geqslant 1$. In the left-hand arm, $Z_{2a}(1 - n)$ will be a negative impedance. Since this cannot be realised *per se* in passive circuits, it follows that the associated impedance Z_{1a} must be of the same nature as Z_{2a} and equal to or greater than $(n - 1)Z_{2a}$ in magnitude. Thus $Z_{1a} = \gamma(n - 1)Z_{2a}$ where γ is a real number equal to or greater than 1.

Turning to Fig. 7(d), the left-hand shunt arm $\dfrac{nZ_{1a}}{n-1}$ must be a positive impedance since the components Z_{1b}, etc., of Z_1 are all series connected. Hence as before $n \geqslant 1$. The impedance $\dfrac{n^2Z_{1a}}{1-n}$ in the right-hand arm is thus negative, so that the associated impedance n^2Z_{2a} must be such that Z_{2a} is of the same nature as Z_{1a} and $n^2Z_{2a} \leqslant \dfrac{n^2Z_{1a}}{n-1}$ or $Z_{1a} = \gamma(n - 1)Z_{2a}$ as before.

The conditions required for an impedance transformation can now be stated :

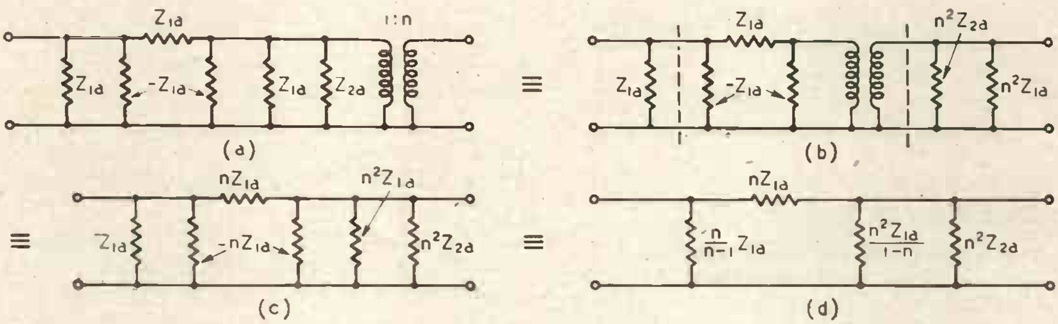


Fig. 7.

Let the series arm be divided into its elementary impedance elements all of which are series connected, and let the shunt arm be divided into its elementary impedance elements all of which are parallel connected. An impedance transformation will be possible, if one of the elementary series impedance elements, Z_{1a}, say, is of the same nature as one of the parallel impedance elements Z_{2a}, say, *i.e.* $Z_{1a} = mZ_{2a}$, where m is a positive real number.

It will be noticed that the above condition

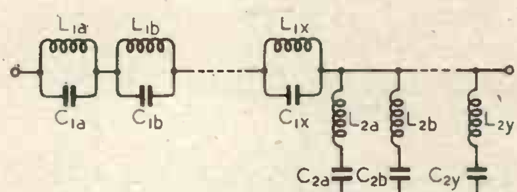


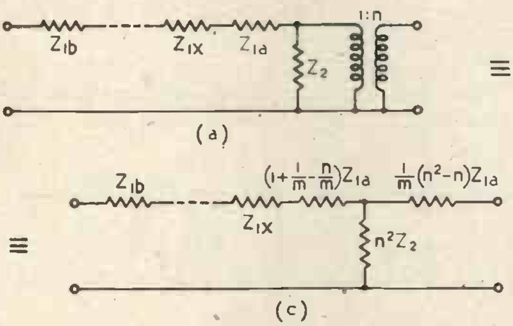
Fig. 8.

is fulfilled if $Z_1 = mZ_2$; but it will be obvious that a structure of this sort, which has similar shunt and series arms, cannot possess the properties of a filter.

The maximum value of the transformation ratio n, is given for Fig. 6(d) by the equation

$$Z_{1a} + (1 - n) Z_{2a} = 0$$
$$\therefore \quad n_{max} = 1 + Z_{1a}/Z_{2a} = 1 + m$$

in Fig. 7(d) by $n^2Z_{2a} + n^2Z_{1a}/1 - n = 0$ giving $n_{max} = 1 + m$, as before.



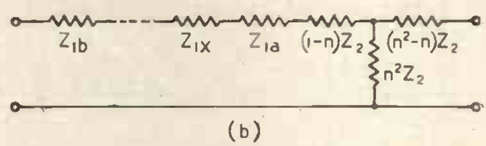


Fig. 9.

5. Limitations on Frequency Range

In the preceding section, it was shown that certain relations must exist between Z_1 and Z_2 if an impedance transformation is to be made. It will now be proved that when such relations exist the filter cannot be a low-pass, high-pass or band-stop filter.

Whatever the way in which the impedance arms Z_1 and Z_2 are composed, they may always be reduced to two equivalent standard forms by the application of Foster's reactance theorem.[3]

This theorem shows two possible ways of realising physically any passive dissipationless two-terminal network with a given impedance-frequency characteristic. The first way gives a series network; the second way a parallel network. It will be convenient to represent the series arm by the first method and the shunt arm by the second method. Fig. 8 shows the general form of Z_1 and Z_2. Each of the networks representing Z_1 and Z_2 may take four general forms identified by their reactances at zero and infinite frequencies. Considering first the series network of Z_1, the four types are:

Type 1. All the elements are finite as shown in Fig. 8. The reactance is zero at frequencies of 0 and ∞.

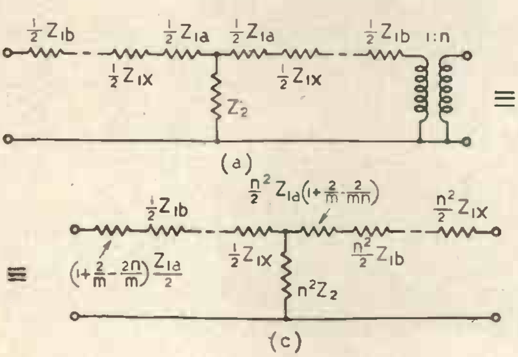
Type 2. L_{1a} is infinite, giving C_{1a} in series with the remainder of the network. The reactance is $-\infty$ at $f = 0$ and 0 at $f = \infty$.

Type 3. C_{1a} is zero giving L_{1a} in series with the remainder of the network. The reactance is 0 at $f = 0$ and ∞ at $f = \infty$.

Type 4. L_{1a} is infinite and, say, C_{1b} is zero giving C_{1a} in series with L_{1b} and the rest of the network. The reactance is $-\infty$ at $f = 0$ and $= +\infty$ at $f = \infty$.

It will be obvious that any further modifications will give a network essentially the same as one of the preceding four.

It will also be clear that when the reactance tends to zero as f tends to zero, it can be expressed at a frequency df as jX_1df. If the reactance tends to $-\infty$ as $f \to 0$ it can be expressed as $-jX_1/df$. As $f \to \infty$ the expressions become jX_1/f and jX_1f. By taking limits, it follows that the ratio of two reactances at $f = 0$ may be either a finite positive number or 0 or $-\infty$; and at $f = \infty$ the ratio of two reactances may be a finite positive number, or 0 or $+\infty$.



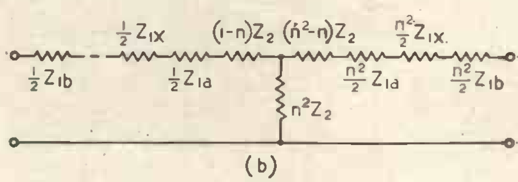


Fig. 10.

Similar to the four types of series arm, there are four general types or shunt arm, obtained from the original network by setting $L_{2a} = 0$ or

$$C_{2a} = \infty \text{ or } L_{2a} = 0 \text{ and (say) } C_{2b} = \infty.$$

The reactance characteristics of the four types of series and shunt arms at zero and infinite frequencies are summarised in Table I.

TABLE I.

	Z_1 type				Z_2 type			
	1	2	3	4	1	2	3	4
$X(f = 0)$	0	$-\infty$	0	$-\infty$	$-\infty$	$-\infty$	0	0
$X(f = \infty)$	0	0	∞	∞	∞	0	∞	0

Now the cut-off frequencies of a filter are determined by the ratio Z_1/Z_2, which has the values of 0 or -4 at the boundaries of

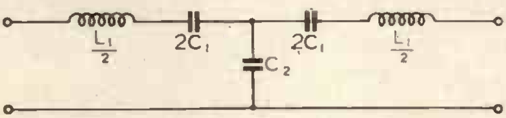


Fig. 11.

transmitting and attenuating bands. Since Z_1 and Z_2 can each have four different general forms, the network of Fig. 8 can have 16 different forms. These 16 possibilities are tabulated in Table II. From Table I and the remarks of the preceding paragraphs the values of Z_1/Z_2 at zero and infinite frequencies can easily be obtained, and the type of filter immediately recognised. Also, by considering the physical arrangement of Fig. 8 in the 16 cases, we can see at

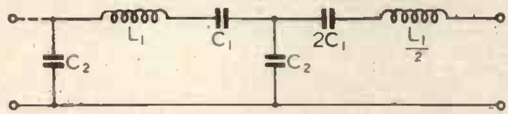


Fig. 12.

a glance if the network fulfils the condition necessary to permit an impedance transformation, viz., a series element of the series arm to be similar to a shunt element of the shunt arm, *e.g.*, for a Type 1 series arm and a Type 1 shunt arm (all elements in each arm finite), it is obvious that no transformation is possible.

From this Table it is seen that an impedance transformation is always possible in band-pass filters, and that no transformation may be made in low-pass, high-pass and band-stop filters.

Obviously the maximum transformation ratio n_{max} is closely related to the cut-off frequencies. The precise value of n_{max} in any particular case may be calculated from the formula given in Section 4. As a general rule the maximum transformation ratio decreases as the bandwidth of the filter increases.

TABLE II.

Z_1 type	Z_2 type	$\frac{Z_1}{Z_2}(f = 0)$	$\frac{Z_1}{Z_2}(f = \infty)$	Filter type	Impedance Transformation.
1	1	0	0	Band stop	Impossible
	2	0	$+ ve$	Low pass	Impossible
	3	$+ ve$	0	High pass	Impossible
	4	$+ ve$	$+ ve$	Band pass	Possible
2	1	$+ ve$	0	High pass	Impossible
	2	$+ ve$	$+ ve$	Band pass	Possible
	3	$- \infty$	0	High pass	Impossible
	4	$- \infty$	$+ ve$	Band pass	Possible
3	1	0	$+ ve$	Low pass	Impossible
	2	0	∞	Low pass	Impossible
	3	$+ ve$	$+ ve$	Band pass	Possible
	4	$+ ve$	∞	Band pass	Possible
4	1	$+ ve$	$+ ve$	Band pass	Possible
	2	$+ ve$	∞	Band pass	Possible
	3	$- \infty$	$+ ve$	Band pass	Possible
	4	$- \infty$	∞	Band pass	Possible

6. Classification of Filter Types

In Section 4 the conditions necessary for an impedance transformation were set forth. It was seen that the transformation could be made in either of two ways (Figs. 6 and 7), and in both cases it was necessary to introduce new impedance elements, $(n^2 - n)Z_{2a}$ in Fig. 6 and $\dfrac{n}{n-1}\,Z_{1a}$ in Fig. 7.

It will now be shown that there are two special types of band-pass filter, in which impedance transformations can be made, in T or π sections, simply by altering the values of the shunt and series arms, without introducing new impedance elements.

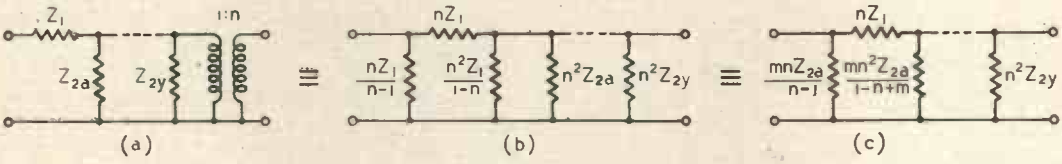
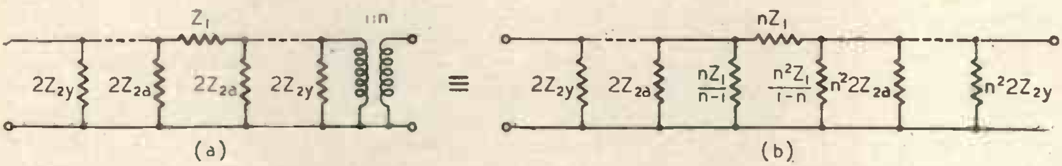


Fig. 13.



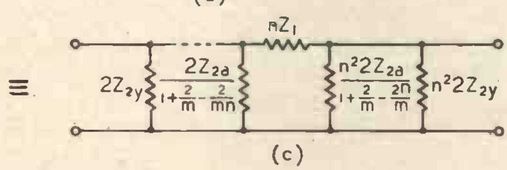


Fig. 14.

Category 1

If Z_2 is such that $Z_{1a} = mZ_2$, the transformation of Fig. 5 takes the form shown in Fig. 9. The series arms of the transformed section contain only impedances of the type Z_{1a}, etc. It is obvious that if we start with a T section, an impedance transformation can be made, simply by altering the values of the impedance elements. This is illustrated in Fig. 10. Since a negative impedance in the sense defined in Section 2 is inadmissible, the limiting values of n are those which reduce the coefficient of Z_{1a} to zero

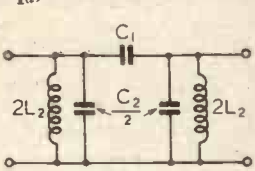


Fig. 15.

$$\therefore \quad 1 + \frac{2}{m} - \frac{2n}{m} \geqslant 0 \text{ or } 1 + \frac{2}{m} - \frac{2}{mn} \geqslant 0.$$

The left-hand equation comes from the left-hand series arm of Fig. 10(c), and the right-hand equation from the right-hand arm.

Solving for n

$$1 + \frac{m}{2} \geqslant n \geqslant \frac{1}{1 + m/2}$$

The two limiting values of n are reciprocal, as might be expected.

Fig. 11 illustrates a filter section of this type. The limiting values of n are $1 + C_2/2C_1$ and $\dfrac{1}{1 + C_2/2C_1}$. If, however, the section forms the end of a filter chain as in Fig. 12 the limiting values of n become

$$1 + \frac{1}{m} - \frac{n}{m} \geqslant 0 \text{ and } 1 + \frac{2}{m} - \frac{2}{mn} \geqslant 0$$

$$1 + m \geqslant n \geqslant \frac{1}{1 + m/2}$$

The maximum value of n has increased to $1 + \dfrac{C_2}{C_1}$, while the minimum value is unchanged.

Category 2

Let Z_1 be such that $Z_1 = mZ_{2a}$. The transformation of Fig. 5 takes the form shown in Fig. 13. The shunt arms in the transformed section contain only impedances of the type Z_{2a}, etc., so that if we start with

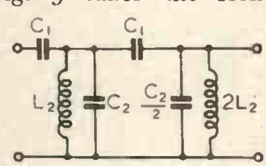


Fig. 16.

a π section, an impedance transformation can be made, simply by altering the values

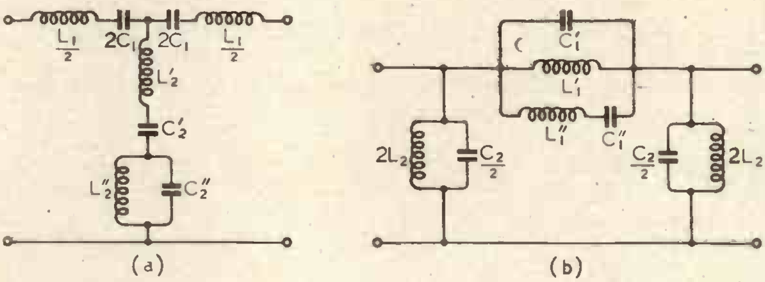
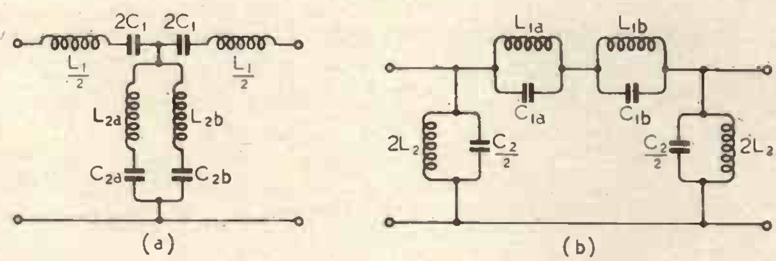


Fig. 17 (*Above*).

Fig. 18 (*Right*).



of the impedance elements. This is illustrated in Fig. 14.

Applying the condition that no impedance element shall be negative, the limits of n are given by

$$1 + \frac{2}{m} - \frac{2}{mn} \geqslant 0 \text{ and } 1 + \frac{2}{m} - \frac{2n}{m} \geqslant 0$$

$$\therefore \quad 1 + \frac{m}{2} \geqslant n \geqslant \frac{1}{1 + \frac{m}{2}}$$

Fig. 15 shows a section of this type, where $m = \frac{C_2}{C_1}$, giving $1 + \frac{C_2}{C_1} \geqslant n \geqslant \frac{1}{1 + C_2/C_1}$. If Fig. 15 forms the end of a filter as shown in Fig. 16, the limiting values of n are given by

$$1 + m \geqslant n \geqslant \frac{1}{1 + m/2}$$

Category 3

There is a third type of band-pass filter in which it appears from casual inspection that no impedance transformation can be made. Fig. 17 illustrates two sections of this type. The shunt arm of Fig. 17(a) is in series form and the series arm of 17(b) is in shunt form, so that the necessary condition for an impedance transformation $Z_{1a} = mZ_{2a}$ does not appear to be realised. If, however, the shunt arm of Fig. 17(a) is replaced by its equivalent circuit Fig. 18(a), and the series arm of Fig. 17(b) is similarly treated, the condition can obviously be met.

All M type band-pass filters fall into this category. Figs. 17(a) and (b) are respectively series-derived and shunt derived from the constant-K prototype.

REFERENCES

[1] E. L. Norton. U.S. Patent No. 1681554. 21st Aug. 1928.
[2] A. C. Bartlett. *Journ. I.E.E.*, Vol. 65, pp. 373–376.
[3] R. M. Foster. *Bell Sys. Tech. Journ.*, Vol. 3. pp. 259–267.

Index to Abstracts

THE index to the Abstracts and References section for the current volume is in course of preparation and, as in the past two years, will be published separately early in the new year.

A charge of 2s. 8d. (including postage) will be made for the index and, as supplies will be limited, it will be necessary for those requiring copies to make early application to our Publishers.

As in former years the index to Articles and Authors for the current volume will be included in the December issue.

Photographing C.R.O. Traces

AT a meeting of the Association for Scientific Photography on November 13th, papers will be given by N. Hendry and W. Nethercot, M.A., B.Sc., on "The Photography of Cathode-Ray Oscillograph Traces." The meeting will begin at 2.30 at the Institution of Electrical Engineers. Further details of the activities of the Association may be obtained from the Hon. Secretary, Tavistock House North, Tavistock Square, London, W.C.1, to whom application should be made for tickets fo the above meeting.

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

554 470.—Gramophone pick-up with means for muting when the needle is being changed.

R. E. Martin. Application date, 2nd December, 1941.

AERIALS AND AERIAL SYSTEMS

554 190.—Aerial of the travelling-wave type with means for feeding back energy from the remote to the input end of the system.

Marconi's W.T. Co. (assignees of P. S. Carter). Convention date (U.S.A.), 24th September, 1940.

554 575.—Screening arrangement for a pair of electromagnetic horn radiators or aerials to prevent diffraction effects and consequent "singing."

Marconi's W.T. Co. (assignees of M. Katzin). Convention date (U.S.A.), 1st March, 1941.

DIRECTIONAL WIRELESS

554 251.—Cathode-ray direction finder wherein the orientation of a distant transmitter is indicated by the momentary illumination of a circularly-moving beam of electrons.

Standard Telephones and Cables (communicated by International Standard Electric Corporation). Application date, 9th January, 1942.

RECEIVING CIRCUITS AND APPARATUS

(*See also under Television*)

554 371.—Means for counterbalancing the noise component, and thus improving the signal-to-noise ratio, in high-frequency amplifiers.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date, 6th June, 1941.

554 388.—Frequency-discriminating circuit for use as a tuning indicator for frequency-modulated signals.

The British Thomson-Houston Co. Convention date (U.S.A.), 12th February, 1941.

554 455.—Hinged tuning dial, arranged outside the receiver cabinet, and capable of rotation about an horizontal axis.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date, 23rd March 1942.

554 668.—Automatic frequency-control system which is designed to give broad selectivity during the process of tuning-in to a desired transmission.

Hazeltine Corporation (assignees of H. A. Wheeler and R. L. Freeman). Convention date (U.S.A.), 23rd January, 1941.

554 675.—Frequency changer for a superhet receiver in which the damping of the signal input circuit is reduced to a minimum.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date, 13th March, 1942.

554 724.—Powdered-iron inductance, provided with means for frequency compensation, particularly for a superheterodyne receiver.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date, 12th January, 1942.

TELEVISION CIRCUITS AND APPARATUS

FOR TRANSMISSION AND RECEPTION

554 172.—Method of feeding a saw-tooth oscillation generator for the deflecting coils of a cathode-ray tube so as to prevent distortion due to the D.C. component flowing through the coils.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date, 9th January, 1942.

554 281.—Synchronising system for the transmission of pictures from a remote point to the main television transmitter.

Marconi's W.T. Co. (communicated by The Radio Corporation of America). Application date, 30th April, 1942.

554 329.—Impedance-matching network for coupling two unequal load impedances over a wide band of frequencies, particularly in a television system.

Standard Telephones and Cables (assignees of S. Darlington). Convention date (U.S.A.), 25th July, 1941.

554 588.—Saw-toothed generator, of the "blocking oscillator" type, particularly for synchronising the scanning frequencies in television.

Standard Telephones and Cables (assignees of R. L. Campbell). Convention date (U.S.A.), 15th July, 1941.

TRANSMITTING CIRCUITS AND APPARATUS

(*See also under Television*)

554 144.—Circuit comprising a saturable inductance and a capacitive reactance for feeding a peaked-wave output to a frequency converter.

The British Thomson-Houston Co. Convention date (U.S.A.), 16th January, 1941.

554 586.—Housing and supporting means for a portable or field radio installation.

Rediffusion Ltd. and P. A. Tiller. Application date, 13th May, 1942.

554 627.—Construction and arrangement of the high-current cathode of a radio transmitting tube.
"Patelhold" Patentverwertungs etc., Holding A.G. Convention date (Switzerland), 13th December, 1940.

554 715.—Device comprising a resonant transmission line associated with a vibrating diaphragm for frequency modulating a carrier wave.
A. D. Blumlein. Application date, 16th November, 1939.

SIGNALLING SYSTEMS OF DISTINCTIVE TYPE

554 214.—Repeater amplifier for an electric-wave transmission line wherein the pilot current for regulation purposes is given a different gain from that of the signal current.
Standard Telephones and Cables (assignees of H. K. Krist). Convention date (U.S.A.), 25th February, 1941.

554 367.—Inductive network designed as a wide-band transformer coupling, or repeater coil, for a line carrier-wave signalling system.
Standard Telephones and Cables (assignees of N. Botsford). Convention date (U.S.A.), 28th June, 1941.

554 456.—Multi-channel signalling system utilising pulse modulation.
Standard Telephone and Cables (communicated by International Standard Electric Corporation). Application date, 23rd April, 1942.

554 491.—Frequency-selective relay for use in a telephone reed dialling system.
Standard Telephones and Cables. Convention date (U.S.A.), 15th October, 1941.

554 542.—Balanced condenser circuit for preventing cross-talk in a multi-channel carrier-wave signalling system.
Standard Telephones and Cables and M. van Hasselt. Application date, 6th January, 1942.

CONSTRUCTION OF ELECTRONIC-DISCHARGE DEVICES

554 154.—Electron-discharge device with a resonant electrode system for the generation of radially-propagated standing waves of very high frequency.
The British Thomson-Houston Co. (communicated by International General Electric Co., Inc.). Application date, 16th August, 1941.

554 424.—Method of mounting, sealing, and brazing the electrodes of an electron-discharge tube.
Westinghouse Electric International Co. Convention date (U.S.A.), 30th April, 1941.

554 574.—Construction and arrangement of the resonator and other electrodes in an electron-discharge tube of the velocity-modulation type.
Sperry Gyroscope Co. Inc. (assignees of S. F. Varian and R. H. Varian). Convention date (U.S.A.), 24th April, 1941.

554 710.—Construction and arrangement of the pointed "cold" cathode of a cathode-ray tube used as an electron microscope.
The British Thomson-Houston Co. Convention date (U.S.A.), 1st May, 1941.

SUBSIDIARY APPARATUS AND MATERIALS

554 161.—Construction of variable condenser comprising two sets of vanes, each of which is independently adjustable relatively to a fixed vane.
Standard Telephones and Cables and H. T. Prior. Application date, 19th December, 1941.

554 202.—Arrangement for accentuating the velocity-modulation effect secured by passing a stream of electrons through a resonant electrode system.
Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date, 18th December, 1941.

554 319.—Means for minimising the screening required to prevent undesired radiation from short-wave diathermy apparatus.
A. S. Milinowski, Junr. Application date, 28th March, 1942.

554 350.—Construction of a concentric-line inductance and switching means for tuning it by short-circuiting the inner and outer conductors.
Marconi's W.T. Co. (assignees of W. H. Conron and B. W. Suckle). Convention date (U.S.A.), 1st March, 1941.

554 361.—Preventing leakage of the liquid or gelatinous content of a condenser of the electrolytic type.
P. A. Sporing and The Telegraph Condenser Co Application date, 27th April, 1942.

554 468.—Automatically controlling the feed back in a relaxation oscillation generator so as to maintain an output of constant amplitude.
V. A. Sheridan. Application date, 6th November, 1942.

554 515.—Automatic cut-out device for protecting a gas-filled rectifier or like discharge tube against excessive current.
Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date, 6th February, 1942.

554 568.—Method of treating the powdered-iron cores of high-frequency inductances as a protection against rust.
Johnson Laboratories Inc. (assignees of A. D. Whipple). Convention date (U.S.A.), 8th January, 1941.

554 630.—High-frequency resistance element, or watt meter, suitable for use with wavelengths shorter than its own dimensions.
The Mullard Radio Valve Co. and K. E. Latimer. Application date, 9th January, 1942.

554 747.—Arrangement of insulator disks in the concentric type of high-frequency cable.
British Insulated Cables; P. Blackburn; and H. R. F. Carsten. Application date, 15th April, 1942.

Abstracts and References

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

PROPAGATION OF WAVES

2932. The Radiation of a Cavity Wave from a Circular-Sectioned Hollow Tube debouching into a Plane Screen [Surface of the Ground]: Parts II and III.—Buchholz. (*See* 2997.)

2933. Beyond the Ultra-Short Waves [Survey, beginning with the Pioneer History].—G. C. Southworth. (*Proc. I.R.E.*, July 1943, Vol. 31, No. 7, pp. 319–330.) A summary was dealt with in 2630 of October.

2934. On the Diffraction at a Circular Aperture and a Circular Disc [Analysis for a Plane Wave at Normal Incidence].—W. Ignatowsky. (*Comptes Rendus* (*Doklady*) *de l'Acad. des Sci. de l'URSS*, No. 9, Vol. 31, 1941, pp. 868–871: in German.) For previous work *see* 3333 of 1940.

2935. The Dielectric Dispersion and Absorption of Water and Some Organic Liquids [Measurements on 9.72 cm Wavelength].—W. P. Conner & C. P. Smyth. (*Sci. Abstracts*, Sec. A, July 1943, Vol. 46, No. 547, p. 139.) For other work *see* 1516 of May.

2936. Frequency Modulation and Foliage [Milwaukee Measurements on Adverse Effect on Reception of F.M. Ultra-Short Waves].—(*Wireless World*, Sept. 1943, Vol. 49, No. 9, p. 276: paragraph only.)

2937. A Clear Presentation of the Theory of the Inhomogeneous Plane Wave.—O. Schriever. (*Hochf:tech. u. Elek:akus.*, Oct. 1942, Vol. 60, No. 4, pp. 100–104.)

"By an inhomogeneous plane wave we mean a wave in which the planes of constant phase do not coincide with those of constant amplitude. Waves of this type are formed, for example, in refraction in absorbing media. The laws governing this phenomenon can be derived from those for perfect insulators by the mere replacement of the real refraction quotients by the complex. With such a procedure, however, clearness is compromised by the fact that the directions (real throughout) of the phase and amplitude planes can only be calculated by a roundabout path through a 'complex angle of refraction' not susceptible to a geometrical interpretation.

"On the other hand, in the present treatment the clear presentation forms the starting point. First, a wave-picture is developed": this is done as follows:—Two of the "rays" (wave-normals), parallel to each other, are selected, and at right angles to each the values of the function Π ($= e^{ik_0 r}$, the time factor being omitted: eqn. 1) are drawn. For an absorbing medium this gives the picture of Fig. 1, characterised by the fact that along an intersecting plane $z = 0$, oblique to the direction of propagation, the amplitude varies continuously, according to the path-difference Δr. Now if the intersecting plane is converted into a surface of separation between two media, the upper loss-free and the lower absorbing, and a plane wave (not shown) is supposed to fall on it, it is obvious that the refracted wave in the lower medium cannot be of the "homogeneous" type. For its amplitude at the frontier points A_1 and A_2 is determined by the incident homogeneous wave, and must therefore (since the upper medium is loss-free) be constant along the whole plane of demarcation. To take this circumstance into account the wave trains are displaced longitudinally with respect to each other, so as to bring points of equal amplitude at the frontier points A_1, A_2. This gives Fig. 2, the picture of an inhomogeneous plane wave in which the upper portion, in the loss-free medium, is to be regarded as a "virtual" backward extension of the lower, "physical" component in the absorbing medium. The planes of constant phase, E', are no longer identical with those of constant amplitude, E'': the former still run perpendicular to the rays, but the latter are now parallel to the boundary surface. If on the other hand the upper medium also is absorbing, the primary excitation at the frontier points will be of unequal value, that at A_2 being greater than that at A_1. In Fig. 3 this is taken into account by a corresponding relative shift of the envelopes: both phase and amplitude planes now run at an angle to the surface and to each other. Thus Fig. 3 is the picture of the most general case of an "inhomogeneous plane wave."

The writer continues: "With the help of this [the wave-picture] the wave-function of the inhomogeneous plane wave is derived [eqn. 3: $\Pi_3 = e^{i(k'r' + ik''r'')}$]; the constants therein involved are finally treated in such a way that both the wave-equation and the boundary conditions are satisfied [Sections II a & b respectively]. In this way the aim is attained without the introduction of the notion of a complex angle of refraction. The phenomenon of total reflection also fits into this treatment" [Section IIe].

Section III deals with the intensity relations, the energy transformation at the surface of demarcation and the polarisation conditions on either side of this. The unequal suitability of the Fresnel formulae for optical and high-frequency problems is discussed: this arises from the fact that in optics the light source is unpolarised, and the artificially polarised ray can be adjusted so that the polarisation can be in any desired direction with respect to the plane of incidence, whereas in h.f. problems the direction is fixed by the radiating source. In optical problems, the principal cases are where the field vector is parallel, or perpendicular to, the plane of incidence, while in h.f. problems that plane loses all significance as a reference system and it is much better to relate all polarisation questions to a coordinate system connected with the surface of demarcation. "Thus the problem is formulated as follows:—The Hertz vector of the incident plane wave has the amplitude F_1, arbitrary as regards direction and amount, with the components F_{1x}, F_{1y}, F_{1z}: it is required to find the amplitude vectors F_2 and F_3 of the reflected and refracted waves in the boundary plane. In this general form the problem has already been dealt with by Violet (441 & 870 of 1936, and 3600 of 1937) and by the writer (628 [and 2600] of 1942), but errors have crept in. Thus Violet believes that he has solved the spherical-wave problem, which is not the case: *cf.* Ott's footnote on p. 461 of the paper dealt with in 18 of January: Violet has undertaken an inadmissible splitting of the boundary condition. A corrected treatment should therefore be of interest," and this is given at the end of the paper.

2938. Radio Observations of the Ionosphere [during 1940 Eclipse at Patos, Brazil].—T. R. Gilliland. (*Sci. Abstracts*, Sec. A, Nov. 1942, Vol. 45, No. 539, p. 277.)

Indicating decreases in the ion density of the E and F_1 layers to 22% of normal within 1 or 2 minutes of second contact, and of F_2 to 50% of normal about 1 hour after eclipse maximum. Recombination coefficients are estimated and inconsistencies discussed. A decrease in ion density occurred as the moon obscured a large sunspot. An unexplained rise of ion density in the E and F_1 layers 2 or 3 minutes before third contact is discussed. Several other reports on this eclipse are dealt with on pp. 276 and 277.

2939. The Part played by Ion Diffusion in the Constitution of the Ionosphere.—E. Bagge. (*Physik. Zeitschr.*, 15th April 1943, Vol. 44, No. 7/8, pp. 163–167.)

Chapman's theory of the absorption and ionising effect of monochromatic radiation in the atmosphere (Abstracts, 1931, p. 202; 1932, p. 27) yields an expression for the density distribution of the charge-carriers which, at great heights, behaves as the square root of the particle density of the ionised gas. Such a course would mean that, from certain ion densities downwards (in cases of practical interest, somewhere between 10^3 to 10^4 ions per cm^3) the density of the carriers of one sign would finally be greater than that of the neutral-atom particles originally present. This difficulty is partly removed in the extensions of the ionospheric theory such as were carried out, with the inclusion of Saha's ionisation-balance theory, by Pannekoek (1926), Woltjer (1925), and Bhar (1348 of 1939). Chapman assumes, in the first place, that the number of ion pairs formed at any instant is proportional to the number of neutral atoms originally present. This is strictly true only at the very beginning of the irradiation: directly some ions have been formed, these naturally cease to be ionisable atoms and must be deducted. This fact is included in Saha's theory and consequently in the work of the other three writers.

But Chapman also makes a second, more serious assumption, which has been taken over unaltered in the extended theories: that the spot at which the ions are formed and the spot where recombination takes place are identical. This assumption is justified over large areas of the ionosphere and particularly in the neighbourhood of the density maximum for the carriers. In regions of low pressure, however, high above the density maximum, it does not hold good. On the contrary, at these heights the diffusion of the ions, between their times of formation and recombination, plays an important rôle and has the effect that the ion densities at all times lag behind the neutral-atom densities by factors of the order of at least 10^{-3}. The taking into account of this diffusion-action eliminates the difficulty still remaining even in the extended versions of the Chapman theory: namely that, according to these, although the ion densities in the regions concerned do not exceed the densities of the neutral atoms, they do practically reach those values, and a purely ionic gas must exist there with a physical behaviour quite different from that of a gas of neutral atoms. Actually, the effect of diffusion is so great that even when Chapman's first assumption is retained, the outward drop in ion density remains practically the same as it would in a theory free from this error. Hence in calculating, as at present, the influence of diffusion on the shape of the carrier-distribution curve it does not matter which theory is taken, Chapman's or the extended versions: but as the first is simpler mathematically, it is used exclusively for the present calculation. The necessary corrections for the extended theory can readily be applied.

Author's summary:—"A differential equation for the diffusion of ions at great heights in the atmosphere is set up, and it is shown that by taking the diffusion effects correctly into account the ion density at the border of the atmosphere falls off in proportion to the number of neutral gas atoms, the ion densities remaining behind the particle-densities of the corresponding gases by factors 10^{-3} to 10^{-6}. The difficulty emerging in earlier theories of the ionosphere, that the calculated ion densities in these regions are either greater than or at least approximately equal to the densities of the neutral atoms, is thus removed, and traced to the previous neglect of ion diffusion".

The differential equation arrived at is eqn. 12 which, if the terms concerned in the diffusion processes are neglected (first two terms in the bracket put equal to zero), reduces to Chapman's relation $y = A\zeta^{\frac{1}{2}}e^{-\zeta/2}$. [Note to reader of the original paper: the jumbled setting of p. 165 can be rectified by following closely the equation numbers: the meanings of ζ ($= \sigma N_o/\alpha \,.\, e^{-az}$), y, and A are shown in eqns. 11 a–c]. An analytical solution of eqn. 12 is hardly possible, as it is an equation of the second order and second degree: it is therefore tackled numerically, and with the help of certain approximations, in Section 3. The equation for the "improved Chapman density distribution" is arrived at in eqn. 19: the expression for y is the Chapman expression, given above, multiplied by tan 1.55 $\zeta^{\frac{1}{2}}A^{-\frac{1}{2}}$, the "correction factor" U. Fig. 2 gives the course of the ion density in a nitrogen atmosphere at 300°K calculated by the Chapman equation (broken-line curve) and by the "improved" eqn. 19 (full-line curve). The steeper fall towards great heights (from about 200 km to 300 km) given by the latter equation is clearly evident: the "correction factor" begins to work when the ion density has fallen to about one-tenth of its maximum value: the further decrease is then completed very quickly.

2940. The Seasonal Height and Ionisation Variations of the F_2 Layer.—O. Burkard. (*Hochf:tech. u. Elek:akus.*, Oct. 1942, Vol. 60, No. 4, pp. 87–96.)

Author's summary:—"The observational data available from the various stations all over the earth regarding the behaviour of the F_2 layer are collected for the present work and are compared with each other. By this means a series of interconnecting relations are disclosed which, to the best of my knowledge, have never appeared in the literature. They are:—

"(a) A connection between geographical latitude and the square of the critical frequency (Figs. 3, 4) [Fig. 3 shows the squares of the half-yearly mean mid-day values of the critical frequency, plotted against latitude; Christchurch, Wellington, Watheroo, Huancayo, Washington, Deal, and Tromsö provide the data. The squared critical frequencies rise almost linearly with decreasing latitude, whereas "according to Appleton the hot equatorial zone would be expected to show the minimum. Even Chapman's simple theory contradicts the relationship represented by Fig. 3, since according to him the max. ionisation is proportional to the cosine of the angle at which the solar radiation enters the layer, so that the relation between critical frequency and geographical latitude would be expected to follow, at any rate roughly, a cosine law. But this is by no means the case, for the observations can be represented very well by a relation of the form $f_0^2 = a - b \,.\, |\Phi|$, a and b being constants which can be taken for the half-years of 1937–1939 from Table 1a. Both constants show only a quite slight variation over this whole period, and it seems to me possible that a may vary according to the sunspot number while b may be practically constant: Φ is the geographical latitude." Fig. 4, another version of the same diagram, brings out clearly the linearity, and also the way the observations from the Northern and Southern hemispheres supplement each other].

"(b) A relation between geomagnetic latitude and the square of the critical frequency (Figs. 5, 6) [if Figs. 4, 5 are modified by replacing the geographical latitude by the geomagnetic, "surprisingly enough, a very simple relationship is found of the form $f_0^2 = a_m + b_m \cos \Phi_m$, where a_m and b_m again are constants, which can be taken from Table 1b. The relationship according to the new equation is shown graphically in Fig. 5/6, where the scattering (greater in this case) of the observations is evident. At the moment it is not clear how the above results can be interpreted, but it is certain that further investigation, particularly when data from a larger number of stations become available, will lead to a deeper insight into the physical relations involved"].

"(c) A relation between the time of occurrence of the yearly maxima and minima of the critical frequencies and the geographical longitude (Fig. 9), due to the fact that the magnetic equator runs partly in the Northern hemisphere and partly in the Southern [consideration of these maxima and minima leads to an understanding of the failure of Maeda & Tukada's attempt to correlate critical frequency and geographical latitude (Fig. 2)].

"(d) A probable connection between the amplitude of the yearly fluctuations of f_0, the critical frequency, and the direction of the earth's field (Fig. 10) [taking as a rough measure of the fluctuaions the ratio f_{min}/f_{max}: the curve of this ratio as a function of Φ_m, the geomagnetic latitude, is seen in Fig. 10a, below which is the curve of sin ϕ (ϕ being the angle between the directions of the field and the dipole axis) as a function of the same quantity: the two curves are strikingly similar, the maximum and minimum, in particular, practically coinciding at about 35°: only in the Polar regions the upper curve slopes more steeply].

"(e) The layer heights h_{min} show a very pronounced variation [through the year], with single or double frequency and greater or smaller amplitude according to the geographical position (Fig. 11) [which shows the monthly means of mid-day effective heights plotted against time through 1938/9 at Watheroo, Washington, and Huancayo, unluckily the only stations to publish the required data. The yearly mean values at all three stations are about equal, between 310 and 320 km (" but the slight rise from 1937 to 1939 should be a real one "), whereas the fluctuations of h_{min} are very different in the three cases : specially remarkable is the doubled frequency of the comparatively small fluctuations at the equatorial Huancayo].

" (f) The layer thickness reaches a maximum twice a year, about simultaneously with the highest value of critical frequency (Section IV) [at the end of the section, where this result is quoted from observations at Kochel (near Munich) which will be reported fully in a later paper. The object was to estimate the layer thickness by measurements of h_{min} and h_0^x (the latter being the virtual height for the extra-ordinary component at the penetration frequency of the ordinary component : *see*, for example, Rawer, 359 of 1942 : and Fig. 1 of the present paper). " In Kochel both the former and the latter maxima appear about February/March and October. The agreement is so striking that I cannot believe it to be merely fortuitous "].

" (g) The rise in ionisation does not coincide in time with sunrise at the layer height (Fig. 12) [another Kochel diagram, covering 1940 and 1941, " from which the following noteworthy result can be read : the ionisation increase, made evident by an increase in critical frequency, begins without exception after sunrise ; half an hour to an hour after, in winter, but in the summer months not until about four hours after. At midsummer there is no sunset at the F_2 layer, but all the same there occurs, through the night, a sharp fall in the critical frequency and a clear rise at about 4 a.m. . . ."].

" (h) The observational material also suggests the conclusion that the strongest ionisation during the day occurs not at mid-day but already in the early morning hours (Section VII). This fact, and the relations found with the earth's magnetic field, point to the necessity for taking a radiation of charged particles into consideration as an ionising agent. The charge of the particles must be positive : the very slight deflectability in the magnetic field can be estimated. But quite a number of difficulties remain to be solved even on the assumption of such a corpuscular radiation as ionising agent " [the existence of such a charged-particle radiation as primary or at least secondary cause of F_2-layer ionisation is supported by measurements at Tromsö, " since in the months of the Polar night there the ionisation (fourth power of the critical frequency) is four times as great as in summer with high sun : if an undeflectable wave-radiation or a radiation of uncharged particles produced the ionisation, the F_2 layer would be entirely absent during winter at Tromsö "].

2941. ON THE TEMPERATURE OF A PLANET HAVING AN ATMOSPHERE WITH SELECTIVE ABSORPTION.—B. G. Fessenkoff. (*Comptes Rendus* (*Doklady*) *de l'Acad. des. Sci. de l'URSS*, No. 9, Vol. 31, 1941, pp. 851–852 : in French.)

Illustrating his general equation by a numerical example in which, among other assumptions, Θ is taken as 6000°K, the absorption coefficient as unity in the absorption bands 1.25–1.75μ, 5.0–7.0μ, 9–10μ, 12–24μ, and as zero in the intermediate parts of the spectrum, and the radius as that of the Earth's orbit, the writer finds that equilibrium between loss and reception is realised for $T = 306$°K. For a body absolutely black or even absolutely grey the temperature is much less : $T = 269$°K.

" Finally, it may be asked whether the variation of the equivalent thickness of the ozone band, which is situated in the neighbourhood of the maximum energy of the terrestrial emission spectrum, can be of importance in the calorific régime of the Earth. A simple numerical calculation shows that a 50% increase in ozone absorption, realised simultaneously over the whole surface of the Earth, would lower the temperature by 4.5°C."

2942. EMISSION AND ABSORPTION OF RADIATION IN THE ATMOSPHERE [Discussion at Joint Meeting], *and* ATMOSPHERIC RADIATION AND THE TEMPERATURE OF THE LOWER STRATOSPHERE.—G. M. B. Dobson & others : G. M. B. Dobson. (*Sci. Abstracts*, Sec. A, Nov. 1942, Vol. 45, No. 539, p. 291 : p. 292.)

2943. METEOROLOGY AND CLIMATOLOGY [Reviews of Five Books].—(*Science*, 25th June 1943, Vol. 97, No. 2530, pp. 580–583.)

2944. PRELIMINARY EXPERIMENTS ON THE ACOUSTICAL PROBING OF THE ATMOSPHERE BY MEANS OF A MONOCHROMATIC RAY [" Acoustical Interferometer " Method]. — V. M. Bovsheverov & V. A. Krassilnikov. (*Comptes Rendus* (*Doklady*) *de l'Acad. des Sci. de l'URSS*, No. 1, Vol. 32, 1941, pp. 44–46 : in English.)

" The method described may prove of some value for the study of atmospheric turbulence, especially after the introduction of an objective method of recording the phase changes (this is now being done). Finally, the method may find a number of applications in acoustical and aerological investigations. Thus, in 1941 it is expected to carry out a number of investigations employing the method of radio-acoustical probes."

2945. PAPERS ON THE METHOD AND EQUIPMENT FOR THE DETECTION AND DISTANCE-MEASUREMENT OF REFLECTING POINTS.—Guanella. (*See* 3016/7.)

2946. CONDENSATION NUCLEI MADE VISIBLE IN THE ELECTRON-MICROSCOPE [Magnification 30 000 : Radii between 25 and 100 mμ, probably 50 mμ Most Abundant (Air of City Room) : Amorphous (Fig. 1a, b) & Crystalline (Fig. 2a, b) Forms].—F. Linke. (*Naturwiss.*, 7th May 1943, Vol. 31, No. 19/20, pp. 230–231.)

2947. THE REPERCUSSIONS OF THE SOLAR OR COSMIC ACTIVITY ON CERTAIN PHENOMENA OF VEGETAL BIOLOGY.—Esclangon. (*See* 3242.)

2948. CORRELATION BETWEEN ATMOSPHERIC-POTENTIAL-GRADIENT ANOMALIES AND SOLAR ERUPTIONS.—F. L. Cooper. (*Sci. Abstracts*, Sec. A, Jan. 1943, Vol. 46, No. 541, p. 28.)

2949. THE NATURE OF THE SOLAR CORONA, *and* AN ATTEMPT TO IDENTIFY THE EMISSION LINES IN THE SPECTRUM OF THE SOLAR CORONA [Results suggesting a Parallel between Coronal Matter & Meteoric Matter].—W. Petrie: B. Edlén. (*Sci. Abstracts*, Sec. A, Feb. 1943, Vol. 46, No. 542, p. 30: p. 30.)

2950. REMARKS ON THE ROTATION OF A MAGNETISED SPHERE [near a Cloud of Ions initially at Rest] WITH APPLICATION TO SOLAR ROTATION.—H. Alfvén. (*Sci. Abstracts*, Sec. A, Feb. 1943, Vol. 46, No. 542, p. 29.) Such a mechanism explains the fact that the sun rotates more slowly near its poles.

2951. A PROPOSED METHOD OF MEASURING THE DERIVATIVES OF THE EARTH'S MAGNETIC FIELD.—Jones. (*See* 3099.)

2952. ON THE ϵ-BAND SYSTEM OF THE NO MOLECULE.—Gerö & others. (*Naturwiss.*, 16th April 1943, Vol. 31, No. 16/18, p. 203.)

2953. SPECTROSCOPIC STUDY OF THE DIFFUSE DISCHARGE IN NITROGEN AT ATMOSPHERIC PRESSURE, *and* ON A GREEN PHOSPHORESCENCE OF ACTIVE NITROGEN [and Its Relation to the Auroral Spectrum].—J. Janin: Renée Herman. (*Comptes Rendus* [Paris], 3rd/30th Nov. 1942, Vol. 215, No. 18/22, pp. 505–506: pp. 506–508.)

2954. THE WINTER TEMPERATURES OF THE AURORA OVER TROMSÖ: PART 1—THE SEASONAL VARIATION OF TEMPERATURE IN THE AURORAL ZONE: PART 2—HARANG'S MEASUREMENTS ON THE CHANGES IN HEIGHT OF THE LOWER LIMIT OF THE AURORA: PART 3—WIND CONDITIONS IN THE E LAYER.—R. Penndorf. (*Hochf:tech. u. Elek:akus.*, Oct. 1942, Vol. 60, No. 4, pp. 106–107.) Summary, by Zenneck, of the paper dealt with in 990 of April.

2955. SPECTROPHOTOMETRIC OBSERVATIONS OF THE LIGHT OF THE NIGHT SKY.—C. T. Elvey & A. H. Farnsworth. (*Sci. Abstracts*, Sec. A, Feb. 1943, Vol. 46, No. 542, pp. 43–44.)

Among other results, "that portion of the twilight effect which is related to the direct illumination of the sun indicates a much larger proportion of O atoms in the upper atmosphere than theoretical considerations require."

2956. ON THE LUMINOSITY OF NOCTURNAL SKY IN DIFFERENT LATITUDES [Collection of Data leading to Empirical Formulae, from which it is possible to determine the Height of the Layer responsible for the Light of the Night Sky].—B. Fessenkoff. (*Comptes Rendus* (*Doklady*) *de l'Acad. des Sci. de l'URSS*, No. 5, Vol. 32, 1941, pp. 320–322: in English.)

2957. AN AUTOMATIC RECORDING PHOTOELECTRIC PHOTOMETER FOR THE STUDY OF THE NIGHT SKY AND TWILIGHT.—R. Grandmontagne. (*Zeitschr. f. Instr:kunde*, April 1943, Vol. 63, No. 4, pp. 146–147: summary only.)

2958. PROPAGATION MEASUREMENTS OVER INHOMOGENEOUS GROUND.—J. Grosskopf & K. Vogt. (*Hochf:tech. u. Elek:akus.*, Oct. 1942, Vol. 60, No. 4, pp. 97–99.)

In the paper dealt with in 1280 of 1942 the writers described their work in measuring the angle of arrival of short waves reflected from the ionosphere. The arrangement of the two receiving aerials 1, 2 and of a calibrating transmitting aerial S is shown in Fig. 1. The phase difference between the voltages excited in 1 and 2 was measured with the phasemeter dealt with in 2048 of 1941. The length of base d between 1 and 2 was on the average 60 m, which was also the length of the normal from the foot of the calibrating aerial to the mid-point of the base d: the calibrating transmitter was intended to excite 1 and 2 in the same phase so as to provide a starting point for the phase measurement. But the validity of the calibration process depended on the equality of phase-velocity over the paths S–1 and S–2. First results, over flat meadow land, seemed to justify the assumption of this equality, but a later checking of the whole arrangement, using a transmitter in an aeroplane, showed that particularly for small arrival-angles (less than 10°) serious discrepancies arose between the optically obtained angle and that given by the phase measurements. These discrepancies led immediately to a test of the phase-equality of the aerial-excitation by the aeroplane flying in the direction of the central normal: a directional error of 0.5° was found, corresponding to a phase error of 9°, explaining the above discrepancies.

The obvious assumption, that such phase errors of the equipment were due to re-radiation effects or to polarisation errors of the aerials, was contradicted by tests made with aerials free from polarisation errors, and by the absence of any signs of re-radiation effects. On the other hand it was established that the ground inhomogeneities in the neighbourhood of the calibrating aerial S, and the consequent differences in phase-velocity, produced a distortion of the phase surface even though, as remarked above, the land gave an impression of great homogeneity. The present paper describes the tests and calculations necessary to establish this result. At twelve positions along a circle of radius 50.2 m around the calibrating aerial (Fig. 2) the field strengths produced by a 2-watt crystal-controlled oscillator working on 14.24 Mc/s were measured as to magnitude (by a Rohde & Schwarz "near-field meter") and phase, and measurements were also made of the dielectric constants and conductivities (by the dipole method, 2955/6 of 1942) and of the ground-ray deflections observed at the test points on the circle (by a frame-aerial equipment). The phase measurements mentioned above were made by carrying a frame aerial round the circle and measuring the phase at the various points against a fixed reference aerial, by the phasemeter referred to at the beginning of this abstract.

The dipole method of measuring ϵ and σ referred to above is briefly discussed on p. 98, where two approximate formulae, 6 and 7, are derived from the original complex expressions of the earlier papers, for use in the short- and medium-wave bands respectively. To get a rough idea of the frequency-dependence of the "effective" ground constants (given by the dipole method) measurements of the ellipse parameters were also made on a broadcast wave of 841 kc/s: the marked difference from the short-wave behaviour is seen in Fig. 3. From Fig. 4, showing the variation, with azimuth, of ϵ and σ on the short wave, it is noted that in spite of the small diameter of the circle (only about 100 m) the effective ground constants vary by a whole order of magnitude, whereas the measured field strengths (Fig. 5) show a variation of only 50%: "the dipole measuring method is always far more sensitive than the field-strength-measuring procedure." This Fig. 5 gives also the results of the phase measurements (curve "ψ"): for the positions of the two aerials used in the arrival-angle measurements a value of 9° is obtained, so that the error found in the arrival-angle, mentioned at the beginning, is attributable to the difference in phase-velocity along *S*–1 and *S*–2. The measured *E* and ψ curves of the diagram show an excellent qualitative agreement with the calculated curves of Fig. 6, obtained from propagation theory (approximate equation 8 for *E*: the Sommerfeld propagation factor is calculated by putting $F = u + jv$, as can be done for small numerical distances such as are involved here) by introducing the measured values of ϵ and σ from Fig. 4.

It is not at first clear that this use of the measured "effective" constants to calculate the numerical distance is justified, in such a case where the ground is obviously stratified and the constants are by no means the true physical constants. "But the good agreement between measurement and calculation suggests that the assumption is justified, and in a later paper [*see* 1361 of May] it will be shown theoretically also to be permissible."

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY

2959. The Determination of the Location and Frequency of Thunderstorms by a Radio Method.—J. S. Forrest. (*Quart. Journ. Roy. Met. Soc.*, Jan. 1943, Vol. 69, pp. 33–46.) A summary was dealt with in 1383 of May. *See* also 2307 of September.

2960. The Thunderstorm and Its Discharge Forms: Part I—The Origin of a Thunderstorm, and Lightning Strokes: Part II—Spherical Lightning and String-of-Pearls Lightning [including a Discussion of Possible Explanations with the Help of Laboratory Results].—F. Wolf. (*Naturwiss.*, No. 7/8, Vol. 31, 1943, & 7th May 1943, Vol. 31, No. 19/20, pp. 215–223.)

2961. Correlation between Atmospheric-Potential-Gradient Anomalies and Solar Eruptions.—F. L. Cooper. (*Sci. Abstracts*, Sec. A, Jan. 1943, Vol. 46, No. 541, p. 28.)

2962. Condensation Nuclei made Visible in the Electron-Microscope.—Linke. (*See* 2946.)

PROPERTIES OF CIRCUITS

2963. Study of the "Band-Pass" Effect [in Low- and High-Pass Filters terminated by Stabilised Negative Impedances] by Cathode-Ray Oscillograph [with Wood's Method of Phase-Angle Measurement (1932 Abstracts, p. 589)].—S. P. Chakravarti. (*Indian Journ. of Phys.*, Feb. 1943, Vol. 17, Part 1, pp. 7–17.)

Further development of the work dealt with in 3267 of 1941 and back references. "The method not only enabled the phase-shift angle at different frequencies to be obtained with sufficient accuracy and comparative ease, but the variation of the sign of phase-shift angle as the frequency altered could be visually observed . . . The method developed here is applicable to determination of gain or attenuation, phase-shift angle and sign of phase-shift angle of all types of wave-filter and network." The disadvantages of the c.r.o. method of Chard (708 of 1939) and of the thermionic-voltmeter method of Hinton, Rendall, & White (*Elec. Communication*, 1929) are discussed, and compared with those of the present method. *See* also 2964, below.

2964. On the Nature of Dynatron-Type Negative Impedance at Frequencies from 1 to 40 Megacycles/Second.—S. P. Chakravarti & P. N. Das. (*Indian Journ. of Phys.*, Feb. 1943, Vol. 17, Part 1, pp. 51–68.)

Continuation of the work dealt with in 51 of 1941 and summarised here in the Introduction: "from the stability point of view, the transitron type has been found to be the best of the three" [dynatron, transitron, and feed-back types of negative-impedance elements], but "the present paper relates to extension of work on the nature of dynatron-type negative impedance obtained from screen-grid tubes over the range 1–40 Mc/s, since this alone of all types of negative impedance has proved suitable from all points of view for use in communication circuits at frequencies up to 1 Mc/s."

The paper deals in turn with the method developed for measuring, over the 1–40 Mc/s range, the negative resistance $-R_a$, the effective capacitance C_a, and the anode/filament capacitance C_{af}: the results, on four types of screen-grid valves: the variation of $|R_a|$ and C_{af} with frequency: the dependence of $|R_a|$, C_a, and C_{af} on the h.f. voltage amplitude: discussion on the nature of the variation of $|R_a|$ with frequency: discussion on the dielectric constant of an electronic medium under secondary-emission conditions, and its dependence upon the h.f. operating voltage and frequency: linearity of negative-impedance element over the 1–40 Mc/s range: phase-shift caused by the element over a range 1–17 Mc/s, measured by the c.r.o. method dealt with in 2963, above.

2965. Radio Data Charts: No. 10—Loudspeaker Dividing Networks.—J. McG. Sowerby. (*Wireless World*, Aug. 1943, Vol. 49, No. 8, pp. 238–240.)

2966. Calculating Coupling Coefficients: Useful Formulae for finding the

OPTIMUM SPACING OF I.F. TRANSFORMER WINDINGS.—S. W. Amos. (*Wireless World*, Sept. 1943, Vol. 49, No. 9, pp. 272–273.)

2967. APPLICATION OF LUCAS'S FUNCTION U_n TO THE CALCULATION OF THE NATURAL FREQUENCIES OF SYSTEMS OF COUPLED CIRCUITS COMPRISING ELECTRONIC RELAYS [*e.g.* a Series of Similar Valves working on Straight Parts of Their Characteristics].—M. Parodi & F. Raymond. (*Comptes Rendus* [Paris], 3rd/30th Nov. 1942, Vol. 215, No. 18/22, pp. 459–460.) *See* also 2336 of September.

2968. A GRAPHO-ANALYTICAL METHOD OF DESIGNING AMPLIFIERS WITH NEGATIVE FEEDBACK.—F. A. Drabkina. (*Izvestiya Elektroprom. Slab. Toka*, No. 7, 1940, pp. 43–47.)

The actual valve stage with negative feedback is replaced by a hypothetical valve in which, it is assumed, the whole of the feedback circuit is enclosed. Methods are indicated for plotting the characteristics of this valve from the known characteristics of the actual valve. Having obtained these, the optimum operating conditions are determined by the use of Lucas's formulae (1932 Abstracts, p. 229). Single-valve and push-pull stages are discussed, and in the latter case circuits with identical and non-identical valves are considered separately.

2969. NEGATIVE FEEDBACK [Letter on Terry's Article (2326 of September): the Necessity for Distinction between "Complete" & "A.C." Feedback: Influence, on the Writer's Results, of his Assumption of the "Complete" Type].—H. Cowling: Terry. (*Wireless World*, Aug. 1943, Vol. 49, No. 8, p. 241.)

2970. WIDE-RANGE *RC* OSCILLATOR: FROM 16 TO 18 000 c/s WITH NEARLY CONSTANT AMPLITUDE.—Ledward. (*See* 3049.)

2971. THE SWITCHING OF PARALLEL-CONNECTED CONDENSERS [Single- and Three-Phase: Transient-Current Equations, etc.].—S. A. Stigant & A. J. Good. (*BEAMA Journal*, July 1943, Vol. 50, No. 73, pp. 222–227: to be contd.)

2972. COUNTING CIRCUITS FOR PULSE-COUNTER AND COUNTER-TUBE ARRANGEMENTS [Survey, from Wynn-Williams (1931) to Kolhörster & Weber (1941): Thyratron & High-Vacuum-Valve Circuits].—H. Pupke. (*Arch. f. Tech. Messen*, April 1943, Part 142, J076-4, Sheets T45–46.)

2973. THE LIMITING SENSITIVITY OF SEISMIC DETECTORS [Treatment by Application of Theory of Brownian Motion].—A. Wolf. (*Sci. Abstracts*, Sec. A, Feb. 1943, Vol. 46, No. 542, p. 32.)

TRANSMISSION

2974. THE ELECTRON-PATH OSCILLATIONS [Posthumus (Rotating-Field, Split-Anode Type: 1370 of 1935) & Megaw (Spiral-Path, Whole-Anode Type: 1933 Abstracts, p. 324)] IN THE MAGNETRON.—E. Zieler. (*Hochf:tech. u. Elek:akus.*, Oct. 1942, Vol. 60, No. 4, pp. 81–87.)

"Existing pictures of the oscillation mechanism, based on the electron paths, are some of them very clear: *see* for instance Herriger & Hülster, 3721 of 1936 and 1319 [and 2499 & 3633] of 1937. Where a mathematical treatment (Fischer & Lüdi, 3265 of 1937) has been attempted, the case of plane electrodes has been calculated first and the results applied to the actual practical problem of cylindrical electrodes. Since, however, the motion of the electrons in radially symmetrical electric fields differs considerably from that in plane fields, the correctness of such a procedure is questionable. In the present calculations, therefore, only the cylindrical-electrode valve is dealt with right from the start. The mathematical treatment of the problem is based on a new potential law on the foundations of Engbert's measurements [with a probe: 1821 of 1938]. Previously, for magnetron calculations, the relation $U = U_a \cdot (r/r_a)^{2/3}$ has always been used, as calculated (among others) by H. G. Möller (2951 of 1936 [not as in ref. "5"] and 63/64 of 1937). Engbert's measurements, however, show definitely that this expression must not be used for magnetic fields over the critical value. We ourselves shall replace Engbert's relation by the assumption of a constant space-charge condition, ΔU=const. (Poisson's equation). Integration then gives . . . $U = U_a \cdot (r/r_a)^2$. This relation agrees very well—and particularly also for an oblique magnetic field—with the curves from Engbert's Fig. 5. Since an oblique magnetic field is also important for the production of 'spiral-type' oscillations, we shall include the angle between field and cathode in our calculations and go over to the mathematically simpler case of the concentric magnetic field only for the calculation of the excitation-mechanism of the Posthumus oscillations."

The writer starts his calculations of the electron paths from the Lorentz formula (eqn. 3), introducing his own constant-space-charge relation and neglecting the field distortion at the ends of the electrodes. He arrives at eqn. 12 for the possible frequencies: for not too strong magnetic fields and small angles of inclination this has the roots given in eqn. 14a, b. When $n \gg 1$ (for n see eqn. 8 defining the various quotients used by the writer so as to eliminate all but the coordinates and dimensionless quantities or frequencies: actually n is a good approximation to the order-number of the oscillation, introduced by Runge, 1371 of 1935) eqn. 14a gives as an approximation $\omega_1 = \bar{\omega}\,(1 + 1/n)$, so that the angular velocity along the circle path agrees approximately with the frequency of the excited oscillation as given by Posthumus.

Section III applies the results so far obtained to form a picture of the exciting and "sorting-out" mechanisms which enable the Posthumus oscillations to occur. The theory here developed will be particularly applicable to the calculation of the building-up process, where only small amplitudes are involved by which the main assumption of the theory—the constant space-charge—is hardly disturbed. Section IV therefore applies it to the setting-in of oscillations, and in its second part measures the " oscillation momentum " (given by the damping required to extinguish the oscillations) by J. Möller's method (2954 of 1940) and compares the measured results with the values calculated by the theory. At 80 cm (the tests were carried out between 70 and 150 cm) the added damping resistance was 70 ohms compared with the theoretical 72 ohms (but this close agreement was naturally " accidental " in view of the rough nature of the theory). The large discrepancy at 115 cm seen in Fig. 1 was due to a resonance effect in the heating circuit.

Section V uses the theory to explain the Megaw " spiral " oscillations in a whole-anode magnetron, for which many useful data have been provided by Döhler & Lüders in their work on these oscillations in the Linder " end-plate " magnetron (409 of 1942 [and not as in ref. " 15 " : for their work on the split-anode magnetron *see* 675 of 1942]. Among other results, " the hitherto inexplicable fact is explained, that the wavelength of the excited oscillation is not dependent on the length of the anode, but rather that the frequency is about equal to twice the angular velocity of the electrons in the x–y plane, which from eqn. 26 coincides with the frequency of the oscillation in the z direction."

Section VII (there is no Section VI) deals first with some of Döhler & Lüders' experimental results from the viewpoint of the theory. Thus Fig. 3, taken from their paper, shows how the measured wavelength, as it decreased towards 40 cm, departed from its linear relation to H, the magnetic field. The dotted line introduced by the present writer represents the " corrected " theoretical characteristic, " since to the frequency according to eqn. 14a there must be introduced the correcting factor $1 + 1/n$: this factor represents, according to Section III, the taking into account of the centrifugal force away from the electron path " : the dotted line agrees much better with the measured points.

Finally, it is pointed out that eqn. 12 (*see* above), when treated approximately, taking second-order terms into account, gives eqn. 27 a, b showing an increase of wavelength with increasing inclination of the magnetic field. Orienting tests, however, show just the opposite—a decrease in wavelength with increasing angle. This discrepancy is explained on p. 86, r-h column ; it is bound up with the fact that the wavelength decrease sets in only when the angle of the field is very large, when the oscillating energy rises sharply. At small angles, where the energy also is small, the theoretical equation is obeyed, as it is (at any rate qualitatively) at certain working points where the valve oscillates badly and the amplitudes do *not* increase with increasing angle of inclination : Fig. 6.

2975. ULTRA-SHORT WAVE ARRANGEMENT WITH A VALVE INSIDE A CAVITY OSCILLATOR [and connected to This in a 3-Point Connection, with Adjustable Cathode-Lead movable in Slit to obtain Optimum Retroaction].—E. Willwacher. (*Hochf:tech. u. Elek:akus.*, March 1943, Vol. 61, No. 3, p. 88.) A Telefunken patent, D.R.P. 725 429 : Fig. 3.

2976. ARRANGEMENT FOR THE GENERATION OF ULTRA-SHORT WAVES BY A BACK-COUPLING CIRCUIT [Triode inside Cavity Oscillator].—F. Borgnis. (*Hochf:tech. u. Elek:akus.*, March 1943, Vol. 61, No. 3, p. 89.) A Telefunken patent, D.R.P. 725 746.

2977. ULTRA-SHORT-WAVE GENERATION WITH A CATHODE RAY.—Philips Company. (*Hochf:tech. u. Elek:akus.*, March 1943, Vol. 61, No. 3, p. 89 : Fig. 7.)

Swiss Patent 220 365. The tube 8 in which an electron beam passes to a collector electrode 6 is surrounded by two coaxial tubes 2, 3 enclosing between them a resonating cavity tuned to the working wavelength. The inner of these two tubes, 2, has an aperture 4, 5 at each end, opposite the points where the beam enters and leaves the surrounded space.

2978. THE ULTRA-SHORT-WAVE RADIO TRANSMITTER OF THE LENINGRAD EXPERIMENTAL TELEVISION CENTRE.—Ivanov & others. (*See* 3078.)

2979. AN INVESTIGATION OF CERTAIN TYPES OF PARASITIC OSCILLATIONS IN [Short-Wave] RADIO TRANSMITTERS.—G. A. Zeitlenok & A. B. Ivanov. (*Izvestiya Elektroprom. Slab. Toka*, No. 7, 1940, pp. 13–28.)

An investigation of parasitic oscillations in amplification and multiplication stages is of importance for high-power short-wave radio transmitters in which triodes are now used almost exclusively. To facilitate this investigation a model was made using two 100 kw triodes in push-pull and operating on long waves. The circuit was neutralised in accordance with the method proposed by Zeitlenok (Fig. 2) and variable condensers and inductances were connected to the valves corresponding to the inter-electrode capacities and self-inductances of the valves when these generate ultra-short-wave oscillations. The wavelength of parasitic oscillations in the model was expected to be between 100 and 200 m, which corresponds to a wavelength of between 5 and 10 m in the real stage. Various types of parasitic oscillations which may appear in the circuit are discussed theoretically and the results achieved were verified experimentally. A number of practical suggestions are made.

2980. THE GENERATION OF ALTERNATING CURRENT OSCILLATIONS WITH THE CONTROLLED ARC [*e.g.* Mercury-Vapour Discharge with Control Grid].—W. O. Schumann. (*Arch. f. Elektrot.*, 28th Feb. 1943, Vol. 37, No. 2, pp. 59–86.)

For previous work *see* 157 of January. The analysis is carried out on the assumptions that during the discharge time of the arc its voltage U_B is constant, independent of the current : that during the " blocking " time, during which the arc is suppressed, the tube is completely non-conductive—no back current, arbitrarily high blocking voltage (this assumption does not hold good for the uncontrolled arc—

Poulsen arc—and consequently the results of the analysis do not apply to this: *see* also footnote on p. 72): and that ignition and extinction occur practically instantaneously.

Author's summary :—" It is found that the choice of the length of the discharge time and blocking time for a vacuum arc with constant arcing voltage has no influence, to a first approximation, on the efficiency, but that it strongly affects, in general, the current, voltage, and output power. If oscillations as purely sinusoidal as possible are desired, a series-resonance circuit requires a long discharge time and a short blocking time, while on the other hand a parallel-resonance circuit requires a short discharge time and a long blocking time." The work of the grid at extinction is much greater for the series circuit than for the parallel circuit, while the reverse holds good for the work at ignition. The danger of sputtering at the grid and of flash-back is greater for the parallel circuit, with which, moreover, it would be difficult to attain the necessary rapid ignition, and with which serious back-current losses are to be expected. " It is seen also why with a high-vacuum valve the series circuit is unfavourable": p. 81.

2981. On the Characteristic Curves of a [Grid-] Controlled Vacuum Arc [in Mercury Vapour].—G. Schöls. (*Ann. der Phys.*, 8th April 1943, Vol. 42, No. 6, pp. 477–486.)

Continuation of the Munich work on these arcs (*e.g.* Fetz, ref. " 3 " [and *see* 2548 of 1940 and 1976 of 1942]. " In analogy to the high-vacuum valve, all the stationary control characteristics of a low-pressure mercury-vapour arc are obtained, and their shape explained by the properties of the controlled arc. The V_a/I_a, V_a/I_g, and I_a/V_g curve families are all plotted. From these curves the characteristic data for the tube, namely the internal resistance $R_i = [\partial V_a/\partial I_a]_{v_g}$, the ' durchgriff ' $D = -[\partial V_g/\partial V_a]_{i_a}$, and the slope $S = [\partial I_a/\partial V_g]_{v_a}$, are derived and plotted as functions of the anode current. Finally the validity of the Barkhausen condition, $R_i \cdot S \cdot D = 1$, is confirmed for a large number of working points."

Comparing these arcs with the high-vacuum valve, it is seen that whereas in the latter the " durchgriff " can in general be taken as constant, while the slope and internal resistance are dependent on the working conditions, in the gaseous-discharge tube all the quantities are dependent, though to varying degrees, on the existing working conditions. S never undergoes such large fluctuations as R_i and D. This is because of the increased control-action with increasing V_a, explained by the ionisation curve. All quantities whose calculation involves a ΔV_a are subject to extreme fluctuations. The writer concludes: " The result of the whole work is a collection of curves, with their physical explanation, with all the data necessary for an orientation as to the application possibilities of the tube."

2982. A New High-Efficiency Modulating System [Doherty System].—N. M. Sankin & M. Ya. Gural'nik. (*Izvestiya Elektroprom. Slab. Toka*, No. 7, 1940, pp. 38–42.)

2983. A Rectifying and Inverting Circuit for Controlling the Oscillations of a High-Power Self-Excited Valve Oscillator.—G. I. Babat & M. G. Lozinski. (*Izvestiya Elektroprom. Slab. Toka*, No. 7, 1940, pp. 60–61.)

For the surface annealing of steel by induction heating, powers of the order of several hundreds of kilowatts are required, and self-excited valve oscillators are normally used. In this paper a circuit (Fig. 1) is proposed for the control of such oscillators. The valve is biased by voltages derived from two full-wave rectifiers fed from the mains and delivering their outputs in opposition across a condenser in the grid lead. One rectifier uses two diodes and the other two thyratrons, the grids of which are fed from the mains through an induction regulator. By adjustment of the latter the phase of the thyratron grid voltage can be varied, giving continuous variation, down to complete suppression, of the output from the oscillator. The advantage of the circuit proposed is that when the thyratrons operate under the inversion régime the h.f. energy in the oscillator grid circuit is converted into 50 cycle energy and fed back into the mains. More important is the absence of rheostats and of the consequent precautions for heat dissipation.

2984. Study of Continuous Oscillations and of Their Applications. — Y. Rocard. (*Génie Civil*, 1st March 1943, Vol. 120, No. 5, p. 60: summary of long paper in *Revue Scientifique*.)

RECEPTION

2985. Frequency Modulation and Foliage [Milwaukee Measurements on Adverse Effect on Reception of F.M. Ultra-Short Waves].—(*Wireless World*, Sept. 1943, Vol. 49, No. 9, p. 276: paragraph only.)

2986. The Behaviour of the Elements of Dry-Plate Rectifiers at Low Current-Densities.—Theillaumas. (*See* 3125.)

2987. High-Fidelity Reproduction: Contrast Expansion [Criticism of Williamson's Views (May issue) & Those of Moir (March issue): Aim should be a Controlled Non-Linear Distortion (rather than the Normal Amplitude Distortion) at Transmitter or Recorder, with Inverse at Reproducer].—J. R. Hughes. (*Wireless World*, Aug. 1943, Vol. 49, No. 8, p. 240.)

2988. Contrast Expansion Unit: Design giving Unequal " Pick Up " and " Decline " Times.—Williamson. (*See* 3048.)

2989. The Radiation from Superheterodyne Receivers, and Methods for Its Elimination.—R. Moebes. (*Génie Civil*, 1st May 1943, Vol. 120, No. 9, pp. 103–104.) Long French summary of the German paper dealt with in 743 of March.

2990. A STATIC NEUTRALISER.—F. Thone: Goodyear Company. (*Science*, 2nd July 1943, Vol. 98, No. 2531, Supp. p. 12.) *See* also 2373 of September: also *Wireless World*, Aug. 1943, p. 229.

2991. RADIO-NOISE FILTERS [and Capacitors] APPLIED TO AIRCRAFT.—C. W. Frick & S. W. Zimmerman. (*Elec. Engineering*, July 1943, Vol. 62, No. 7, p. 316: summary only.)

2992. THE ELECTRICAL SCREENING OF SPARKING APPARATUS FOR USE IN SPECTROGRAPHIC ANALYSIS [Description of Method employed by British Non-Ferrous Metals Research Association, with Results of P.O. Tests].—D. M. Smith & A. Walsh. (*Journ. of Scient. Instr.*, April 1943, Vol. 20, No. 4, pp. 63–64.)

2993. RADIO INTERFERENCE FROM POWER LINES [Letter prompted by Forrest's Article (1876 of July [*see* also 2128 of August: and *cf.* 2375 of September]: His "Difficult Ceramic Problem" solved by Taylor Tunnicliff "Stabilised" Insulators].—G. H. Gillam. (*Wireless World*, Aug. 1943, Vol. 49, No. 8, p. 241.)

2994. METHODS OF H.F. INTERFERENCE SUPPRESSION FOR MACHINES AND APPLIANCES UP TO 500 WATTS.—K. Kegel. (*Elektrot. u. Masch:bau*, 16th April 1943, Vol. 61, No. 15/16, pp. 178–180.) Long summary of the A.E.G. paper dealt with in 1664 of 1942: *see* also 2346 of 1942.

2995. "CLASSIFIED RADIO RECEIVER DESIGN" [Book Review].—E. M. Squire. (*Electrician*, 27th Aug. 1943, Vol. 131, No. 3404, p. 198.)

2996. MURPHY RECEIVERS: FITTING ALTERNATIVE VALVE TYPES [Notice of Booklet].—Murphy Radio. (*Wireless World*, Aug. 1943, Vol. 49, No. 8, p. 244.)

AERIALS AND AERIAL SYSTEMS

2997. THE RADIATION OF A CAVITY WAVE FROM A CIRCULAR-SECTIONED HOLLOW TUBE DEBOUCHING INTO A PLANE SCREEN: PARTS II AND III.—H. Buchholz. (*Arch. f. Elektrot.*, 28th Feb. & 31st March 1943, Vol. 37, Nos. 2 & 3, pp. 87–104 & 145–170.)

For Part I *see* 2294 of September. Part II deals with the strict solution of the radiation problem for the TM wave on the foundation of Maxwell's equations: the assumption being that in every actual case the reflections due to imperfect matching at the end cross section will make it necessary to take into consideration not merely the primary exciting waves but also the presence of an infinite number of other cavity-line waves, the diffraction waves, the determination of whose amplitudes is the essential core of the strict solution. The problem thus becomes the solution of a system of an infinite number of unknowns, and can only be carried through by a process of sectioning. The working-out of an example indicates that the solutions of the equations do actually show, for an increasing number of sections, a definite if only slow convergence.

Part III, the final paper, calculates the characteristic course of the radiation diagrams of TM waves for the lowest orders of this type: Figs. 7–9 show the distant-radiation diagrams of a TM_{10}, a TM_{11}, and a TM_{20} wave respectively, in each case for three values for ak ($= 2\pi a/\lambda$, a being the tube radius) of 3, 5, and 7, all of them greater than that corresponding to the longest limiting wavelength of the cavity line, for which ak has the value 2.4048. These radiation diagrams, in contrast to those of a TE (transverse electric) wave, have the property that they have a crevasse, reaching down to zero, in the middle, since along the axis of radiation the field vanishes. The two principal side-lobes arrange themselves more steeply as the frequency increases. As each higher critical frequency is passed through, a new subsidiary lobe is added to the principal lobes.

2998. ULTRA-SHORT ELECTROMAGNETIC WAVES: V—RADIATION [and the Calculation of the Radiation Field & Radiation Resistance: Part I].—A. Alford. (*Elec. Engineering*, July 1943, Vol. 62, No. 7, pp. 303–312.) One of the series of lectures dealt with in 2632 of October.

2999. A DIPOLE AERIAL WITH IMPEDANCE CHANGING NOT MORE THAN 10% OVER A 10% VARIATION OF CARRIER FREQUENCY.—Philips Company. (*Hochf:tech. u. Elek:akus.*, March 1943, Vol. 61, No. 3, p. 91.) Consisting of at least two closely adjacent radiators, 6, 7, 8 (Fig. 16) whose ends are short-circuited (*e.g.* by the plates 10) over about 1/20th to 1/5th of their length: Swiss Patent 220 368.

3000. A MACHINE FOR CALCULATING THE POLAR DIAGRAM OF AN ANTENNA SYSTEM [Present Model for up to 5 Aerials, Principle allows Extension to Any Number: easily extensible also to Automatic Tracing of Polar Curve: based on Use of Selsyn Motors as Transformers (Phase of E.M.F. in Rotor is Exactly Proportional to Angular Position of Rotor): Inverse Use to determine Current & Phase Relationships giving an Actual Pattern].—H. P. Williams. (*Elec. Communication*, No. 2, Vol. 21, 1943, pp. 103–111.)

3001. APPLICATION OF ARC WELDING TO THE DESIGN AND CONSTRUCTION OF A RADIO TOWER.—C. L. Sammons & J. H. Stewart. (*Science*, 4th June 1943, Vol. 97, No. 2527, pp. 507–508: note on recent paper.)

VALVES AND THERMIONICS

3002. A MAGNETRON WITH SUBDIVIDED ANODE [Anode Segments forming $\lambda/2$ Dipoles radial to Central Cathode and fixed (with $\lambda/2$ Spacing) to Coaxial Ring forming Inner Conductor of Lecher System of Ring Shape: Fig. 4].—K. Fritz. (*Hochf:tech. u. Elek:akus.*, March 1943, Vol. 61, No. 3, p. 88.) A Telefunken patent, D.R.P. 725 490.

3003. THE ELECTRON-PATH OSCILLATIONS IN THE MAGNETRON.—Zieler. (*See* 2974.)

3004. GRAPHO-ANALYTICAL METHODS FOR PLOTTING ELECTRON TRAJECTORIES.—V. S. Lukoshkov, V. L. Il'inski, & T. I. Tamaridze. (*Izvestiya Elektroprom. Slab. Toka*, No. 7, 1940, pp. 47–59.)

In studying processes taking place in electron and ion apparatus the plotting of electron trajectories is of importance. This can be done graphically from charts of equipotential and force lines obtained for a given system of electrodes with the aid of an electrolytic trough. The graphical methods are based on the assumptions that (a) the electrons move in a plane, and (b) the electron trajectories can be replaced by a number of straight-line or curved sections.

In the present paper the following three methods utilising well-known principles but developed independently in Russia are described in detail:—(1) The method of a plane condenser, suitable for cases when electrons move in a field with equipotential lines of small curvature. A special device (Figs. 4 & 5) was developed for this method, consisting of an orthogonator, for drawing orthogonal lines to points on a curve, and a protractor. To reduce errors in the case of fields with axial symmetry certain graphical operations are replaced by calculations. (2) The method of consecutive approximations, suitable for "plane" fields only, in which potentials depend on two coordinates only of a Descartes system. (3) The method of radii of curvature which can be used in the case when a magnetic field is also present. A special device (Figs. 11 & 12) called a "projector-orthogonator" was developed for this method. The device can be used for determining the radii of curvature and drawing smooth continuous curves of varying radii.

3005. ELECTRON - MULTIPLIER NOMENCLATURE [Loman's Suggestion (April issue) of "Sectrode" or "Impactode" for Secondary-Emitting Electrode is unnecessary in view of Existence of "Dynode"].—J. McG. Sowerby. (*Wireless World*, Aug. 1943, Vol. 49, No. 8, p. 241.)

3006. THE QUANTUM MECHANICS OF THE SECONDARY-ELECTRON EMISSION OF TRANSITIONAL METALS [Extension to Nickel of Wooldridge's Work on "True" Metals (*see*, for example, 147 of 1940)].—H. Schlechtweg. (*Naturwiss.*, 16th April 1943, Vol. 31, No. 16/18, pp. 204–205.)

3007. HISTORIC VALVE [Specimen of "Round" Triode, first produced in 1913: used mainly as R.F. Amplifier preceding Crystal Detector].—H. J. Round. (*Wireless World*, Aug. 1943, Vol. 49, No. 8, p. 247: photograph & caption only.) *Cf.* Arnold, 2399 of September.

3008. PAPERS ON GRID-CONTROLLED ARCS IN MERCURY VAPOUR.—Schumann: Schöls. (*See* 2980 & 2981.)

3009. FOUR-FOOT TRANSMITTING VALVE FOR SHORT WAVES: TWO DELIVER 200 kW CARRIER.—I.T. & T. (*Elec. Communication*, No. 2, Vol. 21, 1943, p. 74: photograph & caption only.) "Plans for the production of these tubes are being formulated."

3010. TUBES FOR HIGH-POWER SHORT-WAVE BROADCAST STATIONS: THEIR CHARACTERISTICS AND USE [Design & Construction of the Type 3067A Valve (*see* also 3009, above) and Its Associated Equipment].—G. Chevigny. (*Proc. I.R.E.*, July 1943, Vol. 31, No. 7, pp. 331–340.)

3011. USE OF VALVES: WHAT IS "GOOD PRACTICE"? [Survey of Basic Considerations forming the Justification for the Code of Practice given in War Emergency British Standard B.S.1106: Ratings, Heater Voltages & Currents, Grid Primary Emission, etc.].—J. R. Hughes. (*Wireless World*, Sept. 1943, Vol. 49, No. 9, pp. 256–259.) Concluded in Oct. issue, pp. 306–309.

3012. AMERICAN VALVE DESIGNATIONS: INTERPRETING THE TYPE NUMBERS.—(*Wireless World*, Sept. 1943, Vol. 49, No. 9, p. 271.)

3013. HIGH-FREQUENCY INDUCTION HEAT FOR OUT-GASSING OF VALVES.—General Electric Company. (*Gen. Elec. Review*, July 1943, Vol. 46, No. 7, pp. 407–408.)

DIRECTIONAL WIRELESS

3014. THE RADIATION OF A CAVITY WAVE FROM A CIRCULAR-SECTIONED HOLLOW TUBE DEBOUCHING INTO A PLANE SCREEN [Surface of the Ground].—Buchholz. (*See* 2997.)

3015. METHOD OF SIGNALLING THE ARRIVAL OF A REFLECTING BODY IN THE PROPAGATION FIELD OF ELECTRIC WAVES.—Telefunken. (*Hochf:tech. u. Elek:akus.*, March 1943, Vol. 61, No. 3, p. 91.)

D.R.P. 726 078, applied for 27/3/34. "The fluctuations of received energy due to the appearance of the reflecting body are led back to the transmitter and modulate the radiated h.f. energy, thus causing an increase of sensitivity in the indications."

3016. METHOD AND APPARATUS FOR THE DIRECTION-INDICATION OF WAVES OF PERIODICALLY VARYING FREQUENCY, *and* METHOD AND APPARATUS FOR THE MEASUREMENT OF PATH DIFFERENCES [in Distance Determinations] BY THE CONTROL OF BEAT OSCILLATIONS.—G. Guanella. (*Hochf:tech. u. Elek:akus.*, March 1943, Vol. 61, No. 3, p. 92: p. 92.)

Swiss Patents 220 780/1, applied for 12/5/40. The second arrangement seeks to eliminate interference by producing, at the receiver, a rotating field whose sense and frequency depend on the beat frequency and hence on the path-differences.

3017. METHOD AND EQUIPMENT FOR THE DETECTION AND DISTANCE-MEASUREMENT OF REFLECTING POINTS.—G. Guanella. (*Hochf:tech. u. Elek:akus.*, March 1943, Vol. 61, No. 3, pp. 91–92.)

Swiss Patent 220 877, applied for 26/9/38. For the unequivocal determination of the distance, a wave mixture of several different frequencies is sent out with a constant average energy content, and received again after reflection, while simultaneously some of the mixture is passed through a delaying device. The equality between the known internal path-time of the delayed oscillations and the external path-time of the reflected oscillations is determined, for example, by a mutual modulation between two frequency mixtures derived from the two sets of oscillations after a product-building process: this modulation will produce a quantity showing a maximum when the two path-times agree.

3018. DIRECTION-FINDING LOOP AERIALS FOR AIRCRAFT, WITH DECREASED DIMENSIONS [Reduction of Wind Resistance is needed for High Speeds: Impossibility of Simple Reduction in Size, and of Erection inside Aircraft: Design consisting of Several Turns wound on Insulating Tube with Compressed-Powder Core].—M. Kornetzki. (*Zeitschr. V.D.I.*, 3rd April 1943, Vol. 87, No. 13/14, p. 188: summary only, from *Siemens-Zeitschr.*, 1942.)

3019. AN INVESTIGATION OF CERTAIN ERRORS IN RADIO HOMING DEVICES.—M. P. Dolukhanov. (*Izvestiya Elektroprom. Slab. Toka*, No. 7, 1940, pp. 1–13.)

Continuing a previous work (3633 of 1938 [and not as given here]) the principle of the operation of radio homing devices (Fig. 1) is explained and a mathematical discussion is presented, with certain assumptions, of the effects of the following factors on the accuracy of the readings: (a) asymmetry of the balanced modulator (Fig. 3) components; (b) phase displacement in the non-directional aerial channel; (c) parasitic modulation in this channel; (d) frame aerial effect (additional e.m.f.); and (e) inaccurate tuning of circuits. For each of the above cases formulae are derived for determining the error so introduced. A summary of the conclusions reached is given and a number of practical suggestions are made.

3020. AIRCRAFT INVERTER CONSTRUCTION [for Conversion of D.C. to 400 c/s A.C. for Radio Compass, etc.].—C. T. Button. (*Elec. Engineering*, July 1943, Vol. 62, No. 7, p. 316: summary only.)

3021. ADCOCK AERIAL SYSTEM.—A. Troost & G. Schulz. (*Hochf:tech. u. Elek:akus.*, March 1943, Vol. 61, No. 3, pp. 90–91.)

A Telefunken patent, D.R.P. 725 283. "The electrical lengths of the aerials and their connecting lines are so chosen that an even natural wavelength (open-end resonance) of the system falls about in the middle of the working band, and the uneven natural wavelengths on either side of it (closed-end resonance) are outside that band. Moreover the input impedance of the d.f. receiver is chosen small compared with the aerial impedance at the middle of the band."

3022. A DIRECTION-FINDING AERIAL SUNK BELOW THE SURFACE OF THE GROUND [*e.g.* of an Air-Field] OR A ROOF.—F. Bergtold. (*Hochf:tech. u. Elek:akus.*, March 1943, Vol. 61, No. 3, p. 91: Fig. 15.) A Telefunken patent, D.R.P. 726 143.

3023. DETERMINING THE DISTANCE OF AN AIRCRAFT FROM THE GROUND [Use of Tube of Speed-Measuring Device as One Plate of Condenser whose Capacity varies with the Distance].—H. Heuschmann. (*Hochf:tech. u. Elek:akus.*, March 1943, Vol. 61, No. 3, p. 91.) A Siemens patent, D.R.P. 724 373.

3024. THE PHYSICAL AND TECHNICAL FOUNDATIONS OF THE ACOUSTIC LANDING-ALTIMETER [including Reduction of Error due to Change of Height during the Sounding Process, by "Gliding" Soundings in which a New Cycle is started by the Incoming Echo].—E. Kutzscher & P. Orlich. (*Zeitschr. V.D.I.*, 15th May 1943, Vol. 87, No. 19/20, pp. 298–299: summary of a 1942 paper.)

ACOUSTICS AND AUDIO-FREQUENCIES

3025. PRELIMINARY EXPERIMENTS ON THE ACOUSTICAL PROBING OF THE ATMOSPHERE BY MEANS OF A MONOCHROMATIC RAY ["Acoustical Interferometer" Method].—Bovsheverov & Krassilnikov. (*See* 2944.)

3026. THE PHYSICAL AND TECHNICAL FOUNDATIONS OF THE ACOUSTIC LANDING-ALTIMETER.—Kutscher & Orlich. (*See* 3024.)

3027. CONDITIONS FOR WIDE-ANGLE RADIATION FROM CONICAL SOUND RADIATORS [Loudspeaker Cones: Practically Hemispherical Radiation theoretically possible by Selection of Angle, Number & Depth of Corrugations, and Weight & Stiffness].—R. W. Carlisle. (*Journ. Acous. Soc. Am.*, July 1943, Vol. 15, No. 1, pp. 44–49.)

3028. THE PROPAGATION OF SOUND WAVES IN A HORN OF THE FORM OF A PARABOLOID OF ROTATION EXCITED BY A POINT SOUND-SOURCE AT ITS FOCUS.—H. Buchholz. (*Ann. der Phys.*, 8th April 1943, Vol. 42, No. 6, pp. 423–460.)

"With the ever-increasing importance of the directive radiating of waves of all types it becomes necessary, however [in spite of the great advantages of Webster's 1919 approximate treatment of the subject, on the assumption that the pressure-fluctuations in the horn are dependent only on the longitudinal coordinate], to obtain a more precise knowledge of the laws of sound propagation in horns," at any rate for the most important forms of horn. The writer has already dealt with the rigorous theory of the sound-field of a conical horn (*Akust. Zeitschr.*, Vol. 5, 1940, p. 169 onwards) and

Freehafer (2609 of 1940) has considered the wave types and acoustic impedance of a hyperbolic horn, without however dealing with the influence of the excitation on the production of the various component waves. The writer now deals (on the usual assumption of an infinitely long horn with perfectly rigid inner surfaces) with the parabolic type, excited by a single-frequency point source at the focus. The differences and similarities between this type (together with the hyperbolic type) and the conical horn are discussed on pp. 445–446.

3029. THE DAMPING OF LARGE-AMPLITUDE VIBRATIONS OF A FLUID IN A PIPE [Modification of Helmholtz–Kirchhoff Theory by Addition of Eddy-Viscosity Term].—R. C. Binder. (*Journ. Acous. Soc. Am.*, July 1943, Vol. 15, No. 1, pp. 41–43.)

3030. FREQUENCY-MODULATION LOUDSPEAKER DISTORTION: ITS CAUSE, MAGNITUDE, AND CURE [Discussion leading to Summary of Beers & Belar's Paper, 2159 of August].—(*Wireless World*, Aug. 1943, Vol. 49, No. 8, pp. 248–249.)

3031. A NEW TYPE OF PRACTICAL DISTORTION METER.—J. E. Hayes. (*Proc. I.R.E.*, March 1943, Vol. 31, No. 3, pp. 112–117.) A summary was dealt with in 798 of March.

3032. INTERMEDIATE-IMPEDANCE LOUDSPEAKERS? REDUCING LOSSES IN EXTENSION LEADS [a Suggestion].—(*Wireless World*, Aug. 1943, Vol. 49, No. 8, p. 233.)

3033. RADIO DATA CHARTS: NO. 10—LOUDSPEAKER DIVIDING NETWORKS.—J. McG. Sowerby. (*Wireless World*, Aug. 1943, Vol. 49, No. 8, pp. 238–240.)

3034. SPECIFIC HEAT OF ROCHELLE-SALT SERIES: DIELECTRIC MEASUREMENTS ON KD_2PO_4 CRYSTALS, *and* DIELECTRIC DETERMINATIONS WITH POTASSIUM PHOSPHATE, KH_2PO_4, AND POTASSIUM ARSENATE, KH_2AsO_4, AT LOW TEMPERATURES.—W. Bantle: G. Busch & E. Ganz. (*Sci. Abstracts*, Sec. A, Jan. 1943, Vol. 46, No. 541, p. 14: p. 15.) From *Helvet. Phys. Acta*, 1942.

3035. SPONTANEOUS KERR EFFECT WITH KH_2PO_4 AND KH_2AsO_4 CRYSTALS.—W. Bantle & others. (*Sci. Abstracts*, Sec. A., Jan. 1943, Vol. 46, No. 541, p. 15.)

"The problem in connection with piezoelectric substances of the above type at the lower Curie temperature, *viz.* the apparent disappearance of the spontaneous polarisation owing to the decrease of dielectric constant, and the contradiction of this by specific-heat determinations, is considered."

3036. RAILWAYS AND PUBLIC ADDRESS: NEW INSTALLATION AT WAVERLEY STATION, EDINBURGH.—(*Electrician*, 30th July 1943, Vol. 131, No. 3400, p. 102.)

3037. AN IMPROVED TELEPHONE-RECEIVER ANALYSIS [Extension & Improvement of Method of determining Performance of Electro-Magnetic Receivers from Input Measurements (1934 Abstracts, p. 212, r-h column): Close Agreement with Actual Performance: Application to Absolute Calibration of Microphones].—R. D. Fay. (*Journ. Acous. Soc. Am.*, July 1943, Vol. 15, No. 1, pp. 32–40.)

3038. DIRECTIONAL MICROPHONE WITH A SOUND-AMPLIFYING ARRANGEMENT [for Directional Reception of a Wide Frequency-Band: Combination of a Reflector Microphone & an Exponential-Horn Microphone, with Separating Filter].—H. Batsch. (*Hochf:tech. u. Elek:akus.*, March 1943, Vol. 61, No. 3, p. 92.) A Telefunken patent, D.R.P. 725·745, applied for 7/2/40: Fig. 19.

3039. HISTORIC FIRSTS: THE CONDENSER MICROPHONE.—E. C. Wente. (*Bell Lab. Record*, July 1943, Vol. 21, No. 11, p. 394.) For other "historic firsts" *see* Elmen, 3159, below.

3040. PHONETIC ALPHABET FOR BRITISH AND AMERICAN FORCES.—(*Wireless World*, Sept. 1943, Vol. 49, No. 9, p. 262.)

3041. PICK-UP FILTER CIRCUITS [for High-Quality Pick-Ups: Brierley's Filter (1707 of June) useful also to remove 9 kc/s Heterodyne Whistles: Disadvantages of Present Form: Suggested Low-Impedance Filter worked from an "Infinite Impedance" Detector: Schematic Circuit for Radio-Gramophone].—M. E. Felix. (*Wireless World*, Sept. 1943, Vol. 49, No. 9, p. 284.)

3042. MECHANICAL-IMPEDANCE BRIDGE [primarily for Measuring the Mechanical Impedance, for Frequencies from 30 to 10 000 c/s, of Gramophone Pick-Ups: applicable also to Armatures, Diaphragms, Suspensions, etc.].—A. M. Wiggins. (*Journ. Acous. Soc. Am.*, July 1943, Vol. 15, No. 1, pp. 50–53.) From the R.C.A. Laboratories.

3043. RECORD TRACKING: THE WEIGHT REQUIRED TO KEEP THE NEEDLE IN THE GROOVE [and the Choice of 0.003 in. for Radius of Sapphire Stylus ("Pinch Effect," etc.): Article based on Parts of Beers & Sinnett's Paper, 2160 of August].—G. L. Beers & C. M. Sinnett. (*Wireless World*, Sept. 1943, Vol. 49, No. 9, pp. 260–262.)

3044. NEEDLE CLINIC [for "IM" Long-Playing Needles].—A. Imhof, Ltd. (*Wireless World*, Aug. 1943, Vol. 49, No. 8, p. 249.)

3045. STATIC CHARGES ON RECORDS [and the Methods of Overcoming the Difficulty: Reply to Correspondence prompted by 2162 of August].—D. W. Aldous. (*Wireless World*, Sept. 1943, Vol. 49, No. 9, pp. 283–284.)

3046. LET'S USE OUR MODULATORS: APPLYING IDLE SPEECH-EQUIPMENT TO RECORD PLAYERS [and to Broadcast Receivers, to improve Reproduction: Volume Compressors converted to Expanders: etc.].—I. V. Iversen. (*QST*, July 1943, Vol. 27, No. 7, pp. 35–36 and 72.)

3047. HIGH-FIDELITY REPRODUCTION: CONTRAST EXPANSION.—Hughes. (*See* 2987.)

3048. CONTRAST EXPANSION UNIT: DESIGN GIVING UNEQUAL "PICK-UP" and "DECLINE" DELAYS.—D. T. N. Williamson. (*Wireless World*, Sept. 1943, Vol. 49, No. 9, pp. 266–268.)

"In the usual form of contrast expansion equipment the rates of rise and fall of gain are approximately equal, and a compromise has to be adopted between high rate of change to obtain satisfactory transient response and low rate of change to avoid wave-form distortion. The performance of this type of equipment is mediocre, and has given contrast expansion a totally undeserved reputation for transient and amplitude distortion." With the equipment here described, "quality of recorded music reproduced is greatly enhanced and a considerable improvement results from the apparent reduction in surface noise." The distortion of the first cycle or so of transients which theoretically occurs is completely inaudible. For modified diagrams *see* Oct. issue, p. 315.

3049. WIDE-RANGE *RC* OSCILLATOR: FROM 16 TO 18 000 c/s WITH NEARLY CONSTANT AMPLITUDE.—T. A. Ledward. (*Wireless World*, Sept. 1943, Vol. 49, No. 9, pp. 263–265.)

"An a.f. oscillator based on the multivibrator circuit, with modifications to give sine-wave output, was described by the writer some years ago (2633 of 1937) and different forms of *RC* oscillator have been developed by others [*cf.* 2332/3 of September and 2670 of October]. A careful consideration of the principle of operation of the writer's original circuit has enabled him greatly to improve the practical form of this oscillator while retaining, in essential details, the simplicity of the basic circuit." For a correction *see* Oct. issue, p. 312.

3050. VISUAL FREQUENCY-COMPARISON: NEW "MAGIC EYE" CIRCUIT FOR CALIBRATING AUDIO-FREQUENCY OSCILLATORS.—Brittain. (*See* 3100.)

3051. AN ACOUSTIC-IMPEDANCE METER FOR RAPID FIELD MEASUREMENTS [Pressure & Pressure Gradient measured by Two Microphones combined with Electronic Circuit].—R. H. Bolt & A. A. Petrauskas. (*Journ. Acous. Soc. Am.*, July 1943, Vol. 15, No. 1, p. 79: summary only.)

3052. NEW HYDRODYNAMIC PRINCIPLE FOR THE MEASUREMENT OF SOUND [Decrease in Velocity of Air-Stream under Reduced Pressure is related to Amplitude & Frequency of Sound: detects Very Weak Sounds: can be used for Supersonic Waves].—H. Zickendraht. (*Sci. Abstracts*, Sec. A, Jan. 1943, Vol. 46, No. 541, p. 7.)

3053. A NEW FREQUENCY-SELECTIVE VIBROMETER [Direct-Reading Model & More Precise Model using Photoelectric Pick-Up: Novel Method of Tuning which also produces Variable Damping so as to give an Essentially Flat Frequency-Response].—E. L. Kent. (*Journ. Acous. Soc. Am.*, July 1943, Vol. 15, No. 1, p. 79: summary only.)

3054. AN APPLICATION OF THE CATHODE-RAY OSCILLOGRAPH TO THE MEASUREMENT OF THE WAVELENGTH OF SOUND.—G. N. Patchett. (*Proc. Phys. Soc.*, 1st July 1943, Vol. 55, Part 4, No. 310, pp. 324–325.)

3055. HOW LITTLE DO WE HEAR? [with Curves of Minimum Hearing Stimulus, Power & Pressure Levels corresponding to Various Intensity Levels, etc.]—W. A. Munson. (*Bell Lab. Record*, June 1943, Vol. 21, No. 10, pp. 341–346.)

3056. ESTIMATION OF PERCENTAGE LOSS OF HEARING [Method, involving Audiogram Charts, formulated by Council on Physical Therapy].—H. A. Carter. (*Journ. Acous. Soc. Am.*, July 1943, Vol. 15, No. 1, p. 77: summary only.) *Cf.* Fowler, 3057, below.

3057. IS THE THRESHOLD AUDIOGRAM SUFFICIENT FOR DETERMINING HEARING CAPACITY? [takes No Account of "Mental Deafness", Recruitment & Blurring Phenomena, Binaural & Monaural "Word Deafness", etc.].—E. P. Fowler. (*Journ. Acous. Soc. Am.*, July 1943, Vol. 15, No. 1, pp. 57–60.)

3058. DIRECT OBSERVATIONS OF THE ACOUSTIC OSCILLATIONS OF THE HUMAN EAR [by Optical Recording with Mirrors: of Importance to Physiologists, Otologists, & Hearing-Aid Manufacturers].—H. G. Kobrak. (*Journ. Acous. Soc. Am.*, July 1943, Vol. 15, No. 1, pp. 54–56.)

3059. INHIBITION OF AUDITORY-NERVE ACTIVITY BY ACOUSTIC STIMULATION [apparently not due to Mechanical Interference at Middle Ear or Basilar Membrane: Possibility of Neural Interaction: Implications for Interpretation of Masking].—R. Galambos & H. Davis. (*Journ. Acous. Soc. Am.*, July 1943, Vol. 15, No. 1, p. 77: summary only.)

3060. A REINVESTIGATION OF THE RELATION BETWEEN PITCH AND INTENSITY [Results suggesting that Change of Pitch with Intensity is More Closely Related to Irregularities in Auditory Sensitivity than to Over-All Properties of Ear].—C. T. Morgan & R. Galambos. (*Journ. Acous. Soc. Am.*, July 1943, Vol. 15, No. 1, p. 77: summary only.)

3061. ACOUSTICAL CHARACTERISTICS APPARENT IN A NEW ANATOMY OF THE HUMAN VOICE [with Applications to Voice Training for Speaking & Singing].—Claire Benedict. (*Journ. Acous. Soc. Am.*, July 1943, Vol. 15, No. 1, p. 77: summary only.)

3062. " PIONEERING IN PSYCHOLOGY " [with Special Reference to Applications to Education & the Fine Arts : Book Review].—C. E. Seashore. (*Journ. Acous. Soc. Am.*, July 1943, Vol. 15, No. 1, p. 64.)

3063. SYMPOSIUM ON MUSIC IN INDUSTRY [Morale : Accident Reduction : Growing Appreciation & Effect on Choice : Statistical Method in determining Effects : etc.].—H. Burris-Meyer & others. (*Journ. Acous. Soc. Am.*, July 1943, Vol. 15, No. 1, pp. 77–78 : summaries only.)

3064. THE PROBLEM OF THE KEYBOARD INSTRUMENT.—Ll. S. Lloyd. (*Phil. Mag.*, July 1943, Vol. 34, No. 234, pp. 472–479.)

3065. MEAN-TONE TEMPERAMENT : THE CLASSICAL SYSTEM OF INSTRUMENTAL TUNING.—W. B. White. (*Journ. Acous. Soc. Am.*, July 1943, Vol. 15, No. 1, pp. 12–16.)

3066. OBSERVATIONS ON THE VIBRATIONS OF PIANO STRINGS [including Three-Dimensional Figures showing Partial Amplitudes *versus* Time : Suggested Correlation between Inharmonicity & Subjective Tone-Quality Rating, etc.].—O. H. Schuck & R. W. Young. (*Journ. Acous. Soc. Am.*, July 1943, Vol. 15, No. 1, pp. 1–11.)

3067. CRITERIA OF EXCELLENCE IN VIOLINS.—F. A. Saunders. (*Journ. Acous. Soc. Am.*, July 1943, Vol. 15, No. 1, p. 76 : summary only.) Continuing a series of papers, the last of which was referred to in 759 of 1942.

3068. THE OVERBLOWING OF ORGAN PIPES.—C. P. Boner & R. B. Newman. (*Journ. Acous. Soc. Am.*, July 1943, Vol. 15, No. 1, p. 76 : summary only.)

3069. " OBJECTIVE MEASUREMENT OF INSTRUMENTAL PERFORMANCE " [Book Review].—J. G. Watkins. (*Science*, 28th May 1943, Vol. 97, No. 2526, pp. 488–489.)

3070. THE APPLICATION OF SOUND ABSORPTION TO FACTORY NOISE PROBLEMS.—H. J. Sabine & R. A. Wilson. (*Journ. Acous. Soc. Am.*, July 1943, Vol. 15, No. 1, pp. 27–31.)

3071. VISION, HEARING, AND AERONAUTICAL DESIGN [including the Masking of Communications by Aircraft Noise].—L. D. Carson & others. (*Journ. Roy. Aeron. Soc.*, Aug. 1943, Vol. 47, No. 392, pp. 411–412.) R.T.P.3 Abstract.

3072. DEMOUNTABLE SOUNDPROOF ROOMS [composed of Panels consisting of Two Sheets of Steel cemented to Two Sheets of Composition Board with a Rockwool Blanket between : Rubber Mountings : etc.].—W. S. Gorton. (*Journ. Acous. Soc. Am.*, July 1943, Vol. 15, No. 1, p. 80 : summary only.)

3073. ACOUSTIC LABORATORY IN THE NEW R.C.A. LABORATORIES [including Free-Field Room, Standard Living Room, etc.].—H. F. Olson. (*Journ. Acous. Soc. Am.*, July 1943, Vol. 15, No. 1, pp. 80–87 : summary only.)

3074. A THEORETICAL INVESTIGATION OF THE ACOUSTICAL CONDUCTIVITY OF A CIRCULAR APERTURE IN A WALL PUT ACROSS A TUBE, *and* AN EXPERIMENTAL STUDY OF THE ACOUSTICAL CONDUCTIVITY OF A CIRCULAR ORIFICE IN A PARTITION PLACED ACROSS A TUBE [in Connection with Resonant Sound Absorbers developed in U.S.S.R.].—V. A. Fock : V. S. Nesterov. (*Comptes Rendus* (*Doklady*) *de l'Acad. des Sci. de l'URSS*, No. 9, Vol. 31, 1941, pp. 875–878 : pp. 879–882 : both in English.) *See*, for example, 1414 of 1942.

3075. INTERACTION ACOUSTICAL IMPEDANCE OF SPHERICAL RADIATORS AND RESONATORS.—M. I. Karnovsky. (*Comptes Rendus* (*Doklady*) *de l'Acad. des Sci. de l'URSS*, No. 1, Vol. 32, 1941, pp. 40–43 : in English.)

" Interaction impedances for all amplitudes and phases are expressed in terms of interaction resistances, the oscillations being of equal amplitude, either in phase or 90° out of phase. This method, which is similar to that employed in the theory of aerials (ref. " 4 "), has proved extremely convenient for calculations. Further, the theory of interaction impedances has formed the basis for a theory of the operation of resonators in the sound field. The effect of resonators on the impedance of sources is ascertained, and it is shown that the radiation of sources may be diminished [as well as increased] considerably by the use of a system of resonators ".

3076. EXHIBITION OF FORCE AT THE ENTRANCE OF A RESONATOR [Methods of Demonstration : Interpretation as a " Pulsating Self-Charging Rocket " : also a Directive Effect " More Difficult to Explain "].—R. L. Leadbetter. (*Journ. Acous. Soc. Am.*, July 1943, Vol. 15, No. 1, p. 78 : summary only.)

3077. DISTRIBUTED SYSTEMS OF RADIATORS EMPLOYED IN ARCHITECTURAL ACOUSTICS [and Their Advantages over " Decentralised " & " Lumped " Systems : General Considerations : Preliminary Tests with 24 Radiators in Two Chains, Each Loudspeaker embedded in " Trapezoidal Reverberators " : Good Results in Broadcast Reproduction & Speech Reinforcement].—L. D. Rosenberg & B. D. Tartakovsky. (*Comptes Rendus* (*Doklady*) *de l'Acad. des Sci. de l'URSS*, No. 9, Vol. 31, 1941, pp. 883–885 : in English.) The basic theory for technical design is given in a paper by Rosenberg (reference " 3 ").

PHOTOTELEGRAPHY AND TELEVISION

3078. THE ULTRA-SHORT-WAVE RADIO TRANSMITTER OF THE LENINGRAD EXPERIMENTAL TELEVISION CENTRE.—B. I. Ivanov, A. I. Lebedev-Karmanov, & G. F. Solov'ev.

(*Izvestiya Elektroprom. Slab. Toka*, No. 7, 1940, pp. 28–38.)

A description of the transmitter is given with a number of illustrations including a block diagram and a theoretical circuit diagram. The transmitter operates on a wavelength of 8 m. The carrier power output is 2.5 kw with a maximum modulation of 100%. The so-called "American" method of transmitting the d.c. component is adopted. 25 frames of 240 lines with progressive scanning are transmitted per second, so that the modulating frequencies lie within the limits of 25 and 870 000 c/s. There are 9 high-frequency stages, of which 4 are frequency doublers. The original wavelength of 128 m is generated by a crystal-controlled oscillator. Negative modulation of the image is employed, and this is effected by varying the grid bias of the output stage. The modulating circuit comprises three resistance-coupled stages with frequency-correcting circuits. The aerial consists of a half-wavelength vertical radiator supported by a wooden mast 68 m high (Fig. 8).

3079. Implosions [of Cathode-Ray Tubes: Some Experiences: the Question of Fatigue].—"Diallist". (*Wireless World*, Aug. 1943, Vol. 49, No. 8, p. 251.)

3080. Train Orders by Facsimile Telegraphy ["Telefax" Recorders & Their Installations].—J. H. Hackenberg & G. H. Ridings. (*Elec. Communication*, No. 2, Vol. 21, 1943, pp. 95–102.)

MEASUREMENTS AND STANDARDS

3081. The Torque exerted on a Solid Insulating Body suspended in an Ultra-High-Frequency Rotating Field.—Hartmann & Stürmer. (In letter dealt with in 3145, below.)

3082. Measurement of Dielectric Losses in Solids at Ultra-High Frequencies.—M. Divilkovsky. (*Comptes Rendus (Doklady) de l'Acad. des Sci. de l'URSS*, No. 4, Vol. 32, 1941, pp. 249–251: in French.)

Measuring difficulties with metric and still more with decimetric waves are specially acute when the electrical properties of solids are in question. Attempts to measure loss-angles on metric waves by methods involving a condenser containing the material under test give unreliable results owing to the effects of distributed capacitances and self-inductances and to contact effects between the material and the metal electrodes. These difficulties are avoided, in the case of liquids, by the "thermometer" technique of the writer and Filippov (264 of 1936, 1079 of 1937, 1958/60 of 1940, and 653, 1611, & 2771 of 1941). For solids, the writer has constructed an air thermometer (resembling a micromanometer) made entirely of transparent quartz (Fig. 1). It is calibrated by hanging in it (from a silk thread) a metal sphere whose thermal and electric constants are known, and observing the displacement x of the spot of benzene or toluene in the horizontal capillary when the thermometer is placed in an u.h.f. magnetic field. The strength of this field is measured independently by a spherical mercury thermometer (653 of 1941): the power developed in the metal sphere is calculated by the formula given (from 727 [and *see* 1958] of 1940). Table 1 shows the results of calibration made with spheres of four different metals: the sensitivity γ ($= dx/dT$ cm/degree) thus obtained has a mean value of 0.95 ± 0.02.

The solid under investigation is similarly suspended, in the form of a sphere, in the chamber of the thermometer, and subjected to an u.h.f. electric field whose intensity has been measured by a calibrated spherical thermometer filled with a KCl solution of concentration 0.01 N; the constants of this solution as a function of temperature and wavelength are already known (653 of 1941). The power developed in the solid sphere in the electric field of frequency ω is given, when $\epsilon'' \ll \epsilon'$, by an equation which yields directly the quantity $k = \epsilon''/(\epsilon' + 2)^2$, from which $\tan\delta$ $(= \epsilon''/\epsilon')$ can be determined provided ϵ' is known: to find ϵ' the writer "has developed a special method which will be reported on later." Table 2 shows preliminary results of measurements of k for an optical glass, on 457, 388, and 23.6 cm wavelengths: the values of $\tan\delta \times 10^4$ are obtained by putting $\epsilon' = 6.2$. These values are 39, 39, and 56 respectively. Attempts to measure the constants of rock salt and amorphous quartz in very strong fields (8000 v/cm at 460 cm) gave an upper limit of $k < 0.1 \times 10^{-4}$: this limit was set by the warming-up of the silk thread, which exceeded that of the sphere.

3083. Comparison of Methods of Phase-Angle Measurement [including Wood's C.R.O. Method].—Chakravarti. (In paper dealt with in 2963, above.)

3084. Insulation-Resistance Meter: Up to 20 000 Megohms conveniently measured with New, Portable Electronic Instrument designed for Production and Service Testing [Mains-Driven, with Thyrite Bridge (regulating Rectified Output to 500 V in spite of Mains Fluctuations) & Valve Voltmeter].—R. N. Bushman. (*Gen. Elec. Review*, July 1943, Vol. 46, No. 7 pp. 403–405.)

3085. An Electrical Insulation Testing Laboratory [at Turners Asbestos Cement Company's Laboratories, Trafford Park].—H. S. Carter. (*Met. Vick. Gazette*, July 1943, Vol. 20, No. 341, pp. 184–191.)

3086. A Direct-Reading Capacitance-Meter for Small Condensers [for Production Testing, at 100 kc/s, with Over-All Accuracy within about ± 1%: applicable also to Parts already Built-In].—A. Klemt. (*Arch. f. Tech. Messen*, April 1943, Part 142, V3533-1, Sheet T39.)

The principle is as follows:—If the grid-control potential of a grid-current-limited oscillator is increased, the grid current will also increase, and with it the voltage-drop across a high ohmic grid-leak resistance: the grid bias becomes negative and the anode current falls. If the control potential is made dependent on the capacitance C_x under test the anode-current change will be a measure of the value of the capacitance. This dependence on C_x is obtained by connecting C_x in parallel to one of the two condensers C_1, C_2 (Fig. 1) which form a capacitive potential-divider for the grid-control potential. The indicating instrument is connected in a bridge circuit to compensate the anode feed current: by adjusting the bridge ratio by the variable resistance P_1 the zero is obtained, while the sensitivity is controlled by P_2: both these adjustments are by external knobs, so that by connecting standard capacitances the calibration can be checked and any changes in the slope of the valve can be compensated. "In this connection it must be pointed out that, contrary to a view often met with, it is perfectly possible to construct a calibration from the anode-current/grid-potential characteristic of a valve working in the oscillating connection. Tests on this point showed that only about 5% of all valves tried were unusable (P_1 and P_2 would not reach the necessary values): all the others gave a reproducibility of the capacitance-reading, after adjustment of P_1 and P_2, within 2‰ (not including the error of the indicating instrument) so that the possibility of changing valves is established. For the potential-dividing of the grid-control potential to be strictly dependent on the reactances of C_1 and C_2, these condensers must be of a low-loss type: appreciable errors, however, are not found until a loss-factor of 10% is reached. The practical circuit is seen in Fig. 2, the actual instrument in Fig. 3.

3087. "FIXED CAPACITORS: BRITISH STANDARD 1082: 1942" [Book Notice.] — British Standards Institution. (*Journ. of Scient. Instr.*, April 1943, Vol. 20, No. 4, p. 67.)

3088. STANDARDISATION OF VALUES FOR FIXED RESISTORS.—Inter-Service (Communications) Components Committee. (*Journ. of Scient. Instr.*, April 1943, Vol. 20, No. 4, p. 68.)

3089. SHEET AND WIRE GAUGE REFORM, *and* THE "PREFERRED NUMBER" SYSTEM.—(*Engineer*, 25th June 1943, Vol. 175, No. 4563, pp. 506–507: p. 511.)

3090. D.C./A.C. CONVERTER: A SENSITIVE METHOD OF MEASURING SMALL D.C. VOLTAGES [Comparison of D.C. Amplifiers developed by Miller (2314 of 1942) and Gall (2577 of September): Writer's Converter using D.C.-Polarised Magnetic (Stalloy, Mumetal) Closed Cores (*cf.* 1723 of 1939) with High-Impedance Valve Input Circuit: Sensitivity may be increased by D.C. Feedback (or Extra Stage of A.C. Amplification)].—T. A. Ledward. (*Wireless World*, Aug. 1943, Vol. 49, No. 8, pp. 230–233.)

3091. METHOD OF MEASURING SMALL PHOTOELECTRIC CURRENTS [using an Electrometer Valve: the Difficulty of Drift (due to Battery-Voltage Drop) eliminated by replacing the Usual Compensating System by an Arrangement making the Galvanometer function Ballistically].—J. Baurand. (*Génie Civil*, 15th April 1943, Vol. 120, No. 8, p. 93: summary, from *Comptes Rendus* [Paris], 10th Aug. 1942.)

3092. MEASURING BRIDGES AND COMPENSATORS: SURVEY, PART II [D.C. Compensators: A.C. Bridges: A.C. Compensators].—W. Geyger. (*Arch. f. Tech. Messen*, April 1943, Part 142, J90-2, Sheets T49–50.) All literature references are to papers in the same journal.

3093. MECHANICAL-IMPEDANCE BRIDGE [primarily for Gramophone Pick-Ups: applicable also to Armatures, Diaphragms, Suspensions, etc.].—Wiggins. (*See* 3042.)

3094. MEASUREMENT OF THE HARMONIC CONTENT OF ALTERNATING VOLTAGES [Survey of Linckh, Befils, & Poleck Methods].—C. Moerder. (*Elektrot. u. Masch:bau*, 7th Nov. 1941, Vol. 59, No. 45/46, pp. 537–539: long summary.)

3095. A NEW TYPE OF PRACTICAL DISTORTION METER.—J. E. Hayes. (*Proc. I.R.E.*, March 1943, Vol. 31, No. 3, pp. 112–117.) A summary was dealt with in 798 of March.

3096. DESIGN OF SIMPLE OHMMETERS: I—GENERAL PRINCIPLES AND DETAILS OF A METER FOR HIGH RESISTANCES: II—FORMULAE AND PRACTICAL HINTS FOR DESIGNING A LOW OHMMETER.—F. L. Hogg. (*Wireless World*, Aug. 1943, Vol. 49, No. 8, pp. 224–227: Sept. 1943, No. 9, pp. 269–271.) Based on work done with Standard Telephones & Cables, Ltd. For a correction *see* Oct. issue, No. 10, p. 303.

3097. ON THE ACHROMATISM OF CENTRED OPTICAL SYSTEMS [with Practical Application to Mirror Galvanometers, etc.].—A. Maréchal. (*Comptes Rendus* [Paris], 3rd/30th Nov. 1942, Vol. 215, No. 18/22, pp. 503–504.)

3098. AN EXPERIMENTAL METHOD FOR THE GRAPHICAL CONSTRUCTION OF THE MAGNETIC FIELD FOR BODIES OF ARBITRARY SHAPE: METHOD OF THE "COORDINATE FIELD METER" [using a Steadily Rotating Coil (1 to 4.5 mm Diameter: One Galvanometer Scale Division equals 7.5 to 0.01 Oersted, correspondingly) moving along the Three Coordinate Axes: Accuracy within 0.5%].—A. G. Kalashnikov. (*Comptes Rendus (Doklady) de l'Acad. des. Sci. de l'URSS*, No. 1, Vol. 32, 1941, pp. 47–49: in German.)

3099. A PROPOSED METHOD OF MEASURING THE DERIVATIVES OF THE EARTH'S MAGNETIC FIELD.—J. H. Jones. (*Sci. Abstracts*, Sec. A, July 1943, Vol. 46, No. 547, p. 142.)

"It is shown that a detector of this type [based on change in e.m.f. induced in secondary of detector with core of suitable material, caused by small steady magnetic field] is equivalent to an inductor coil rotating with angular speed equal to the periodicity of the alternating magnetic field."

3100. VISUAL FREQUENCY-COMPARISON: NEW "MAGIC EYE" CIRCUIT FOR CALIBRATING AUDIO-FREQUENCY OSCILLATORS [Eye opens & closes More & More Slowly as Zero-Beat is approached, until Shadow Angle remains Constant at True Zero Beat: Advantages of Suitable Use: Extension as Harmonic Comparator: etc.].—G. D. Brittain. (*Wireless World*, Aug. 1943, Vol. 49, No. 8, pp. 243–244.) In the September issue (p. 283) Mullard's write to point out the use of the "magic eye" in their GM2304 audio oscillator since early 1938.

3101. ON THE THEORY OF VISUALLY OBSERVED OSCILLOGRAMS OF PERIODIC PROCESSES ANALYSED IN TIME [with Special Reference to the Exact Measurement of Frequency (or Revolutions) Errors by Comparison with a Standard Frequency].—W. Härtel. (*Zeitschr. f. Instr:kunde*, April 1943, Vol. 63, No. 4, pp. 132–140.)

If the direction of deflection of the magnitude under test, $y = \phi(t)$, is represented by the ordinate y of the oscillogram, the deflection in the abscissa direction, x, can be proportional either to the time t or to a further magnitude $x = \chi(t)$. In the first case the oscillogram gives directly the course in time of the process $y = \phi(t)$, in the second case it gives the function $y = \psi(x)$ with the parameter t. Because the angular velocity of the polygonal mirror used with a loop oscillograph depends only on time, the ground-glass screen of such an instrument shows always the process $y = \phi(t)$, but with a cathode-ray oscillograph either form of representation is possible, and in the investigation of the interdependence of two processes, $y = \psi(x)$, the well-known Lissajous' figures are formed. The present paper deals only with oscillograms with abscissa deflections proportional to time.

The observation, on the ground-glass or fluorescent screen, of two periodic processes of frequencies f_0 and f_1 and of periods T_0 and T_1 is discussed; if, by adjusting the time-base, the f_0 process is brought to a standstill on the screen, the "migration time" t_{10} of the f_1 process (with respect to the f_0 process) over one whole period T_0 is given by eqn. 11, which for a very small difference between T_1 and T_0 simplifies to eqn. 13, $t_{10} = T_0T_1/(T_0 - T_1)$. This would apply to a nominal frequency f_0 and an actual, slightly erroneous frequency f_1. But if the nominal frequency f_0 is not itself available, and the comparison has to be made with a standard frequency f_2, such that $T_0 = T_2 \cdot p/q$, then t_{10} is given by eqn. 16a, derived from eqn. 11. In this case it is not possible to observe directly the required migration of the frequency under test over a period of the nominal frequency, but merely over one complete wave of the standard frequency. What is measured is therefore $t_{12} = t_{10} \cdot q/p$, from which t_{10} can easily be derived.

As an illustration of the calculation, the case of a frequency f_1 of 125.79 c/s, which ought actually to be $f_0 = 125$ c/s, is taken: the standard frequency for comparison is 50 c/s. From eqn. 13, t_{10} comes out at 1.272 second, and since (by eqn. 19) Δf_1 ‰ $= 1000/t_{10}f_0$, the frequency error is $\Delta f_1 = +6.3$ ‰, which agrees with the data. Two cases are considered, for a "kipp" (time-base) period $T_k = 40$ ms and 12 ms: *i.e.* for time-base periods greater and less than that of the standard frequency (Figs. 9 & 10 respectively).

3102. A PRECISION WAVEMETER AND FREQUENCY-DEVIATION MEASURING APPARATUS [for Frequency-Modulation Investigations] FOR THE WAVELENGTH REGION DOWN TO λ = 14 CM.—A. Weissfloch. (*Zeitschr. f. tech. Phys.*, No. 2, Vol. 24, 1943, pp. 22–27.)

From the Julius Pintsch laboratories. If a 5-metre long concentric uniform line closed at the far end is coupled to a 14-cm generator, the standing waves produced form some 70 potential nodes, the nearest to the input end being at the point A (Fig. 2). Its position can be determined by an exploring detector, and if the wavelength is changed by (say) 0.01 mm this position will move away from A over a distance $\frac{1}{2} \times 70 \times 0.01 = 0.35$ mm, so that with a sufficiently long line even so small a frequency-change will produce a measurable displacement of the potential-minimum at A: the limit is given by the ohmic attenuation, a point examined in Section V. Unfortunately a wavemeter several metres in length would be very unwieldy.

But the precision wavemeter shown in Fig. 1 corresponds in its action to the principle of Fig. 2, and its length is only about 40 cm, thanks to the use of suitable "transformation sections" based on the writer's previous work: *see* 711 of March [and 2084 of August]. Thus the transformation section II, as designed for the particular case, has the property of transforming any impedance $\mathfrak{R}$ at the point C beyond it to a value, referred to the point B on the input side of it, of about $50\mathfrak{R}$. This transformation figure of 50 is slightly dependent on frequency, a fact which enters into the calibration of the wavemeter but does not interfere with the explanation of its mode of action. The point D is to be regarded as a short-circuit, for the transformation sections III and IV on its far side have the effect that a potential node is formed at D: D therefore corresponds to the short-circuited end of the long line in Fig. 2.

The wavemeter is so dimensioned that the distance CD is equal to a half-wavelength in the middle of the working band. If an electrical short-circuit exists at D for this middle wavelength, it must also exist at C, so that at C the impedance $\mathfrak{R} = 0$. But since $50\mathfrak{R}$ is also zero, a potential node must also occur at B. For the precise determination of the point of minimum potential around B, a probe/detector combination slides along the tube between two fixed collars G & H as stops. The minimum occurs exactly at B when the values of the rectified detector current are exactly equal when the combination is at the two ends of its slide. The spacing of the two stops can be so chosen that a small displacement of the potential node produces the greatest difference between the detector currents at the two limiting positions (current-curves of Fig. 5): G and H must be arranged to give positions of the probe where the ratio of the slope of the rectified-current curve to the absolute value is as large as possible.

If the wavelength is varied by $\Delta\lambda$, the potential node will no longer be at C but at a distance of $\Delta\lambda/2$ from C. The effect of the transformation section II is to make the potential minimum at B displace itself by $50 \times \Delta\lambda/2 = 25\Delta\lambda$, an amount correspondingly easier to recognise. But the apparatus does not depend on the *measurement* of the displacement at B: what is done is to displace the short-circuit at D until the potential minimum comes again exactly at B. The transformation sections III & IV help to make possible the very smallest displacements of the short-circuit in a reproducible way. The actual short-circuiting piston is at F, and has the transformation section IV rigidly connected to it. By a micrometer-like adjustment (with back-lash prevented by springs) this short-circuit can be adjusted reproducibly to a fraction of a millimetre. Experience shows, however, that contact fluctuations are liable to occur which make this degree of accuracy illusory. This difficulty is overcome by the action of the transformation section IV which moves with the piston; for a contact fluctuation has the effect of a small displacement of the short-circuit at F, and IV is so designed and so spaced from F than an apparent displacement at F is transformed down 20 times at a point in front of IV. Thus an electrical short-circuit can be adjusted between III and IV to the actual accuracy mentioned above.

The transformation section III also has a transforming-down action: in the model considered it is so designed that any impedance at E appears at D about eight times smaller, so that a minimum-shift on the far side of III is related: o an effective shift in front of III according to the curve of Fig. 3, and if the short-circuiting piston is so adjusted that a potential minimum occurs exactly at E, there will be a node also at D, and a piston shift of 0.01 mm will produce a movement of its transformed value at D of only 0.0012 mm. This point, and in particular the effect in limiting the frequency-range of the apparatus, is elaborated on p. 24.

The action of the remaining transformation section, I, has to do with the coupling of the wavemeter to the circuit under test, the object being to ensure that the detector shall be provided with sufficient energy without the need for a tight coupling such as might cause (in view of the marked frequency-dependence of the wavemeter) a frequency-jump on the part of the generator. The section I is so designed, and so spaced from the point B, that the impedance $50\mathfrak{R}$ referred to B appears at A as $50\mathfrak{R}/30$; then a large potential-minimum displacement at D, when referred to A, is reduced again to one-thirtieth of its value, as is also the frequency-dependence of the whole wavemeter, with a consequent reduction of the danger of a frequency-jump.

To make the best use of the precision of the wavemeter, provision is made for bolting the input end to the apparatus under test, into which the adjustable coupling pin K projects. Among many other points discussed are the attainable precision of measurement (including the question of the thermal expansion of the instrument under variations of temperature: since the interval CD is the chief frequency-determining factor, the inner conductor could, for this portion of its length, be made of metallised quartz rod. The connection between the frequency-changes and the detector-current readings is also dealt with—nomogram of Fig. 7): the use of the instrument for measuring the frequency-deviation of a sinusoidally frequency-modulated wave (p. 26, r-h column): and the possibilities of increasing the transformation figure of the transformation section II above the assumed value of 50: to make full use of the advantage of a figure of (say) 100 in increased accuracy, the losses in the length CD must be reduced: one way of doing this is to make this length a cavity line instead of coaxial, in which case the transitions from coaxial line to wave-guide, and back again from wave-guide to coaxial line, replace the two transformation sections II and III.

The first model of the apparatus, without any such refinements, allowed frequency deviations as small as 5×10^{-6} to be measured.

3103. Measurements on the Rochelle-Salt Series.—Bantle: Busch & Ganz. (*See* 3034 & 3035.)

SUBSIDIARY APPARATUS AND MATERIALS

3104. On the Theory of Visually Observed Oscillograms of Periodic Processes Analysed in Time.—Härtel. (*See* 3101).

3105. Implosions [of Cathode-Ray Tubes: Some Experiences: the Question of Fatigue].—"Diallist." (*Wireless World*, Aug. 1943, Vol. 49, No. 8, p. 251.)

3106. Mechanism of Luminescence in Phosphors [including the "Tunnel" Effect].—Antonov-Romanovsky. (*Comptes Rendus (Doklady) de l'Acad. des Sci. de l'URSS*, No. 9, Vol. 31, 1941, pp. 863–865: in English.)

A fuller account was dealt with in 2804 of October. The theory suggested explains, among other things, the independence on temperature, during the very first stages (fractions of a second), of the decay of many phosphors whose general decay curve depends largely on temperature.

3107. The Excitation of Ultra-Violet Phosphorescence in Alkali-Halide Phosphors activated with Thallium.—Katz. (*Comptes Rendus (Doklady) de l'Acad. des Sci. de l'URSS*, No. 3, Vol. 32, 1941, pp. 178–180: in German.) Measurements with a highly sensitive counter tube with platinum photocathode.

3108. A Note on the Decay of the Phosphorescence of Crystal Phosphors.—Schön. (*Naturwiss.*, 16th April 1943, Vol. 31, No. 16/18, pp. 203–204.)

In connection with the work of Antonov-Romanowsky and of Birus on the question of the exponential character of the decay curve, the writer announces that in the course of his researches shortly to be reported on (*see* 3109, below) he has developed a technique for the thorough examination of the non-radiative processes in crystal phosphors, for the determination of their occurrence-frequency in comparison with that of the luminescent processes and of their dependence on the mode of production of the phosphor, and above all for the establishment of the fact that their frequency is proportional only to the concentration of the excited electrons and not to its square, as is the case for the luminescent processes. Among other points discussed in the present letter, it is mentioned that the writer's own experience, that the non-radiative transitions are very sensitive to structure, fits in with Romanowsky's findings that only two of his phosphors showed an exponential characteristic, while the remainder did not : and also that the fact that the exponential decay sets in earlier as the temperature is raised agrees with the present results.

3109. On the Temperature Dependence of the Brightness of Crystal Phosphors for Monochromatic Excitation.—Schön. (*Naturwiss.*, Vol. 31, 1943.) Referred to in 3108, above.

3110. On the Destruction of Phosphorescence [of Maier Phosphor 453 (Pure Finely Pulverised ZnS–Cu with 4% CdS, with Emission Maximum close to Sensitivity Maximum of Eye) by Alpha Rays].—Becker & Schaper. (*Ann. der Phys.*, 8th April 1943, Vol. 42, No. 6, pp. 487–500.)

Continuation of the work dealt with in 1222 and 1351 of April, reporting new experimental results "which not only contain profitable view-points for practical utilisation but also serve to deepen our knowledge of the luminescent mechanism and of the structure of the light centres in phosphors."

The difference in behaviour to alpha-ray excitation and excitation by light, combined with the previously obtained fact (*loc. cit.*) that a similar destructive effect can be obtained by pressure, appears to establish the conclusion that the problem of the light centre is less a question of the metal *content* than of its incorporation, *i.e.* a question of structure. It thus becomes comprehensible that a centre should respond, according to the mechanism of the energy transmission, differently to different types of excitation.

3111. Fluorescent Fatigue [in connection with Fluorescent Lamps].—Marden & Beese. (*Sci. Abstracts*, Sec. B, June 1943, Vol. 46, No. 546, p. 112.)

In the Discussion, the effect in question is attributed not to fatigue but to other factors, including the drop of sensitivity of the phosphor with rise of temperature, and the reduced efficiency of production of the 2537 AU radiation at high current densities.

3112. On the Nature of the Latent Images formed in Photographic Emulsions due to Light Absorption and to the Passage of Ionising Particles [including the Derivation of an Expression for the H & D Curve for Ionising Particles, similar to that of Webb for Light Quanta (208 of 1942), and Comparison with Experimental Curve for Protons & Alpha Particles].—Bose. (*Indian Journ. of Phys.*, Feb. 1943, Vol. 17, Part 1, pp. 27–37.)

3113. Grapho-Analytical Methods for Plotting Electron Trajectories.—Lukoshkov & others. (*See* 3004.)

3114. The Acceleration of Electrons by Rotational Electric Fields [Writer's 1937 American Patent anticipating Kerst's Work].—Steenbeck : Kerst. (*Naturwiss.*, 7th May 1943, Vol. 31, No. 19/20, pp. 234–235.)

3115. On the Development of the Electron Microscope [and the Conflicting Claims of Various German Groups].—Brüche. (*Physik. Zeitschr.*, 15th April 1943, Vol. 44, No. 7/8, pp. 176–180.)

3116. The Electron Reflecting-Microscope, a New Supermicroscope [" Table " Model]. —Mahl & Pendzich. (*Zeitschr. f. tech. Phys.*, No. 2, Vol. 24, 1943, pp. 38–42.)

In spite of many attempts to reduce its size, the present electron microscope is a big affair, its great height being a consequence of the desire for high magnification and the impossibility of attaining suitably short focal lengths. This applies equally to magnetic and electrostatic types. A marked step forward is possible by the introduction of the reflecting microscope, where the electron-mirror takes over the rôle of the projecting lens and eliminates the additional length of tube required for the second magnifying stage. Preliminary tests, on an arrangement obtained by converting an existing model of an electrostatic microscope, yielded the results seen in Figs. 4b, 5, 6, showing no appreciable inferiority, either in resolution or freeness from distortion, to the ordinary images. A "table microscope" taking full advantage of the offered advantages is under construction, and its general lines are indicated in Fig. 7 : first results with this model have just been obtained and will be reported in a later paper. Nearly a third of the total height of the instrument lies below the table-top, the electron gun being at the lower end and the electron-mirror at the top. All the adjustments (including the manipulation of the locks for object and photographic plate) can be carried out in a sitting position. The literature on the theory of an electron-mirror, and the development of the practical mirror for the present investigations, are dealt with on p. 39.

3117. Condensation Nuclei made Visible in the Electron-Microscope.—Linke. (*See* 2946.)

3118. Electron-Microscopic Fine Structure of the Cleavage Surfaces of Glass.—Gölz. (*Zeitschr. f. Phys.*, 6th April 1943, Vol. 120, No. 11/12, pp. 773–777.) The writer ends with the suggestion that still further progress may be made by utilising the increased contrast provided by Mahl's technique using slantingly deposited metallic layers as "impression foils", 2065 of 1942 [and *cf.* Müller, 1219 of April].

3119. A McLeod Gauge of High Accuracy and Sensitivity [for Pressures down to 3×10^{-7} mm Hg : Comparison with Rosenberg's Design (4120 of 1939)]. — Haase. (*Zeitschr. f. tech. Phys.*, No. 2, Vol. 24, 1943, pp. 27–34.)

3120. Time Lag of Impulse Breakdown at High Pressures [Tests in Pre-Purified Nitrogen].

—Cobine & Easton. (*Journ. Applied Phys.*, July 1943, Vol. 14, No. 7, pp. 321–331.) "The observations suggest methods for speeding the action of spark plugs and protective gaps as well as for increasing the reliability of gas-insulated apparatus . . ."

3121. THE GENERATION OF ALTERNATING-CURRENT OSCILLATIONS WITH THE CONTROLLED ARC. —Schumann. (*See* 2980.)

3122. ON THE CHARACTERISTIC CURVES OF A CONTROLLED VACUUM ARC [in Mercury Vapour]. —Schöls. (*See* 2981.)

3123. MERCURY-VAPOUR SEALED-OFF MUTATORS WITH STEEL CONTAINERS AND RARE-GAS FILLING.—Gerecke. (*Bull. de l'Assoc. Suisse des Élec.*, 22nd April 1942, Vol. 33, No. 8, pp. 226–228: Discussion pp. 228–230: in German.)

3124. A RECTIFYING AND INVERTING CIRCUIT FOR CONTROLLING THE OSCILLATIONS OF A HIGH-POWER SELF-EXCITED VALVE OSCILLATOR [for the Surface Annealing of Steel].—Babat & Lozinski. (*See* 2983.)

3125. THE BEHAVIOUR OF THE ELEMENTS OF DRY-PLATE RECTIFIERS AT LOW CURRENT-DENSITIES.—Theillaumas. (*Génie Civil*, 15th March 1943, Vol. 120, No. 6, p. 70: summary, from *Comptes Rendus* [Paris], 6th July 1942.)

It is generally considered that a dry-plate rectifier inserted into a circuit carrying an alternating current behaves like a capacitance shunted by a resistance. It is assumed, also, that at a given frequency, and within wide limits, the capacitance is practically independent of the effective strength of the a.c., while the resistance decreases markedly as the intensity increases.

When the current density is low, of the order of some microamperes per sq. millimetre, this representation is not always correct. The writer has found elements which have no apparent capacitance and which on the contrary show a paradoxical effect of self-inductance: this applies both to selenium and copper-oxide rectifiers, manufactured normally and possessing a suitable coefficient of rectification. In the full paper he gives the results of systematic tests which he has made to study this phenomenon.

3126. THE ELECTRIC PROPERTIES OF THIN FILMS OF NICKEL [Sputtered in Hydrogen].—Colombani. (*Génie Civil*, 15th March 1943, Vol. 120, No. 6, p. 70: summary, from *Comptes Rendus* [Paris], 6th July 1942.)

The writer has already (2536 of 1939) reported his results on the influence of heat treatment on the conductivity of these films: the present work deals with films which have had no such treatment. The resistivity decreases exponentially as the thickness is increased from 70 to 178 mμ, reaching a constant value, 80 times higher than that of ordinary nickel, above this thickness. *See* also *ibid.*, 15th April 1943, No. 8, p. 93.

3127. STUDIES ON THE STRUCTURE OF THIN METALLIC FILMS BY MEANS OF THE ELECTRON MICROSCOPE [Surface Structure explainable by Migration of Atoms over the Surface: Observed Structure explains Electrical Conductivity, Optical Reflectivity, & Adsorptivity of Thin Films].—Picard & Duffendack. (*Journ. Applied Phys.*, June 1943, Vol. 14, No. 6, pp. 291–305.)

3128. RESISTANCE LAMPS [and the Small Types with One or Two Tungsten Filaments, sometimes with Gas Filling].—Insley. (*Bell Lab. Record*, July 1943, Vol. 21, No. 11, pp. 399–402.)

3129. STANDARDISATION OF VALUES FOR FIXED RESISTORS.—Inter-Service (Communications) Components Committee. (*Journ. of Scient. Instr.*, April 1943, Vol. 20, No. 4, p. 68.)

3130. FIXED CAPACITORS: BRITISH STANDARD 1082: 1942 [Book Notice].—British Standards Institution. (*Journ. of Scient. Instr.*, April 1943, Vol. 20, No. 4, p. 67.)

3131. A.C. ELECTROLYTIC CONDENSERS.—Godes & Zakgeym. (*Izvestiya Elektroprom. Slab. Toka*, No. 7, 1940, pp. 62–64.)

The difficulties of operating electrolytic condensers in a.c. circuits for long periods of time are enumerated, and the design of a 5 μF, 127 V condenser assembled in a cylinder of 35 mm diameter and 90 mm length is discussed. Formulae are quoted for checking that there will be no over-heating of the condenser, and it is pointed out that the usual method of depositing oxide films on the condenser plates is not satisfactory. Accordingly, a new method was developed in which a forming electrolyte of a different composition is used (no details of the method or electrolyte are given). The condensers are quite stable, as can be seen from table 2, in which C and tan δ are shown for condensers operated 8 to 10 hours every day for 6 months.

3132. THE TECHNIQUE OF MATERIALS TESTING: III—ELECTRICAL TESTS [particularly of Insulator Breakdown: Surface Carbonisation ("Tracking"), etc.].—Owen. (*BEAMA Journal*, July 1943, Vol. 50, No. 73, pp. 203–209.)

3133. THE FORMATION OF SURFACE-LEAKAGE PATHS ON INSULATING MATERIALS AT HIGH VOLTAGES.—von Cron. (*Arch. f. Elektrot.*, 31st March 1943, Vol. 37, No. 3, pp. 123–137.)

Author's summary:—"It is found that discharges which spread over the surface and move rapidly distribute the thermal energy over a wide surface and are consequently harmless. Such forms of discharge can only occur when the moisture is uniformly distributed over the insulator, and above all when the degree of moisture is not too high. Even discharges of comparatively high current strength (2 mA) then behave without any leakage-path action. If on the other hand the degree of moisture is high or the moisture is unevenly distributed, stationary discharges are formed which lead to creep-path formation even for very small currents (about 0.1 mA). Since a contact discharge ('break' discharge) begins at zero length, even currents of a fraction of a milliampere can produce a brush-discharge arc with a highly heated 'footing' [starting point on the surface]. The forces exerted by the electric field [sections 6, 8] play a decisive rôle at high voltages.

"The non-uniform distribution of conductivity on the surface is a generally valid condition for the formation of surface-leakage paths. In the case of path-formation without gaseous discharges [*see* Stäger & Siegfried, 3144 of 1941] an enrichment of the electrolyte occurs along the boundary surfaces, with a consequent concentration of the ionic conductivity into channels. In path-formation through gaseous discharges there is an analogous concentration of conductivity, leading to the production of dense-current gaseous discharges.

"The final stage of the path-formation, in which the charred conductive track is produced, is as a general rule a gaseous discharge with falling characteristic and a hot (sometimes thermally active) footing. For the prevention of leakage-path formation, therefore, the most useful steps are those which hinder the occurrence of gaseous discharges with falling characteristic" [but in such discharges the current-strength is different for different path lengths: short discharges can pass into arcs even for currents of a fraction of a milliampere, so that the limitation of the current-strength alone does not eliminate the danger of surface leakage: p. 129].

Other factors are discussed in section 9: points and corners favour surface leakage, but on the other hand sharp edges produce a dispersion of current which tends to oppose leakage-path formation. Thermal conductivity plays an important rôle; so does polarity in the case of direct current, since the negative portions of the brush and glow discharges are much hotter and less mobile than the positive. Dense-current discharges such as occur in the "stalks" of a brush discharge scorch the surface, and a similar preparatory effect is produced by surge discharges, in the form of a rapid succession of sparks.

3134. MECHANISM OF CREEP-PATH FORMATION [in Organic Insulating Materials: Paper in *Plastics*, Jan. 1943].—(*Sci. Abstracts*, Sec. B, June 1943, Vol. 46, No. 546, p. 100.) *Cf.*, for example, 3144 of 1941, 2815 of 1942, 206 of January, and 1513/4 of May: also 3132/3, above.

3135. ATMOSPHERIC INFLUENCES ON THE INSULATING POWERS OF HIGH-VOLTAGE INSTALLATIONS, ESPECIALLY AT HIGH ALTITUDES [Comprehensive Survey].—Jacottet. (*Arch. f. Elektrot.*, 30th Nov. 1942, Vol. 36, No. 11, pp. 629–651.)

3136. VISCOSITY AND CRYOSCOPIC DATA ON POLYSTYRENE: DISCUSSION OF STAUDINGER'S VISCOSITY RULE.—Kemp & Peters. (*Sci. Abstracts*, Sec. A, Jan. 1943, Vol. 46, No. 541, p. 21.)

3137. LOSS OF PLASTICISERS FROM POLYVINYL-CHLORIDE PLASTICS IN VACUUM, *and* EFFECT OF SOLVENTS UPON SOLID ORGANIC PLASTICS.—Liebhafsky & others: Delmonte. (*Sci. Abstracts*, Sec. A, Oct. 1942, Vol. 45, No. 538, p. 263: p. 263.)

3138. WELDING OF THERMOPLASTICS [particularly Polyvinyl Chlorides]: I, II, and III.—(*Sci. Abstracts*, Sec. B, July 1943, Vol. 46, No. 547, p. 135.)

3139. THE SOFTENING OF THERMOPLASTIC POLYMERS: I—THEORETICAL.—Tuckett. (*Sci. Abstracts*, Sec. A, July 1943, Vol. 46, No. 547, p. 144.)

3140. "HIGH POLYMERS: A SERIES OF MONOGRAPHS ON THE CHEMISTRY, PHYSICS, AND TECHNOLOGY OF HIGH POLYMERIC SUBSTANCES: VOL. IV—NATURAL AND SYNTHETIC HIGH POLYMERS" [Book Review].—Meyer. (*Review Scient. Instr.*, April 1943, Vol. 14, No. 4, p. 107.) The series is edited by Mark, Kraemer, & Whitby.

3141. "PHYSICAL CHEMISTRY OF HIGH POLYMERIC SYSTEMS," *and* "HIGH POLYMERIC REACTIONS: THEIR THEORY AND PRACTICE" [Book Review].—Mark: Mark & Raff. (*Gen. Elec. Review*, June 1943, Vol. 46, No. 6, p. 359.) Vols. II & III of a series entitled "High Polymers" (*see* 3140, above).

3142. A VARIETY OF MYCALEX FOR MOULDING.—Mycalex Company. (*Electrician*, 27th Aug. 1943, Vol. 131, No. 3404, p. 211.)

3143. THE STRUCTURE TYPE OF PEROWSKITE ($CaTiO_3$).—von Náray-Szabó. (*Naturwiss.*, 16th April 1943, Vol. 31, No. 16/18, pp. 202–203.) *See* also Goldschmidt & Rait, *Nature*, 25th Sept. 1943, Vol. 152, p. 356.

3144. "A HANDBOOK OF SHELLAC ANALYSIS" [Book Review].—Rangaswami & Sen. (*Sci. & Culture* [Calcutta], March 1943, Vol. 8, No. 9, p. 384.)

3145. THE BEHAVIOUR OF SOLID BODIES IN A HIGH-FREQUENCY ROTATING FIELD.—Hartmann & Stürmer. (*Naturwiss.*, 16th April 1943, Vol. 31, No. 16/18, p. 206.)

Debye calculated that a body suspended in an electric rotating field would be subjected to a torque when the frequency of the rotating field was of the same order as a dispersion frequency of the body. This effect was first shown experimentally for liquids, by Lertes in 1921. "Investigations of the effect in solid bodies are not known till now. In the course of an investigation on the dielectric losses in solids we have succeeded in showing experimentally the theoretically predicted torque. The measurements were carried out with rotating fields of wavelength 1.2–5 m. For the generation of the oscillations a Holborn transmitter was used, in which two indirectly heated triode systems were mounted in parallel in a common bulb. To produce the necessary phase displacement the transmitter was coupled to a Lecher-wire system, a condenser consisting of four quarter-cylinder plates being interposed between this and the anode loop. By a continuous variation of the transmitter frequency the frequency-dependence of the torque could be shown. Measurements were carried out on vinidur, calit, paraffin, alberit, benzophenon, *p*-nitrophenol and *p*-nitrochlorbenzol. This preliminary communication will be amplified at a later date by a full report."

3146. DIELECTRIC LOSSES IN PHOTOELECTRIC CONDUCTIVITY. — Sikorsky. (*Comptes Rendus* (*Doklady*) *de l'Acad. des Sci. de l'URSS*, No. 1, Vol. 32, 1941, pp. 35–36 : in German.)

"The study of the behaviour of photoelectric conductors in an electric alternating field on irradiation can contribute to the elucidation of the mechanism of photoconductivity. . . The increase in losses on illumination suggests that a quantitative relation must exist between the magnitude of the losses and the strength of the light." By a Lecher-wire method the writer has measured the effect in röntgenised NaCl and additively-coloured KI crystals, and in polycrystalline sulphur. In all cases the intensity of light was directly proportional to the sine of the loss-angle.

3147. PLATINUM–TUNGSTEN ALLOY AS CONTACT MATERIAL [Advantages over Platinum–Iridium & Gold–Zirconium Alloys : specially suitable for Communications Technique].—Döring. (*Zeitschr. V.D.I.*, 15th May 1943, Vol. 87, No. 19/20, p. 302 : summary, from *E.T.Z.*, No. 9/10, 1943.)

3148. NEW CONTACT MATERIALS WITH TUNGSTEN BASE [Sinter-Alloys with Titanium, Hafnium, etc.].—Mallory & Company. (*E.T.Z.*, 6th May 1943, Vol. 64, No. 17/18, p. 252 : critical summary of an American patent.)

3149. CARBON AS CONTACT MATERIAL FOR SWITCHING AND CONTROL APPARATUS.—Hoffmann & Weiler. (*E.T.Z.*, 8th April 1943, Vol. 64, No. 13/14, pp. 181–184.)

3150. POSSIBILITY OF REDUCING THE ELECTRICAL CONTACT RESISTANCE OF ALUMINIUM AND ALUMINIUM ALLOYS.—Wagner & Stein. (*Journ. Roy. Aeron. Soc.*, June 1943, Vol. 47, No. 390, pp. 293–294.) R.T.P. 3 Abstract.

3151. SENSITIVE RELAYS: LIGHT - CURRENT DEVICES FOR RADIO AND ALLIED USES [Data on M.C. Relays, Moving-Iron & "Telephone" Relays : Mercury, Gas-Discharge, & Glow Relays : Contact Materials & Surfaces : Sparking & Its Reduction : Maintenance].—Jupe. (*Wireless World*, Aug. 1943, Vol. 49, No. 8, pp. 234–237.)

3152. THERMAL RELAYS [Type OT, a Satisfactory Bimetallic-Strip Relay primarily for protecting Motors against Overloading].—Reyrolle & Company. (*Journ. of Scient. Instr.*, April 1943, Vol. 20, No. 4, pp. 65–66.)

3153. CONTACT BOUNCE [and a Special Recorder (using Teledeltos Chemical Paper) with Many Advantages : Time Intervals from 0.2 msec. (Accuracy within 0.1 msec.) to 0.5 sec.].—Estes. (*Gen. Elec. Review*, June 1943, Vol. 46, No. 6, pp. 321–323.)

3154. D.C./A.C. CONVERTER [Magnetic Principle] : A SENSITIVE METHOD OF MEASURING SMALL D.C. VOLTAGES.—Ledward. (*See* 3090.)

3155. "MAGNETIC CIRCUITS AND TRANSFORMERS" [Book Review].—Staff of M.I.T. (*Elec. Engineering*, July 1943, Vol. 62, No. 7, p. 327.)

3156. NEW INSTRUMENT TRANSFORMERS, DESIGNED TO CONSERVE CRITICAL MATERIALS AND ALSO FULFIL TODAY'S FUNCTIONAL REQUIREMENTS.—Dickinson. (*Gen. Elec. Review*, June 1943, Vol. 46, No. 6, pp. 331–334.) For an abridged version see *Electrician*, 6th Aug. 1943, Vol. 131, No. 3401, pp. 127–129.

3157. ELECTRODYNAMIC DETERMINATION OF THE MAGNETIC MOMENT OF [Thin Circular] PLATES [and Its Use for the Rapid Approximate Measurement of the Coercive Force of a Material].—Benedikt. (*Review Scient. Instr.*, Feb. 1943, Vol. 14, No. 2, pp. 43–45.)

3158. ON THE DEPENDENCE OF THE MAGNETIC PROPERTIES OF A SUBSTANCE ON FREQUENCY [Mathematical Treatment : the Important Part played by Microscopic & Macroscopic Irregularities (producing a Law-Conforming Dependence on Frequency which is Not Actually a Property of the Material, but which may be Extremely Like That due to Presence of Viscosity].—Polivanov. (*Comptes Rendus* (*Doklady*) *de l'Acad. des Sci. de l'URSS*, No. 3, Vol. 32, 1941, pp. 181–184 : in English.)

3159. HISTORIC FIRSTS : PERMALLOY [and the Subsequent Development of Perminvars].—Elmen. (*Bell Lab. Record*, June 1943, Vol. 21, No. 10, p. 340.) For previous "Historic Firsts" *see* Arnold, 2399 of September, and 3039, above.

3160. AN EXPERIMENTAL METHOD FOR THE GRAPHICAL CONSTRUCTION OF THE MAGNETIC FIELD FOR BODIES OF ARBITRARY SHAPE : METHOD OF THE "COORDINATE FIELD METER," *and* A PROPOSED METHOD OF MEASURING THE DERIVATIVES OF THE EARTH'S MAGNETIC FIELD.—Kalashnikov : Jones. (*See* 3098 & 3099.)

3161. SPECIAL METALS IN THE ELECTRICAL INDUSTRY [Resistors, Bimetals, Trimetals, Glass-Sealing Alloys, Contact Alloys, Magnetic Materials, etc.].—Hensel & Wiggs. (*Elec. Engineering*, July 1943, Vol. 62, No. 7, pp. 296–302.)

3162. PRINCIPAL STAGES IN THE HISTORY OF INDIUM IN THE EARTH'S CRUST, *and* DISTRIBUTION OF INDIUM IN TRANS-BAIKAL.—

Prokopenko. (*Comptes Rendus* (*Doklady*) *de l'Acad. des Sci. de l'URSS*, No. 9, Vol. 31, 1941, pp. 903–906 : pp. 907–908 : in English.) For uses of indium *see* 2843 of October.

3163. THE WOLFRAM BEDS OF MANDELESSE, HAUTE-VIENNE, NEAR LIMOGES.—(*Génie Civil*, 1st May 1943, Vol. 120, No. 9, p. 104.)

3164. A FINDING OF FERRITHORITE IN NORTH KIRGHIZIA, *and* ON SOME NEWLY DISCOVERED MINERALS IN THE PEGMATITES OF ADUN-CHOLON, TRANS-BAIKALIA.—Stark & others : Nefedov. (*Comptes Rendus* (*Doklady*) *de l'Acad. des Sci. de l'URSS*, Nos. 4 & 5, Vol. 32, 1941, pp. 254–255 & 361–364 : both in English.)

3165. BERYLLIUM–COPPER [including a Note on Beryllium–Nickel].—Foster. (*Electrician*, 16th July 1943, Vol. 131, No. 3398, pp. 56–58.) *Cf.* 1286/7 of April.

3166. BRAZING ALLOY [" Phos-Copper "].—Westinghouse. (*Review Scient. Instr.*, June 1943, Vol. 14, No. 6, p. 192.)

3167. SOLDERING-IRON DESIGN [" Pyrobit " Irons held like a Pencil : Heating Element housed in Copper Bit itself].—Acru Company. (*Wireless World*, Aug. 1943, Vol. 49, No. 8, p. 229.)

3168. THE SILVER–ZINC ACCUMULATOR.—André. (*Génie Civil*, 15th March 1943, Vol. 120, No. 6, p. 71 : summaries only.)

3169. THE EFFECTS OF THE FREEZING OF THE ELECTROLYTE IN MOTOR-CAR ACCUMULATORS.—Blaich. (*Génie Civil*, 1st April 1943, Vol. 120, No. 7, p. 83 : summary only.)

" The ill effects are not so serious as might be feared. . . . Russian manuals contain rules as to the density of the electrolyte, which should be modified according to latitude and season."

STATIONS, DESIGN AND OPERATION

3170. FREQUENCY MODULATION [Claims regarding Better Quality & Freedom from Interference are Unjustified so far as Normal Broadcasting in This Country is concerned : Fuller Advantage should be taken of Quality possible with A.M.].—Baggs. (*Wireless World*, Sept. 1943, Vol. 49, No. 9, p. 284.)

3171. " DEAD SPOTS " OUT [Replacement of A. M. by F. M. eliminates " Dead Spots " from which Police could Not talk to Patrol Cars or Headquarters].—Chesnut. (*Gen. Elec. Review*, June 1943, Vol. 46, No. 6, p. 352 : paragraph & photograph only.)

3172. HIGH FIDELITY [Hopes of High-Fidelity Transmissions from Alexandra Palace after the War : the Benefit to Television Expansion : Suggestion of F.M. Relays].—" Diallist." (*Wireless World*, Aug. 1943, Vol. 49, No. 8, pp. 252–253.)

3173. *Wireless World* BRAINS TRUST : BROADCAST DISTRIBUTION—THE CASE FOR WIRELESS [particularly on Political & Economic Grounds].—(*Wireless World*, Aug. 1943, Vol. 49, No. 8, pp. 227–229.)

3174. "ISOLATIONIST" BROADCASTING, *and* AGAINST WIRED BROADCASTING : EXPLAINING OUR ATTITUDE [Editorials] : *also* IN SUPPORT OF THE WIRE [Correspondence]. — (*Wireless World*, Aug. 1943, Vol. 49, No. 8, p. 223 : Sept. 1943, No. 9, p. 255 : pp. 282–283.)

3175. OVERCROWDING THE ETHER [Marked Increases, in 1942, in Channels used in 6 and 20 Mc/s Band, and in 30 to 300 Mc/s Band : etc.], *and* FREQUENCY DISTRIBUTION IN NORTH AMERICA.—(*Wireless World*, Aug. 1943, Vol. 49, No. 8, p. 245 : p. 246.) Notes on *U.I.R. Bulletin* figures.

3176. POST-WAR BROADCASTING [Arguments in Favour of a 10 kc/s Spacing for European Stations].—Thomas. (*Wireless World*, Sept. 1943, Vol. 49, No. 9, p. 283.) " Now, if ever, is the time to prepare for this change—a change which is essential if post-war broadcasting is to run smoothly."

3177. NEW 50-KILOWATT C.B.S. INTERNATIONAL BROADCASTERS [on Long Island, New York].—Romander. (*Elec. Communication*, No. 2, Vol. 21, 1943, pp. 112–123.) Supplementing Chamberlain's paper, 2528 of 1942.

3178. THE H.F. [2–24 Mc/s] MARINE RADIO UNIT : NEWLY ADOPTED EQUIPMENT INFLUENCING SHIP DESIGN [Companion Unit to the " I.F. Marine Radio Unit " (1816 of 1942)].—Girard. (*Elec. Communication*, No. 2, Vol. 21, 1943, pp. 85–88.) From the Federal Telephone & Radio Corporation.

GENERAL PHYSICAL ARTICLES

3179. THE BLACKBODY : PART I—ITS PHYSICAL THEORY AND ITS SPECTRAL DISTRIBUTION AND OTHER RADIATION CHARACTERISTICS.—Benford. (*Gen. Elec. Review*, July 1943, Vol. 46, No. 7, pp. 337–382.)

3180. THE ENERGY LOSS BY RADIATION OF FAST ELECTRONS IN A COULOMB FIELD.—Jaeger. (*Proc. Cambridge Phil. Soc.*, June 1943, Vol. 39, Part 2, pp. 127–130.)

3181. APPLICATION OF PHOTON STATISTICS [as developed by the Writer in 1938 : Summary given Here] to THE SPECIFIC HEAT OF A MONATOMIC SOLID.—Biswas. (*Indian Journ. of Phys.*, Feb. 1943, Vol. 17, Part 1, pp. 1–5.)

3182. THE PHOTON IN THE QUANTUM THEORY OF RADIATION [Notion of Photon can be Incorporated directly in the Theory : Neglect to do so causes Incorrect Statements & complicates Expression].—Yvon. (*Comptes Rendus* [Paris], 3rd/30th Nov. 1942, Vol. 215, No. 18/22, pp. 410–412.)

3183. THE RELATION OF THEORY TO EXPERIMENT IN PHYSICS, *and* RELATIVITY, THE FITZGERALD-LORENTZ CONTRACTION, AND QUANTUM THEORY.—Swann. (*Reviews of Mod. Phys.*, July 1941, Vol. 13, No. 3, pp. 190–196: pp. 197–202.)

3184. THE FUNDAMENTAL EQUATION OF QUANTUM MECHANICS.—Flint. (*Phil. Mag.*, July 1943, Vol. 34, No. 234, pp. 496–502.)

3185. "EINFÜHRUNG IN DIE QUANTENTHEORIE DER WELLENFELDER" [Book Review].—Wentzel. (*Naturwiss.*, 21st May 1943, Vol. 31, No. 21/22, pp. 251–252.)

MISCELLANEOUS

3186. THE MOSCOW SCHOOL OF TOPOLOGY.—Kolmogorov. (*Science*, 25th June 1943, Vol. 97, No. 2530, pp. 579–580.)

3187. "THE HYPERGEOMETRIC AND LEGENDRE FUNCTIONS WITH APPLICATIONS TO INTEGRAL EQUATIONS OF POTENTIAL THEORY" [Book Review].—Nat. Bur. of Standards. (*Journ. Applied Phys.*, July 1943, Vol. 14, No. 7, p. 369.) No. MT. 15 of the series of mathematical tables sponsored by the Bureau: the others are listed on pp. 368–369.

3188. PROOFS OF SOME FORMULAE FOR THE HYPERGEOMETRIC FUNCTION AND THE E-FUNCTION.—MacRobert. (*Phil. Mag.*, June 1943, Vol. 34, No. 233, pp. 422–426.)

3189. A THEORY OF THE SIZE DISTRIBUTION OF PARTICLES IN A COMMINUTED SYSTEM [leading to One of the Particular Integrals of the Differential Probability Equation].—Griffiths. (*Canadian Journ. of Res.*, June 1943, Vol. 21, No. 6, Sec. A, pp. 57–64.)

3190. "MICROMERITICS" [General Guide to Behaviour & Characteristics of Fine Particles: Book Review].—Dalla Valle. (*Elec. Engineering*, July 1943, Vol. 62, No. 7, p. 328.)

3191. REACTANCE SLIDE RULE [keeping Track of Decimal Point].—Shure Bros. (*Journ. Acous. Soc. Am.*, July 1943, Vol. 15, No. 1, pp. 62–63.)

3192. "THE MATHEMATICS OF WIRELESS" [Book Review].—Stranger. (*Proc. I.R.E.*, June 1943, Vol. 31, No. 6, Part I, p. 312.) "In the attempt to convince the reader that mathematics is not the repellent subject he has supposed, the author has been particularly successful. . . ."

3193. "A COURSE IN RADIO FUNDAMENTALS" [Book Review].—Grammer. (*Wireless World*, Aug. 1943, Vol. 49, No. 8, p. 233.) A favourable review of the book referred to in 2540 of September.

3194. "THE RADIO AMATEUR'S HANDBOOK, TWENTIETH (1943) EDITION" [Book Review].—A. R. R. L. (*Proc. I.R.E.*, June 1943 Vol. 31, No. 6, Part I, p. 313.)

3195. "APPLIED ELECTRONICS" [Book Review].—Staff of M.I.T. (*Elec. Engineering*, July 1943, Vol. 62, No. 7, p. 327.)

3196. "INTRODUCTION TO ELECTRICITY AND OPTICS" [Book Review].—Frank. (*Proc. I.R.E.*, June 1943, Vol. 31, No. 6, Part I, p. 312.)

"An excellent book . . . very satisfactory way he has harmonised the interests of those interested primarily in high-frequency radio phenomena and those interested primarily in optical phenomena. . . The chapter on 'Dispersion and Scattering' . . . is particularly good".

3197. "DICTIONARY OF SCIENCE AND TECHNOLOGY IN ENGLISH–FRENCH–GERMAN–SPANISH" [Book Review].—Newmark. (*Elec. Engineering*, July 1943, Vol. 62, No. 7, p. 329.)

3198. SCIENTIFIC RESEARCH [Excerpts from Speech in House of Lords].—Cherwell. (*Engineer*, 6th Aug. 1943, Vol. 176, No. 4569, pp. 108–109.) For an Editorial *see* p. 110.

3199. RADIO RESEARCH AND PRODUCTION [Speech by Parliamentary Secretary to Ministry of Production, at Radio Industries Club: including the Work of the Radio Research Board and of the Radio Board & Its Two Committees].—Garro-Jones. (*Engineering*, 13th Aug. 1943, Vol. 156, No. 4048, p. 135: abridged.) *See* also *Wireless World*, Sept. 1943, Vol. 49, No. 9, pp. 275–276.

3200. IS WAR THE PROGENY OF SCIENCE, OR SCIENCE THE PROGENY OF WAR, OR ARE BOTH OF THESE SUPPOSITIONS FUNDAMENTALLY FALSE?—Millikan. (*Science*, 28th May 1943, Vol. 97, No. 2526, pp. 485–486.)

3201. ORGANISATION OF AMERICAN SCIENTISTS FOR THE WAR [Substance of Pilgrim Trust Lecture].—Compton. (*Nature*, 29th May 1943, Vol. 151, No. 3839, pp. 601–606.) For the full lecture see *Proc. Roy. Soc.*, Ser. A, 6th Sept. 1943, pp. 1–17, and *Science*, 23rd & 30th July 1943.

3202. SCIENCE AND THE PUBLIC [Leading Article on Compton's Royal Society Lecture & Martin's Suggestion of a Press Bureau].—(*BEAMA Journal*, July 1943, Vol. 50, No. 73, pp. 199 and 201.) *Cf.* Raestad, 2273 of August.

3203. SCIENCE AND THE PRESS [Editorial on the B.A. Conference on "Science & the Citizen"].—(*Nature*, 29th May 1943, Vol. 151, No. 3839, pp. 595–597.)

3204. ENGLISH SCIENTIFIC FILM ASSOCIATION [Note on Formation].—(*Nature*, 29th May 1943, Vol. 151, No. 3839, p. 613.)

3205. CONSERVING VITAL MATERIALS FOR WAR: PART I.—Horn. (*Gen. Elec. Review*, July 1943, Vol. 46, No. 7, pp. 385–389.) "Some of the ways in which our supply of critical materials is made to go farther, and our speed of manufacturing products is increased."

3206. The Conservation of Materials [in War-Time: Address by President, A.I.E.E.].—Osborne. (*Elec. Engineering*, July 1943, Vol. 62, No. 7, pp. 290–293.)

3207. Air-Raid Warnings: Valve Equipment for "Imminent Danger" Signals [at Hove].—(*Wireless World*, Sept. 1943, Vol. 49, No. 9, p. 285.) *See* also *Electrician*, 23rd July 1943, pp. 86–87.

3208. Mechanical Lecturer [" Synchrophone "].—Sandor. (*Wireless World*, Aug. 1943, Vol. 49, No. 8, p. 244: picture & caption only.) *See* also 2413 of September.

3209. Teaching Radio in High School: Pre-Induction Training at Northbridge Senior and Junior High Schools.—Saunders. (*QST*, June 1943, Vol. 27, No. 6, pp. 9–12.)

3210. A Hand Perforator for Code-Practice Tape: Building a Practical Punching Device from Junk-Box Materials.—Grammer. (*QST*, June 1943, Vol. 27, No. 6, pp. 20–24 and 74..78.)

3211. Combined Receiver-Converter/Code-Oscillator/Induction-Transmitter.—Burnett. (*QST*, July 1943, Vol. 27, No. 7, pp. 56–57.)

3212. Phonetic Alphabet for British and American Forces.—(*Wireless World*, Sept. 1943, Vol. 49, No. 9, p. 262.)

3213. Japanese Morse: Symbols for a 48-Letter Alphabet.—Lee. (*Wireless World*, Aug. 1943, Vol. 49, No. 8, p. 242.) From *Radio*, 1940. *Cf.* Holden, 652 of February.

3214. Service-Men's Examination: Draft Syllabus Issued.—Radio Trades Examination Board. (*Wireless World*, Sept. 1943, Vol. 49, No. 9, pp. 284–285.) For the final syllabus *see* Oct. issue, No. 10, p. 296.

3215. " Industry and Education " [Private Conference under Auspices of Nuffield College: Review of Pamphlet].—(*Journ. of Scient. Instr.*, July 1943, Vol. 20, No. 7, p. 119.)

3216. A British Electrical Research Board [Letter on the Publication of Research Results in an Unapplied State, prompted by Leading Article under Same Title].—Paterson. (*Engineering*, 30th July 1943, Vol. 156, No. 4046, p. 94.) For the I.E.E. Report see *BEAMA Journal*, July 1943, Vol. 50, No. 73, pp. 209–211.

3217. The Radio Engineer's Responsibilities of Tomorrow.—Haraden Pratt. (*Proc. I.R.E.*, July 1943, Vol. 31, No. 7, pp. 316–317.) " The flood of radio-and-electronic instrumentabilities about to pour upon us cannot be dammed. If not controlled and diverted into ordered channels, it will seek its level, wreaking along the way a toll of confusion and much disorder . . ."

3218. Wireless Pioneers [Letter on the Work of Popov, prompted by the *Wireless World* " Brains Trust " Discussion (2623 of September): with an Editorial Note].—Field. (*Wireless World*, Aug. 1943, Vol. 49, No. 8, pp. 240–241.) Of particular interest in view of 2884 of October.

3219. Beyond the Ultra-Short Waves [Survey, beginning with the Pioneer History].—Southworth. (*Proc. I.R.E.*, July 1943, Vol. 31, No. 7, pp. 319–330.) A summary was dealt with in 2630 of October.

3220. High-Frequency Heating of Non-Metallic Materials.—A. D. Little, Inc. (*Engineer*, 13th Aug. 1943, Vol. 176, No. 4570, p. 134.)

3221. A Rectifying and Inverting Circuit for Controlling the Oscillations of a High-Power Self-Excited Valve Oscillator [for the Surface Annealing of Steel].—Babat & Lozinski. (*See* 2983.)

3222. Versatile Electronic Heaters [Standard Sizes 5 & 15 Kilowatt Outputs: Hardening, Brazing, & Soldering Operations " in Seconds instead of Minutes "].—General Electric. (*Gen. Elec. Review*, July 1943, Vol. 46, No. 7, p. 407 and Frontispiece.)

3223. Thin Case-Hardening with Radio-Frequency Energy [Technique: Cost: Results (with Macro- and Microphotographs): Use of Frankel's Temperature-Distribution Equation: etc.].—Sherman. (*Elec. Communication*, No. 2, Vol. 21, 1943, pp. 127–140.) *See* also p. 81.

3224. Dehydration of Food by Radio-Frequency Energy.—Sherman. (*Elec. Communication*, No. 2, Vol. 21, 1943, pp. 125–126.)

3225. Method of separating Isotopes based on the Use of High-Frequency Rotating Electric Fields.—Martelly. (*Génie Civil*, 1st April 1943, Vol. 120, No. 7, p. 81: summary, from *Comptes Rendus* [Paris], 27th July 1942.)

3226. X-Ray Counting Tubes [Some Applications of Improved G.M. Counters in Industrial Testing].—(*Engineer*, 13th Aug. 1943, Vol. 176, No. 4570, p. 134.) From *Iron Age*.

3227. Counting Circuits for Pulse-Counter and Counter-Tube Arrangements.—Pupke. (*See* 2972.)

3228. Miniature Geiger–Müller Counter [Tube 0.8 mm in Internal Diameter: for Locating & Measuring a Beam of Gamma Radiation or X-Rays, etc.].—Curtiss. (*Journ. of Res. of Nat. Bur. of Stds.*, Feb. 1943, Vol. 30, No. 2, pp. 157–158 and Plate.)

3229. ON THE NUCLEAR PHOTOEFFECT IN BERYLLIUM.—Houtermans & Bartz. (*Physik. Zeitschr.*, 15th April 1943, Vol. 44, No. 7/8, pp. 167–176.)

Among the motives behind this investigation (carried out at the von Ardenne laboratories) is the fact that "in beryllium we possess the material for a nuclear photocell which of all elements has the longest wavelength limit. The sensitivity of this photocell for gamma radiation, and its variation with wavelength, are therefore of great interest".

3230. METHOD OF MEASURING SMALL PHOTOELECTRIC CURRENTS.—Baurand. (*See* 3091.)

3231. MAGNETIC BALANCE WITH PHOTOELECTRIC CONTROL, FOR THE MEASUREMENT OF THE FRICTION OF PIVOTS OF PRECISION MECHANISMS.—Vieweg & Gottwald. (*Génie Civil*, 15th March 1943, Vol. 120, No. 4, p. 69: summary, from *Zeitschr. V.D.I.*, 14th Nov. 1942.)

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3241. SPECTRAL STUDY OF A LUMINESCENT REACTION [Chlorine (or Bromine) acting on Mixture of Hydrogen Peroxide & a Caustic Alkali: Beautiful Red Light (Two Bands, very close to Janssen's α and α' Bands encountered in Atmospheric Absorption, and attributed to Oxygen)].—Groh & Kirrman. (*Comptes Rendus* [Paris], 5th/27th Oct, 1942, Vol. 215, No. 14/17, pp. 275–276.)

3242. THE REPERCUSSIONS OF THE SOLAR OR COSMIC ACTIVITY ON CERTAIN PHENOMENA OF VEGETAL BIOLOGY [Correlations, sometimes Far-Fetched, of Biological Phenomena with 11-Year Solar Cycle: Certain Other Phenomena which are Not so linked but which seem to have a Connection with Solar or Cosmic Radiation: such as the Rare Flowering of the Japanese Black Bamboo (Simultaneous in All Parts of the Globe), Abundant 1942 Fruit Harvest: Need for Research].—Esclangon. (*Comptes Rendus* [Paris], 7th/28th Sept. 1942, Vol. 215, No. 10/13, pp. 212–214.)

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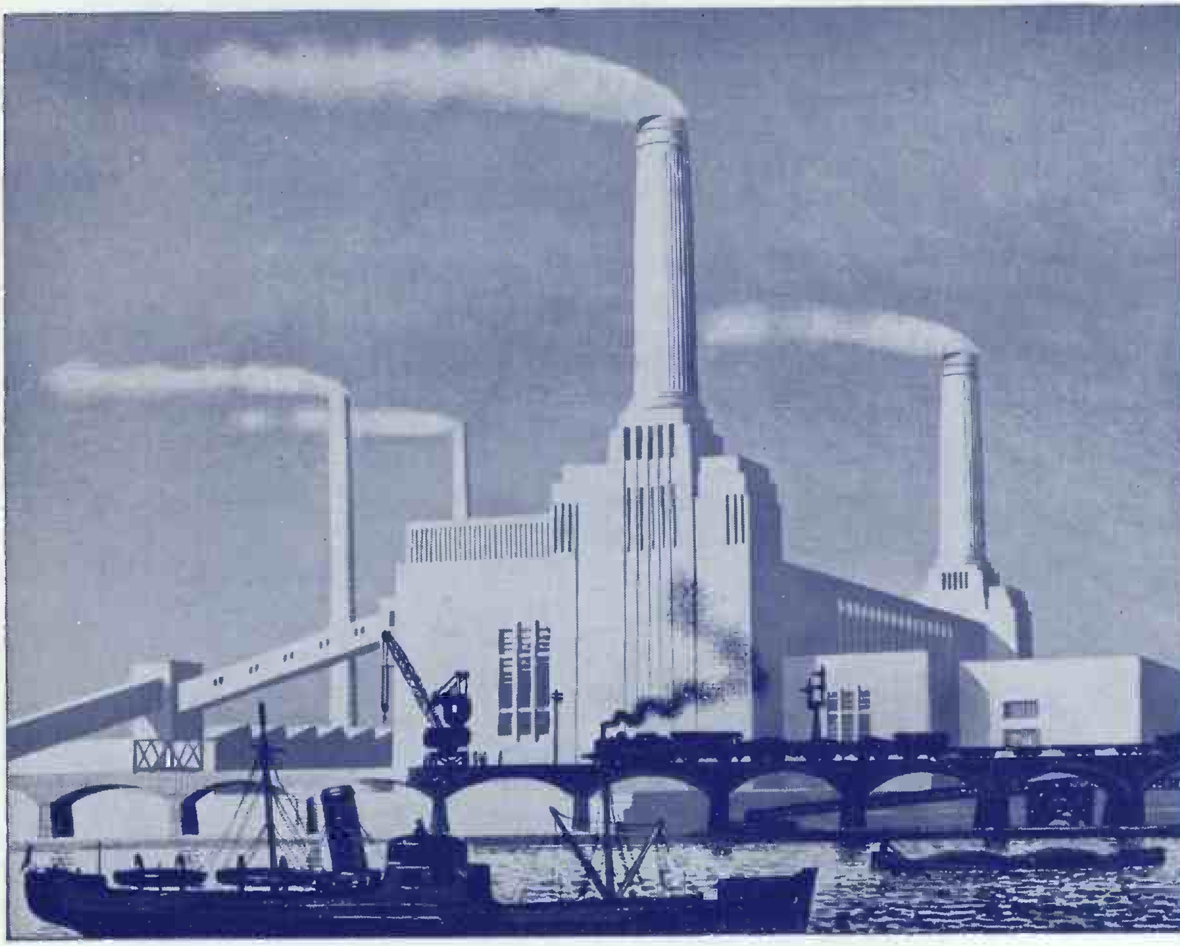

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