EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

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Editorial Views.

Calibrations.

READERS are requested to note particularly that as from 1st December our Calibration Department will be closed down for a short period, as we are sending our standard wave-meter and condenser to be re-calibrated.

While we have no reason to suspect their accuracy, it is most desirable to have them tested at regular intervals, and this seems a suitable time. Some of our readers—especially those who have just completed their apparatus!—will probably disagree with our choice of a time; but in actual fact we note quite a strong "slump" at the moment, due to the fact that most experimenters got their apparatus into action in the summer or early autumn, ready for the winter's work: it is only the belated who are using the department now.

We hope that it will be possible to accept apparatus again in January, but in any case an announcement will be made in our next issue.

Patents.

Two patent matters of interest to amateurs have cropped up just recently, both involving the same point. The Standard Telephone Co. (ex-Western Electric) warn our readers that all supersonic receivers should pay royalty; Burndept Wireless, Ltd., point out that all tantalum rectifiers infringe their patents.

Several readers have written to us, stating that these claims cannot be maintained, on the ground that "anyone is entitled to use a patent for experimental purposes." The point is such an important one that we have asked a patent agent of our acquaintance to write an article giving the actual law on the subject. But in advance of this article we propose to give our own "layman's" view of the case for what it is worth.

Broadly speaking, we believe that one is only entitled to free use of a patent for research work on *the actual subject of* the patent. For example, one is probably entitled to build up a supersonic circuit for the express purpose of research into improved supersonic circuits. But if one wishes to do research on distortionless reception, or fading, etc., the mere fact that a "supersonic" is a useful instrument for the purpose does *not*, as far as we can make out, give one any right to use it. Even if it were the only possible receiver for the purpose, one would still be legally liable for infringement.

The same principle applies generally. One may build a patented article for the purpose of studying it and improving on it; but not as a tool in other research—much less as a means of getting musical entertainment.

In putting forward this expression of opinion, it must not be taken that we are necessarily supporting the line of action of either of the two firms, nor expressing any opinion as to the validity of these patents. As regards the latter point, any patent must be presumed valid until the contrary has been decided in court. As regards the former, it is true that the Marconi Co. has announced that it gives the amateur permission to use its patents for experimental work. An interesting point arises in that (we believe) both the Marconi Co. and the Standard Co. claim to hold the basic patent for the supersonic receiver; and we hear that they have arranged that either is entitled to license users of it. If this is so, can an amateur use it under the Marconi "free gift," or not?

Our Correspondents.

Just recently we have been regretfully compelled to refuse publication to one or two letters sent to us for that purpose in connection with some rather controversial subjects which have arisen in our "Correspondence" pages.

As the senders of these letters seemed at first puzzled at our action, thus making further explanatory letters necessary, it may be as well to explain our own views on the subject.

Our guiding principle is that the correspondence pages, like the remainder of E.W. & W.E., are published to give technical information to readers. Now, as a general rule, readers (as a whole) are not frightfully interested in the fact that Mr. Mugsworth, of Snorton-on-the-Flitch, disagrees with Professor Tallboy, of Brighton University, as to the influence of atmospheric conditions on fading. But they are interested in the question itself, and will welcome from Mr. Mugsworth any facts or serious reasoning tending either to confirm or disprove the Professor's theory.

In other words, it is useless for correspondents to send us letters such as the following:—

> SIR,—
>
> I am disgusted at your allowing Mr. ——'s letter to appear in E.W. & W.E.
>
> Had he not been an advertiser you would not have printed it.
>
> He is talking obvious nonsense.
>
> Yours, etc.

(Which is the pith and essence of an actual letter received.)

As a matter of fact, we ourselves disagreed with the previous letter, but it stated a case for which some apparently sound arguments could be brought up. After reading the above criticism, we were inclined to view the original letter more favourably!

We do not wish to discourage correspondents: in fact, we believe in the great value of the free criticism of all published work; and we have no objection to hard hitting—but the weapon must be the club of reasoned argument, and not the jawbone of an ass.

The Alignment Principle in Calibration.

By W. A. Barclay, M.A. **[R208·2**

Whereby the calculations incidental to calibration work are greatly simplified.

THE Principle of Alignment as an aid to computation is a comparatively recent mathematical development, the first work on the subject being published towards the close of the last century by M. d'Ocagne. The formula which it is desired to interpret numerically is illustrated by a diagram on which the variables are represented by numerically graduated scales (and, in more complicated cases, by a series of numbered curves). A straight line being applied in any position across the diagram, corresponding numerical values of the variables are found in alignment on their appropriate scales. Thus, when numerical values of certain of the variables are given, the related values of the others are immediately ascertained.

It will be seen that the Alignment Diagram constitutes a great advance on ordinary graphical processes. In the graphical solution of impedance relations, for example, a separate construction is necessary for the solution of each individual problem as it arises, the labour involved when several results are required being considerable. Using the alignment principle, on the other hand, once the diagram is constructed, it is available for all problems of similar type, whatever be the numerical magnitudes involved. Moreover, the same diagram may be used to find the value of any one of the variables concerned when the others are given, and thus provides the automatic solution of inverse as well as direct problems with equal facility.

The scope of the alignment principle in the numerical problems which arise in wireless work is very wide, and charts may be constructed to provide numerical solutions for such varied questions as impedance, equivalent series values for parallel combinations, damping and decrement, valve constants, etc. It is not, however, generally known that the new methods may be of the greatest service in the experimental determination of the constants of a piece of apparatus. This obtains by virtue of the extraordinary facility with which three, four, or even more variables can be shown, and their relations exhibited, on the plane surface of the diagram. This convenient method of representing the simultaneous variations of several variables is immediately applicable to problems of calibration, and in the present article two simple examples of its use in this connection alone will be discussed, to the exclusion meantime of its more important computational aspect.

Nothing in the nature of mathematical proof is here attempted, it being desired solely to describe the procedure in the special cases under discussion, and to demonstrate the advantages of the method. The general theory of the subject is of quite an elementary nature, and its uses in calculation, with instances of its application to various types of wireless formulæ, may be described in a future issue of E.W. & W.E. should sufficient interest render this desirable.

We shall now describe alignment methods of correlating inductances, capacities and wave-lengths, (A) neglecting resistance, and (B) including resistance as a fourth variable.

First, then, we consider the simple circuit of Fig. 1, in which an inductance is tuned by a capacity, there being no resistance present. Such conditions are approximately true of the "rejector" portion of the ordinary "tuned anode" circuit, where the D.C. resistance is generally very low, and where, of course, the coil is uninfluenced by magnetic coupling. We shall assume that the condenser used is of the semi-circular movable vane type, so that variation of capacity is proportional to change of scale reading except in the immediate vicinity of the values 0° and 180° on the scale. Under these conditions we have,

$$\lambda = k.\sqrt{LC}$$

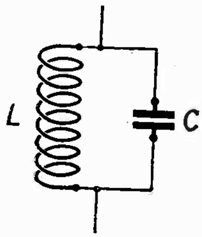


Fig. 1.

where C includes the stray capacities of the circuit, and k is a constant.

It being desired to correlate the wave-lengths with the corresponding condenser settings for the different coils used in such a circuit, it is usual to plot condenser readings taken on the abscissa against ordinates giving the corresponding wave-lengths obtained with a particular coil. The different coils are thus represented by a series of curves on the diagram, and though by a simple device these curves may be transformed to straight lines, thus attaining a certain simplification, it is obvious that a number of inductances gravely complicates the diagram.

It is claimed for the alignment method that it is much simpler both in construction and use. Set out a scale of wave-lengths OA such that the distance from the zero o to any graduation is proportional to the *square* of the corresponding wave-length. (See Fig. 2.) This may be done to any desired scale, so that any selected band of wave-lengths may be conveniently represented. Next, draw a line BC parallel to OA and at any distance from it. Again, to any desired unit, take equal divisions on BC to represent condenser readings from 0° to 180°. It should be noted that the order of the graduations on BC is in the reverse sense from those on OA.

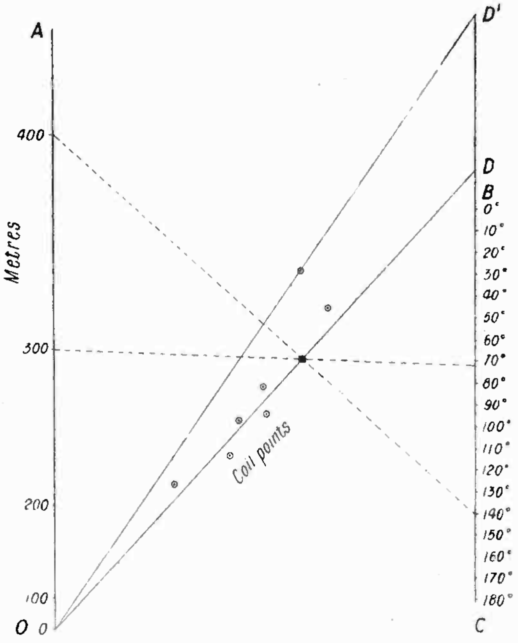


Fig. 2.

It will now be found that, for any given coil, all straight lines through corresponding values of wave-length and condenser setting will meet in a point, to which may be given the number of the coil in use. It will be seen that two such pairs of values are sufficient to determine the position of this inductance point, and that thus, from the known wave-lengths and condenser settings of but two stations, the point so found may in turn be used to determine the settings for other wave-lengths. Instead of a series of curves, we now have a series of points representing the inductances, to the great simplification of the diagram. Although, owing to the unavoidable presence of a minute resistance, the true position of these points is not exactly defined, it will be found in practice in ordinary tuned anode circuits that the triangle of error formed by the intersection of any three lines obtained by the use of one inductance is exceedingly small, and will not affect the use of the diagram. If the effect of resistance is large, however, as is the case in some other types of circuit, it will be necessary to adopt the procedure detailed below.

Meantime it is of interest to remark that, if the zero point O be joined to the point representing any coil, and is produced to meet the line BC, the resulting point D serves as a zero from which the total capacity in the circuit may be measured along the capacity scale DC. The portion DB between this zero and the commencement of the scale readings represents the amount of the stray capacity due to the coil and the wiring, while the graduated portion BC represents the variable capacity due to the condenser. An interesting measure of the efficiency or otherwise of our circuit is here afforded, as the length DB should obviously be as small as possible. Moreover, if our condenser is already calibrated in microfarads, we can obtain by proportion the numerical value of the actual capacity present at any time in the circuit. It is to be noted that the zero D from which this latter quantity is measured is not a fixed point, but varies slightly in position along BC according to the self-capacity of the coil in use. The graduations of the condenser scale-readings are, on the other hand, fixed. If the variable condenser has not already been calibrated, a fixed condenser of known value should now be placed across it, and the procedure repeated. This will entail a new position being found for the point which represents the coil, while the corresponding point of zero capacity D^1 is also found in the same manner as was D. The length DD^1 will now represent to the same scale the value of the capacity of the fixed condenser. The differences between the capacities at various scale-readings of the variable condenser may then be read off in proportion, while the total absolute capacity of the circuit is similarly reckoned proportionately from D^1 or D according as the fixed condenser is or is not included.

Incidentally this method provides an admirable means of comparing the values of small fixed condensers. The beautiful generality of the construction by which quite arbitrary units and distances may be used makes it a very powerful means of correlating the variables with which it deals.

It will be seen that, although we can distinguish between the capacities due to the variation of the condenser and those due to other causes, we cannot further analyse these latter into their constituents. Prominent among them are the minimum capacity of the variable condenser itself, the self-capacity of the coils, and that of the associated wiring. Though the fluctuations due to the changes of the coil capacities are shown on the diagram, it must be remembered that they are always associated with a certain fixed capacity of indeterminate amount. We cannot therefore proceed to an estimation of the actual magnitudes of these self-capacities, although we can observe the amounts of the differences between them.

It will also be noticed that no account has been taken of the numerical values of the inductances in use. While it is theoretically possible to derive them from the diagram of Fig. 2, it will be better, when these are desired, to resort to the procedure now to be described, which also takes account of the factor of resistance, and thus approximates to more usual conditions. The advantages of the alignment method in appropriating for each variable a particular form of geometrical representation here become strikingly apparent.

Our problem is now to correlate the condenser settings, wave-lengths and coil constants for the circuit of Fig. 3, in which the condenser, being assumed to possess no resistance itself, is placed across an inductance and resistance in series. Such a combination approximates closely to the conditions obtaining in most tuned circuits with plug-in coils, where the effective resistance of the circuit may be considered to act as a series load to the inductance, while the self-capacity of the coil is, in effect, added to the variable capacity placed across it. The combination, as is known, is resonant when

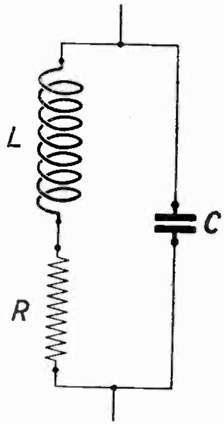


Fig. 3.

$$\omega = \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

It is our intention to isolate geometrically each of the variables of this formula in order that the relation to each to the others may be easily and rapidly demonstrated. Owing to the small variations in the self-capacities of the coils, it will perhaps be better at first to draw out a separate diagram for each coil considered; a modification by which all coils may be represented on the same chart will be indicated later.

Taking ordinary Cartesian axes OX, OY (Fig. 4), we set out on OY to any convenient unit a scale of "Squares of Wave-lengths," similar to that of our first example. Upon OX, and measured linearly from O, is to appear our scale of capacity, part of which will be represented by the variable condenser readings. Unlike the capacity scale of the previous example, this scale of capacity values is always to be reckoned from the fixed point O, whereas before the absolute values of capacity were measured from a variable zero. We are thus confronted with the difficulty that we are unable, for the moment to assign the position on OX of the point from which the condenser readings are to start. If Q denote this point, the distance OQ represents the minimum capacity of the circuit with the condenser at zero. Though we cannot as yet fill in the actual condenser readings, we may, however, select the scale to which we desire these readings to appear. Having decided upon this, the actual

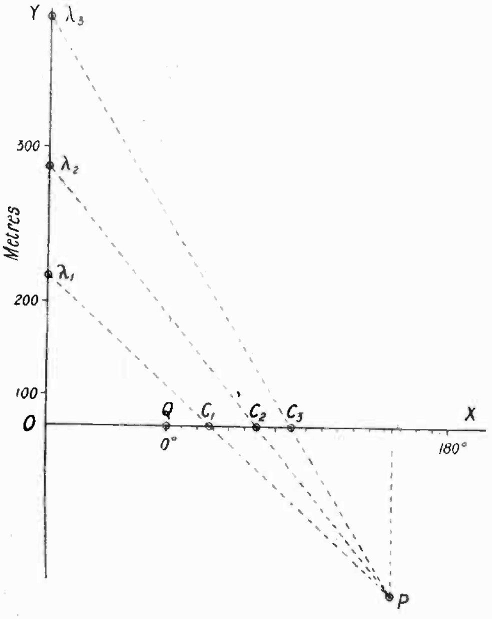


Fig. 4.

positions of the readings may be determined in the manner following.

The present calibration, involving as it does the extra variable of resistance, will necessitate a third correspondence between condenser setting and wave-length in addition to the two only which were required in the previous example. Suppose, then, that when using a certain coil of unknown inductance and resistance, which we may call (L,R), we obtain for the condenser readings r_1, r_2, r_3 the known wave-lengths λ_1, λ_2, λ_3. Let us assume further that $\lambda_3 > \lambda_2 > \lambda_1$. If, now, we can find one only of the points C_1, C_2, C_3 which are to represent r_1, r_2, r_3 to the desired scale on OX, the whole of the variable condenser graduations may be set out from this point, since the scale to which these are to appear has been already selected. Although the positions of C_1, C_2, C_3 are so far undetermined, the length of C_2C_3 is known in terms of the scale fixed upon for these markings. The ratio of this length to the distance OC_2 may now be obtained from the formula

$$\frac{C_2C_3}{OC_2} = \frac{(r_3 - r_1)}{(r_2 - r_1)} \cdot \frac{(\lambda^2{}_2 - \lambda^2{}_1)}{(\lambda^2{}_3 - \lambda^2{}_1)} \cdot \frac{\lambda^2{}_3}{\lambda^2{}_2} - 1$$

By this means the distance OC_2 is found, and the position of C_2, and hence of the whole condenser scale, is determined. The derivation of the above equation for the ratio of C_2C_3 to OC_2 need not here detain us, being obtained from theory to give the diagram the properties which will appear in the sequel. In order to dispense with the arithmetical work involved in using the formula, an Alignment Chart for its numerical solution is described in the Appendix.

We are thus in possession of our wave-length and capacity scales along OY and OX, and it should now be found that straight lines joining the points λ_1 to C_1, λ_2 to C_2, and λ_3 to C_3 will all meet in a common point P, situated below the axis OX, to which we may assign the distinguishing letters (L,R) of the coil in use. Using P as a pivot, a straight-edge will now intersect the wave-length and capacity scales in appropriate values for both these quantities for the particular inductance and resistance possessed by the coil. It may be of interest to note that a line through P perpendicular to OX will meet the scale of wave-lengths OY at infinity. The point at which this line meets OX may or may not lie within the limits of the condenser scale, and represents the limiting value of capacity beyond which the circuit will not tune. This, of course, corresponds to the fact that in the formula

$$\omega = \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

when $C = L/R^2$, λ becomes infinite, while if $C > L/R^2$, the radical becomes imaginary. The abscissa of P, therefore, is proportional to the quantity L/R^2, a fact which will become otherwise apparent later. The distance from O to Q, the zero point of condenser readings, represents, of course to the same scale, the total stray capacity of the circuit, including that of the coil (L,R).

The above procedure may now be repeated for a different coil (L^1,R^1), care being taken to preserve the same scale for wave-lengths, and the same distances between similar graduations on the capacity scale. In general, the position of the condenser scale as a whole as found with the coil (L^1,R^1) will be slightly different from the position as obtained with the coil (L,R), due to the small variation in the self-capacities of the two coils. In Fig. 5, the new position of the zero point of the condenser readings is indicated by Q^1, the distance QQ^1 representing to the same scale of capacity the difference between the self-capacities of coils (L,R) and (L^1,R^1). Using the new position of the condenser scale on OX, a new point P^1 will be similarly found to represent the coil (L^1,R^1). In general, the co-ordinates of P^1 with respect to the axes OX, OY will differ from those of P, while by using P^1 as pivot, appropriate values of λ and C for the coil (L^1,R^1) will be found in alignment.

We may now proceed to compare the inductances and resistances of the two circuits which contain respectively the coils (L,R) and (L^1,R^1). Referring again to Fig. 5, let x and y represent the distances measured in any convenient units of the point P from the axes OY and OX respectively, neglecting the negative sense of y. Then it may be shown by the theory of alignment that the diagram possesses the following properties:—

(A) The inductance of the coil is always proportional to the quotient y/x.

(B) The resistance of the coil is always proportional to the quotient

$$\frac{\sqrt{y}}{x}$$

It follows, therefore, that if x^1 and y^1 denote the corresponding co-ordinates for the point P^1, the ratio of the inductances of the two coils (L,R) and $L^1,R^1)$ is given by

$$\frac{L}{L^1} = \frac{x^1y}{xy^1}$$

while the ratio of their resistances is given by

$$\frac{R}{R^1} = \frac{x^1}{x}\sqrt{\frac{y}{y^1}}$$

A very convenient and simple means of comparing the inductances and resistances of coils is thus presented to our use. The geometrical interpretation of the above equations is seen to be as follows:—

(A) All the points representing coils of the same inductance value lie on the same straight line through O, *i.e.*, the gradient of the line OP is a measure of the inductance.

(B) All the points representing coils of the same resistance value lie on the same parabola whose vortex is at O and to which OX is a tangent.

All numerical values of inductance and resistance are thus represented by a series of straight lines and parabolas respectively, the point corresponding to any particular coil being located at the intersection of the line and parabola which are appropriate to it.

In order conveniently to compare the numerical values attaching to the individual members of such a series of lines and curves, we may select any point on OX and draw through it a line parallel to OY. This line will meet the pencil of inductance lines in points whose distances from OX are proportional to the inductances concerned. The same line, or any other parallel to it, will similarly meet the resistance parabolas in points whose distances from OX are proportional to the squares of the resistances represented. A valuable means of comparing the numerical values of coil constants without elaborate apparatus is thus afforded. The experimenter will easily adapt the procedure to suit his own requirements, incorporating, wherever possible, known standards in his circuits, so that values in practical units may be obtained.

To simplify the above description a separate diagram has been drawn out for each coil to be represented. When it is remembered, however, that on each drawing the wave-lengths are represented on the same scale, while on each the distance between similar graduations on the condenser scale remains the same, it will be seen that this is not strictly necessary. The small variations of the condenser scale on OX do not, of course, affect the absolute values of total capacity as reckoned from O. Hence the change in position of the condenser markings as shown on the different diagrams does not affect the derivation of the inductance and resistance estimations. It thus appears that if a sliding scale be attached to the axis OX, upon which the condenser readings are inscribed, a single diagram will be achieved whereon can be exhibited at sight the relations obtaining between condenser settings and wave-lengths for all desired coils. In practice, such a movable strip is easily held in the required position with the requisite security by closely fitting slits in the surface of the paper. The sliding scale can be adjusted in position to suit the self-capacity of the coil in use, the position of the zero point Q for each coil being determined once for all, and inscribed on the fixed axis OX. The points P for the coils themselves are found in the usual manner after the position of the condenser scale has been adjusted.

The total range of such adjustment of the condenser scale is very small, the self-capacities of ordinary plug-in coils being usually very small in comparison with the other capacities in the circuit, besides being themselves remarkably uniform in value. The introduction of the sliding scale to compensate for the minute variations arising from this source may seem in some cases a needless refinement. The size of the variable condenser used will be a chief factor in determining whether the use of the slide may be dispensed with without prejudice to accuracy.

In conclusion, it may be well to reiterate that the procedure detailed above is a particular case of a very general method. The rationale of the constructions which have been given, and their validity, will be self-evident to those acquainted with the theory of alignment diagrams for calculation. It was, indeed, while the writer was preparing some similar charts for computational purposes that the possibility of using the principle inversely for calibration work first occurred to him. If he has succeeded to any degree in arousing interest in a new and powerful weapon lying to the hand of the experimenter, his purpose has been achieved.

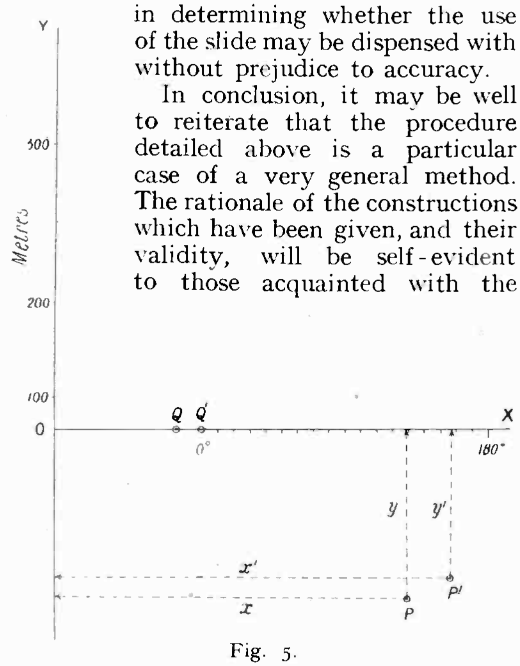


Fig. 5.

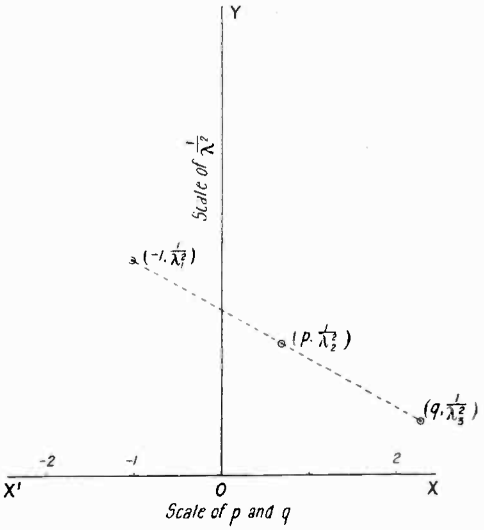


Fig. 6.

APPENDIX.

An alignment diagram for the solution of the equation

$$\frac{C_2C_3}{O\ C_2} = \frac{(r_3-r_1)}{(r_2-r_1)} \cdot \frac{(\lambda^2{}_2-\lambda^2{}_1)}{(\lambda^2{}_3-\lambda^2{}_1)} \cdot \frac{\lambda^2{}_3}{\lambda^2{}_2} - 1$$

is constructed as follows :—

Let us write,

$$\frac{C_2C_3}{O\ C_2} = p \text{ and } \frac{r_3-r_2}{r_2-r_1} = q.$$

Then, using Cartesian co-ordinates, the above relation is sufficiently expressed by the statement that the points $(-1,\ 1/\lambda_1^2)$ $(p,\ 1/\lambda_2^2)$ and $(q,\ 1/\lambda_3^2)$ are in alignment. (See Fig. 6.)

If now we replace the ordinary cartesian network by another in which, while retaining uniform graduations along OX to represent p and q, the graduations along OY are proportional to the inverse squares $1/\lambda^2$, we obtain a rectangular numbered network whereon the position of such points is obtained with extreme facility. Joining $(-1,\ 1/\lambda_1^2)$ to $(q,\ 1/\lambda_3^2)$ on this diagram with a straight-edge, we note where this line meets the ordinate line for λ_2. The abscissa of this point will then have the numerical value of p, the required ratio.

Triode Valve Rectification. [R134

An attempt to show in simple form some of the lessons to be drawn from the paper on "Valve Rectification," by F. M. Colebrook, which is now appearing in E.W. & W.E.

As there may be some readers of E.W. & W.E. who find that Mr. Colebrook's important paper on the valve detector makes rather heavy demands on their attention, an attempt is made in the following notes to present a few of the conclusions in the simplest possible form, with especial reference to broadcast working.

The problem of finding out just what occurs in grid rectification is notoriously a very difficult one; but by attacking it from a novel point of view, Mr. Colebrook has succeeded in reducing it to a much more manageable form, and applying much of the analysis already carried out in his recent paper on rectification in general.[1]

The author begins his paper by giving the results of an investigation into the actual shape of the grid current curves of various values, and makes an interesting discovery which is of great service in simplifying the mathematical work. It appears that, within the usual working limits, the current follows a compound interest law: the addition of a given grid voltage *multiplies* the anode current by a certain amount. Hence there are, for any valve, two figures which can be given, which can be got mathematically from the grid current curve, and which express its rectifying power.

One of these, called a by Mr. Colebrook, depends mainly on the filament heat, anode voltage, etc.; the other, called b, depends on the design of the valve itself. Luckily the latter is the most influential as regards performance; so if we have it for any valve we can judge what to expect. Values of b in valves actually tested range from 3 to 7, the larger being the better.

If we know b, we can work out, from curves in the article itself, the probable performance of the valve under various conditions.

Unfortunately, even now the problem is not completely simple, involving the use of logs. But anyone with a fair knowledge of algebra can get, from section 7 of the article and the figures given, the steady voltage with a given leak, and the grid voltage drop produced by an incoming signal. It is interesting to note that in a typical case worked out, a signal voltage of .5 volt r.m.s. produced a fall in steady grid volts of .33 approx. It may be mentioned that the method of finding these results is fully checked by experimental results.

A method is also given of finding the H.F. resistance of the valve to input voltage—or rather, that part of it due to actual grid current: the already existing resistance due to capacity effects is not dealt with. The author shows that taking the lower end of the input circuit to a point of positive potential apparently increases the rectified output; but calls attention to the fact that this also increases the damping on the input circuit and may thus actually give worse results. His final conclusion is that a small positive voltage is likely to be advantageous.

The next part of the paper goes on to consider the rectification of modulated waves, and the author finds some exceptionally interesting facts on this. It has been generally believed (and the present writer pleads guilty also!) that the undoubted distortion which is found is due to the time taken to discharge the grid condenser *via* the leak. But it is shown by Mr. Colebrook that the most important trouble is not here at all.

The worst defect is that the actual efficiency of rectification depends on the modulation frequency, being greatest for low notes. On broadcast wave-lengths, modulation below 1 000 cycles may be rectified three times as strongly as the upper end of the scale, while with longer waves the defect is more serious still. It is also certain that audio-frequency harmonics will be set up; but these do not appear to be large so long as the percentage modulation of the transmitter is low.

Consideration of the effects obtained by variation of the resistance of the "leak" and the value of grid condenser leads the

[1] Colebrook: "The Rectifying Detector," E.W. & W.E., March, April and May, 1925.

author to express the view that the present tendency is towards unnecessarily high leaks. His figure 21 shows that there is little gain by going above .5MO. But it seems advisable also to control the potential of the bottom end of the grid circuit—a point that we ourselves have found useful. In fact, he shows that for the best results, there should be variable grid-leak and condenser as well as a potentiometer! It would appear that accepted values of the condenser (.1 to .2$m\mu$F) are correct for broadcast wave-lengths.

After discussing anode rectification, the author finally draws up some general conclusions. Unfortunately, however, he finds it impossible to say definitely that one type or another is the best. For the efficiency of a given detector depends on the output load and the input circuit; on whether reaction is used, and on whether sensitivity or freedom from distortion is the prime object. He does point out, however, that anode rectification, while undoubtedly less sensitive than grid rectification for C.W., has particular advantages on telephony—especially on the longer wave-lengths or as second detector in supersonic work. He also draws attention to the advantages, for telephony, of a crystal coupled with a valve to provide regeneration. But it is impossible to abstract this section satisfactorily, and since it contains no mathematics, all readers are referred directly to it.

Marine Wireless. [R530·4

Inaugural Address by Major B. BINYON, O.B.E., M.A., Chairman of the Wireless Section, I.E.E.

THE opening meeting for the 1925-26 Session of the I.E.E. Wireless Section was held in the Institution Theatre, on Wednesday, 4th November, when Major B. Binyon (Managing Director of The Radio Communication Co., Ltd.) delivered his inaugural address as the new Chairman for the session.

The subject of the address was "Marine Wireless." This, said the Chairman, was a branch of wireless activity which—save perhaps for direction-finding—had received little attention at the Institution. He then gave a brief description of several different ship transmitters, illustrated by photographic slides. The sets shown were all of the "switchboard" self-contained and enclosed pattern, ranging from a $\frac{1}{4}$ to a $3\frac{1}{2}$kW set suitable for either ship or shore station use. The lecturer commented on the advantage of this mode of assembly, as compared with the alternative plan of individual parts mounted in the cabin. The switchboard type was compact and convenient to handle, and was much superior in the ability which it gave to test both parts and the transmitter as a whole before installation.

A comparison was then given between the use of I.C.W. and spark transmission (both by quenched and synchronous gaps) for such transmission purposes. Whatever theoretical advantages either system might have, the ultimate test was necessarily one of audibility. An interesting table showing test results for the three different types of transmission was exhibited. The tests of transmission and reception fell into three classes, *i.e.*, (*a*) Equal Input Powers, (*b*) Equal Aerial Powers, (*c*) Equal Audibility Factors. The tests were all done under exactly similar conditions and received field strength and audibility of signals measured. Audibility was measured by the shunted telephone method, the shunt being reduced until signals were *just readable*, this method being found more uniform and reliable than the alternative of reduction to inaudibility. In the Equal Input Power Test, the I.C.W. system was distinctly superior both in audibility and field strength. For Equal Aerial Powers the I.C.W. gave the greater field strength measurement, but, curiously, the synchronous gap system gave superior audibility. The Equal Audibility Factors test show distinctly in favour of the I.C.W.

The lecturer next dealt with emergency apparatus in general, and more especially with this type of apparatus applied to the needs of lifeboat service. A complete transmitter and receiver set suitable for lifeboat installation was shown in the theatre, and further illustrated by slides, one of which showed the set suitably disposed in the lifeboat. This type had been thoroughly tested for weather-proofness, and contained the points of detail which these tests had shown necessary for the maintenance of the set. A waterproof sleeve permits the operator's arm to get weatherproof access for work, and one tuning control on the outside serves for both transmitting and receiving adjustment.

After briefly discussing ships' aerials and insulators, the Chairman then dealt with automatic call devices. In particular he described and illustrated an automatic call arrangement developed by his company, explaining the operation of the different relays and cams involved, by the aid of an extremely well-made diagram in which relay tongues could be closed, and the cam contacts moved to assist the following of its operation. The apparatus was demonstrated in actual working, responding to a call of three dashes each of four seconds' duration and separated by one second spaces. This call was superimposed on two already interfering signals which failed to actuate the apparatus.

The final part of the lecture was devoted to direction finding. The well-known Robinson D.F. system was explained, with diagrams showing the combination of the E.M.F.s due to the main and the auxiliary coils which this system employs. The lecturer referred to the additional "90 degree ambiguity" which was possible, and demonstrated a neat model of "steering wheel" for frame control, incorporating the reversing switch which is used to determine when the main coil is on the maximum line of the transmitter. A slight backlash is deliberately introduced into the motion of the wheel, and this backlash movement used to operate the reversing switch. A simple rule to "follow the weak direction" then enables the operator to obtain the final setting. The system was being made semi-automatic by the use of a galvanometer, giving zero deflection on either side of the reversing switch when the frame is correctly oriented. This was still in a "laboratory stage of development," as was also a further modification rendering the system completely automatic, *i.e.*, so that the main coil automatically set itself to lie in the plane of the transmitting station. This arrangement was briefly described, and very successfully demonstrated. A small loop at the back of the theatre served as transmitter and the frame as a receiver set itself parallel to the plane of the transmitter loop. Relays operated "Port and Starboard" lights on the frame, one or the other being lit so long as the frame was incorrectly oriented, flickering alternately and finally being extinguished as the frame assumed its final direction. "Quadrantal error" was well demonstrated by the holding of a large loop of metal more or less around the receiving frame. Finally the transmitter was slowly moved along the back of the theatre, its attendant receiving frame swinging with its transit.

A vote of thanks to the Chairman for his lecture was carried with acclamation, on the motion of Admiral of the Fleet, Sir Henry Jackson, and Mr. E. H. Shaughnessy, the retiring Chairman.

The Evershed Generator—A Further Note.

IN our report on the Evershed H.T. Generator (E.W. & W.E., November, p. 922), we qualified our otherwise entirely favourable report by a note that there was some difficulty in supplying by hand sufficient power to get full voltage when feeding an LS5 valve; and we suggested tentatively that since the modern tendency is towards the use of such valves (of fairly low impedance) it might be advantageous to wind the generator for slightly lower voltage and greater current.

The makers, Messrs. Evershed & Vignoles, Ltd., Acton Lane Works, Chiswick, point out that the type of generator tested by us is essentially designed for high impedance valves, and that another type is supplied for low impedance work with just the modification suggested.

It is probable therefore that we were rather overloading the one tested, and that with the other type we should have found the ripple even smaller than we did, for overloading usually increases this.

The Rectification of Small Radio Frequency Potential Differences by means of Triode Valves.—Part II. [R134

By F. M. Colebrook, B.Sc., A.C.G.I., D.I.C.

12. *The transient condition.*

It is well known that a combination of a capacity and a resistance is unable to respond instantaneously to a change of potential distribution. In fact, the time required to pass from one equilibrium to another is theoretically infinite, but in practice the system will reach a condition indefinitely close to its real final equilibrium after a very short time. The circuits involved in grid rectification are of this character, and it will therefore be necessary to see what effect this will have on the rectification process.

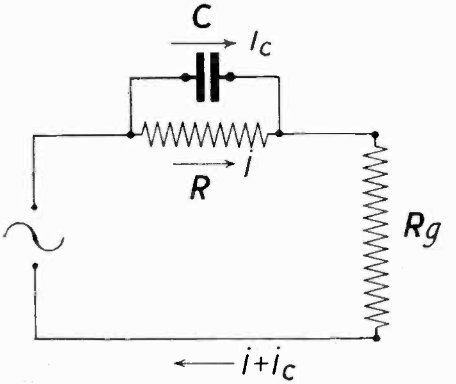


Fig. 17.

In order to simplify the problem the circuit will be considered in the form shown in Fig. 17, where the grid-filament path is represented as a constant resistance R. Actually it is, of course, a resistance which varies with the potential difference acting across it, this being the nature of its rectifying property. As far as the transient condition is concerned, however, it will be a sufficiently close approximation to consider it as constant at its mean value over the range of the changes involved.

If q be the charge on the condenser at any given instant the application of Kirchhoff's laws will give the equations

$$e = (i + i_c)R_g + iR \quad .. \quad (12.1)$$
$$= i(R + R_g) + i_c R_g \quad .. \quad (12.2)$$
$$\frac{q}{C} = iR \quad .. \quad .. \quad .. \quad (12.3)$$
$$i_c = \frac{dq}{dt} = CR\frac{di}{dt} \quad .. \quad .. \quad (12.4)$$

whence

$$\frac{de}{dt} = \frac{R + R_g}{CR} i_c + R_g \frac{di_c}{dt} \quad .. \quad (12.5)$$

There will be in general two parts to the solution of this equation. The first, known as the particular integral, is the solution of the equation as it stands, having regard to the nature of the time variation of the E.M.F. e.

The remaining part of the solution is known as the complementary function, and is derived from the equation

$$i_c \frac{(R + R_g)}{CR} + R_g \frac{di_c}{dt} = 0 \quad (12.6)$$

Dividing through by $\frac{R + R_g}{R}$ and putting

$$\frac{RR_g}{R + R_g} = R_0 \quad .. \quad (12.7)$$

(*i.e.*, R_0 is the resistance of R and R_g in parallel)

$$i_c + CR_0 \frac{di_c}{dt} = 0 \quad .. \quad (12.8)$$

of which the solution is

$$i_c = k\epsilon^{-\frac{t}{CR_0}} \quad .. \quad (12.9)$$

where k is a constant dependent on the initial conditions.

The time constant of the circuit is seen to be CR_0. It should be specially noted that the resistance involved in the time constant is not, as is sometimes stated, the grid-circuit resistance, but it is the latter in parallel with the (slope) resistance of the grid filament path.

As far as the reception of a continuous wave is concerned the modification of the foregoing analysis due to the existence of the time constant will be as follows: The change of mean grid potential will not take place instantaneously, the change of potential at any instant t being given by

$$v = v_c (1 - \varepsilon^{-t/CR_0}) \quad .. \quad (12.10)$$

This equation shows that the potential change will reach 99 per cent. of its final steady value in 4.606 CR_0 seconds. For an illustrative example we will take the following values :—

$$a = 3 \times 10^{-6}$$
$$b = 5$$
$$R = 2 \times 10^{6}$$
$$C = .2 \times 10^{-9}$$
$$E = .25$$
$$v = 0$$

The initial magnitude of R will be

$$\left(\frac{dv_g}{di_g}\right)_{-v_0} = \frac{1}{ab\varepsilon^{-bv_0}} \quad .. \quad (12.11)$$

and the final magnitude

$$\left(\frac{dv}{di}\right)_{-v_0-v_c} = \frac{1}{ab\varepsilon^{-b(v_0+v_c)}} \quad (12.12)$$

Both of these can be determined as already shown from the given data. The first is $.806 \times 10^6$ and the second 1.03×10^6, giving a mean value of $.918 \times 10^6$. This gives $.63 \times 10^6$ for R_0 and $.126 \times 10^{-3}$ for CR_0. Under these conditions the potential change will reach 99 per cent. of its final value in $.58 \times 10^{-3}$ seconds. A time constant of this magnitude will cause only a negligible loss of sensitivity even with high speed automatic transmission.

It is clear from the preceding section that the time constant could be still further reduced by the application of a small positive voltage to the grid, since this will very greatly reduce the slope resistance of the grid-filament circuit.

The exact analysis of the effect of the time constant in the reception of speech or music modulated waves is a very difficult matter. It would seem probable that where the modulation consists of a pure musical tone there will be no effect at all, and that even in the case of more or less "explosive" modulation such as might be associated with certain consonants in speech and with percussion in music the effect will be exceedingly small, especially as the time constant can be reduced to an exceedingly small value at the short wave-lengths used for broadcasting.

13. *The grid rectification of a modulated continuous wave.*

The preceding sections have all been devoted to the discussion of the rectification of a pure continuous wave. This is the fundamental case from a theoretical point of view, but one which in itself is of very little practical importance, since in the great majority of practical applications the E.M.F. to be rectified consists either of a modulated continuous wave or the sum of two high-frequency E.M.F.s of nearly equal frequency (*i.e.*, heterodyne reception). The first of these is of very general interest at the present time on account of its relation to broadcast reception. It must not be forgotten, however, that the term "modulated continuous wave" also includes those cases in which a single tone modulation is imposed on a carrier wave for the purposes of morse transmission.

The following discussion of the rectification of a modulated continuous wave seeks to answer the questions :—

(i.) What will be the nature and the magnitudes of the changes of grid potential given by the rectification of a modulated continuous wave ?

(ii.) What will be the nature and the magnitude of the output circuit currents given by these changes of grid potential ?

(iii.) To what extent will the changes of grid potential and the output circuit currents faithfully reproduce the modulation of the carrier wave ?

(iv.) What are the best conditions of operation ?

It will be shown that these questions can be answered more or less completely by a suitable extension of the analysis already given.

In view of the practical importance of the subject, it will be desirable to deduce as much as possible from the most general form of rectifying characteristic, considering separately the special applications of the analysis to the exponential form of characteristic.

It can be shown* that equation (5.6), which refers to the rectification of a con-

* See Appendix III.

tinuous wave in the case of the general grid current characteristic, can be written in the form

$$i_0+i_c=F(E)+(v-v_0+v_c)\,F^1(E)+\frac{(v-v_0-v_c)^2}{2}F_2(E)+\frac{(v-v_0-v_c)}{3!}F_3(E)\quad \text{etc., } ad\ inf. \quad (13.1)$$

where i_0 is the initial grid current and i_c is the continuous current produced by the rectification. Also

$$F(E)=\frac{1}{T}\int_0^T f(E\ sin\ \omega t)dt \quad (13.2)$$

$$F_1(E)=\frac{1}{T}\int_0^T \frac{\delta f\,(E\ sin\ \omega t)}{\delta E\ sin\ \omega t}\,dt \quad (13.3)$$

etc., etc.

A modulated continuous wave can be written in the form

$$e=(E+m)\,sin\ \omega t \quad (13.4)$$

where E is the amplitude of the carrier wave and where m is the instantaneous value of some at present unspecified function of time constituting the modulation. It is shown in the appendix referred to above that for an E.M.F. of this character equation (13.1) becomes :—

$$i_0+i_c+i_m=F(E)+mF'(E)+\frac{m^2}{2}F''(E)\quad \text{etc., } ad\ inf.$$

$$+(v-v_0-v_c-v_m)\left\{F_1(E)+mF_1'(E)+\frac{m^2}{2}F_1''(E)\ldots \text{etc., } ad\ inf.\right\}$$

$$+\frac{(v-v_0-v_c-v_m)^2}{2!}\left\{F_2(E)+mF_2'(E)+\frac{m^2}{2}F_2''(E)\ldots \text{etc., } ad\ inf.\right\}$$

$$+\frac{(v-v_0-v_c-v_m)^3}{3!}\left\{F_3(E)+mF_3'(E)+\frac{m^2}{2}F_3''(E)\ldots \text{etc., } ad\ inf.\right\}$$

etc., etc., etc., *ad inf.* (13.5)

where

$$F'(E)=\frac{dF(E)}{d(E)}\ldots \text{etc., etc.} \quad (13.6)$$

In the above i_m is written for the whole group of currents due to the modulation, and v_m for the back E.M.F. due to the passage of these currents through the grid circuit impedance, *i.e.*, the grid-circuit resistance in parallel with the grid condenser.

The rather formidable collection of equations (13.5) can be analysed by the well-known principle of equating separately the components of equal frequency. Thus, the continuous component is given by

$$i_0+i_c=F(E)+(v-v_0-v_c)F_1(E)+\frac{(v-v_0-v_c)^2}{2}F_2(E)\ \ldots \text{etc.,}\ +(\qquad) \quad (13.7)$$

where the last brackets contain a number of terms derived from the square and higher powers of m multiplied by the higher derivatives of $F\ (E)$, and terms containing products of m and v_m and powers of v_m. The detailed examination of any practical case will show that these terms are very small compared with the remainder. If they are omitted equation (13.7) becomes the same as equation (13.1), indicating that the continuous component is not appreciably affected by the modulation. This is a fact which can be confirmed experimentally, at least for transmissions such as broadcast telephony where the modulation percentage is kept low.

For the determination of the modulation frequency terms, it will be necessary to specify the nature of the time variation of m. In general this will be a periodic function of irregular and changing wave shape. The analysis of such a case would be so complex as to obscure the important features of the solution. It will be preferable, therefore, to consider the simplest possible case, that of a single sine wave modulation

$$m=M\ sin\ nt \quad (13.8)$$

This will make it possible to form some idea of what will happen in the general case.

In the first place, it will be seen that equation (13.5) contains terms in m^2 and higher powers of m, and also product terms containing m and v_m and higher powers of v_m. It is clear therefore that the modulation frequency currents will comprise a whole Fourier series. Since the modulation contains one frequency only all the other frequencies are extraneous and are introduced by the rectification process. The latter therefore involves some degree of frequency distortion, since, with a modulation of irregular wave form it will alter the relative intensities of the harmonics, each harmonic giving rise to a complete Fourier series of its own. In practice, however, these extraneous frequencies will be of very small amplitude compared with the fundamental, since the higher derivatives of the rectification characteristic $F(E)$ will be relatively small, and since terms containing powers of v_m will be very small indeed. This is particularly true for carrier wave amplitudes greater than about .4 volt associated with modulation percentages not exceeding 15 per cent. or so.

The fundamental frequency equation derived from (13.5) is comparatively simple in form. Putting i_n and v_n for the fundamental frequency components,

$$i_n = m\Big\{ F'(E) + (v - v_0 - v_c)F_1'(E) + \frac{(v - v_0 - v_c)^2}{2} F'_2(E) \ldots \text{etc. } ad\ inf. \Big\} - v_n/R_c$$

where (13.9)

$$\frac{1}{R_c} = F_1(E) + (v - v_0 - v_c)F_2(E) + (v - v_0 - v_c)F_3(E) \ldots \text{etc. } ad\ inf. \quad .. \quad (13.10)$$

It should be noted that the expression multiplying m and the expression for $1/R_c$ depend only on the circuit and on the carrier wave amplitude. They are constants with respect to the modulation.

The physical significance of the above equation can be made more clear by expressing it in terms of $\frac{\delta v_c}{\delta E}$, *i.e.*, the slope of the rectification characteristic for the given carrier wave amplitude. It then becomes*

$$i_n = \left(\frac{1}{R} + \frac{1}{R_c}\right)\frac{\delta v_c}{\delta E} m - \frac{v_n}{R_c} \quad .. \quad (13.11)$$

Since i_n and v_n are simple harmonic functions, they can conveniently be expressed in vector form as the vectors $\mathbf{V}_n$ and $\mathbf{I}_n$. The modulation can be similarly represented by the vector $\mathbf{M}$. Then, since

$$\mathbf{V}_n = \dot{Z}_n \mathbf{I}_n \quad .. \quad (13.12)$$

where $\dot{Z}_n$ is written for the grid circuit impedance operator at the frequency $n/2\pi$, equation (13.11) becomes

$$\mathbf{I}_n = \left(\frac{1}{R} + \frac{1}{R_c}\right)\frac{\delta v_c}{\delta E}\mathbf{M} - \frac{\dot{Z}_n \mathbf{I}_n}{R_c} \quad .. \quad (13.13)$$

i.e.,

$$\mathbf{I}_n = \frac{\left(1 + \frac{R}{R_c}\right)\frac{\delta v_c}{\delta E}\mathbf{M}}{R_c + \dot{Z}_n} \quad .. \quad (13.14)$$

*See Appendix III.

The current is therefore that which would be produced by an alternating E.M.F. represented by a vector $\mathbf{E}_n$, associated with an internal resistance R_c, acting in a circuit of external impedance $\dot{Z}_n$, where

$$\mathbf{E}_n = \left(1 + \frac{R}{R_c}\right)\frac{\delta v_c}{\delta E}\mathbf{M} \quad .. \quad (13.15)$$

i.e.,

$$\mathbf{I}_n = \frac{\mathbf{E}_n}{R_c + \dot{Z}_n} \quad .. \quad (13.16)$$

In grid rectification, however, the important quantity is not $\mathbf{I}_n$ but $\mathbf{V}_n$, the change of grid potential. This is obviously given by

$$\mathbf{V}_n = \frac{\dot{Z}_n}{R_c + \dot{Z}_n}\mathbf{E}_n \quad .. \quad (13.17)$$

It should be noted that the limiting value for $\mathbf{V}_n$, which occurs when $\dot{Z}_n = R$, *i.e.*, at low frequencies, is

$$\mathbf{V}_n = (\delta v_c/\delta E)\mathbf{M} \quad .. \quad 13.18$$

which is otherwise obvious. At any frequency for which $\dot{Z}_n$ differs appreciably from R (being always less than R) the magnitude of $\mathbf{V}_n$ will be correspondingly reduced. This is an exceedingly important point, for it shows that the rectification efficiency depends on audio-frequency. The effect of this in producing amplitude distortion will be considered later.

To determine the magnitude of the frequency effect it will be necessary to express $\dot{Z}_n$ in terms of C and R. Since $\dot{Z}_n$ is the impedance of these two in parallel,

$$\frac{1}{\dot{Z}_n} = \frac{1}{R} + jpC, \text{ where } p = 2\pi \times \text{frequency.} \quad (13.19)$$

Substituting this value for $\dot{Z}_n$, the frequency factor can be expressed in the form

$$\frac{\dot{Z}_n}{R_c + \dot{Z}_n} = \frac{-j\dfrac{\frac{1}{R} + \frac{1}{R_c}}{pC}}{-j\dfrac{\frac{1}{R} + \frac{1}{R_c}}{pC} + 1} \cdot \frac{R}{R + R_c} \quad (13.20)$$

$$= \frac{-jx}{1 - jx} \cdot \frac{R}{R + R_c} \quad (13.21)$$

where

$$x = \frac{1}{pC}\left(\frac{1}{R} + \frac{1}{R_c}\right) \quad .. \ (13.22)$$

Therefore

$$\mathbf{V}_n = \frac{-jx}{1 - jx} \quad \frac{R_c}{R_c + R} \cdot \frac{R_c + R}{R_c} \quad \frac{\delta v_c}{\delta E} \ \mathbf{M} \quad (13.23)$$

This gives as the amplitude equation

$$\mathbf{V}_n = k_n \frac{\delta v_c}{\delta E} \mathbf{M} \quad .. \ (13.24)$$

k_n being the frequency factor, of magnitude

$$k_n = \frac{x}{\sqrt{1 + x^2}} \quad .. \ (13.25)$$

The curve of the function k is shown in Fig. 18. By means of this curve the variation with frequency can be determined for any given values of R, C, and R_c.

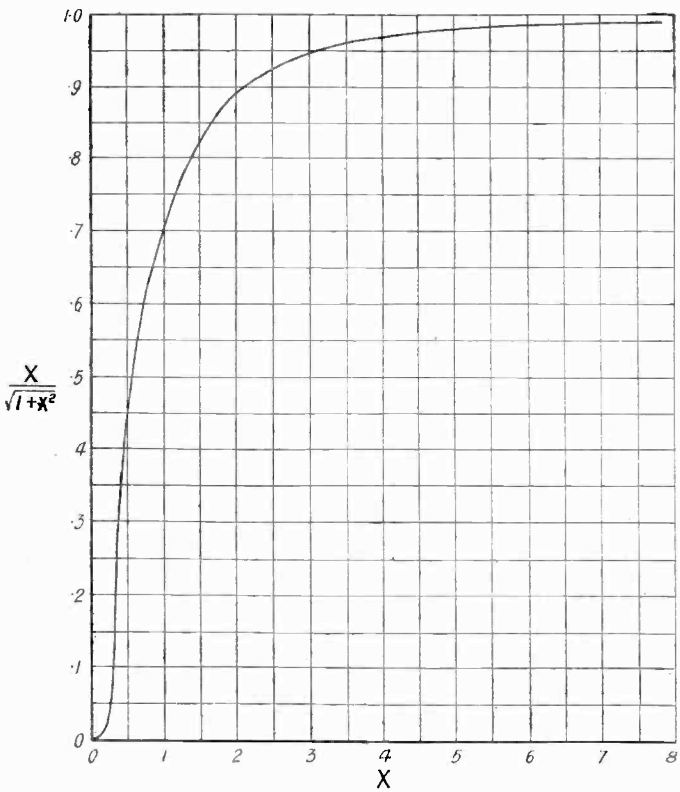


Fig. 18.

APPLICATION TO THE EXPONENTIAL CHARACTERISTIC, AND NUMERICAL EXAMPLE.

The above analysis refers to any grid-current characteristic. To relate it to the exponential characteristic given by small receiving valves it is only necessary to put

$$f(e) = a\varepsilon^{be} \quad .. \quad (13.26)$$

The substitution presents no difficulty and is given in outline in Appendix IV. It will be found that, using symbols already defined,

$$\frac{1}{R_c} = \frac{b(v_0 + v_c)}{R} \quad .. \quad (13.27)$$

For this type of characteristic, therefore,

$$x = \frac{1 + b(v_0 + v_c)}{pCR} \quad .. \quad (13.28)$$

The variation with frequency can thus be calculated for any given values of a, b, C, R, v, and E. As a typical example, consider the valve used for the experimental confirmation described in Section 8, assuming a value of two megohms for R, $v = 0$, and $E = .5$ volt. The corresponding value of $b(v_0 + v_c)$ is 3.75. It will be shown later that C cannot be reduced below a certain value at any given radio-frequency without a loss of sensitivity due to a fall of high-frequency voltage. Suppose that this value is about .000 2 microfarads at a wave-length of 365 metres. The variation of the frequency factor over an audible frequency range of 250 to 6 000 p.p.s. for this value of C is shown in the upper curve of Fig. 18a. It will be seen that there is a variation of nearly 300 per cent. with frequency. Now suppose that the above signals are superheterodyned to about 3 500 metres, requiring a grid condenser of about .002 microfarads if a drop of high-frequency voltage is to be avoided. The lower curve of Fig. 18*a* shows the variation of the frequency factor in this case, *i.e.*, from about .7 to about .035, amounting to 2 000 per cent. The greater part of this variation occurs at the lower frequencies, so that the distortion effect will not be as pronounced as the analysis would suggest. It is obvious, however, that there is a very material loss of sensitivity.

The above example shows that the grid rectification of modulated continuous waves has certain inherent defects which increase in importance as the wave-length of the carrier wave increases. Even at a wave-length of 365 metres the frequency variation, associated also with a loss of sensitivity at high audible frequencies, is very pronounced. As the wave-length increases there is clearly a compromise to be made between a loss of sensitivity due to a fall of high-frequency voltage in the grid condenser, about which more will be said later, and a loss of sensitivity associated with frequency distortion on account of the audible frequency effect described above. The physical interpretation of the effect is that the grid condenser is required to fulfil two conditions :—

(*a*) Its radio-frequency impedance must be low compared with R_1, the radio-frequency input resistance.

(*b*) Its audio - frequency impedance must be high compared with the resistance of R in parallel with R_c, the effective internal modulation frequency resistance of the rectifying circuit.

Only at very short wave-lengths can these conditions be even approximately fulfilled simultaneously. Also, an applied positive grid voltage is not likely to improve matters very much, since this will decrease R_1 and consequently call for a larger value of C to fulfil condition (*a*).

In considering the effect of this frequency factor on the purity of reproduction question (ii) above must be answered. The analysis need not be given in full, since it is well known that the anode circuit can be thought of as very approximately a simple series circuit in which a certain multiple of the grid voltage acts in series with a certain internal resistance and the load impedance. (Equation (4.3).) The mutual efficiency of the load-impedance—internal resistance combination is necessarily one which varies with frequency in an easily calculable manner, increasing or decreasing with frequency according as the load impedance is less than

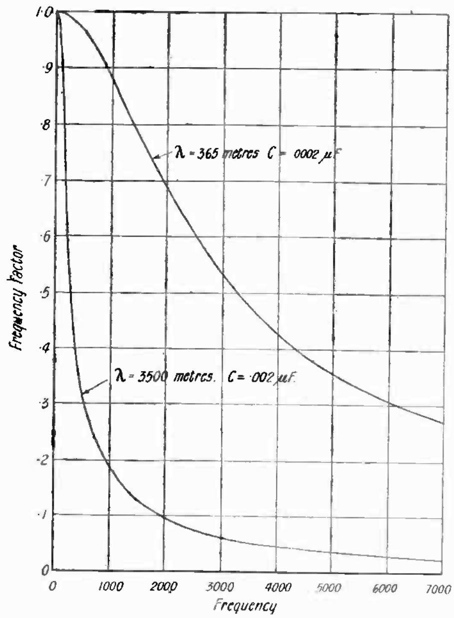


Fig. 18*a*.

or greater than the internal resistance. In general, unless the load impedance is very high, even at low frequencies, the anode circuit will tend to a higher efficiency at the higher audible frequencies. This is likely to be the case when the load is a pair of ordinary telephones. The two distortions are in such a case opposite in character, and may partially neutralise one another. The matter is further complicated by the response characteristic of the telephones themselves, a matter on which information is lacking. It is therefore impossible at this stage to make any general pronouncement as to the seriousness of the frequency distortion effect described above. It is desirable, however, that its existence should be known, and in no case can the associated loss of sensitivity be advantageous.

In conclusion, it would admittedly be much more satisfactory to have direct experimental confirmation of this frequency effect. Such measurements, however, would present formidable practical difficulties. A certain degree of practical conformation can be obtained by substituting a variable condenser up to, say, .002 or .003 microfarads for the usual small fixed condenser in a grid rectifying circuit, and then listening to any convenient broadcast transmission. It will be found that there is a very pronounced loss of apparent sensitivity as the grid condenser is increased. The effect on quality is not so easy to judge owing to the great variation in intensity of the signals.

It will be shown later that the frequency factor plays an equally important part in heterodyne reception.

14. *Heterodyne reception with grid rectification.*

It was shown in the paper on the general theory of rectification referred to above* that given a continuous wave signal

$$e_1 = E_1 \sin(\omega_1 t + \theta_1) \quad .. \quad (14.1)$$

and a locally induced E.M.F.

$$e_2 = E_2 \sin(\omega_2 t + \theta_2) \quad .. \quad (14.2)$$

acting together on the terminals of a rectifying circuit, then the sum of the two could be represented by

$$e = e_1 + e_2 = E \sin(\omega t + \alpha) \quad .. \quad (14.3)$$

where

$$E^2 = E_1^2 + E_2^2 + 2 E_1 E_2 \cos(nt+\beta) \quad (14.4)$$

$$n = (\omega_1 - \omega_2) \quad .. \quad .. \quad .. \quad (14.5)$$

$$\omega = \frac{(\omega_1+\omega_2)}{2} \quad .. \quad .. \quad .. \quad (14.6)$$

$$\beta = \theta_1 \sim \theta_2 \quad .. \quad .. \quad .. \quad (14.7)$$

and

$$\tan\alpha = \frac{E_1 \sin\left(\frac{nt}{2}+\theta_1\right) - E_2 \sin\left(\frac{nt}{2}+\theta_2\right)}{E_1 \cos\left(\frac{nt}{2}+\theta_1\right) - E_2 \cos\left(\frac{nt}{2}+\theta_2\right)} \quad (14.8)$$

For convenient abbreviation the resultant amplitude can be expressed in the form

$$E^2 = E_r^2 + e_n \quad .. \quad .. \quad (14.9)$$

where

$$E_r^2 = E_1^2 + E_2^2 \quad .. \quad .. \quad (14.10)$$

and

$$e_n = 2 E_1 E_2 \cos(nt + \beta) \quad .. \quad (14.11)$$

i.e., e_n is an E.M.F. the amplitude of which is twice the product of the signal and local E.M.F. amplitudes, and whose frequency is the difference between the signal and the local oscillation frequencies.

* "The Rectifying Detector." E.W. & W.E., March, April, May, 1925.

The discussion of the effect of an E.M.F. such as e on a grid rectifying circuit will clearly be very similar to that already given for the case of a modulated continuous wave. To save space and avoid repetition the analysis will not be given in full, as it will be sufficient to indicate the necessary modifications of the expressions involved.

In equation (13.2) the mean value of the characteristic function is expressed as a function of the amplitude of the high-frequency E.M.F. It could, of course, be equally well expressed as a function of the square of the amplitude, *i.e.*,

$$\frac{1}{T}\int_0^T f(e)\,dt = S(E^2) \quad .. \quad (14.12)$$

and similarly for the related functions $S_1(E^2)$, $S_1'(E^2)$, etc.

The Taylor Theorem expansion will then take the form

$$S(E^2) = S(E_r^2 + e_n) \quad .. \quad .. \quad (14.13)$$

$$= S(E_r^2) + e_n S'(E_r^2) + \frac{e_n^2}{2!} S''(E_r^2) + \frac{e_n^3}{3!} S'''(E_r^2)$$

etc., etc., *ad inf.* .. (14.14)

The development of the analysis will then follow exactly the same lines as in Section 13, but the result will be expressed in terms of $\delta v_c/\delta E_r^2$, *i.e.*,

$$i_n = \left(\frac{1}{R} + \frac{1}{R_c}\right)\frac{\delta v_c}{\delta E_r^2} e_n - \frac{v_n}{R_c} \quad (14.15)$$

where R is now expressed in terms of the S functions, but has exactly the same value as before.

In the above, i_n and v_n are respectively the current and back E.M.F. of fundamental beat frequency $n/2\pi$. As explained in Section 13, double and higher multiple frequencies will also be produced, derived from the second and higher derivatives of $S(E_r^2)$, but these will be of relatively small amplitude.

The final amplitude equation will be similar to (13.24), *i.e.*,

$$V_n = \frac{x}{\sqrt{1 + x^2}} \cdot \frac{\delta v_c}{\delta E_r^2} E_n \quad .. \quad (14.16)$$

where x has the values already given in Section 13.

Expressed in terms of $\delta v_c/\delta E_r$ this becomes

$$V_n = \frac{x}{\sqrt{1 + x^2}} \frac{\delta v_c}{\delta E_r} \frac{E_1 E_2}{E_r} \quad (14.17)$$

In practice E_2 will be large compared with E_1, so that very approximately

$$E_r = E_2 \quad .. \quad .. \quad .. \quad (14.18)$$

therefore

$$V_n = \frac{x}{\sqrt{1+x^2}} \cdot \frac{\delta v_c}{\delta E_2} E_1 \quad .. \quad (14.19)$$

The variation of the frequency factor has already been discussed. It will in all cases be less than one and, under certain conditions, particularly at long wave-lengths, it may be as low as .01. It will therefore profoundly modify the effective sensitivity of this method of reception.

Apart from this beat frequency effect, the change of grid potential is proportional to $E_1 \frac{\delta v_c}{\delta E_2}$. In Fig. 19 is shown as a typical example the variation of the slope of the rectification characteristic with amplitude for the valve and circuit conditions described in Section 8. The slope is obviously not proportional to E, so that with grid rectification V_n is not proportional to the product of the two E.M.F.s, as is usually stated. In fact, for large values of E, beyond the limit of the exponential range, the rectification characteristic becomes very nearly a straight line, *i.e.*, $\delta v_c/\delta E$ becomes constant. Beyond this point no further increase of signal strength will be obtained by increasing E_2.

It must be clearly understood that the above discussion applies only to heterodyne reception with a separate oscillator. Reception of the same type in which the receiving valve is also the source of the local oscillation is generally known as autodyne, and will be considered later.

15. *Suitable magnitudes for the grid condenser and the grid-circuit resistance.*

So many factors enter into the determination of the most suitable magnitudes for C and R that, in spite of the comparatively simple analysis of the rectification process which has been given in the preceding sections, no comprehensive statement can be made as to the best values for these quantities in terms of the grid constants a and b, and the frequency of operation. All that will be attempted in this section will be a brief discussion of the dependence of the rectification process on the magnitudes of C and R.

It has already been shown that the product CR should be kept as small as is consistent with efficiency in order that the time constant of the rectifying circuit shall be small, and in order that the frequency factor in the rectification of modulated continuous waves shall vary as little as possible. Both C and R must therefore be kept as small as possible. These two factors will be considered separately.

(*a*) *The grid-circuit resistance.*

In the general case, the change of mean grid potential v cannot be expressed explicitly in terms of R. By taking a numerical example it was found that the nature of the dependence of v on R did not vary greatly with the signal amplitude. This indicates that conclusions obtained from the simpler case of small signal amplitudes will not be misleading in the general case. As shown in Section 9, for small signal amplitudes

$$v_c = \frac{bv_0}{1+bv_0} \cdot \frac{G(bE/2)-1}{b} \quad .. \quad (15.1)$$

also

$$bv_0\epsilon^{bv_0} = abR\epsilon^{bv} \quad .. \quad (15.2)$$

Now the right hand side of equation (15.1) contains a factor of the form $x/(1+x)$ where $x\epsilon^x = abR\epsilon^{bv}$. A curve showing the variation of $x/(1+x)$ with $x\epsilon^x$ will therefore indicate the nature of the variation of v_c with $abR\epsilon^{bv}$, *i.e.*, with R for given values of the other constants. The curve is illustrated in Fig. 20 (overleaf). Its chief characteristic is its extreme flatness for values of $x\epsilon^x$ greater than about 10. As a general

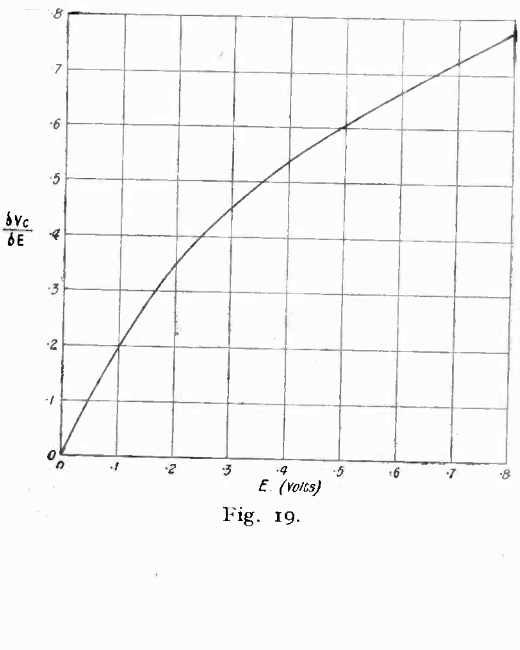


Fig. 19.

efficiency condition it can therefore be stated that $abR\epsilon^{bv}$ shall not be less than about 10. It is true that v_c will continue to increase with R beyond this point, but the increase will be relatively small. The right value for R will obviously depend very greatly on v. By way of illustration the curves of Fig. 21 show the calculated variation of v_c with R for $v = 0$ and $v = .5$, for a valve having the grid constants

$$a = 3 \times 10^{-6}$$
$$b = 5$$

and for a signal amplitude of .1 volt. It will be seen that they are of the same general shape as the curve of Fig. 20, being in point of fact, simple multiples of this curve. Since the theory on which these curves are based has been verified as described by experiment, they are probably very accurately representative of the variation concerned.

It seems likely from these results that the general tendency is to use grid-resistances of much higher value than is really necessary, especially if a positive continuous potential is applied to the grid. Further, it would appear that the most reliable way to ensure the best conditions in any given case will be to use both a variable grid resistance or "grid-leak" as it is usually called, and a grid potentiometer.

(*b*) *The grid condenser.*

The function of the grid condenser is to provide, for the high-frequency components of the current in the grid circuit, a path of which the impedance is low compared with that of the grid-filament path. As already stated, its magnitude should be no larger than is necessary to fulfil this condition.

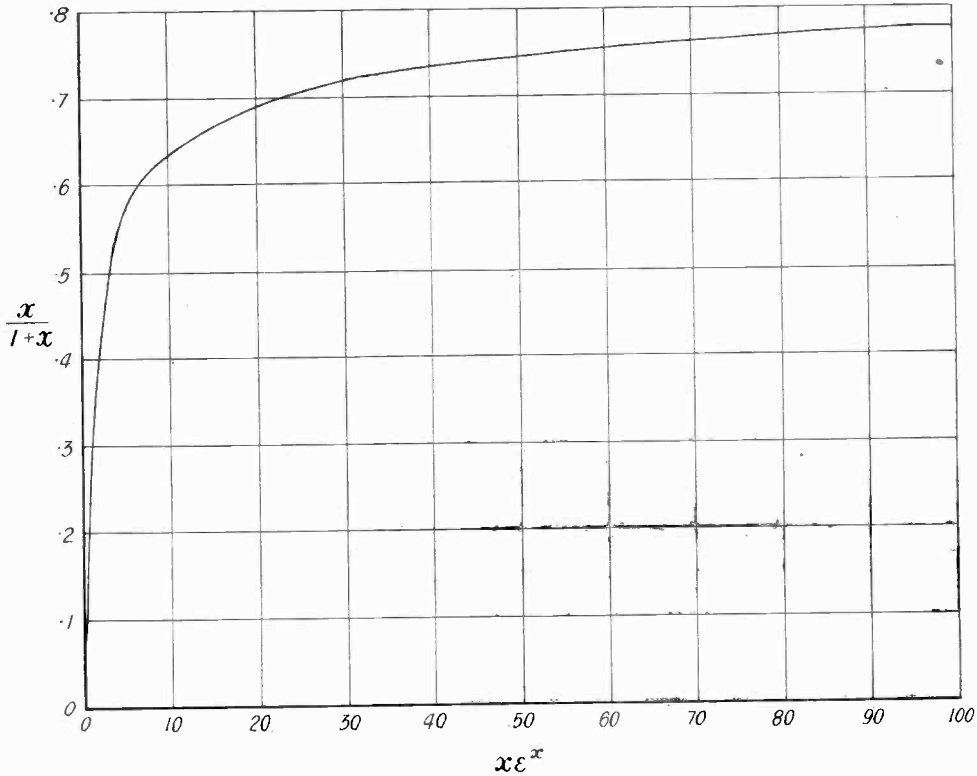


Fig. 20.

The actual effect of the magnitude of C on v_c is not easy to calculate in the general case. Some idea of the nature of the variation can, however, be obtained from the following approximate analysis, which will be nearly correct for small signal amplitudes and provided C is not far removed from a value which fulfils the above condition.

For a small signal amplitude the high-frequency resistance of the grid-filament path approaches $1/bi_0$, i_0 being the initial value of the continuous grid current. For

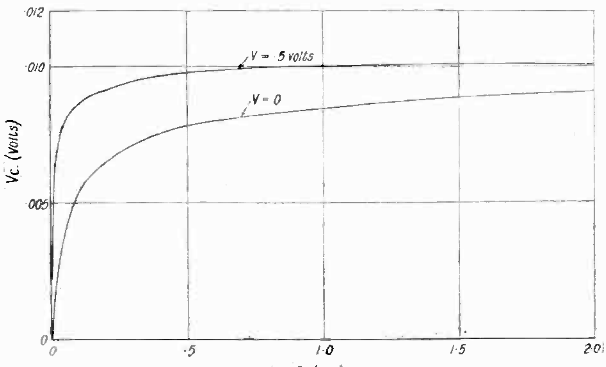


Fig. 21.

a signal frequency $\omega/2\pi$ the impedance of the grid condenser will be $1/j\omega C$. Assuming that the condenser impedance is small compared with the grid-filament resistance, it will be even smaller compared with the grid-circuit resistance or "grid-leak" and the shunt effect of the latter on the condenser impedance can be neglected. If **E** and **E**′ represent respectively the vector signal E.M.F. and the vector E.M.F. which operates on the grid of the valve, then,

$$\mathbf{E}' = \frac{1/bi_0}{1/bi_0 + 1/j\omega C}\,\mathbf{E} \quad (15.3)$$

$$= \frac{j\omega C/bi_0}{1 + j\omega C/bi_0}\,\mathbf{E} \quad (15.4)$$

Thus the variation of **E**′ with **E** is represented by an operator fraction of which the magnitude is of the form $x/\sqrt{1+x^2}$, where $x = \omega C/bi_0$. For small signal amplitudes the change of mean grid potential will be proportional to E_s^2, E_s being the root mean square value of the signal E.M.F., so that the variation of v_c with C will be of the form $x^2/(1+x^2)$. The curve of this function is shown in Fig. 22. Its most important characteristic from the present point of view is its extreme flatness for values of x greater than about 4.

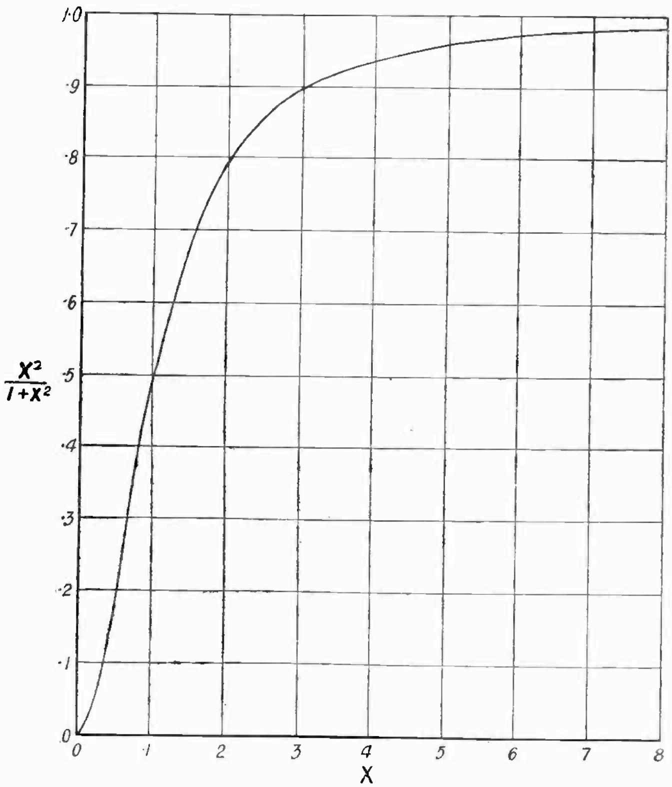


Fig. 22.

This therefore specifies approximately the minimum value for C, *i.e.*,

$$\omega C/bi_0 < 4 \text{ or } C < 4bi_0/\omega \quad (15.5)$$

The best value for C thus depends not only on the signal frequency but also on the grid-filament resistance for the point of operation. No general figure can therefore be given, and all that can be said is that the admittance of the condenser at the given frequency should be at least four times the grid-filament slope conductivity. Very little is to be gained by increasing C beyond this point as far as continuous wave rectification is concerned, and, as already shown, the rectification efficiency for modulated continuous waves or for heterodyne may be considerably reduced by doing so.

It should be clear that the minimum value of the grid condenser will increase very rapidly with the initial grid potential, owing to the increase of bi_0. Thus in practice the increase of sensitivity which should result from an increase in bi_0 may

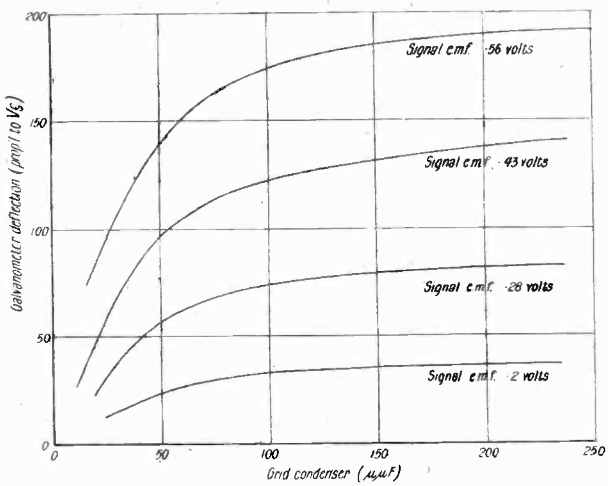


Fig. 23.

sometimes be cancelled by the opposite variation of the ratio of ωC to bi_0. It appears that the most efficient conditions in any given case can only be ensured by means of independent variation of R, of C, and of the initial grid potential.

As an illustration of the above analysis, we have for the valve considered in Section 8,

$$a = 3.16 \times 10^{-6}$$
$$b = 5.55$$
$$R = 1.89 \times 10^{6}$$
$$v = 0$$

$\lambda = 400$ metres, *i.e.*, $\omega = 4.72 \times 10^6$

For this case the calculated value of bi_0 is 1.35×10^{-6}. It will be found that $\omega C/bi_0 = 4$ corresponds to about $114\mu\mu$F for C. Thus, for small amplitudes at least, the curve showing the variation of v_c with C should flatten out in the neighbourhood of this value for C. The curves of Fig. 23, which were obtained by actual measurement, give a very satisfactory confirmation of this simple analysis.

APPENDIX III.

The initial equation is

$$i_0 + i_c = \frac{1}{T}\int_0^T f(v - v_0 - v_c + e)\, dt$$

where

$$e = E \sin \omega t.$$

By Taylor's Theorem, the integrand can be expanded into

$$f(v - v_0 - v_c + e) = f(e) + (v - v_0 - v_c) f'(e) + \frac{(v - v_0 - v_c)}{2!} f''(e) + \frac{(v - v_0 - v_c)}{3!} f'''(e) \ldots \text{etc.}$$

where

$$f'(e) = \frac{\delta f(e)}{\delta e} \ldots \text{etc., etc.}$$

The integration therefore gives

$$i_0 + i_c = F(E) + (v - v_0 - v_c)\, F_1(E) + \frac{(v - v_0 - v_c)}{2!} F_2(E) + \frac{(v - v_0 - v_c)}{3!} F_3(E) \ldots \text{etc., } \textit{ad inf.}$$

where

$$F(E) = \frac{1}{T}\int_0^T f(E \sin \omega t)\, dt$$

$$F_1(E) = \frac{1}{T}\int_0^T f'(E \sin \omega t)\, dt \ldots \text{etc., etc.}$$

For the solution of the case in which the E.M.F. is modulated it will be necessary to consider certain integrals of the form

$$\frac{1}{T}\int_0^T f\{(E + m) \sin \omega t\} dt.$$

For these integrations it will be necessary to assume that m does not change appreciably during one high-frequency cycle. Under ordinary conditions of practical wireless telephony this assumption will not introduce any appreciable error. We shall then have

$$\frac{1}{T}\int_0^T f\{(E + m) \sin \omega t\} dt = F(E + m).$$

The above equation will now take the form

$$i_0 + i_c + i_m = F(E + m) + (v - v_0 - v_c - v_m) F_1(E + m) + \frac{(v - v_0 - v_c - v_m)}{2!} F_2(E + m) \ldots \text{etc., } \textit{ad inf.}$$

Also, by Taylor's Theorem,

$$F_n(E + m) = F_n(E) + m F_n'(E) + \frac{m^2}{2!} F_n''(E) + \frac{m^3}{3!} F_n'''(E) \ldots \text{etc., } \textit{ad. inf.}$$

where

$$F_n'(E) = \frac{\delta F_n(E)}{\delta E} \ldots \text{etc., etc.}$$

Equation (13.5) can now be obtained by the expansion of the $F_n(E + m)$ functions above. In these equations i_m is written for the whole group of modulation frequency currents, and v_m for the back E.M.F. due to these currents.

For expression in terms of $\delta i_c/\delta E$,

$$\frac{\delta(i_0+i_c)}{\delta E} = F'(E)+(v-v_0-v_c)F_1'(E)+\frac{(v-v_0-v_c)^2}{2}F_2'(E)\ldots\text{etc.}$$

$$-\frac{\delta(v_0-v_c)}{\delta E}\left\{F_1(E)+(v-v_0-v_c)\,F_2(E)+\frac{(v-v_0-v_c)^2}{2}F_3(E)\ \ldots\ \text{etc., } \textit{ad inf.}\right\}$$

i.e.,

$$\frac{1}{R}\frac{\delta v_c}{\delta E} = F'(E)+(v-v_0-v_c)F_1'(E)+(v-v_0-v_c)F_2'(E)\ldots\ldots-\frac{\delta v_c}{\delta E}\frac{1}{R_c}$$

Therefore

$$F'(E)+(v-v_0-v_c)F_1'(E)+\frac{(v-v_0-v_c)^2}{2}F_2'(E)\ \ldots\text{etc., } \textit{ad inf.}$$

(To be continued.)

Two New "Silvertown" Products.

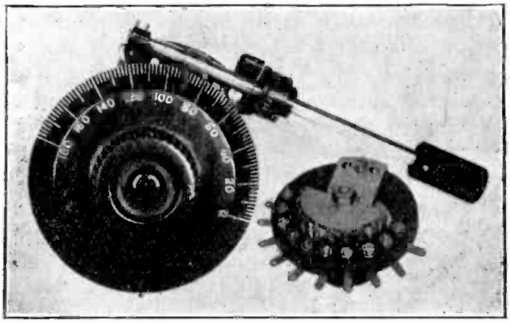
FROM the Silvertown Company, Silvertown, E16, we have received two components for test—their "Verniometer" and a 10-way switch.

The verniometer is a slow-motion device for use with condensers, variometers, and so on. It consists essentially of an ebonite knob and dial of the ordinary type, screwed rigidly to a brass plate of the same diameter as the dial and toothed at its periphery.

A worm drive is mounted separately on the panel, so that the worm gearing engages with the toothed plate on the dial. The worm spindle also carries a vernier indicator and a pointer for the main dial reading is provided on the worm bracket. The gearing, which can be thrown out of action at will for the main adjustment, provides a reduction of 240 to 1, is very smooth in action, and there is a noticeable absence of backlash. The device is very well made, and reasonably priced at 6s.

The 10-way switch is designed for mounting under the panel, and requires only two screws for fixing. The switch consists of a circular ebonite former, with the spindle mounted in the centre, and 10 contact points mounted radially around half its circumference.

A semi-circular contact segment, notched at each end, moves round the contact points, and it will be appreciated that as the contact segment is moved, connection is made to each contact point successively.



The two "Silvertown" accessories.

The switch is equally useful for connecting inductances or condensers. It is priced at 5s. 6d., complete with white ivorine scale and drilling template.

Proposed Institute of Radio Engineers.

At a meeting held on Saturday, 31st October, at the Hotel Russell, London, it was decided that the registration of the Institute should be proceeded with. In the absence of Mr. Nelson, who was indisposed, Mr. C. E. Baldwin occupied the Chair.

The following officers and members of the Council were elected :—

Chairman, Mr. Nelson ; Vice-Chairman, Mr. E. H. Turle ; Hon. Sec. and Treasurer, Mr. Y. W. P. Evans ; Assistant Hon. Sec., Mr. H. King.

Council : Mr. A. F. H. Baldry, Mr. H. W. Gambrell, Mr. C. E. Baldwin, Mr. J. H. Tanton, Mr. W. E. Cooper, Mr. A. Woodmansey.

The following were appointed district representatives : Mr. J. H. Tanton, London Area ; Mr. C. E. Baldwin, S.E. Counties ; Mr. Lowe, S.W. Counties ; Mr. Gambrell, Midlands ; Mr. Woodmansey, N.E. Counties ; Mr. Bradshaw and Mr. Simpson, N.W. Counties. Others will be appointed as necessary. The Headquarters of the Institute will be situated in London.

The next General Meeting will be held at the International Correspondence School, Kingsway, where a room has been placed at the disposal of the Institute, through the kind offices of Mr. R. P. Baker, the managing director.

Official Recognition of Esperanto.

In accordance with the recommendation of the Fifth General Assembly of the League of Nations, the International Conference of the Member States of the Universal Telegraphic Union has just accorded official recognition to Esperanto.

Article 7 of the International Telegraphic Regulations, dealing with the use of international languages has been completed as follows :—

"The use of Latin and Esperanto is allowed in the same way."

Esperanto is therefore officially recognised as a "clear language" for international telegraphy.

Notes on the Conditions Governing Transatlantic Reception.

By S. K. Lewer (6LJ). **[R113**

SINCE the work of Cash and Burne, carried out during the latter end of 1923,* all interest in the reception of transatlantic signals seems to have disappeared. In all probability this was because it became a simple matter to log dozens of American amateurs on even a single-valve receiver. Most of the tests were in connection with the phenomenon of fading, but as this practically disappeared when shorter waves (80-100 metres) were used, there was apparently no need for further tests in that direction. At my own station throughout the whole of last year I listened to the American amateurs regularly, and a study of the log of reception has yielded a very interesting graph. This will be discussed in detail later in this article.

The first attempt at reception was made on the morning of 2nd December, 1923, and resulted in a log of 23 Americans. The next two mornings on which I listened, 9th and 16th December, the totals were 37 and 46 respectively. This increase was thought to be due to the gain in experience and the increase in the efficiency of the receiver, and consequently the results of these nights were neglected for the purposes of the graph. It was found that the best time for listening was from 03.30 G.M.T. onwards on Sundays, which is from 22.30 onwards on Saturdays on the East Coast of the United States. This, of course, was before the days of no "quiet hours." Consequently, a regular watch was kept at this time, and the total number of different Americans heard went up in leaps and bounds. The totals for the separate nights varied enormously and did not appear to be connected in any way with other observations.

During February several improvements were made in the receiver, but after that I decided to listen right through the summer and to study the conditions of reception without varying anything at the receiving end. The receiver was therefore maintained at constant efficiency.

A detailed log of reception was kept, including time, station called, station calling, audibility, tone, wave-length, and if necessary, notes on fading. All these details were recorded in the interest of checking the reports with the transmitters' logs. Much valuable time was lost by doing this, but in view of the fact that, in all, about 800 Americans have asked for detailed reports, I feel that my time has not been spent in vain.

Nothing really remarkable happened until 13th April, when 73 Americans were logged. This beat the previous record of 46 on 16th December. On 13th April conditions were exceptionally good, and signals from about 60 of the stations logged were read on a loud-speaker of the home-made variety and which was somewhat inefficient. It may be mentioned at this point that the receiver consisted of L.F. with the usual low-loss tuner. The aerial was a single wire, 50 ft. long and 25 ft. high, and was 10 to 20 ft. below the tops of the neighbouring houses. I was rather surprised at being able to log so many stations "on one hook," and decided to try the next night. I succeeded in logging 48, and being still more enthusiastic, I sacrificed several hours of sleep during the next night, and was rewarded with a total of 4. At this stage conditions were rather erratic. On 27th April static was terrific and very few Americans were logged. The totals, however, rose to 16 on 4th May, and to 21 on 18th May, after which the figures never reached higher than 9 until 3rd August with a total of 27.

The chief trouble that I experienced during the summer months was the very short time in which signals could reasonably be expected to be audible in England. The Atlantic Coast stations did not begin their "brass-pounding" until 22.30 E.S.T., which is 03.30 G.M.T. The sun rises in

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* E.W. & W.E., Vol. III, p. 132.

London at about 03.45 G.M.T. in the middle of June, leaving a period of approximately 15 minutes during which the Atlantic is in darkness. Consequently, it was useless to listen before 03.30 G.M.T. and the Americans faded out completely shortly after 04.00 G.M.T. Static was generally very bad and blotted out all weak signals. Another reason for the smallness of the figures is that a large number of the best stations suspended their activities during the summer on account of static and external attractions.

After the year's work a graph was drawn showing the totals per night against the time measured in Sundays, but it was apparently of no interest, except for several erratic changes which could not be explained.

The wave-lengths used throughout these tests varied from time to time. During the first few months the reception was carried out on the 150-200 metre band only. Following this, however, the region of 100 metres proved very fruitful, and since the autumn hundreds of Americans tried the new wave-band of 75-80 metres. The strength of their signals at this end increased enormously, and they pounded into Europe in such numbers that they became almost beyond control. A comparison of the logs of several English receiving stations showed that very few Americans were received at more than one station during a period of several hours. In other words, many more American stations are being heard in this country than can be logged with one receiver. As an example of the increased efficiency of the 75-80 metre band over the old 150-200 metre band, I may say that the total number of different Americans logged at my station increased from 200 to 300 during February, when the 150-200 metre band was used. This was with a 2-valve receiver. The total increased from 800 to 1 000 during November, while using the 75-80 metre band and only a single-valve receiver. The increase of 200 in November is remarkable, because the total was already very high, and one would naturally expect new stations to be scarce, especially on a single-valve receiver. The change of wave-length did not alter the shape of the graph, which seems to hold even for the 40-metre and 20-metre bands.

Another factor which found its way into transatlantic reception with the coming of short waves was the change of the operating hours. The American amateurs were prohibited, during the 150-200 metre days, from beginning the night's work until 22.30 local time, on account of the possibility of interfering with the transmissions from broadcasting stations. With the advent of the use of short waves (below 80 metres) the interference caused to broadcast listeners by transmitters working on the short waves was considered to be negligible, and transmission at any time of the day or night was permitted. This is now proving very useful in obtaining more accurate figures.

Since the graph showing the variations in the periodic totals was useless, it seemed that the periodic watch had been useless apart from bringing joy into the hearts of scores of American amateurs at having " got over on a fiver." A graph showing the variations in the strength of one particular station from week to week, or better, the variations in the average strength of several stations, would have yielded much useful information. The measurement of signal strength is, however, a difficult operation, and is rarely accurate. If measurements were taken on one transmitting station, the results would hold only for that particular location; and to measure the strength of the signals received from dozens of American stations in a few hours would indeed be very tedious, if not impracticable. On looking through the logs, however, it was found that on some nights many stations were logged in a short time, but on other nights very few were logged in a comparatively long time.

Now, fortunately, every transmission intercepted had been logged, which means that some stations were logged several times in one night. The idea of this was to give the transmitting operator as much information concerning his signals as possible. The number of log entries in a given time could therefore be taken as a measure of the conditions. This method was perfectly satisfactory while the 150-200 metre band was in use, but when the 75-80 metre band was introduced the number of stations logged was simply a measure of the operator's efficiency, since there were always crowds of stations that could be heard at the same time. For this reason only a single-valve receiver was used for the 75-80 metre band, so as to bring the number of stations logged within controllable limits. Changing the receiver was quite permissible, since, for the purpose of plotting a graph, only the variations in the number of stations logged from week to week were required.

A graph was then plotted showing the number of log entries per night divided by the number of successful listening hours per night against the time measured in Sundays, and is reproduced in Fig. 1. The dotted portions will be referred to later. This was certainly not so erratic as the graph showing the totals per night. The year was divided into the four seasons, the dates of the divisions being 23rd March, 22nd June, 21st September and 21st December. At this stage the graph assumed a very interesting aspect. By comparing the shape of the section of the graph for the winter season with that for the summer we observe a definite similarity. In fact, the variations coincide from week to week. There is also Americans we may hope to receive in a given time.

The portion of the graph covered by the dates 31st August to 21st September marks a much needed rest. The shape during this interval is based upon observations made at two or three other receiving stations. It will be observed that this section conforms to one's expectations on comparing with the winter section. At the four divisions the conditions are temporarily bad. It is interesting to note that at the winter and summer solstices, that is to say, when the sun is "standing still," the graph slowly comes down to a minimum and then rises yet more slowly as if tending to remain thus; and at the vernal and autumnal equinoxes, when the sun is in the middle of its swing "crossing the equator," the graph makes a very sharp dip.

Again, at the end of every two months

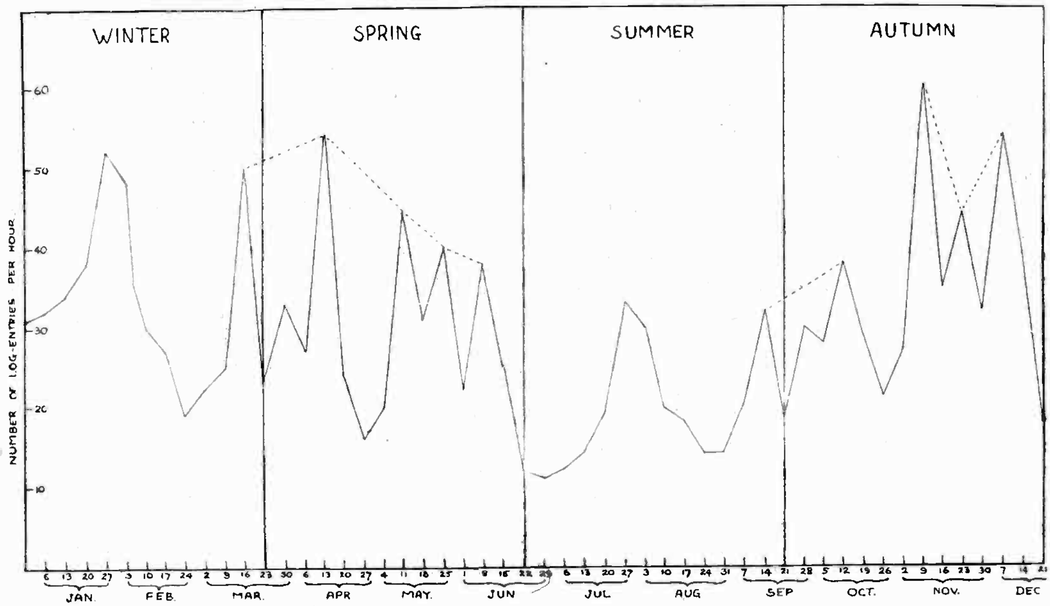


Fig. 1.

a similarity between the spring and autumn sections, but in these the graph has a different shape. Of course, the rates at which stations were logged on the various nights are not the same in these sections, but this is immaterial, since we are concerned for the moment with the variations in conditions and not with the number of beginning with February, April, the conditions are exceptionally unfavourable. These bi-monthly periods, however, do not seem to fit in with the seasonal variations and solar influence. Notwithstanding this, it was found that, on comparing these dates, there was a new moon in the vicinity of the bi-monthly minimum. The mention of the moon may come as a surprise to many, and in fact, no explanation concerning its influence is forthcoming. Some recent experiments made in America have indicated the doubtful presence of a connection between the phases of the moon and atmospheric interference. Referring again to the graph, the conditions during the winter seem to be favourable whenever there is a full moon. When all facts are taken into consideration, however, it is very doubtful whether long distance communication is affected by the moon in any way.

One interesting point in the graph is the height of the summer section. Contrary to one's expectations, the conditions were quite favourable during this period. Accurate measurements could not be taken because of the very small numbers of log entries, which were accounted for by the fact that the listening period was so very short, as previously explained.

Another method of measuring the variations in conditions would be to determine the length of time after sunrise in England during which the Americans could be heard. This method would certainly be much less tedious than the one that I employed but, unfortunately, there are three objections to this. Firstly, in winter, when sunrise is very late, the American stations may close down before daylight would decrease their range. Secondly, in mid-winter and mid-summer, daybreak occurs very slowly, indirectly making accurate determination of the time of complete fading next to impossible. Thirdly, complications may be introduced by having a mixed medium of darkness and daylight. It would be a difficult task to investigate the conditions covering the intervening space if a portion of it were in darkness and the remainder in sunlight, since, as is now well-known, the sun has a very marked effect upon the refracting and reflecting properties of the ionised layers in the upper atmosphere. A fourth objection may be raised. The range of a transmitter working on waves of the order of 200 metres is increased to a very large extent during the night. The same thing occurs on waves in the vicinity of 100 metres; in this case both day and night ranges were increased. When the wave is reduced to about 40 metres, the day range becomes quite considerable and the night range is increased still more. On further reduction of the wave to the neighbourhood of 20 metres, the day range becomes greater than the night range, and the range of this wave during the day is greater in a direction away from the sun, due to the change in the slope of the reflecting layer with respect to the earth's surface.* Now we can see where the fourth objection comes in.

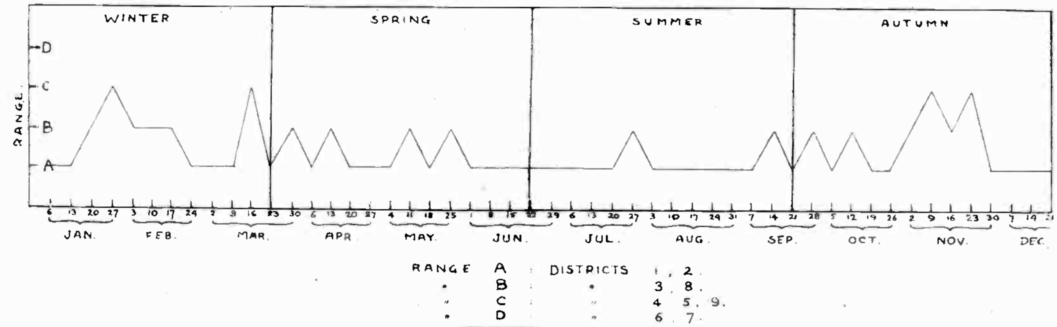


Fig. 2.

The range and the length of time after sunrise during which signals may be audible would depend to a large extent upon the wave-length of the transmitter and the direction of the received wave.

Perhaps a more fruitful but tedious method of determining the changes in the conditions would be to compare the maximum ranges obtained. I used this method in the modified form as a check for the graph in Fig. 1. The graph obtained is shown in Fig. 2. On comparing it with Fig. 1, we can see at once a marked similarity

* *Q.S.T.*, April, 1925.

in the shape. The procedure was as described below.

The numbers of the stations that I had heard in each of the nine districts of the United States were counted and expressed as percentages of the "total percentages." The numbers of the stations in the nine districts heard on each night were counted and expressed as percentages of the total for the night. These were the "nightly percentages." There was found to be, almost invariably, one district having an exceptionally large "nightly percentage" when compared with the "total percentage" for that particular district. If there were two or three districts with an extra large "nightly percentage," they were at approximately the same distance. Thus, if more than the average number of stations in the distant districts are logged on a particular night, the maximum range covered was exceptionally great and conditions were better. The nine districts were divided into four groups or ranges with approximately 1 000 miles between them. The groups were :—

A : 1st and 2nd. 3 000 miles.
B : 3rd and 8th. 4 000 miles.
C : 4th, 5th and 9th. 5 000 miles.
D : 6th and 7th. 6 000 miles.

The graph was then drawn showing the range, *i.e.*, the district or districts in which the extra number of stations was heard. against the time measured in Sundays as before. Although this method of finding the maximum range has not, to the best of my knowledge, been used before, it appears to be very effective. It is interesting to note that the apparent range obtained on 13th April was not exceptional, yet, from the graph in Fig. 1, conditions were undoubtedly very favourable on that date. This discrepancy may be explained either by the fact that so many strong East Coast stations could be heard that the more distant, and therefore weaker, stations were jammed out, or by the fact that the conditions for the reflection of waves from the more distant stations may have been poor. The former explanation seems to be more feasible.

We may therefore assume that the graph in Fig. 1, corroborated by the graph in Fig. 2, is a fair representation of the conditions during 1924 of the reception of American signals in England. It may also represent the conditions of the reception of English signals in America. Mr. A. G. Wood, of G5RZ, has plotted a graph of the conditions of reception during the months of October and November by simple estimation. This coincides approximately with my own graph. He also plotted a graph showing the conditions of the reception of his signals in America by the comparison of reports. This was coincident with the reception graph.

There is another point bearing on this subject. On looking at the graph in Fig. 1, we see that the conditions at the end of the year were very unfavourable. American signals were undoubtedly weaker at that time. One night early in the New Year, while in communication with several American stations, I asked for a report of the strength of European signals during the previous few nights. Some reported that they had heard very few Europeans, and others had not even heard anything of us. This, together with the other evidence, seems to indicate that the conditions are identical for the passage of signals in either direction.

It is doubtful whether this graph would hold for the reception of signals from New Zealand or Australia, since those stations are in the other hemisphere, and also darkness would never, or perhaps only for a few minutes, cover the entire distance between the stations. Yet, considering that our summer season is coincident with the winter season in the Antipodes and that the shape of the graph for the pairs of seasons is the same, we could probably forecast the dates on which signals from the Antipodes would be exceptionally strong. However, it is easier to transmit signals in a direction north-south than in a direction east-west, due probably to the influence of the earth's field, and results would be entirely different.

Now let us consider the possible causes of these variations in the conditions as represented by the graph. Since the earth's surface is curved, and signals are presumed to travel above the earth's surface, then there must be a reflecting surface, so that the waves are returned to the earth. There is ample evidence to show the existence of such a surface. The phenomenon of fading cannot be explained without a variable reflecting surface. The presence of a reflecting surface in the form of a layer of ionised atmosphere is confirmed by the variations in the magnetic field of the earth. This layer is world-wide and more or less permanently ionised. The ionisation is caused by ultra-violet radiation from the sun, and is at a maximum during the day, and diminishes gradually during the night. The conductivity of this layer is greatest when the sun's zenith distance is least, and varies with sunspot minimum to sunspot maximum. Its height has been estimated at 50 kilometres, but this may vary with the time of the day or night.

At first sight this does not seem to be the layer which we use in covering great distances at night. If the intensity of ionisation decreases during the night, it seems that the extent of reflection of the waves must also decrease. But this is not what we find in practice. The ionisation of this layer is at a minimum just before dawn, and we can all agree that conditions are no less favourable at dawn than at any other time of the night (for waves of 40 metres and above, at any rate).

Some experiments were recently carried out in order to plot a graph showing the variations in the strength of signals across the Atlantic over a period of 24 hours. This graph is shown in Fig. 3, together with the intensity of ionisation. From this it appears that (*a*) no use is made of the world-wide ionised layer, and (*b*) the sun's rays reduce the range and the signal strength of a station at a given point. It has been suggested that night-distortion and errors in direction finding work at night prove the existence of an ionised layer during the night.

We may therefore assume that the intensity of ionisation does not fall off to zero during the night. But it seems that, if the intensity is weaker at night, then the signal strength should be less. This, however, does not fit in with practice (for waves above 40 metres). It is commonly thought that the day range of short-wave transmissions is small because the wave energy is absorbed in the ill-defined lower surface of the ionised layer. During the night it is supposed that the lower surface becomes sharper, thus forming a more efficient reflector for the waves. If this layer is the one which is directly ionised during the day and the intensity falls off during the night, we should expect a decrease in the range of a station on the fall of night. But this does not occur (except for ultra-short waves), and we are led to imagine an ionised layer which comes into action after sunset. However, on considering the fact that Fessenden in 1900 found that the world-wide ionised layer is at a height

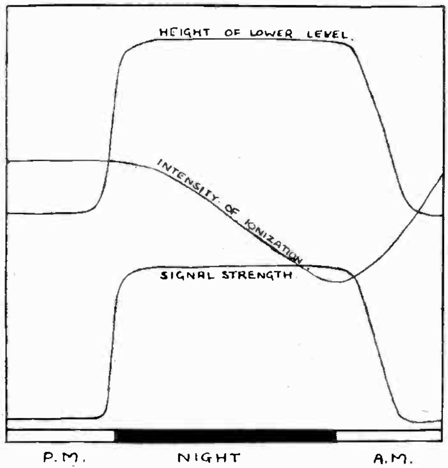


Fig. 3

of about 150 kilometres (*i.e.*, the lower surface) in the daytime, and rises to about 500 kilometres at night, we see the possibility of the varying height being responsible for the varying reflecting properties.

As a matter of fact, the lower figure of 150 kilometres is much higher than the figure generally agreed upon. Auroras have often been observed at a height of several hundred kilometres from the earth's surface, which indicates that the layer is very thick. The reason for the rising of the lower surface at nightfall is, of course, that on the removal of the source of ionisation, the sun, the layer settles out at a higher level.

Before we proceed, however, let us consider the known facts about short-wave long-distance communication. The most important fact is that the shorter the wave-length, the greater the range, either during the day or the night, for waves above 40 metres.

On waves of the order of 10 000 metres, the day and night ranges are the same. The range of 20-metre signals seems to be greater during the day than during the night. As has been explained in an earlier part of this article, the wave-lengths used throughout the year were not the same, but the changes had apparently no effect on the shape of the graph.

Now, it can be proved that shorter waves penetrate into the ionised layer to a greater extent than the longer waves. If the wave-length has no effect on the shape of the graph (for waves below 200 metres, at any rate), it seems that the height to which the waves penetrate in the layer does not affect the shape of the graph. Therefore it is highly probable that the graph does not represent the changes in the height. It is interesting to note that the variations in the signal strength of 20-metre signals from week to week conform remarkably well to the shape of this graph.

Waves in the neighbourhood of 200 metres are particularly suspectible to fading. Around 100 metres little or no fading is noticed, but in the region of 40 to 20 metres, fading is often very bad. It has been found that fading for waves of about 200 metres is regular and proceeds in cycles, the frequency being inversely proportional to the distance covered. Moreover, the fading cycles often occur superimposed on much slower cycles, but this is not often very noticeable. No tests have yet been carried out on the band around 20 metres.

Another peculiarity is that fading, even on one wave-length, does not always occur. According to the theory of the late Dr. Heaviside, the wave, in the process of being reflected from the ionised layer, remains in it for a short space of time, and on arrival at the receiving station meets the direct or earth wave with which it sets up very slow beats, and fading of the signal is the result. This assumes that the waves travel through the earth, or, at any rate, along the surface of the earth, with reasonable efficiency.

There is, however, a belief that short waves are very readily absorbed by solid bodies, and, in fact, it has often been shown that a hill or a building acts very effectively as a screen for short waves. Yet fading occurs even in signals from the Antipodes, in which case the path of the earth wave is at least 8 000 miles long. At this distance the earth wave would probably be inaudible, and no fading would result ; and again, fading is often noticed on waves of 20 metres at great ranges, where the chances of the earth wave getting through are very small. In view of what has been said on the phenomenon of fading, it is hardly possible that the graph in Fig. 1 is a curve of very slow fading throughout the year.

It is interesting to note that magnetic storms occurred on 23rd January, 30th March and 21st May, which are near three maxima on the graph, and also on October 25th, a minimum. When any magnetic changes occur there are always parallel changes in the sunspot frequency or area. A sunspot may exist for any length of time from a few minutes to several weeks, and its area is of the order of 6 by 10^7 square miles; but, unfortunately, no information on the activities of sun spots on these dates is available. Beyond this, there is apparently no connection between the graph and terrestrial magnetism with its attendant phenomena. Magnetic storms are generally accompanied by auroras, but there has been found to be no connection between auroras and wireless waves.* It has been said by some investigators that wireless waves do not penetrate into the auroral layer, but this is to be doubted if the auroral layer indicates the height of the ionised layer.

It has been suggested by Fleming† that the variation of the inductivity of the air with height might be an aid or an alternative to ionic refraction, *i.e.*, the bending of the space wave. It therefore seems probable that the graph in Fig. 1 may be a representation of the variation of the inductivity of the air.

There is a very interesting connection between this graph and the graph showing the variations in the air-earth current in Fig. 4. This is the curve which is most similar to Fig. 1, and is the graph taken at Potsdam during some experiments made eleven years ago. This air-earth current is dependant on the intensity of ionisation at a given height, and is carried almost entirely by the heavy ions of low mobility. The light ions are much less numerous and have about 3 000 times the mobility of the heavy ions.

If the graph in Fig. 1 does represent the changes in the ionisation of the upper atmos-

* *British Assoc. Comm.*, 1914.

† *Proc. Phys. Soc.*, Aug., 1914.

phere, it is not necessarily a representation of the variations in solar ionisation, since, besides ultra-violet radiation from the sun, the other possible sources of ionisation include radioactive emanation in the air, photo-electric effects at the ground, and gamma rays from radium and thorium in the ground. The breaking of waves has been suggested as a source of ionisation over oceans.* Consequently, the graph in Fig. 1 may represent the variations in any of these sources. This is hardly possible, however, in view of the connection with solar influences in the seasonal variations, and the only source of ionisation we may suspect is ultra-violet radiation.

Interest also centres around tropical storms which, according to one report, cause variations in signal strength, generally an increase.

There is an ionised region in the polar caps caused by collision of corpuscles emitted from sun spots, and brought to rest at a distance of about 80 kilometres from the earth's surface by the viscosity of the atmosphere. The effect of these ionised zones would probably be felt only in communication with the Antipodes, in which case the path of the wave would pass through the auroral zone and the polar caps. It is therefore unlikely that the graph represents the changes in the ionisation of the atmosphere in these regions.

It is probable that the graph represents the variations in the atmospheric ionisation caused by the sun and other sources, and if the effects of these supplementary sources could be removed, the graph due to solar variations would, in all probability, be a simple curve.

In conclusion, it may be said that the shape of the graph for this year and also on waves around 20 metres is coinciding with the shape of the graph for last year. A most important point is that if the graph is repeated every year—twice yearly in fact—we shall know exactly when conditions will be favourable and when to arrange our long distance tests. At present we are at the end of a sunspot cycle which lasts 11.1 years, and this may have an effect upon the shape of the graph.

Unfortunately, in practically all experiments of this nature, there is an enormous amount of what we may call "spade work" to be done, and all the tests are necessarily spread over a long period of time. The writer hopes, however, that his investigations will be one step further in the explanation of the facts concerned with atmospheric ionisation on which so much depends at the present time. The work that has been done recently on 20 metres is not yet thoroughly understood, and doubt still hangs over our ideas of wave propagation, reflection and refraction. At any rate, the entire subject depends upon atmospheric ionisation, and it appears that this will have to be thoroughly understood before we can succeed in interplanetary communication.

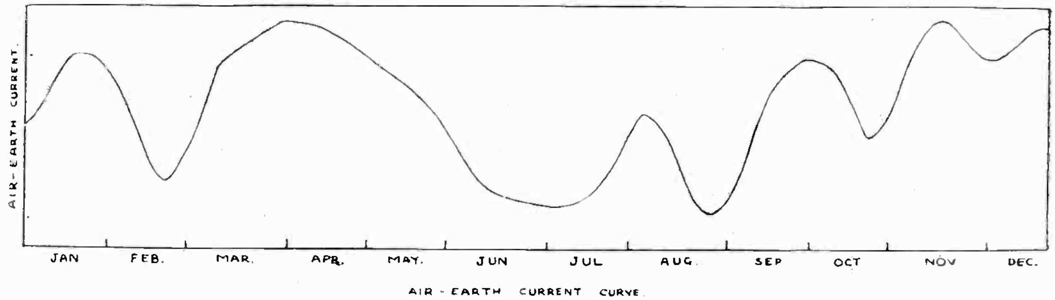


Fig. 4.

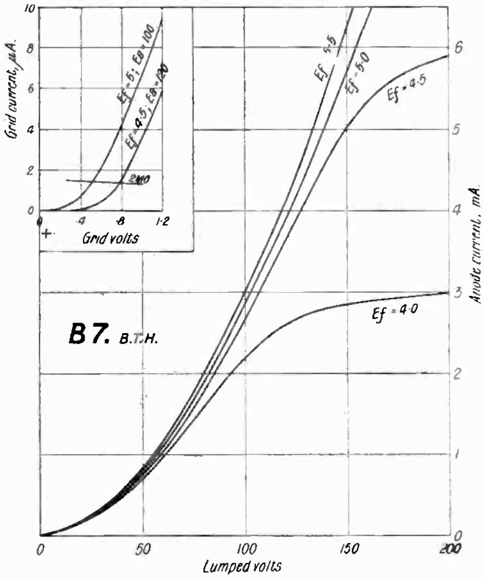
* *Proc. Phys. Soc.*, Feb., 1925.

Some Valves Tested. [R333·009

We have now tested a fairly large batch of new valves in our laboratory, eight of which are described below. A further selection will be given in a later issue.

The B.T.-H. B7.

THIS is a dull emitter power valve, similar in construction to the B4 and B6, and designed for a 6-volt filament battery, but taking much less current than the B4. It is, in fact, a member



of our "606" class, and since the makers put the voltage amplification factor at 8.0, it just comes within the HL 606 class. It may, if desired, be used with dry batteries.

The sample submitted, we found, could be run successfully at less than 6.0 volts on the filament, though since the filament currents were somewhat

Fil. Volts. Ef	Fil. Cur. If	Sat. Plate Cur. Is	Anode Imped-ance. Ra	Voltage Ampli. μ	Power Ampli. P. $\left(=\frac{1\,000\mu}{Ra}\right)$	Filament Efficiency. F $\left(=\frac{Is}{Watts}\right)$
4.0	.066	3.2	31 000	11.5	4.2	12
4.5	.072	6.5	21 000	9.4	4.2	20
5.0	.078	11	17 000	9.3	5.1	29
5.5	.083	21	12 500	8.0	5.1	46

greater than those given in the makers' rating, the actual filament wattage was about normal.

We tested the valve at 4.0, 4.5, 5.0 and 5.5 volts on the filament, the corresponding currents being .066, .072, .078 and .083 amp.

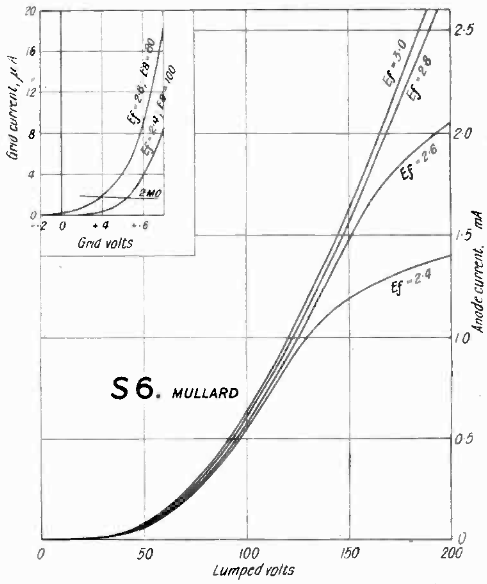
The saturation current, 21mA at 5.5 volts on the filament, is rather low, but should reach the normal value at 6.0 filament volts. The amplification factor was found to be in the neighbourhood of 8, as will be seen from the table of results. The impedance, 12 500 ohms at 5.5 filament volts, is rather higher than usual, although not seriously so.

The curves show that for distortionless L.F. work a fairly high anode voltage will be required (with suitable grid-bias), with at least 5.0 volts on the filament. The valve will probably work best as a first stage L.F. amplifier.

For use as a detector, a valve with a sharp bend in the grid current curve is essential. If this valve is used for this purpose, a fairly high value for the grid-leak is advisable.

Mullard S6.

This is made by the Mullard Radio Valve Co., Ltd., and is a dull emitter valve of the "test-tube" type, made with a special helmet shaped cap, and designed to fit into standard anti-capacity clips.



It is intended, so the makers state, for rectification, though it may be used satisfactorily as an H.F. amplifier or a resistance-coupled L.F. amplifier.

Being rated at 3 volts, 0.2 amp, and having a very high amplification factor, it comes in our HH. 320 class.

We tested it at filament voltages of 2.4, 2.6, 2.8 and 3.0. As will be seen from the table, the filament currents ranged from 0.19 to 0.22 amp. The maximum saturation current obtained (at 3.0 volts) was 7.75mA, which is sufficient for the purpose for which the valve is designed. The anode impedance dropped to 36 000 ohms at 3.0 volts, though the makers rate it as high as

Fil. Volts. Ef	Fil. Cur. If	Sat. Plate Cur. Is	Anode Impedance. Ra	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\,\mu^2}{Ra}\right)$	Filament Efficiency. F $\left(=\frac{Is}{\text{Watts.}}\right)$
2.4	.19	1.5	70 000	16.6	3.8	3.3
2.6	.20	2.5	60 000	22	8	4.8
2.8	.21	4.75	40 000	18	8	8.2
3.0	.22	7.75	36 000	20	11	11.9

100 000 ohms. Since the amplification factor proved to be 20 at this voltage (rated at 22), the valve is better than would be expected from the makers' rating.

As a detector it should perform quite well. A 2 MO leak is about right.

As an amplifier. nothing much is gained by exceeding 2.8 volts on the filament. The curve, at high lumped voltages, straightens out nicely, and since the amplification factor is high, the valve should perform well as an H.F. amplifier. It is doubtful whether it could handle enough power for resistance coupled L.F. work, at least in stages other than the first. Nevertheless it is a good valve and the anti-capacity mounting should be useful in short-wave work. Price, 27s. 6d.

Mullard PM4.

This is a power valve, rated at 3.8 volts, 0.1 amp. In construction it is novel. The electrodes are

Fil. Volts. Ef	Fil. Cur. If	Sat. Plate Cur. Is	Anode Impedance. Ra	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\,\mu^2}{Ra}\right)$	Filament Efficiency. F $\left(=\frac{Is}{\text{Watts.}}\right)$
2.8	.110	4.5	17 000	4.8	1.35	14.6
3.2	.116	11.0	15 000	6.9	3.2	30
3.6	.123	18.0	11 500	6.9	4.1	41
4.0	.130	25.0	9 000	6.3	4.4	47

arranged horizontally, and are of a flattened box shape. The filament is in the shape of an "N." The bulb is pipless and slightly tapered.

The makers state that the valve can be run from dry cells, but a 4-volt accumulator is preferable, particularly as the filament current was found to exceed the rated value somewhat.

The results we obtained for the other constants of the valve agree very well with those of the makers.

At 4.0 volts on the filament, as will be seen from the table, the saturation current was 25mA, the anode impedance 9 000 ohms and μ was 6.3.

For first stage L.F. work, where the grid swing is fairly small, the valve could be worked at 4.0 volts on the filament and 120 lumped volts. With a grid-bias of —3 volts, this would involve an anode voltage of 120+(3×6.3), say, 140 volts. For second stage work, the lumped voltage would probably need to be higher for distortionless results.

From the grid current curves, it can be seen that the valve should be a good detector at 4.0 filament volts and 60 anode volts, with a 2 MO leak. Price, 22s. 6d.

Ediswan PV6. D.E.

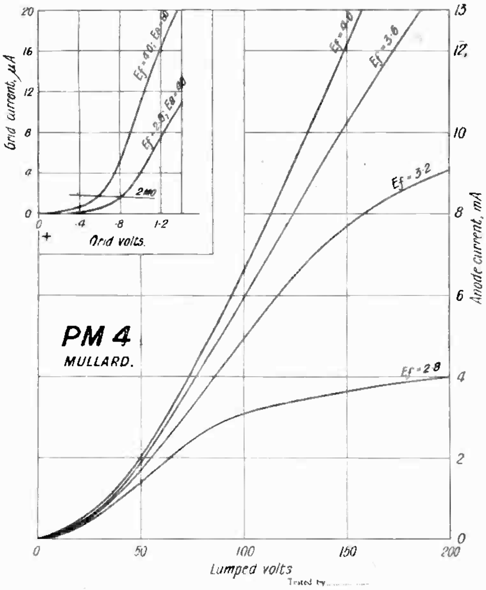
We have recently received a sample of the new type P.V.6. D.E. valve, made by the Edison Swan Electric Co., Ltd.

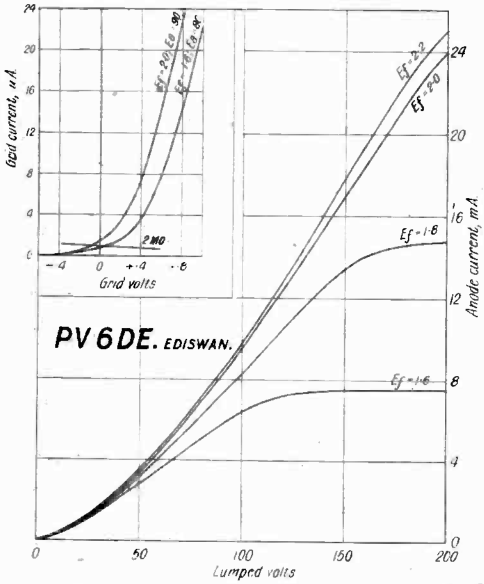
This differs slightly from the previous model, several improvements, both in construction and characteristics, having been made.

The shape of the anode and grid has been changed from the cylindrical to the oval box type, and the filament is of V pattern. The bulb is pipless and the base is of moulded material.

Fil. Volts. Ef	Fil. Cur. If	Sat. Plate Cur. Is	Anode Impedance. Ra	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\,\mu^2}{Ra}\right)$	Filament Efficiency. F $\left(=\frac{Is}{\text{Watts.}}\right)$
1.6	.43	8	14 000	4.9	1.7	11.6
1.8	.46	15	8 500	3.3	1.3	18
2.0	.49	36	7 400	3.6	1.75	37
2.2	.52	40	7 000	3.9	3.4	36.5

The filament voltage rating is the same as before, *i.e.*, 1.8-2.0, but the filament current has been increased from 0.4 to 0.5 amp. The impedance and amplification factor have been lowered.

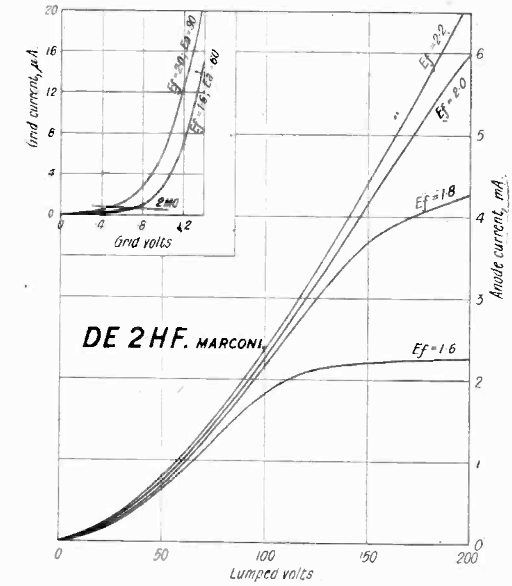




As will be seen from the table, we found the saturation current to be 40mA at 2.2 filament volts, which is ample for large loud-speaker work.

The impedance, rated at 10 000 ohms by the makers, was found, in the case of the sample tested, to be as low as 7 000 ohms at full filament heat. The amplification factor was in the neighbourhood of 4.0.

The valve should be an excellent one for the last L.F. stage, since it can handle a large power. For this purpose the valve should be run at a filament voltage of 2.0 or 2.2 and a lumped voltage of about 140. With a grid-bias of —9 volts, the anode voltage will be about 180. The price is 18s. 6d.



Marconi D.E.2 H.F. and D.E.2 L.F.

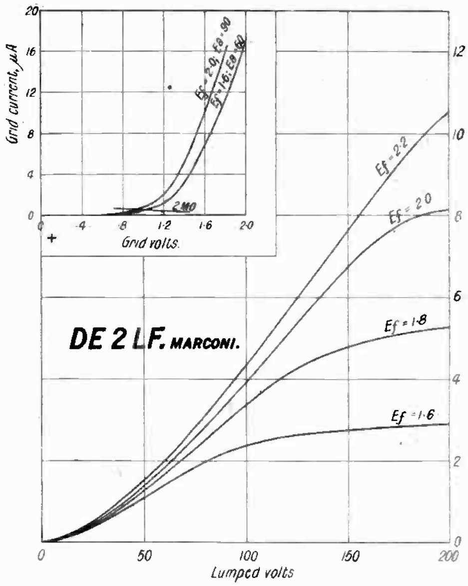
These are two valves of similar construction and filament rating, but designed for H.F. and L.F. work respectively. They are for use with 2-volt accumulators, and come in our "215" class.

D.E.2 H.F.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts}}\right)$
1.6	.126	2.5	45 000	9.5	2.0	12.4
1.8	.135	4.75	29 000	8.1	2.3	19.5
2.0	.143	7.5	25 000	8.9	3.2	26.2
2.2	.151	11.0	22 000*	9.3	3.9	33.0

* At 200 V.

The caps are of the new moulded type, the bulb being pipless and slightly tapering. The electrodes are small and cylindrical and arranged vertically.



From our tables, it will be seen that the filament voltage and current are similar in both cases, as are also the saturation current and filament efficiency.

D.E.2 L.F.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts}}\right)$
1.6	.128	3	36 000	6.75	1.25	14.6
1.8	.135	5.7	23 500	5.9	1.58	23.4
2.0	.143	9.5	18 500	6.65	2.4	33.0
2.2	.150	12.0	15 000	5.4	2.0	36.5

Between the anode impedance there was not so much difference as would be expected. In the case of the L.F. valve, the impedance could have been made less with advantage.

The amplification factor, in the case of the H.F. valve, was not so high as was indicated by the makers' rating. Possibly our sample was slightly different in characteristics.

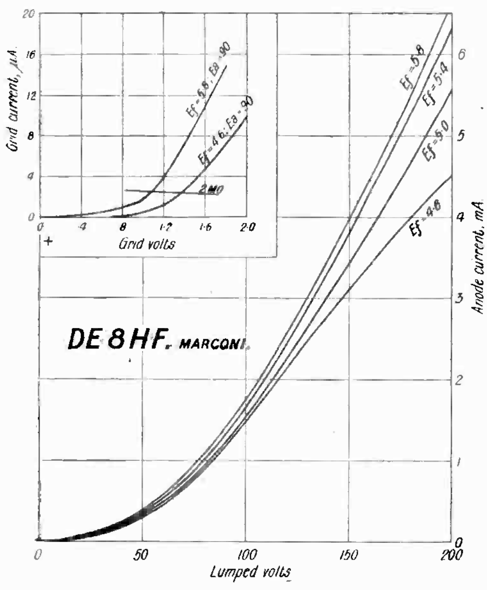
D.E.8 H.F.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. Is	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
4.6	.102	6.5	30 000	14	6.3	13.8
5.0	.108	11	24 000*	15.5*	9.9	20.3
5.4	.114	15	20 000*	15.6*	12.0	24.4
5.8	.120	20	18 000*	16.5*	15.0	28.7

* At 200 V.

From the curves it can be seen that the L.F. valve must be run at full filament heat to enable it effectively to deal with any large grid swing. As a detector, with a fairly small leak, say, 1 MO, it should be quite efficient.

The H.F. valve could probably be worked quite efficiently as such with a filament voltage of 1.8 and a lumped voltage of about 110, but for L.F. resistance-coupled work at least 2.0 volt should be used on the filament, with a lumped voltage of 140 or 150.



This valve should also be a good detector, with a 2 MO leak. The price of either type is 15s. 6d.

Marconi D.E.8 H.F. and D.E.8 L.F.

These two valves have the same filament rating, and are intended for H.F. and L.F. work.

They are designed for use with a 6-volt accumulator, and are in the "612" class.

The electrodes are arranged vertically, and are flattened, the filament being V shaped. The cap is of the moulded type, which is now standard.

It will be observed from the tables that the filament ratings and emissions in each case are practically identical. The saturation current of 20mA at 5.8 volts in each case almost puts the

D.E.8 L.F.

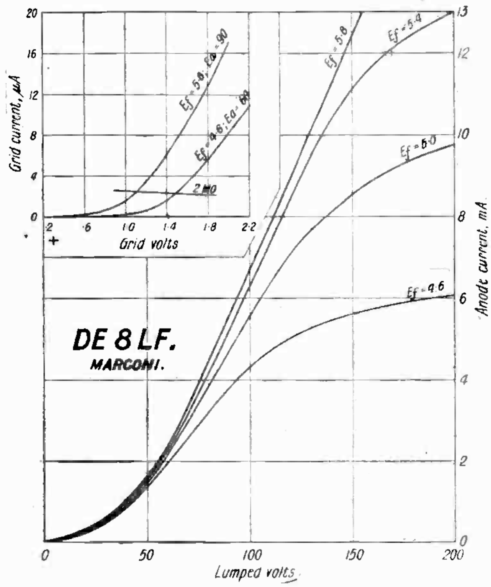
Fil. Volts. E_f	Fil. Cur. I_f	Sat. Plate Cur. Is	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. P $\left(=\frac{1\,000\mu^2}{R_a}\right)$	Filament Efficiency. F $\left(=\frac{I_s}{\text{Watts.}}\right)$
4.6	.101	6.5	16 000	4.8	1.4	14
5.0	.107	11	13 000	5.5	2.3	20.6
5.4	.112	15	10 000	5.6	3.2	24.8
5.8	.118	20	8 500	6.0	4.2	29.2

valves in the power valve class, and they should perform quite well as power valves.

The L.F. type has a nice low impedance with an amplification factor of about 6 at full filament heat. It will be seen from the curves that at 5.4 or 5.8 filament volts the valve should make an excellent L.F. amplifier. If only used for first stage work, 5.4 filament volts would suffice.

As a detector, the valve is not brilliant, but, of course, it has not been designed for this purpose.

The H.F. type has a very high μ, and comes in the HH. 612 class. Considering this high amplifi-



cation factor, the impedance is quite low, and the valve should prove quite effective both for H.F. and L.F. (resistance coupled) work. It will be observed that the valve does not answer greatly to increased filament heat and 5.4 volts on the filament should prove sufficient.

As a detector, for which purpose it is recommended by the makers, it should give good results. The grid current curve for 5.8 volts on the filament and 90 volts on the anode has a very sharp bend. A 4 MO leak would be suitable.

The price of either H.F. or L.F. type is 22s. 6d.

The Screening of Small Variable Air Condensers.

[R387·1

By D. A. Oliver.

Showing that it is important to take into account the earth effects when it is necessary to know accurately the capacity in a circuit.

MANY perhaps have noticed the deleterious effects of bringing the hand near the unscreened condenser in tuned circuits, or have built into simple wavemeters the ordinary variable condenser without paying much, if any, attention to the important question of shielding, only to discover that the completed instrument resents being moved about to any great extent by promptly changing its reading, to the bewilderment of the operator.

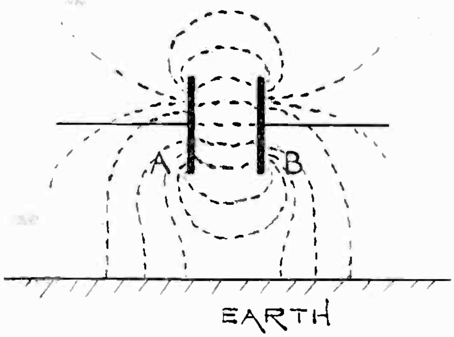


Fig. 1.

Then, again, those who attempt to make quantitative measurements on short wavelengths find it very disconcerting when their tuning condenser settings depend so largely on the proximity of the hand and neighbouring objects, to say nothing of the doubts which arise in the minds of careful workers as to which really is the true capacity reading.

Let us take the case of two sets of condenser plates *A* and *B* near earth and at some arbitrary unequal potentials above it.

To follow the usual lines of thought, we must imagine "tubes" or "lines" of electrostatic flux between the plates and between each plate system and earth (Fig. 1).

These tubes have the properties of tending to contract longitudinally and to expand laterally, and if set in motion by means of alternating potentials on the plates, then "capacity currents" will flow between *A* and *B* and between *A* and *B* separately to earth due to the production of what are called "displacements" in the dielectric medium (in this case air) in which the plates are buried.

The capacities of Fig. 1 can be represented diagrammatically as in Fig. 2 where

(x) = true mutual capacity between *A* and *B*.

(y) = true mutual capacity between *A* and earth.

(z) = true mutual capacity between *B* and earth.

Now the capacity between any two conductors depends upon the distance between them; in the case of a parallel plate condenser, it varies inversely as the distance.

It will be at once evident that y and z will vary accordingly as *A* and *B* are moved nearer to or farther away from "earth" and by "earth" is meant any conducting bodies near the plates.

The effective capacity of the plates between the terminals *A*, *B*, for any given values of y and z is

$$\left(x + \frac{yz}{y+z}\right)$$

as y and z are in series themselves and in parallel with x. Thus an unshielded condenser, tested for effective capacity between terminals, has a calibration which is largely indeterminate, as the effective capacity is a function of the position of the instrument relative to "earth."*

It is for this reason that a tuned circuit can be thrown out of resonance merely by bringing the hand near the condenser when unshielded.

The screen serves the purpose of making the capacities y and z in Fig. 1 definite and independent of position, as the screen, if not specially insulated, actually forms part of the "earth."

Let us now examine the three true internal mutual capacities of a condenser. In Fig. 3 let

(A) be capacity between moving plates and fixed plates;

(B) be capacity between moving plates and screen;

(C) be capacity between fixed plates and screen.

It will be evident that A and, to some extent, B and C will depend directly on the setting; B will have a maximum value at the minimum setting of the instrument and will decrease as the moving plates are turned into the fixed ones which shield them, to some extent, from the screen.

C will be nearly constant, provided the moving system revolves entirely within the fixed bank. Some condensers, however, have two extra moving plates fitted, which enable both sides of the two end plates of the fixed set to be utilised. The moving system will then tend to shield the fixed

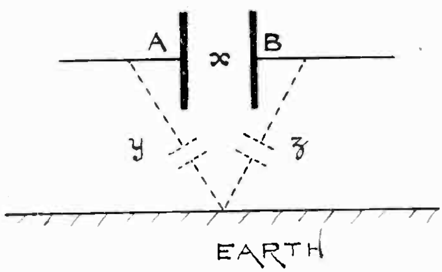


Fig. 2.

plates. In this case B will be practically constant, while C must diminish as the setting increases.

Manufacturers who fit screens to their instruments often engrave them with such statement as the following :—

(i.) "Calibrated with screen connected to moving system."

(ii.) "Calibrated with screen connected to fixed system."

(iii.) "Calibrated with screen earthed" (*i.e.*, not connected to either system).

Let us now consider to what extent these conditions are independent of position and applied voltage.

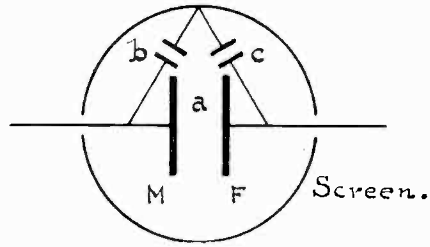


Fig. 3.

In case (i.) capacity b disappears as it is short-circuited and the effective capacity

$$C_i = a + c$$

Case (ii.) is identical, except that c is eliminated and the effective capacity

$$C_{ii} = a + b.$$

Either value is a constant of the instrument and is independent of position and applied voltage, the more usual condition being represented by case (i.).

Case (iii.), however, is capable of two interpretations for a given setting.

(p) The mutual capacity $C_p = a$

(q) The quantity $C_q = a + \dfrac{bc}{b+c}$

b and c being themselves in series and in parallel with a. Experience shows that the effective capacity given by C_q is the one usually implied.

As has been shown by Mr. Hartshorn (*Journ. Sci. Instruments*, Vol. 1, No. 10, July, 1924, it will suffice to state the result here) the value C_q is a constant only when the current flowing into one bank of plates is exactly equal to that flowing out of the other set. This implies an additional condition, other than the screen being earthed, viz., that the potential relation,

$$b\frac{dV_{MS}}{dt} + c\frac{dV_{SF}}{dt} = O$$

is satisfied, where V_{MS} and V_{SF} represent the simultaneous potential differences between the moving system and the screen, and the fixed system and the screen respectively. The potential condition, in practice, is rarely satisfied and the capacity thus defined becomes a variable.

If the shield is insulated and not connected to either system, the effective capacity between moving and fixed plates becomes somewhat more complicated, and, in addition to the values of the mutual capacities, depends on the potentials of all three conductors. This condition will not be considered here.

Actual Measurement of the Quantities a, b, and c.

If an alternating current bridge is set up, or a method of measuring capacity is available, then, by combinations of connections, we can obtain values for pairs of the quantities a, b, c, and hence effect a separation.

Measure

(1) Capacity between moving plates and fixed plates with screen connected to moving plates.

(2) As before, only screen connected to fixed plates.

(3) Capacity between the screen and moving and fixed plates connected together.

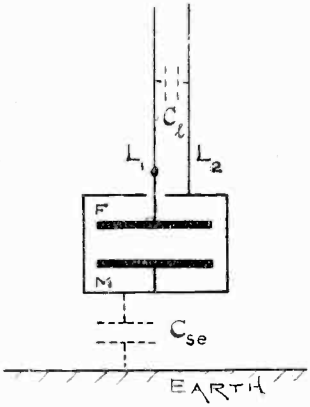


Fig. 4.

Let $(1)=C_1$, $(2)=C_2$, $(3)=C_3$

Then $C_1=a+c$

$C_2=a+b$

$C_3=b+c$

Hence

$a=\frac{1}{2}(C_1+C_2-C_3)=\frac{1}{2}(C_1+C_2+C_3)-C_3$

$b=\frac{1}{2}(C_2+C_3-C_1)=\frac{1}{2}(C_1+C_2+C_3)-C_1$

$c=\frac{1}{2}(C_1+C_3-C_2)=\frac{1}{2}(C_1+C_2+C_3)-C_2$

In the measurements, owing to the limitations of the particular method employed, it may be impossible to keep the screen "earthed" or at zero potential. On the contrary, often the best insulation possible is required, such as that provided by paraffin blocks.

Usually the condenser is connected in parallel with a calibrated variable standard or in an arm of a bridge network. Precision tests then involve readings with the instrument connected and disconnected, the difference being taken up on the standard.

As the screen is insulated, it has a capacity to earth C_{se} (Fig. 4) and therefore should be left in for both measurements, the lead to the fixed system only being disconnected. On disconnecting L_1 (Fig. 5) care should be taken not to alter the configuration of the leads L_1 and L_2 appreciably, or their mutual capacity C_l will be affected. The breaking of the connection has, however, introduced an extra capacity C_t, which is the capacity between L_1 and any unscreened part of the insulated system, such as the terminal, which must, of necessity, protrude. If C be the actual value required for the condenser, then the difference from the measurements referred to above will be actually

$$C-\frac{C.C_t}{C+C_t}.$$

Now C_t in practice is of the order of 0.2 micro-microfarads, while C may be a few hundred, thus the expression reduces to $C-C_t$, so that by a single disconnection it is not possible to measure C, whatever be its value, to a greater accuracy than that determined by C_t. C_t can be made small by having the last few cms. of the lead L_1 of fine wire and by moving it 1 to 2 cms. away from the condenser terminal on disconnection.

In high-frequency measurements, it is desirable to earth the system connected to the screen and to introduce the detector or thermo-heater into the lead on the shielded side, in order to make detector earth-capacity effects negligible. This would hold good, for example, in the case of the ordinary wavemeter circuit used for measurements of effective self-inductance, capacity, self-capacity and effective resistance. Mcullin has ably discussed the arrangement of circuits in general terms to eliminate earth- and cross-capacity effects, in *World Power*, May, 1925.

Typical Values for the Quantities Discussed.

A number of measurements was made in order that some idea of the magnitudes of the quantities discussed might be obtained.

As a screened laboratory standard variable air condenser of about 1 000 micro-microfarads is commonly found where serious measurements are undertaken, we will take this as our first example.

Case 1.—Using the notation as before, the values for three conditions of setting are given in Table I.

TABLE I.

Condenser Setting.	Frequency.	Capacity: $\mu\mu$F.		
		a	b	c
Minimum ..	1 000	27	26	30
Half scale ..	1 000	492	24	30
Maximum ..	1 000	1 002	20	30

The screen on the above instrument was square, while the plates were semi-circular. This would account for part of the variation in b.

The ordinary capacities for the cases given, (*i.e.*, $a+c$) are 57, 522 and 1 032$\mu\mu$F.

Case 2.—For these detailed experiments, a typical 500$\mu\mu$F semi-circular plate condenser was chosen.

Attempts to calibrate accurately were made as first received, *i.e.*, unshielded. The values were obtained on a capacity bridge by substitution against a well-screened vernier standard condenser "S," and results are recorded for disconnection on both the moving and fixed sides of the instrument. The effect of proximity to the screen of "S" was also investigated.

The values are given to demonstrate the uncertainty of attaining high accuracy of calibration without screens, and the absolute errors as shown above are of much the same order on a condenser of half the range. These become more important as the value diminishes. Thus, on a 200$\mu\mu$F condenser, the accuracy would probably not be greater than 2 per cent. at the maximum, up to about 30 per cent. near the minimum.

The effect the hand produced near the condenser tested was 2—3 $\mu\mu$F.

Case 3.—The instrument of Case 2 was now closely fitted with a cylindrical metallic screen and the three internal capacities separated as described in this article. The frequency was 1 000 cycles, as used throughout.

The results are given in Table 3.

TABLE II.

Condenser Setting.	Frequency.	Remarks.	Capacity: $\mu\mu$F. System Disconnected.	
			Moving.	Fixed.
Minimum	1 000	20 cms. away from shield of "S"	13.3	15.3
Maximum	,,	Ditto	519.5	521.5
Minimum	,,	Close up to shield of "S"	12.0	16.4
Maximum	,,	Ditto	517.1	521.3

TABLE III.

Condenser Setting.	Capacity: $\mu\mu$F.						
	$C_1 = a + c$	$C_2 = a + b$	$C_3 = b + c$	$\frac{1}{2}\Sigma C = \frac{1}{2}(C_1+C_2+C_3)$	$\frac{1}{2}\Sigma C - C_3 = a$	$\frac{1}{2}\Sigma C - C_1 = b$	$\frac{1}{2}\Sigma C - C_2 = c$
Minimum	29.2	42.8	46.7	59.4	12.7	30.2	16.6
Maximum ..	535.2	547.7	45.4	564.4	519.0	29.2	16.7

The values are representative of the usual wireless condenser fitted with a screen and range 500$\mu\mu$F. The constant c is seen to check to 0.1 $\mu\mu$F while b diminishes slightly as the moving plates are turned into the fixed ones. It is anticipated that b and c will not vary greatly with the various sizes of condensers on the market, should they be fitted with screens.

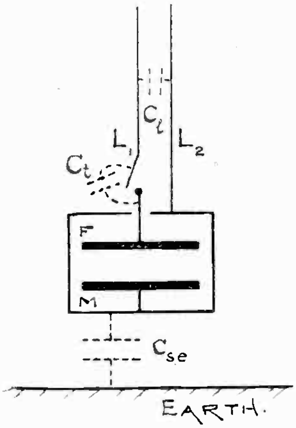


Fig. 5.

The one and only apparent disadvantage of the screen is its effect in increasing the minimum value. As the screen fitted for the measurements of Case 3 was a good fit on the body of the instrument, but, of course, insulated from it, the increase in the minimum value—about 15$\mu\mu$F—due to calibrating with the moving plates connected to screen, probably represents about the maximum increase likely to be met with for this size of condenser. It is anticipated that the increment would decrease only very slightly for a 250$\mu\mu$F condenser, and *vice versa* for one of, say, 1 000$\mu\mu$F value.

It must be realised that no screening is absolutely perfect, but the uncertainty can be made negligibly small by careful attention to detail, and by allowing to protrude outside of the screen no more than is absolutely necessary of that system not connected to it.

For this reason, amongst others, the fixed system is usually insulated on account of the difficulty of screening the bearing and spindle. The insulation of the latter also presents difficulty, and if carried out efficiently, puts up the manufacturing cost of the instrument.

It is urged therefore that condensers should be provided with screens to avoid outside disturbing influences and stray electrostatic couplings, and to make the capacity calibration independent of position and potential by connecting one system to the shield or screen, and calibrating under this condition. The point raised as to single disconnection on the insulated side should also be borne in mind whether the screen is earthed or insulated.

In conclusion, it is hoped that what has been written will help those desiring accuracy and refinement to attain their object, at any rate so far as the condenser is concerned.

MICA:

A Lecture to the Radio Society of Great Britain.

By P. R. Coursey, B.Sc. [R281·38

[*We regret that owing to the large number of slides used by Mr. Coursey—there were over 70—it has been impossible to reproduce more than a small representative selection.*]

An ordinary meeting was held at the Institution of Electrical Engineers on Wednesday, 28th October, Brig.-Gen. Sir H. C. Holden presiding.

The minutes of the previous meeting were taken as read and confirmed.

The Chairman: The lecture to-night is by Mr. Coursey, who hardly requires any introduction, seeing that he is our Hon. Secretary. He is going to tell us all about mica, and I am sure his lecture will be most interesting.

Mr. Coursey: Not only for radio purposes but for many general electrical uses as well, mica is an extremely important material. It may indeed be said that to-day every unit of electrical energy that is used has involved the employment of mica in one form or another in its generation and distribution. It is equally true to say that very many modern applications and developments of radio communication are just as dependent upon this material. If mica had never been discovered it is probable that other materials would have been used in its place, but its great superiority over many other electrical insulating materials for certain purposes, has led to its very extended use. Mica and micanite are both used in the insulation of electrical machinery generally and mica is used in radio work as a dielectric in electrical condensers.

The subject is one obviously which is not radio in the sense in which one may describe many of the lectures which are given before this Society. Nevertheless I hope that some of the slides which I have to show you—because my lecture will consist mostly of slides and telling you a few things about them—may be of some interest as illustrating some of the things which are used in commercial apparatus and the ways in which these materials are produced.

Mica is a very general name covering many different varieties of material. Primarily the name is typical of compounds consisting mainly of aluminium silicate, which may be combined with various other materials in varying proportions. There are in general two main classes or groups of mica, one which may be referred to as alkali micas, and the other, those containing magnesium or ferro-magnesian compounds in addition to the aluminium silicate base. The mineral Muscovite may be cited as representative of the alkaline class, whilst Biotite is representative of the second group, or ferro-magnesian class.

In the first group are contained most of the clear and lighter coloured micas which are of the most commercial use and have the greatest electrical utility. The second class contains the brown and dark coloured micas.

The commercial sources of mica are mainly India, the U.S.A. and Brazil. Some comes from Canada and Africa, but for many purposes the Indian mica is the only one which is of particular value. The Indian mica is practically all of the Muscovite class, *i.e.*, the alkaline mica and contains an alkaline base, such as potassium or sodium, in addition to aluminium. In India generally the micas, which come from the neighbourhood of Bengal, are mostly ruby in colour, whilst those from the Madras region are of a greenish colour. The term Muscovite has some connection, I believe, with windows, because at one time there was a trade in this material for window panes and for portholes of Russian men-of-war. It consequently was called Muscovy glass.

In the old days, I mean 50 years ago, mica was produced in a very primitive manner as compared with modern mining methods. The methods then employed involved only very shallow working, practically only scratching the surface where the material might be found on or near the surface. These methods have been greatly improved upon in modern times, and the history of mica mining in India has gone through several stages. As I indicated just now, the Indian mica is one of those which has particular importance for many electrical purposes, and the slides I am going to show you are concerned mostly with the production of Indian mica.

It may perhaps interest some of you to have the formula for this material. Its composition is somewhat indefinite and the different classes of mica differ very considerably in composition. The general type of formula, however is :—

$$H_2KAl_3(SiO_4)_3$$

That is typical of the constitution of the alkaline class. Another alkali mica has potassium replaced by sodium :—

$$H_2N_aAl_3(SiO_4)_3.$$

The ferro-magnesian or magnesian micas have a very complex structure. Some of them are dark in colour, but there is still some alkali element in the constitution of the material. A general formula is :—

$$(HK_2)_2(MgFe)_2(AlFe_2)_2(SiO_4)_3.$$

That material is obviously rather complex and it is not a simple salt.

Another one of the same class may be written as follows :—

$$[HK(M_gF_e)]_3M_{g3}Al(SiO_4)_3$$

The chemical analysis of the different classes shows up the difference between the compositions. Taking Muscovite as representing one class and a representative of the darker mica for the second, the silica content is practically 48 per cent. in Muscovite and 43 per cent. in the dark mica; aluminia is 30 per cent. and 19 per cent. respectively; ferric oxide is 2½ per cent. and 17½ per cent. respectively; lime is 0.9 per cent. and 1.8 per cent. respectively; whilst the potassium is 10 per cent. and 8 per cent. respectively. The main difference is in the iron content which is 17 per cent. in the dark mica as against 2½ per cent. in the Muscovite. The other materials, lime, potassium, sodium, etc., are in similar proportions. Typical analyses are set out in the following table:

	Muscovite.	Dark Mica.
Silica (SiO_2)	47·95	43·42
Alumina (Al_2O_3) ..	30·26	19·00
Ferric Oxide ($F_{e2}O_3$)	2·43	17·64
Ferrous Oxide (F_eO)	3·10	—
Magnesia (M_gO) ..	0·94	0·54
Lime (C_aO)	0·98	1·81
Sodium Oxide ($N_{a2}O$)	2·00	3·66
Potassium Oxide(K_2O)	10·19	8·77
Water	1·13	4·30

Mica is a crystal; probably many of you have seen pieces of mica in its raw state at one time or another, and there are a few samples here to-night to illustrate the different appearances which this material may have. It crystallises in what is known as the monoclinic system, but its crystal form is not perfect. The chief characteristic of mica from the crystalline point of view is its perfect basal cleavage over large planes. The pieces of mica which are shown here can all be split down into many layers, and out of the larger pieces of mica, as it occurs in nature, it is easy to pull off flakes, whilst if a suitable knife is used to part the flakes it is possible to separate them into very thin laminæ. Some of these are less than 1/1 000 inch in thickness, although obviously the thinner the laminæ the greater the difficulty in splitting a clear lamina without fracture.

The different micas have very different colours and by holding them in front of the lamp it is possible to see how different the colouring is. People often wonder why a mica is called ruby mica, because in thin layers it is difficult to appreciate that it is ruby, but if a piece of the original thick mica is placed in front of the lamp it may be seen that it is obviously ruby in colour, although the thin flakes seem clear, with, if anything, a brownish tinge. Some mica has a greenish colour, but it is the clear and the ruby mica which has the greatest commercial importance for radio purposes, and for insulation material for high frequency work or for fitting into condensers. Sometimes one finds mica which is stained with a number of red and black spots all over the material. These specks are of different composition, being very frequently iron or iron oxide, and from an electrical point of view such mica has great disadvantages.

Most of the commercial use of mica involves comparatively small pieces and the larger pieces of mica are much more rare. Pieces several feet across are not nearly so common as the smaller pieces, although pieces up to several feet across do occur. Mr. Elwell has kindly brought for me, a very thin lamina of mica about 1 ft. across, which gives an idea of the size it is possible to split mica into, this piece being about 1/1 000 in. thick. The extraordinary strength of these crystalline cleavages is rather remarkable, considering that it is possible to split off laminae like that without breaking.

The cost nowadays is rather prohibitive for the large sizes of mica sheet, the price per unit weight going up very rapidly as the size increases.

In India mica mining has gone through three main stages. About 50 years ago the mica field property was rented to a few people who paid rent direct to the Government and, as I said just now, the mica was mined mostly on the surface and in very shallow workings. That work was very haphazard. People got the mica when they wanted it and there was no particular supervision of the work or any particular control of how it was carried out.

In the second period the Indian Government auctioned the existing mines at a rental per year, so that each man tried to get out as much mica as he could in that time, and did not care about the property so long as he got out the maximum amount of mica possible.

The result was that the mining was done very hurriedly, no particular care being taken to prepare plans of the mine workings or to strengthen the workings structurally to prevent their collapse. Consequently the mines rapidly went to ruin under that treatment and, furthermore, no records were kept as to where mica had been dug out. The result is that to-day some of the old workings are come across accidentally because their positions were not known.

There is no indication very often on the surface or even below ground of the position of the mica veins. Very frequently searches go on underground for quite a long time to discover the veins, but without any success. An instance of this occurred in connection with a mine called the Bent Mica Mine. It was a disused mine and the exact locality of the underground workings had been lost. The mine was re-opened by new shafts which had been sunk vertically on the modern method.

Two of these shafts were sunk 300 feet deep and modern pumping plant was put in. The search went on underground for about 2½ years before the mica vein which was known to exist in that locality was rediscovered.

In these old workings very primitive methods of mining were sometimes carried on. There was no adequate machinery for lifting the debris, water, etc., from the mine, and it was customary to arrange rows of ladders and get lines of women and children to pass trays of the debris, water, broken rock, mud, etc., from the underground workings up to the service. These women and children were in two lines passing the trays up one way and down the other and as many as 300 people had been employed in chains of ladders in this way, a very laborious and obviously very primitive process, and not conducive to rapid production.

Illustrating the primitive method (described above) by which the debris, etc., was removed from the mica mines of India.

The third and modern period of mica mining development in India is the one in which vertical shafts with machinery, frequently with electric light as well, is adopted, the result of this much more scientific mining, of course, being very greatly increased production.

Mica mines in India now are usually partitioned up by the Government into definite regular squares, separated by clearings to divide the squares which are approximately 40 acres each in extent. The clearings may be about 20 ft. wide and the lines are laid out in a chess board pattern north, south, east and west. Some of these clearings are practically roads through the jungle.

Hand-drilling in a mica mine.

Showing the curious shapes of the mica as it is brought from the mine.

Many of the new mines have electric light throughout and where electricity is available it is used for hauling, pumping, etc. In others steam haulage is used with candles as the illuminant below ground. Some of these modern mines extend a distance of 500 ft. below ground level.

One illustration shows the method of drilling the rock face and blasting it out with dynamite. The hand method is found much more practical than machine drilling and the reason apparently is, that the natives get used to the feel of what the drill is going into and they can feel when they are getting contact with the mica, and so can prevent going through the mica crystals which a mechanically driven drill would not be able to detect. Therefore, the hand method is largely in use and is found much more successful than machine drills.

The rough mica got out below ground is hauled to the surface and tied up into bundles for storing and subsequent treatment.

The material is very dirty and the method of cleaning it is by cutting the edges of it with a peculiarly shaped sort of sickle knife with which the edges are trimmed and the bits of dirt, stone and other foreign material is removed. That accounts for the extraordinary shapes of the rough mica pieces when they come over here.

The rough block mica reaches us mostly in roughly shaped pieces a few inches in dimensions, and being usually something less than $\frac{1}{4}$ in. in thickness. These roughly shaped pieces are then sorted out to size and graded into different qualities, because the different sizes and grades obviously fetch varying prices in the London market. Finally it is packed in boxes ready for despatch to the railway for conveyance to London.

The lecture concluded with a long series of slides illustrating a tour through a Bengal mica mining area, together with pictures of work being carried on with mica for building condensers in the Dubilier Condenser Company's factory.

The Discussion.

The CHAIRMAN: It is now my pleasant duty to call upon somebody to open the discussion. I quite appreciate that the subject Mr. Coursey has dealt with, and the manner in which he has dealt with it, does not lend itself very much to discussion. That is unfortunate, but no doubt some members of the audience will like to ask some questions even if we do not have a regular discussion. (After a pause.) It appears rather that the audience is a little bit afraid of asking any questions, but there are one or two which I should like to ask. The first is, to what extent does the electrical conductivity of mica mined in one mine vary from that mined in another? It is affected very much, I believe, by iron.

Mr. COURSEY: Yes, that spoils it for many electrical purposes.

The CHAIRMAN: Do you get good and bad samples from the same mine, so that you get from the same mine, mica which can and mica which cannot be used for condensers?

Mr. COURSEY: Yes, there is an enormous variation in the quality of mica obtained from the same spot in a mine.

The CHAIRMAN: There is another question which is more curiosity than anything else. What is the thinnest sheet of mica that can be obtained? You spoke of 1 oooth inch, but can it be split to a thinner sheet than that?

Mr. COURSEY: It can be split thinner than that, but I am not sure of the limit. The crystalline structure permits of almost indefinite cleavage, but the difficulty is mechanical more than anything else.

The CHAIRMAN: How do they manage to split it? I take it that it has to be split within limits and that therefore it requires a good deal of skill and, I take it, a certain amount of measurement afterwards.

Mr. COURSEY: It requires measurement afterwards and it certainly requires skill in splitting. It is easy enough to split pieces off, but it is not easy to split off flakes of a given thickness. That only comes by experience in that particular work and some people can do what others cannot. It is mostly a matter of skill in handling the knife to make the first incision. When it is used for building condensers, it all has to be measured afterwards and sorted into different thicknesses. I do not profess to be a geologist or a chemist and so cannot tell you very much more about the structure of material.

Mr. FOGARTY: I am sure you will all endorse me when I say that we owe a very hearty vote of thanks to Mr. Coursey for his very interesting lecture. As he says, it does not perhaps seem directly applicable to radio, but, after all, as the Chairman has said, mica is of very great importance and, in fact, in radio we would be very badly off without it. My own recollection goes back to the time when mica condensers of various qualities were not available and in those days we had to use glass or metal plates strung up in air and, as you know, mica condensers were not made in anything like large quantities nor were they very satisfactory until the whole art of applying mica to condenser manufacture was studied by Dubilier, who was one of the principal workers in that direction. Therefore we really do depend upon mica very largely, not only in radio but in the electrical engineering industry generally. There is one particular point upon which I should like a little information, if Mr. Coursey can give it to me, and that is this. If one takes a sheet of mica and brings two metal surfaces in contact with it on either side, one obtains a condenser of a certain capacity, but the capacity seems to change, not altogether proportionately, but it can be changed by pressing the two metal plates into contact with the mica up to a certain point. It seems that the capacity can be varied in that way. Another point is that if you take a piece of mica and lay two pieces of tin-foil against it, you do not seem to get a maximum effect. In other words, the capacity is smaller, but if you moisten the surfaces of the metal with shellac varnish or some other varnish, and then put them in contact with the mica, you get a very efficient condenser; you get a larger capacity. Can Mr. Coursey tell us why that is? I now ask you to give Mr. Coursey a very hearty vote of thanks.

Mr. REEVES: I have great pleasure in seconding the proposal. I am sure we have all listened with very great pleasure to the lecture.

The vote of thanks was given with acclamation.

Mr. COURSEY: I thank you very much for the kind way in which you have received the lecture. With regard to Mr. Fogarty's query, when a sheet of mica is placed between two metal plates, there is a layer of air between the metal and the mica, and air has a dielectric constant of 1, whereas mica has a dielectric constant of about 8. Therefore, obviously, as you reduce the amount of air by pressure, the effective dielectric constant of the mixture rises from something in the neighbourhood of 1 when the mica is direct from the metal, to something in the neighbourhood of 8 when they are closely touching. When the metal is moistened, the air is replaced by something else having a higher dielectric constant. Obviously the resultant dielectric constant and the capacity rise. I think that is really what happens when the mica is stuck on with shellac.

The CHAIRMAN announced the election of 7 new members.

Precision work at Messrs. Dubilier's factory—measuring the thickness of small sheets.

Long-Distance Work.

By Hugh N. Ryan (5BV). **[R545·009·2**

WE have now arrived at the time of the year which we have come to regard as the beginning of the real DX season. This year, however, the work has gone on so well during the summer that the winter will have to produce some very startling results indeed if it is to retain its accustomed place in the experimenter's calendar. Indeed, such results as have been obtained so far would seem to suggest that summer conditions are actually better than those of winter for the wave-lengths now in general use. However, one remembers that in previous years very good winters have sometimes been immediately preceded by brief spells of bad conditions, and history may repeat itself this year.

This seasonal variation of DX conditions is closely related to the general question of the connection between weather and range of signals, which question is at present occupying the attention of quite a number of experimenters. The summer did not provide a very wide range of weather this year, and so the greater changes which occur about this time of the year should provide those interested with some very useful data supplementary to that which they obtained during the summer, and (perhaps) checking up with any theories which they may have evolved from their earlier observations. At all events, those working on this subject should, by the middle of December, have had time to collect fairly complete data, and so I propose to give, in the next report, a summary of all observations reported to me, together with any theories the observers have deduced from them. I already have quite a number of such reports, and I hope everyone concerned will let me have any results they care to publish in time for next month's issue.

It would be interesting to know whether anybody has been making systematic observations upon the distribution of intelligible telephony upon 20- and 40-metre waves. Even when telephony from a given station is always audible at another given station, its intelligibility always varies greatly at different times of the day, and also the telephony of any station varies with the distance of the listening station. A station may sound like slightly mushy sustained C.W. at ranges up to 50 miles, be inaudible up to a thousand miles or so, and produce perfect, undistorted telephony at the Antipodes. Ten minutes later the same station's phone may be perfect at short ranges and sound like 25-cycle A.C. C.W. at 12 000 miles. The phenomena experienced are altogether too involved to be explained by guesswork (though I have heard some pretty wild guesses), but systematic observations might be interpreted into a solution.

In connection with observations at various distances, it is, I think, to be deplored that so little work is now done with the nearer countries. It is something of an anomaly that we can work daily with the ends of the earth, but cannot at all readily work with other stations in Europe—not because we are unable to do so, but because we have got into the habit of not listening for any station less than a few thousand miles away, and not answering one under about six thousand. Working over great distances may be more exciting, but we have had time to get over the excitement now, and we shall not solve the many problems of short waves by collecting all our data at one end of the scale and ignoring the other. Let us get QSO Europe again, and meet again the men we used to enjoy working a few years ago. It will probably not be so very easy, and will, I think, provide more interest than the routine daily working of A's and Z's exclusively. After all, the A's and Z's work each other, so do the U's and the Continental stations, but how often do we?

Britain is at last in touch with Western America, which has hitherto been out of our range for two-way work. We are still far from being in regular touch with that part of the world, but G2SZ has worked U6VC and U6CTO. FB,OM! 2SZ has also got phone through to the States, Australia, New Zealand and India.

5BV has been "off the air" all the month.

6YK has now come down to 45 metres, with slightly greater power, and has worked all Europe on this wave, both by day and night, but finds the daylight work easier.

Mr. Guy, of Pinner, has been doing some more good work with the receiver this month, his log including twenty-three A's and Z's. In common with many others engaged in intensive reception, he reports that calls heard in the mornings are steadily decreasing, and those heard in the evening increasing.

6VP, after several months of very good work on the longer waves, has now started up on 45 metres. Results in daylight are greatly improved by the change, but no results at all have been obtained at night. He wants to know whether low-power short-wave signals get anywhere at all at night. (So do lots of us, OM! They certainly don't seem to.)

Mr. Erith, of Sutton, is continuing his very methodical observations on signal strength and weather conditions, and there will be more about his results in next month's summary. He has a fine bag of South Americans this month.

Stations in the Eastern Counties would appear to have passed a less active month than usual, 2LZ and 5QV having done most of the work, both being QSO most of the world, while 2TO has added Russia to his list of countries worked.

2AO has recently worked several Australians in the evenings. It seems certain that our signals now get to Australia better in the evenings than in the mornings, while the number of A's reported here in the evenings increases steadily.

5AX has been doing little transmitting, but quite a lot of receiving. His log this month includes an American "six" and "seven" and a Canadian "four." 2KK also has a good log of distant stations received during the month.

2NB has worked BER, a station in Bermuda being the first British station to work this country. Besides this work on the 40-metre band, 2NB is transmitting on 9.2 metres every Thursday at 23.30 G.M.T. and every Sunday at 11.00 G.M.T., and would be glad of reports.

A damaged hand has kept 5MO off the air, but the cessation of transmitting has given him plenty of time for receiving, though under difficult operating conditions. His most interesting log entries are three new South Africans, OA3E, OA4L, and OA4V, in addition to our old friend OA4Z. (By the way, the South African call-signs were misprinted last month. O4F and O4Z should, of course, have been OA4F and OA4Z). 5MO also reports a good number of Argentines.

5NJ (near Belfast) has now got a generator working, and has been QSO several Australians, all of whom report strong signals. I have had no reports from either Scotland or Wales this month.

Before going on to foreign work, I should like to mention the visitors at present with us in London—NPCTT and NOAW (respectively president and traffic manager of the Dutch section of the I.A.R.U.) and A2BJ. We extend to them a "Ham welcome."

The Spanish stations are now going well ahead with DX. EAR1 has been heard in Australia with 90 watts. EAR2 is just returning to the work after having been inactive all the summer, and will soon be going with considerable power. EAR9 is working the United States nightly with 90 watts. EAR10, on 80 metres, has reached Paris with 30-watt phone. EAR22 has started working Americans with 50 watts.

A number of Swedish stations are now QSO Australia and New Zealand, with really small power. SMTN is in regular communication with Australia with 18 watts and has worked with only 3 watts. SMWF and SMXU often work New Zealand. SMZS's owner has practically given up DX chasing, and is working on signal strength measurement, but his second operator is still working the station.

Most of the Italian stations are now on about 40 metres. I1ER has led most of the DX work, and was the first Italian to work New Zealand. His signals are also reported to be the best heard in America. I1MT, I1NO, I1RG and I1AF have worked New Zealand, while I1AS has worked 17 Z's with only 15 watts input.

I hope to have more foreign reports next month. I thank those foreign amateurs who have sent me reports, and would be glad to have news from France and Belgium.

Please let me have all reports by the 10th of each month.

Rectifiers for High-Tension Supply.

By R. Mines, B.Sc. [R355 5

Addition to Part IV.

Arc Rectification at Atmospheric Pressure.*

Dunoyer and Toulon† state that "polarisation" of the arc is more easily obtained when it is long, for then the metal anode, which must be relatively cool, is further removed from the hot cathode. They succeeded in obtaining stable rectification by using an auxiliary "maintenance" arc, running on D.C. between carbon electrodes, the rectifying arc playing between the cathode of the maintenance arc and a water-cooled anode lowered into the flame of the arc after it had been struck.

The maintenance arc was also successfully run on A.C.; with this arrangement multiple anodes were tried. Four water-cooled copper tubes arranged symmetrically around the auxiliary arc (whose axis was vertical) were connected in cyclic order to the four-phase secondary of a transformer (or a two-phase one with mid-point tappings): the rectified output was drawn from the star point (negative) and the auxiliary arc circuit (positive). Trouble was experienced from shorting between adjacent anodes, through the conducting vapour of the arc.

* E.W. & W.E., Vol 2, p. 899, Nov., 1925.
† *Journ. de Physique*, Vol. 3, p. 389, Nov., 1922.

Part V—Vacuum Discharge Rectifiers.

I.—Effect of Rarefying the Gas.

OUR preceding articles have described how a gas and atmospheric pressure is capable of conducting electricity, and how this conduction can be utilised for rectification purposes with suitable arrangements. Nevertheless, the conductive condition cannot be established without the application of a high electric stress, and this is a distinct disadvantage, because in the case of a rectifier this means a high drop of potential in the rectifier in the conductive direction, involving a loss of power large in proportion.

It has been shown also that, according to the Kinetic Theory of Gases, every molecule is in motion, moving a certain distance, colliding with another, rebounding and moving away, colliding again, and so on. It is possible to determine the average distance travelled between collisions (averaged over the motion of any molecule and averaged for all the molecules); it is called the "Mean Free Path" of the molecule. By similar argument, when an ion is moving along a potential gradient, the average distance it travels between successive collisions is called its mean free path. The value of this quantity is dependent upon the nature of the molecule (kind of matter) or the nature of the ion; and upon the physical state of the gas (its pressure and temperature).

It would appear obvious from these considerations (and it is, in fact, borne out by experiment) that one may exert a certain amount of control over the mean free path. Thus if the pressure of the gas is reduced, its density becomes less, there are fewer molecules present in unit volume, and the mean free path is increased.

There is also a secondary effect which is nevertheless important—at normal pressures electrons tend to collect around themselves neutral molecules (actually these condense on the electrons as nuclei), and only under the influence of high temperature or of high electric stress do they become freed from this burden and show their inherent mobility; whereas, under reduced pressure, the negative ions are usually free electrons, remaining so even in weak electric fields.

II.—The "Geissler" Discharges.

These two factors wreak a profound change in the manner in which a gas will conduct electricity. Thus the first reduction of pressure of the air in which a spark discharge is taking place causes a drop in the

P.D. required to pass the spark ; also the spark becomes quieter and is soon replaced by sinuous streamers, showing that the conduction is approaching nearer to a condition of regularity.

When the pressure has passed about 1/100 of its original value the air is highly conducting ; the preceding visible discharge has disappeared but there is an intense glow of light over each electrode, indicating the regions where ionisation is taking place. Townsend calls this the "first type" of Geissler Discharge.

With further decreasing pressure, these glows expand and take on beautiful forms and colours, depending on the shape and disposition of the electrodes, and also on the gases present. These succeeding forms of the vacuum glow discharge do not help our present subject, so the reader is referred to the text-books for detailed descriptions of them. We shall have occasion, however, in a later section to describe the "fourth type" and the conduction mechanism underlying it, and the "cathode ray" discharge.

III.—The Neon Tube Rectifier.

It has been found that when only a small current is passed through the discharge tube (the gas pressure being appropriate to the first type of discharge) the glow on the cathode may cover only a portion of its surface ; under this condition, the fall of potential near the cathode is approximately constant, not dependent upon the current flowing. But as soon as the electrode is wholly enveloped, the potential fall increases with increase of current. These phenomena do not take place to the same extent at the anode ; hence it is possible to produce an asymmetric conductor, or rectifier, by making the two electrodes of unequal areas.

Then if an alternating P.D. is applied to such an apparatus, and its value chosen appropriately, the discharge may be adjusted to the condition of "constant cathode fall" with the larger electrode as cathode, while in the reverse direction the cathode fall (taking place at the smaller electrode) becomes greater due to the higher current density at its surface. The result is that the current wave flowing through the device is not symmetrical—partial rectification is obtained. The "rectification ratio" (defined as the ratio of the mean currents flowing during the two half-cycles) is of the same order as the ratio of the electrode areas.

It is to be noted that if too small an alternating P.D. is used, or too little current drawn from the output terminals when the device is used in a rectifying circuit, the discharge may assume the "constant cathode fall" condition in both directions. In this event there will be no asymmetry in the conductance of the tube and hence no rectification. Similarly, if the apparatus is loaded excessively, the current density will rise above this condition at both the electrodes ; the discharge will again tend to become symmetrical and the "rectification ratio" to approach unity.

The "Osglim" type of Neon lamp lends itself moderately well to use in this manner due to the disparity of size of its electrodes ; but a more practical form for the apparatus is a tubular glass bulb, containing a metal cylinder and a concentric metal rod of small diameter as the electrodes (see Fig. 1). The bulb is exhausted and then filled with Neon to a pressure a little over 1/100 of an atmosphere—Neon being chosen because it "conducts" more easily than other gases ; by this is meant that the P.D. at which conduction commences is much lower.

IV.—Properties of the Neon Rectifier.

The first point to notice about the glow discharge in such a rectifier is that the conduction will not take place until the applied P.D. rises above a certain value, called the "striking P.D." and similarly when the P.D. falls below approximately the same value (usually a little lower than the striking point) the glow extinguishes itself. The value attained in the modern Neon tube lies between 140 and 170 volts.

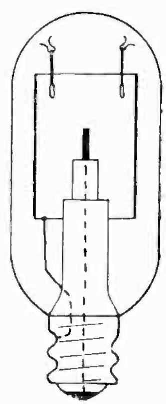


Fig. 1.
Neon rectifier tube.

Another feature of the Neon tube is its "flat" characteristic, rendering it unstable to almost the same extent as the spark and arc discharges, which have negative characteristics. Hence, unless the circuits in which the tube is used contain means for limiting the current (the load receiving the rectified current will sometimes act thus), it is necessary to connect in series with it a stabilising resistance. (The value of this is a few thousand ohms for a small Neon lamp connected direct to the mains—it is wound in the lamp cap—but need not be so high for rectifier tubes which carry much heavier currents.)

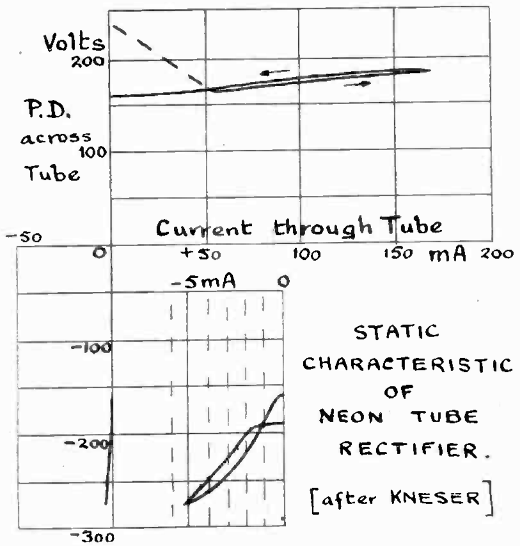


Fig. 2.

The P.D.-current characteristics of a typical rectifying tube (containing a mixture of helium and neon) are shown in Figs. 2 and 3. From the latter is will be seen that when the alternating P.D. only just passes the striking point, the valve action is reversed in direction—this is a condition which it is important to avoid when a reservoir condenser is used on the D.C. output.

Thus, unless a stabilising resistance is used which is absurdly high, the potential drop in the rectifier will not rise much above the striking value, and it is this drop which determines the power lost in the rectifier. We see immediately that there is an immense difference in this respect between the vacuum type of rectifier and the atmospheric types that we have previously described.

Fig. 4, which is reproduced from an oscillogram given by Kneser* shows the waveform of the current flowing through a rectifier of this type into a non-reactive load. It will be noticed that in this case there is no back E.M.F. in the circuit receiving the rectified power; for, when no current is flowing, the whole of the supply P.D. comes across the rectifier, and it is when this attains the striking point that the current suddenly commences, ceasing again when the P.D. falls past the extinction point. These conditions hold for both half-cycles of the wave; but the degree of inequality between the positive and the negative current pulses show a very satisfactory rectification ratio.

V.—Effect of a Steady Back E.M.F.

It is agreed that the wireless experimenter requires essentially a steady high tension on his apparatus; it is important to consider the effect of supplying this with a vacuum discharge rectifier, such as the Neon tube described above. The high-tension power has to be pumped against a steady back E.M.F., and the effect of this condition on the P.D. and current waves is shown in Fig. 5. It will be seen that no current can flow in the positive direction until the alternative P.D. supplied to the apparatus reaches a value $E + e$, where e is the steady

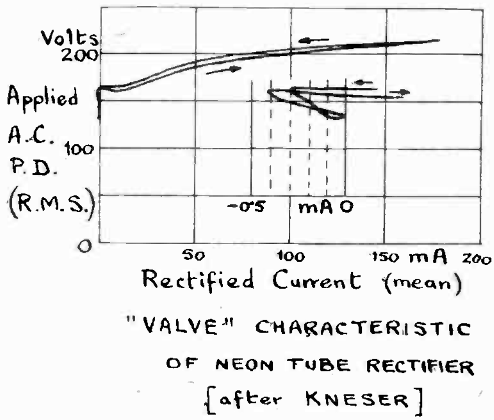


Fig. 3.

back E.M.F., and e is the striking P.D. of the rectifier tube; because it is not till then that the potential drop across the rectifier becomes equal to the striking P.D. The immediate effect of this is a considerable reduction in the duration of the pulse of positive current. Conversely, the glow discharge becomes established whenever the supply P.D. falls below (algebraically) the value $E - e$. Evidently then e should be less in value than E (as it should be if the

* *Ann. der Physik*, Vol. 72, p. 519, Nov., 1923.

proportion of power lost in the rectifier is to be kept reasonably small) which means that the inverse current will be flowing for more than half of the cycle.

Thus, even should there be no increase in the maximum value of the inverse current as a result of the high peak of reverse P.D. applied to the rectifier, the quantity of electricity passed during the inverse pulse is considerably increased. A point is soon reached, in fact, where it becomes equal to the positive pulse of electricity, and here

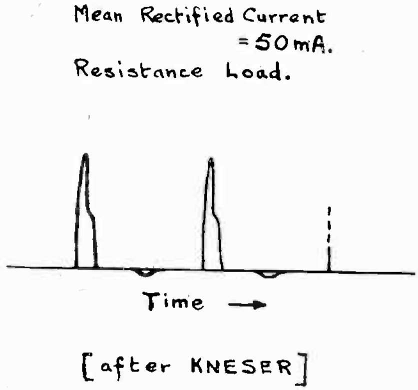


Fig. 4. *Oscillogram showing current wave through Neon rectifier.*

obviously all rectification effect ceases. Beyond this point the D.C. circuit would begin pumping power into the A.C. circuit, should it be capable of so doing !

The importance of using perfect rectifiers for wireless work is apparent.

VI.—Limitations of the Glow Discharge Rectifier.

It has been stated that, with the type of discharge tube described above, the ratio of the maximum currents passed in the two directions is of the same order as the ratio of the surface areas of the electrodes. There are obvious limits to the magnitude of this ratio obtainable, imposed not only by constructional considerations but also by heating ; for if the small electrode is made too small, the surface density of the energy dissipation due to positive ion bombardment rises too high, resulting in overheating of the electrode. In general, this will give trouble due to evolution of gas from the electrode, upsetting the discharge conditions in the rectifier; but should this difficulty be overcome by use of suitable material for and " degassing " of the electrode, care has still to be taken that its temperature shall not rise sufficiently to cause thermionic emission, for then conduction will take place when this electrode becomes negative, and with this polarity the tube is supposed to be non-conductive.

VII.—The Positive Space-Charge.

Given then that the electrodes are cold, the supply of electrons is due mainly to the bombardment of the cathode surface by positive ions, just as is the case with heavy discharges at higher gas pressures. The electrons in turn ionise the gas, thus maintaining the supply of positive ions. There are present then ions of both signs in the conducting gas ; but the negative ions being free electrons, show a very much higher mobility under an electric field, and as a result they move along the potential

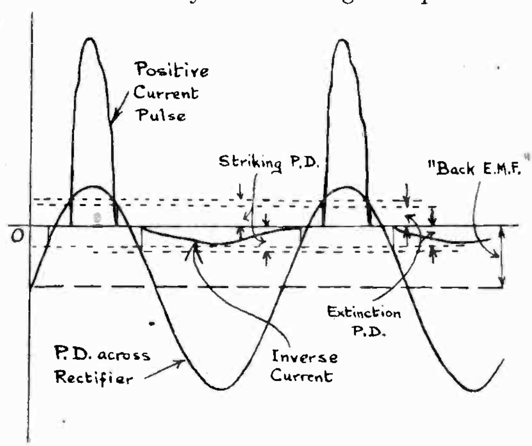


Fig. 5. *Oscillograms for a neon rectifier working against a back E.M.F.*

gradient in the discharge tube proportionately faster than the positive ions.

Hence the electrons tend to collect at the anode and become scarce at the cathode, whereas the distribution of the positive ions remains comparatively even. The resulting preponderance of positive ions constitutes a *powerful positive space charge*, and being situated in the immediate vicinity of the negative electrode, causes a high value of electric field ; the major portion of the whole potential drop between the electrodes occurs within this region.

The above conditions obtain when a steady (D.C.) P.D. is maintained between the electrodes. In the ordinary discharge tube, when an alternating P.D. is applied, the discharge conditions reverse completely for each half-cycle, at power frequencies—even the positive ions have sufficient mobility for this. At high frequencies there is not sufficient time each half-cycle for the space-charge to build up ; the conduction current becomes more a capacity current, ions moving only between adjacent regions of gas. The distribution of potential tends to remain uniform over the whole length of the discharge path.

VIII.—The " S-Tube " Rectifier.

Evidently a space-charge that reverses itself with reversal of the applied P.D. is of no use in producing asymmetrical conduction in the discharge. However, Bush and Smith* in their "S-tube" rectifier, have succeeded in making the space-charge "stay put" in one direction.

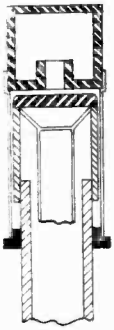


Fig. 6. *Section of "S-tube" rectifier.*

It will be seen from Fig. 6, which shows a diagrammatic section of the electrodes of this apparatus, that there is one large hollow electrode with a hole in one face, and opposite this hole and close to it a small flat electrode is placed. We shall see in a later section that the discharge *avoids* the short path between the edge of the small electrode and the edge of the hole in the other electrode, and takes place only along the long paths to the inside of the latter. Similarly, conduction between the outer faces of the electrodes is prevented by the proximity of the supporting tubes shown.

Let us consider first the application of a steady P.D. to this arrangement in such a direction that the hollow electrode is cathode and the small one anode. Then, as we have seen, a positive space-charge will build up in proximity to the active cathode surface, giving rise to the "cathode fall" of potential at this surface. The cloud of positive ions is found to occupy most of the volume inside the cathode, and therefore the whole inside surface is subject to bombardment, and the electrons emitted from it are accelerated by the cathode fall and maintain the density of the positive ion cloud by ionisation.

* *Journ. Amer. I.E.E.*, 41, 627, Sept. 1922.

So far nothing abnormal has happened. But let us start *de novo* and make the hollow electrode anode instead of cathode. This time it is the face of the small electrode that is subjected to bombardment (if any) and from which electrons are released and accelerated by the cathode fall there. Such electrons produce ionisation *inside the hollow electrode*, which is where it occurred before ! Further, with a space-charge in the hollow electrode of the same sign as the charge on it (*i.e.*, positive) there is no potential gradient in the inner space. There is therefore no tendency for positive ions to move out of the cloud, except from the very small volume next the surface of the small electrode. In addition to the reduction of ionic bombardment due to this cause, the "short path" effect already referred to, which inhibits conduction, comes into action because of the close spacing of the electrodes.

Thus there are two favourable properties possessed by this arrangement. First, in whichever direction the P.D. is applied the tendency is to produce a preponderance of positive ions inside the hollow electrode ; it is obvious, therefore, that this condition will be equally as well established with an alternating P.D. as with a steady P.D. Secondly, this condition gives rise to an asymmetric conduction ; and here it must be recalled

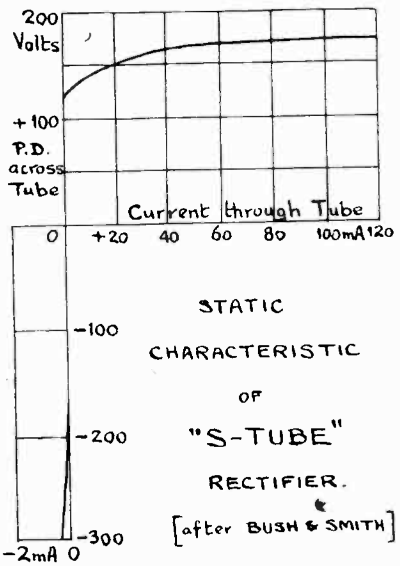


Fig. 7.

that, in addition to the inequality of the active electrode areas, there are two further factors contributing to the smallness of the current flow with the small electrode negative as compared with the current in the reverse direction; these are the small depth of the positive ion cloud available for supply of bombarding ions, and the "short-path" effect.

The "S-tube" therefore represents a big improvement on the type of glow discharge rectifier previously described. Its D.C. characteristic is shown in Fig. 7; it may be noted that the "inverse current" is of the order of 1/10 of that of the Neon tube, at moderate values of back E.M.F.

IX.—Practical Points in the "S-Tube."

It has been stated (see also Fig. 6) that by means of the small clearance between the supports of the electrodes, the discharge is prevented from creeping to any external region; first, this ensures that the rectification effect shall not be short-circuited along external long discharge paths, although the containing bulb be made considerably larger than the electrodes to allow for the safe dissipation of the heat generated in them. Secondly, the only bodies that are in contact with the discharge are conductors; this gives a steady and stable discharge; it is

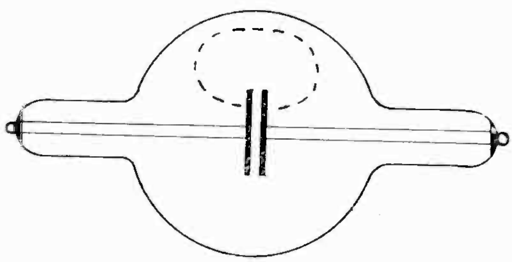


Fig. 8.
Discharge tube showing "long path" conduction.

known that the ordinary glass discharge tube is erratic in its behaviour, due to the accumulation and leakage of charges on the inner surface of the glass affecting the electric field distribution.

A further constructional feature is the use of specially prepared carbon for the electrodes; this material is found to resist disintegration under the positive ion bombardment, and as a result the "clean-up" or disappearance of the working gas that accompanies the disintegration is largely eliminated. The tube therefore maintains a correct degree of vacuum over a reasonable working life.

X.—The "Short-Path" Principle.

This effect, which has already been mentioned in connection with the "S-tube," is nothing more than the condition that the longest path available in the discharge tube for an electron to pass from one electrode to the other is shorter than its "mean free

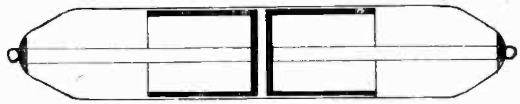


Fig. 9. *"Short path" tube, non-conducting.*

path." Under this condition, each electron, on an average, makes no collisions with any gas molecule during its complete passage; there is therefore no ionisation and no glow discharge is possible. The only conduction that can take place is the minute amount discovered by Coulomb for ordinary air, called the "dark discharge."

The effect has been demonstrated experimentally. In a discharge tube, such as that shown in Fig. 8, conduction takes place along paths similar to the one shown dotted; the glows appear on the backs and edges of the electrodes, but not on the opposed faces. On the other hand, by constructing a tube in the manner shown in Fig. 9, all lines of electrostatic force between the electrodes are made short compared with the mean free path of the electron, or else are interrupted by an isolated body capable of accumulating a charge. Such a tube will not pass as much as one microampere with a P.D. of 10 kilovolts applied to its electrodes.

XI.—Controlling the Length of the Electron Path.

One may describe the "S-tube" as an apparatus in which the length of path available for ionising electrons is controlled by *electrostatic means* (*i.e.*, by the positive ion cloud within the hollow electrode), in such a manner as to cause rectification. That electrons, being charged particles, should be susceptible to control by an electric field, has, in fact, been postulated as an essential characteristic of their behaviour in a gaseous discharge of electricity, whether under reduced pressure or not.

It is possible, however, to control the electron *electromagnetically*, or rather, their *motion* may be controlled by such means. For an electron in motion is a moving charge of electricity, and so constitutes an *electric current* : in fact a current flowing in a conductor is nothing more than a flow of electrons along a specified path. Therefore an electric charge moving in a magnetic field experiences a transverse force just as an electric current does ; and its path becomes deflected in the same way as the conductor carrying the current would be, assuming it to be perfectly flexible.

Thus, if the discharge tube shown in Fig. 9 is immersed in a uniform magnetic field parallel to the planes of the electrode faces (and for convenience let it be perpendicular to the plane on which the figure is drawn) an electron moving from the face of one of the electrodes under the influence of the electric field between them is deflected laterally in a path like one of those shown in Fig. 10. The mathematics of the problem show that these paths are cycloids. The important point, however, to be noticed here is that, if the curvature of the path is sufficient, *i.e.*, the magnetic field strong enough, the electron will miss the further electrode and return to the one it originally left. This has the effect of *lengthening* the path, and if the gas pressure and the gap between the electrodes is suitably chosen, the path becomes greater than the mean free path, so that the electron stands a change of colliding with and ionising a gas molecule. Thus, by applying a magnetic field of sufficient strength, the tube of Fig. 9 may be made conducting.

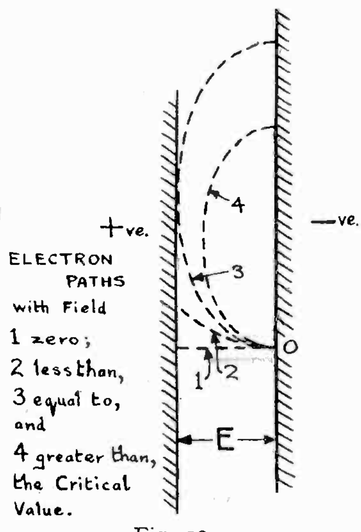


Fig. 10.
Showing cycloidal paths of electrons in magneton rectifier, produced by magnetic field parallel to electrodes. (The field is perpendicular to the plane of the figure.)

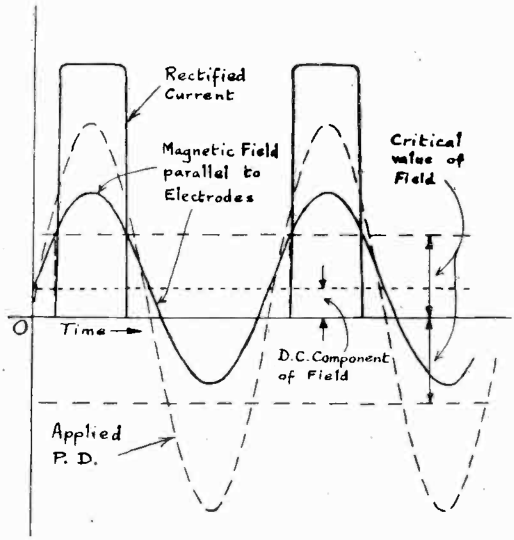


Fig. 11.
Oscillogram showing control of magneton by a variable field.

A second important point is to be noted—that as soon as the magnetic field exceeds the critical value, the electron path is immediately *doubled*. This is a valuable property of the arrangement, in that (theoretically) it allows a margin of 2 : 1 in the choice of the electrode gap or the gas pressure. It is found in practice that these should be such that the mean free path is three or four times the electrode gap.

By varying the magnetic field that is applied, the tube may be made to act as a switch, on the same principle as the Vibrating Flame Rectifier described in our last article.* The field used is provided by two windings, one carrying a continuous current, and the other an alternating current taken from the supply to be rectified. The currents are adjusted so that the field rises to the critical value for one peak of the supply P.D. but is too small when the reverse peak of the P.D. wave occurs ; thus a pulse of current will flow in one direction but the tube will remain insulating during the other half cycle. Note that the alternating component of the field (and hence the A.C. in the winding) must be kept closely in phase with the P.D. of the supply. The relationship described is depicted in Fig. 11.

(To be continued.)

* E.W. & W.E., Vol. II., p. 897, Nov. 1925.

For the Esperantists. Distordado.

[R800

Alia populara sofismo, rilate al senfadena ricevado, estas nun pritraktata: nome, ke kristalo kiel detektoro estas nebona. Ni ne povas tro emfazigi nian kontraŭstaron kontraŭ tiu kredo.

PARTO VA.

MALLONGIGOJ: A.F., Alta Frekvenco; M.F., Malalta Frekvenco; A.T., Alta Tensio; M.T., Malalta Tensio; K.K., Kontinua Kurento; A.K., Alterna Kurento.

LA A.F. AMPLIFIKATORO.

ANTAŬAJ artikoloj en tiu ĉi serio pritraktis distordadon kaŭze de l'amplifaj valvoj aŭ de l'intervalvaj kuploj. Ni devas nun pensi pri la restantaj eroj, el kiuj kompleto konsistas; la A.F. amplifikatoro, se tia ekzistas; la detektoro; la telefoniloj aŭ laŭtparolilo.

Ni unue pritraktos la A.F. parton, ĉar ĝi estas la plej simpla. La solaj fontoj de distordo tie-ĉi estas troaj selektiveco kaj oscilo. Ĉe ia A.F. amplifikatoro, krom multvalva, ambaŭ tiuj ĝenoj, se ili ekzistas, estos kaŭzitaj kredeble pro tro da reakcio. Reakcio, malpliigante la efektivan rezistecon de l'kompleto, povas ĝin tiel selektivigi, ke la altaj tonoj, kaj la altaj harmonikoj de la malaltaj tonoj, estos parte foragorditaj. Tiu-ĉi ĝeno estas tre malofta je mallongaj ondolongoj, kiel tiuj de la ordinaraj britaj kaj aliaj mallongondaj stacioj, sed ĝi povas esti tre evidenta ĉe la Daventry'a Stacio kaj aliaj longondaj stacioj.

La simptomoj estas plene evidentaj: malalta sonorega tono kiam la kompleto estas ĝuste agordita, ŝanĝiĝante al akra tono kiam iomete foragordita. Oni devas diri tute definitive, ke la ĉeesto de ĉi tia efekto estas tute nepardoninda, ĉar ĝi signifas, ke la aparato estas troŝarĝita, kaj estas preskaŭ kaŭzonta interferon al aliaj aparatoj.

FAKTOJ PRI LA DETEKTORO.

Nun, pri la detektoro. Ĉiu leganto kredeble aŭdis la diron—kaj tute ne kredis—ke kristala rektifo estas la plej bona por brodkastado. Ni tre deziras ripeti tiun diron kun tiom da emfazo, kiom nia sperto kaj rango rajtas; sed ni ĝin diros iom alimaniere :—

KRAD-REZISTANCA REKTIFO ESTAS LA PLEJ MALBONA METODO POR EVITI DISTORDON; KAJ LA PLIBONIĜO, POST ĜIA FORIGO, ESTAS REALA KAJ AŬDEBLA.

Aŭdebla, tio estas, se la M.F. amplifikatoro ne estas tiel malbona, ke ĝi difektos tion, kion la detektoro alportas.

La kialo por tiu-ĉi emfaza aserto estas simpla, kvankam detala teknika klarigo estus iom komplika. La krad-rezistanca detektoro, funkciante je modulitaj A.F. signaloj, rektifas tiujn de malalta aŭdfrekvenca modulo multe plibone ol tiujn de alta aŭd-frekvenco. La efekto estas pli malbona ĉe longaj ondoj, kiel ekzemple 5XX, ol ĉe mallongaj ondoj.

Se, pro aparta kaŭzo, oni *devas* uzi ĉi tian detektmetodon, oni povas ĝin plibonigi laŭjene: La krada rezistanco, kiel nune uzata, devas plenumi du celojn. Ĝi ebligas la solan konekton por K.K. inter krado kaj filamento, kaj tial malebligas al krado daŭre ŝarĝiĝi; kaj ĝi helpas, pro sia alta rezisteco, teni la kradon je unu K.K. tensio—iom malpli alta ol la tensio ĉe la punkto, al kiu la malsupro de la rezistanco estas konektita.

Konsideru Fig. 1. Jen la malsupro de la rezistanco estas konektita al punkto je + 4 voltoj. La malsupro estas ĉe iu

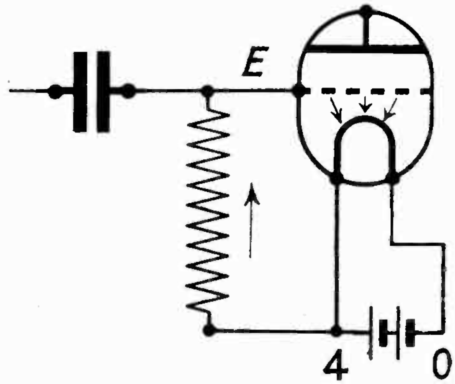


Fig. 1.

voltkvanto E, nunmomente nekonata. Nu, ni scias pere de l'valva kurvo. kiom da krada kurento fluos je ioma ajn kvanto de E, kaj ni scias per la rezisteco de l'rezistanco kiom da kurento fluos tra ĝi pro iu

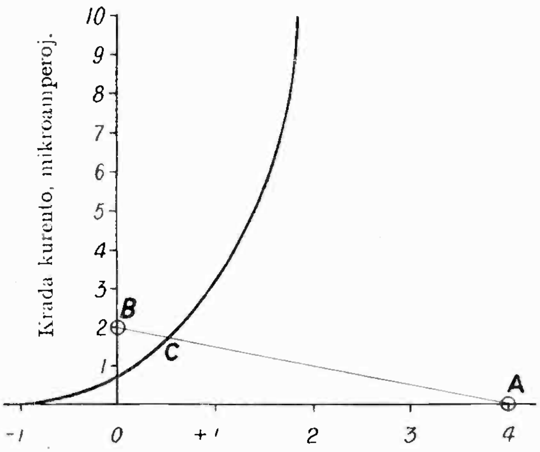


Fig. 2.

kvanto de (4 — E), kiu estas la tensio ĉe ĝi; do, oni devus povi trovi E, ĉar la kurento kiu trairas la rezistancon *devas* esti la sama kiel tiu, kiu pasas tra la valvo.

La figuro 2 bone ilustras tion. Tie la dika linio montras la kradan kurenton por iomajna voltkvanto ĉe la krado mem. Ni supozu, ke ni deziras uzi 2-megoman rezistancon. Marku la punkton A, kies voltkvanto egalas tiun punkton, al kiu estos konektita la malsupra fino de l'rezistanco —ekzemple la + de 4-volta baterio. Poste marku la punkton B, kiu reprezentos la kurenton, kiun la voltkvanto de A pasigos tra la rezistanco. Je la nuna ekzemplo, 4 voltoj dividitaj de 2 megomoj egalas 2 mikroamperojn. Kunligu A kaj B. La punkto C, ĉe kiu tiu-ĉi linio tranĉas la kurvon de la valva kradkurento, montras la voltkvanton, ĉe kiu la krado restos dum ne envenas signaloj. En nuna okazo, tio estas ĉirkaŭ $\frac{1}{2}$ volto +.

Fig. 3 montras la efekton de rezistancoj diversgrandaj. Ili funkciigas la valvon ĉe diversaj punktoj de ĝia kurvo. Evidente unu punkto estas la plej bona. Sed povas esti, ke la grandeco de rezistanco, kiu produktas tiun punkton, *ne* estas la plej bona por ĝia alia funkcio—permesi la ŝarĝon elflui el la kondensatoro. Kiel oni povas solvi tion? Facile: ni uzu la ĝustan grandecon de rezistanco *kiel resistanco*, kaj variu la punkton, ĉe kiu la malsupro estas konektita. Tiel, Fig. 4 montras 1-megoman rezistancon konektitan al 1, 2, 3, kaj 4 voltoj. Efektive, kompreneble, la plej simpla rimedo estas uzi potenciometron transe de la filamenta baterio.

Kiam tio estas farita, provu rezistancojn ĝis eĉ 100 000-oma. Oni kredeble trovos, ke rezistanco ĉirkaŭ 250 000-oma produktos grandan plibonigon tonan; se oni provos ankoraŭ plimalgrandajn rezistancojn, povos esti malfortiĝo de signaloj.

KRISTALO KONTRAŬ VALVO.

Sed estas multe plibone eviti tiun metodon. Tion oni povas fari per du rimedoj. Unu estas uzi valvon kiel "anodan" rektifikatoron. Tio tamen kaŭzas perdon de signalforto, kaj, kiel ni montros poste, ne plene solvos la problemon. Al la kristala detektoro mankas ambaŭ tiuj difektoj. Ni baldaŭ montros, kiel oni povos forigi de ĝi distordon.

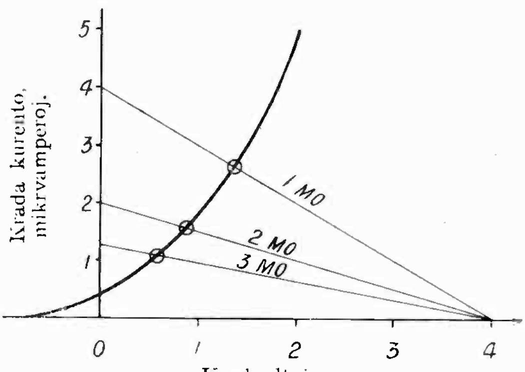


Fig. 3.

Sed, unuavide, ŝajnas absurde pretendi, ke neniom da perdo de signalforto okazos. Jen la argumento: la kosto kaj komplikeco de aparato kuŝas ĉe la valvoj. Tial ne estas juste kompari kristalon kaj 1-valvan aparaton kontraŭ 2-valva aparato. Ni devus kompari aparaton 2-valvan kontraŭ aparato 2-valva kaj kristala. Alivorte, ni devus konservi la valvon, kiu antaŭe funkciis kiel detektoro, sed ni devus utiligi ĝin kiel amplifikatoron kaj uzi kristalon por detekti. Oni trovos ĉiam, ke tio rezultiĝos je pliiĝo de forteco por la sama nombro da valvoj.

Ni nun pritraktu la kutiman kriegon de la valvamanto kontraŭ kristaloj—malstabileco. Tio estas absoluta sofismo *kiam oni ĝustmaniere uzas kristalon.*

La "ĝusta" maniero uzi kristalon *ne* estas meti ĝin transe de antena bobeno kaj provi ricevi malfortajn signalojn. Sub tia stato, oni bezonas ekstreman sentemecon, kiu signifas (A) tre malpezan kontakton—kun mekanika malfidindeco; (B) nur malmulte da egale bonaj lokoj; (C) iom da distordo; (D) selektivecon ne tiel bonan, kiel per valvo.

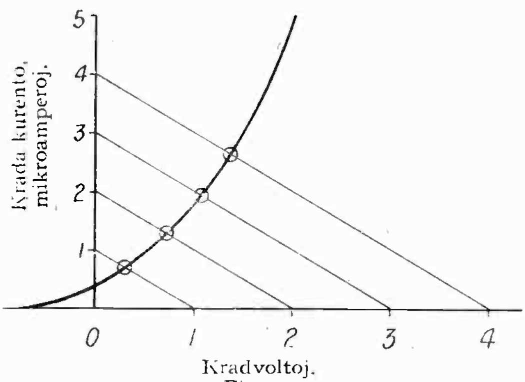


Fig. 4.

Kontraŭe, ni supozu, ke ni metos la kristalon post unu aŭ pli da A.F. valvoj uzantaj reakcion, kaj zorgos, ke estas forta enmeto ĉe la detektoro. Jen la rezulto: (A) firma kontakto estas uzebla; (B) preskaŭ iu ajn loko taŭgos por forta enmeto; (C) distordo tute for, aŭ almenaŭ nekonsiderinda; (D) reakcio kompensos kontraŭ la kristala ŝarĝo, kaj donos selektivecon egalan al tiu de valva detektoro.

GRAVECO DE BONA DETEKTORO.

Unu grava afero estas, uzi vere bonan kristalingon kaj kontaktilon, aŭ detektoran aranĝon, krom la kristalo mem.

Generale, la sinteza zinkita speco de kristalo ne estas tiel sentema kiel la galena; sed pro la grandaj enmetoj rekomenditaj, la diferenco ne estas granda. Estas tamen grave meti tian detektoron transe de iom pligranda bobeno kaj plimalgranda kondensatoro, ol taŭgus por galena detektoro.

La moderna speco de daŭraj detektoroj estas bonega por ĉi tiu celo, kondiĉe, ke ili ja estas de la zinkita speco, kaj ne simple galenaĵoj.

KELKAJ NOTINDAĴOJ.

Jen noto, *kial* kristalo donas sendistordan rektifadon. Ni supozu, ke ni aplikos konatajn A.F. voltkvantojn al detektoro, kaj mezuros la K.K. elmeton. Ni obtenos kurvon, kiel tiun de Fig. 5. Nu, ni supozu, ke la portanta ondo naskas konstantan tension A. Ni ricevos konstantan kontinuan kurenton B ĉe la telefonilo. Kiam la modulo komenciĝos, la A.F. tensio varios je aŭda frekvenco de, ekzemble, C ĝis C', kaj la elmeto varios de D ĝis D'.

Nu, *se, kaj nur se, la parto EF de la kurvo estas rekta linio,* la rektifita kurento estos ĝusta reprodukto de la sendila modulo. Praktike, la plimulto de bonaj galenoj *ja* montras tiun ĉi rektan linion, kondiĉe ke la tensio A estas ne malpli ol $\frac{1}{2}$ ĝis $\frac{3}{4}$ de volto; kaj zinkitaj detektoroj ĝin montras se A estas nemalpli ol 1 ĝis $1\frac{1}{2}$ voltoj. A devas ne esti *pli* ol, ekzemple, 3 aŭ 4 ĉe galeno, aŭ 6 ĝis 8 ĉe zinkito.

Tiurilate la kristalo estas la plej taŭga detektoro. Al valvo sen kradrezistanco mankas la ĝenoj klarigitaj jam en ĉi tiu artikolo, sed ĝenerale ĝi *ne* montras rektan parton ĉe sia rektifa kurvo.

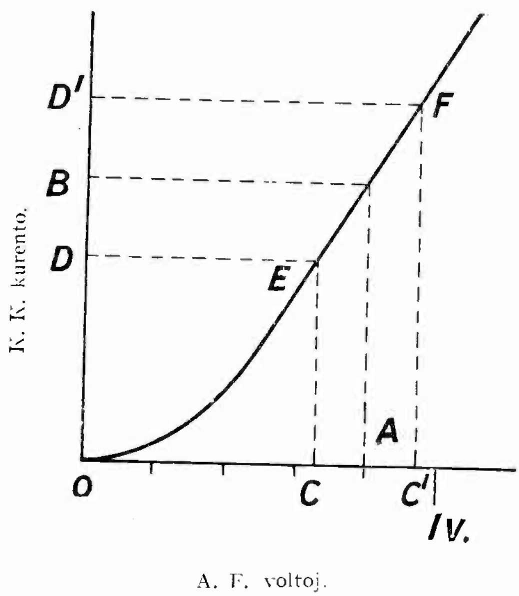


Fig. 5.

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

The Tantalum Rectifier.

The Editor, E.W. & W.E.

SIR,—Our attention has been called to the article on page 889 of your issue for November. We notice that you describe a system of rectification which is employed in the Balkite Battery Charger, marketed by us in this country.

We would ask you to be good enough to state in your next issue that the basic patents employing the use of Tantalum as a rectifier are covered in this country under British patent No. 235658/1925, and that our associated Company, Radio Accessories, Ltd., of Hythe Road, Willesden, are the sole licensees for the manufacture of Tantalum Rectifiers in this country.

The patent stands in the name of the Fansteel Products Co. Inc., of North Chicago.

Various units incorporating this principle of rectification will be manufactured by Radio Accessories, Ltd. in due course and marketed by *this* Company. It is also our intention, in the near future, to sell to the amateur complete strips of Tantalum, so that he can, if he wishes, construct his own rectifier, in accordance with detailed instructions which will be issued, as soon as we have been able to make the necessary arrangements with the owners of the patent.

BURNDEPT WIRELESS LTD.,
W. W. Burnham,
Managing Director.

Aldine House,
Bedford Street,
Strand, W.C.2.

The Editor, E.W. & W.E.

SIR,—As we know you get inquiries from time to time from your readers who wish to purchase special materials for Wireless work that are difficult to obtain, we should like to mention that if any of your readers are anxious to obtain supplies of Tantalum metal in sheet form (which is being much experimented with now for Rectifiers), and any other special metals such as Tungsten, Molybdenum, and rare metals generally, we can supply these specialities.

GEO. G. BLACKWELL SONS & CO., LTD.,
H. A. Blackwell,
Chairman.

The Albany,
Liverpool.

The "R.I." Transformer Curve.

The Editor, E.W. & W.E.

SIR,—I have read with interest the reply of Messrs. Radio Instruments to Mr. Anson's letter on the above subject.

As I understand it, the "R.I." theory is that small amplitudes are amplified less than large and that in consequence the deficiency in harmonics, the amplitudes of which are small, can be counteracted by the employment of a transformer which exaggerates the higher frequencies.

This theory is, in my submission, fundamentally unsound for the following reasons :—

(A) There is abundant theoretical and experimental evidence that the amplification factor of a transformer amplifier is not reduced to an insignificant value the smaller the input energy. On the contrary the variation is slight and the limiting amplification for very small amplitudes is definite and determined by the limiting permeability of the core at low alternating flux densities.

(B) If there were such a reduction in amplification a rising transformer characteristic would not improve matters, since the amplification of a fundamental note plus a harmonic would then produce a different effect from the sum of the effects of amplifying the fundamental note and the harmonic separately. Such a state of affairs would give rise to greater distortion of weak signals than of strong ones, and the fact that even very bad transformers do not exhibit this defect is the best practical evidence that Mr. Appleton's theory is wrong.

I enclose some measurements made on a single stage of transformer amplification at varying input amplitudes on two different frequencies, which support the contentions above outlined.

6, Bedford Square, W.C.1.
P. W. WILLANS.

[NOTE.—Unfortunately we have no space to reproduce the test curves. They show no change of amplification with strength between input voltages of .01 and .035 volts ; and the actual amplification is apparently the same as at quite large inputs.—ED. E.W. & W.E.]

The Editor, E.W. & W.E.

SIR,—I have read with interest the letter of your correspondent, Mr. Appleton, of Radio Instruments, Ltd. in the current issue of EXPERIMENTAL WIRELESS with reference to the required frequency response curve of an intervalve transformer. The ideas put forward are, to say the least of it, new to me.

In the first place, if the value of amplification differs considerably at different amplitudes, distortion of the "non-linear" variety will occur ; that is to say, if the wave form of the input E.M.F. is sinusoidal, then the output E.M.F. on the secondary of the transformer will depart from this shape by a greater or lesser extent, according to the difference in amplification for different amplitudes. It is well known that any wave form other than a sine wave can be analysed by a Fourier series into a wave form of a fundamental frequency plus a number of harmonics.

It will be seen, therefore, that if the amplification is not the same for all amplitudes certain undesired frequencies, which are harmonics of the input frequency, will be present. The intensity and number of these undesired frequencies will be a function of the non-linearity of amplification.

Further, if two sinusoidal E.M.Fs. of frequencies $f_1 - f_2$ be applied to the input of any non-linear amplifier, then owing to the fact that the amplification varies with amplitude, a certain amount of rectification will take place, resulting in the production of an E.M.F. of another frequency equal to the beat tone frequency of f_1-f_2. The intensity of this beat tone frequency will again be a function of the non-linearity of the apparatus.

It would therefore appear that if the average transformer has the characteristics alleged by Mr. Appleton, then the amplification of music by such apparatus will result in a most serious distortion: that such distortion is not present can be proved in a very simple manner by performing the experiments indicated by the statements. What distortions are present in an amplifying chain are usually due to lack of grid bias on the valves, the overloading of valves, or a bad frequency response curve; that is to say, a curve indicating unequal amplification at various frequencies.

It is our considered opinion that all frequencies between 50 and 10 000 cycles are required for the perfect reproduction of speech and music; actually the frequencies between 100 and 1 000 cycles are very necessary for the warmth of musical tone and the naturalness and intimacy of the voice. The frequencies between 800 and about 2 500 cycles are required for intelligibility of speech and character and brilliance in music. The frequencies above 2 500 are required in order to produce the correct timbre of certain musical instruments and also to reproduce certain of the higher sibilants in speech.

Your correspondent further states that in order to amplify efficiently the frequencies of the order of 200 per second, it is necessary to increase the number of turns on the windings to such an extent that the amplification of high frequencies falls very considerably. That this is not necessarily the case is indicated by the fact that in the apparatus in use by the British Broadcasting Company there are several transformers whose performance is such that the frequency characteristic is essentially flat from 100 cycles up to 8 000. The falling off below 100 cycles and above 8 000 cycles is very small, however, and is not appreciable to the ear.

It may be of interest to note, however, that with certain types of loud-speakers which are bad reproducers of low tones, it is an advantage to use a transformer which removes the low tones completely. This, however, is not consistent with progress and development. H. L. KIRKE.

The British Broadcasting Co., Ltd.,
2, Savoy Hill, London, W.C.2.

The Editor, E.W. & W.E.

SIR,—In your journal and elsewhere Messrs. R.I., Ltd., have published statements relating to low-frequency intervalve transformers that have given rise to much criticism and comment.

Many of these contentious statements have been received with incredulous amazement because they are advanced with the authority of experience.

One is, however, reminded of the remark of an indignant Silvertown mother concerning the young unmarried municipal nurse whose duty it was to visit the woman shortly after the birth of her seventh child. "The idea!" she fumed, "Fancy sending a person like that to teach me how to rear children. Me that 'as buried five!"

Mr. Appleton's letter in your November issue appears to furnish an explanation of the somewhat original views which gave rise to the protest to which he replied. In this letter we are told:—

(A) That musical sound is made up of a fundamental wave with a number of harmonics superimposed upon it, the latter having a very small energy-value in comparison with the fundamental.

(B) That transformers do not amplify these weak harmonics to the same degree as the fundamental.

(C) That it is consequently more desirable to discriminate against the low frequencies than to amplify all frequencies to the same extent.

(D) That the characteristic they publish "is a decidedly incomplete characteristic of the apparatus under test."

If your correspondent succeeds in establishing the truth of these contentions he removes the last shred of justification for publishing the curve as a symbol of merit, and for basing comparisons on any two such curves.

To the majority of your readers it will be obvious that the contentions are not in accord with current knowledge. The energy in individual overtones is often many times as great as that in the fundamental. I will give a few examples from the masterly analysis published by the Smithsonian Institution in *Physical Tables* (7th Edition).

Violin (A string): The fifth partial has 27 per cent. of the total sound energy while the fundamental has but 26 per cent.

Oboe: Only 2 per cent. of the total energy is in the fundamental, while 29 per cent. is in the fourth, 35 per cent. in the fifth, and 14 per cent. in the sixth partial, etc. Even the tenth has twice as much sound energy as the fundamental.

Clarinet: Of the twelve frequencies identified, the eighth, ninth and tenth have each more energy than the fundamental.

Trombone: More than one-third of the total sound-energy is in the third partial, while the fundamental has but one-seventeenth.

From these figures it is clear that any such discrimination as that suggested in (C) above, will exaggerate the peaks of the complex sound wave and produce harsh or squeaky sound such as we are in the habit of correcting by means of shunt condensers. If Mr. Appleton will turn to p. 745 of the September, 1924, issue of E.W. & W.E., he will find that the editorial report finishes up with the words, "We found a small condenser an improvement." Thus is Mr. Appleton's contention negatived both in theory and practice.

I would remind your correspondent that the question at issue is, "Which of two published curves is the more correct?" and lest there be any doubt as to the interpretation of the term "correct" in this connection I refer again to the editorial view as expressed on p. 56 of Vol. 2 of this journal.

The tendency of modern practice leaves no doubt as to the obsolescence of transformers that fail to "pick up" below 2 000 periods per second. In the hands of a specialist they may have a limited application for purposes of discriminative correction, but they are now superseded as "general purpose" transformers by later designs based on the intensive experience of the past two years.

In conclusion I would suggest that a debate be arranged between Mr. Appleton and one of his critics, to take place before the Wireless Section of the Institution of Electrical Engineers or the Radio Society of Great Britain, the subject to be "Which of the two published curves is the more correct for a general-purpose intervalve transformer?"

WILLIAM D. OWEN.

Palmer's Green,
N.13.

The Editor, E.W. & W.E.

SIR,—I was very interested in Mr. Appleton's reply *re* the R.I. transformer curve, and was glad he called attention to the fact that "when the input energy applied to the transformer is below a certain value, the amplification factor practically disappears." However, I do not quite see how the harmonics suffer most in this respect. Harmonics are simply a part of a complex wave, and provided that the necessary energy is there, it appears to me that the harmonics would be fully amplified even though they were so weak that, had they existed separately, the amplification factor would have practically disappeared.

The question of impedance is another matter, and I agree that it is preferable to sacrifice something of the lower frequencies, if necessary, in order to preserve the overtones. None of the curves, in my opinion, are carried far enough. What kind of curves should we get if they were taken up to 10 000 cycles?

Just a word *re* your notes on amateur research. I find that there are so many problems in telephony reception, that I could spend my whole time experimenting instead of the few occasional hours which I can spare, and yet I know amateur experimenters who look on broadcast reception as beneath their dignity. Then there are others whose sole idea seems to be to get terrific volume from the loud-speaker with stunt circuits, and not appearing to mind that speech and music are quite unintelligible. May I congratulate you on the excellence of E.W. & W.E. and your avoidance of the stunt stuff. I feel that it is chiefly up to the amateurs to raise broadcast reception above the level of the demonstrations usually given in wireless shops, and it is here that the fundamental principles dealt with so thoroughly in E.W. & W.E. are so helpful. I have only one grumble, it is that we have to wait a month for the next issue.

H. H. DYER.

22, Leopold Street,
Derby.

Grid Rectification.

The Editor, E.W. & W.E.

SIR,—I have read with much interest Mr. F. M. Colebrook's paper on grid rectification in the November issue of E.W. & W.E.

From the tables of numerical values of his functions $G(x)$ and $\psi(x)$ on pages 870 and 874, I conclude that he has obtained these by summing the series given. I also think he has not taken enough terms of the series, for in every case his results are slightly out, especially for the higher values of x.

Mr. Colebrook has evidently not noticed that these functions are already well-known and accurately tabulated; they are in fact imaginary Bessel functions of orders Zero and Unity.

Thus, for his $G(x)$:—

$$G(x) = 1 + x^2 + \frac{x^4}{2!^2} + \frac{x^6}{3!^2} + \&c: = J_0(2jx)$$

Values to four places are given in Jahnke & Emde's *Funktionentafeln* (Teubner, Leipzig), page 130 of the 1923 edition, from $x=0$ to $x=11$, by intervals of 0.1 from 0 to 6, and of 1 from 6 to 11.

From these tables I take the figures in column 4 of the attached schedule, column 2, giving Mr. Colebrook's values of $G(x)$.

$x=$	$G(x)$ (Colebrook)	$2x$	$J_0(j.2x)$ (*J. & E.*)	$-jJ_1(j2a)$
0	1	0	1	0
.25	1.0634	.5	1.0635	0.2579
.50	1.2660	1.0	1.2661	0.5652
.75	1.6466	1.5	1.6467	0.9817
1.00	2.2795	2.0	2.2796	1.5906
1.25	3.2882	2.5	3.2898	2.5167
1.50	4.8790	3.0	4.8808	3.9534
1.75	7.3690	3.5	7.3782	6.2058
2.00	11.2990	4.0	11.3019	9.7595
2.25	17.4800	4.5	17.4812	15.3892
2.50	27.2700	5.0	27.2399	24.3356
2.75	42.7600	5.5	42.6946	38.5882
3.00	67.5000	6.0	67.2344	61.3419

In the same way, Mr. Colebrook's function $\phi(x)$ is:—

$$\phi(x) = x + \frac{x^3}{1!2!} + \frac{x^5}{2!3!} + \frac{x^7}{3!4!} + \&c: = -j.J_1(2jx)$$

The values of this from Jahnke & Emde (pp. 131 to 133) are in the fifth column of the attached schedule.

Thus, finally, for Mr. Colebrook's $\psi(x)$:—

$$\psi(x) = \frac{x.G(x)}{\phi(x)} = \frac{x.J_0(2jx)}{-j.J_1(2jx)} = j.\frac{x.J_0(2jx)}{J_1(2jx)}$$

Numerical values of these functions may also be found, for larger intervals of the argument, in Dale's *Five Figure Tables of Mathematical Functions* (Arnold, London), where they are tabulated with a slightly different notation,

$$G(x) = I_0(2x)$$
$$\phi(x) = I_1(2x)$$

whence, in Dale's notation:—

$$\psi(x) = \frac{x.I_0(2x)}{I_1(2x)}$$

Dale's tables also give values of I_2, I_3, etc. : up to I_{11}, which are not found in Jahnke & Emde ; but at intervals of 0.2 in the argument only, from 0 to 5.

I would suggest that Jahnke & Emde's "Funktionentafeln" are most useful to anyone engaged upon the mathematical side of wireless. They can be found in any good library, or bought through a bookseller who deals in foreign books (for about 7s. 6d.). These "tafeln" not only give numerical values of an immense variety of the less common functions, but also graphs of these functions and invaluable lists of integrals which can be found in terms of the functions, and of differential equations to which the functions are solutions.

Hoping that this suggestion may save Mr. Colebrook a vast deal of arithmetical work in the summing of series. C. R. COSENS.

13, Millington Road, Cambridge.

The Editor, E.W. & W.E.

SIR,—I am much indebted to your correspondent, Mr. Cosens, for his information with regard to the series in my paper on valve rectification. At the time of writing the paper I anticipated that the series were actually known and tabulated functions, but failed to recognise them. I certainly wish I had done so, as the series are by no means rapid in their convergence. As it is, I must be thankful that my arithmetic has not let me down, for the values I have given are in agreement with the tabulated values to a greater degree of accuracy than experiment on the subject is likely to require.

F. M. COLEBROOK.

The National Physical Laboratory,
Teddington.

H.T. Supply from the Mains.

The Editor, E.W. & W.E.

SIR,—One notices from time to time various articles describing how current can be obtained from the lighting mains to supply wireless sets.

A perusal of some of these articles indicates that the authors are not familiar with the regulations governing electricity supply.

I notice in one paper a paragraph which reads as follows :—

> "Incidentally the potential of the 'earth' side of the switch to earth *can* be used as an absolutely gratis source of current, but it is subject to remarkable fluctuations which make it unreliable for charging accumulators."

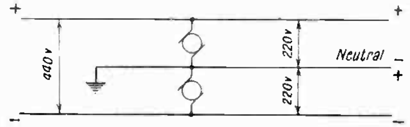
The text matter preceding it does somewhat modify it, but I can imagine a schoolboy getting hold of this particular paragraph and causing the supply authorities a good deal of trouble in trying to trace earths.

I think it would be of general benefit if you would point out that the Electricity Regulations specifically lay down that the neutral of a distribution system must only be earthed at one point. This point is usually at the generating station, or, in the case of an isolated network, at the sub-station.

This does not prevent a wireless set being earthed by the means of condensers, but it does prohibit *any other kind of earth* such as one side of the high tension supply.

The attached two little diagrams may make the method of supply clear to amateurs.

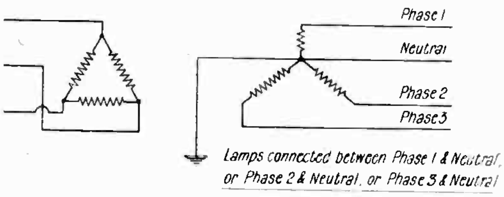
In the first case we have a very common form of distribution, namely, 3-wire direct current with, say, 220 volts between each conductor and the neutral, and 440 volts across the neutral. In this case the lighting load is connected to the main so that half would be on the positive side and half on the negative.



DIRECT CURRENT, 3 WIRE

This is a point which should be remembered when using the main for high tension supply, as it will be obvious from our diagram that approximately 50 per cent. of the houses will be connected in such a manner that the positive is earthed.

Large motors are usually connected across the outers, *i.e.*, across the 440 volts so that neither pole will be earthed. This form of distribution is



ALTERNATING CURRENT 3 PHASE 4 WIRE DISTRIBUTION

being largely superseded by 3-phase alternating current. The distribution connections for this system are also shown in the sketch, the neutral being earthed at the transformer.

JAMES NELSON.

7, High Street,
Prescot, Lancs.

"Wipe Out."

The Editor, E.W. & W.E.

SIR,—I should like, if space permits in your columns, to reply to the letters of Dr. R. L. Smith-Rose and Mr. Marcus G. Scroggie which appeared in the November issue of E.W. & W.E.

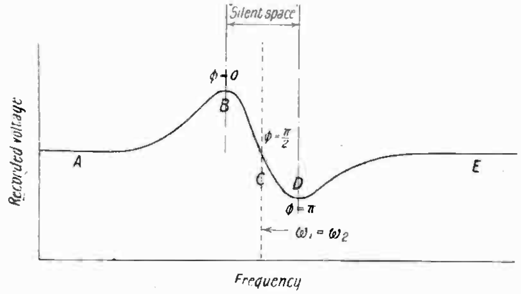
(1) I, personally, am entirely in agreement with Dr. Smith-Rose that the term "Wipe Out" is undesirable when applied to "Automatic Synchronisation," and should only be applied to the case he quotes.

Owing, however, to certain correspondence I had on the subject some time ago, I was under the impression that the term "Wipe Out" was not uncommonly used amongst amateurs to include "Automatic Synchronisation." It was in order to try and clear up a fallacy which seemed to be held by many, and classed, it appeared, under the general heading of "Wipe Out," that I originally wrote the article which appeared under the heading of "Wipe Out" in the October issue of E.W. & W.E.

(2) With regard to the phenomenon which puzzles Mr. Scroggie, I am rather inclined to think that he has only struck one of the ordinary features characteristic of "Automatic Synchronisation."

The question of the phase difference between the voltages of two coupled oscillating circuits during the period of synchronisation is dealt with very fully in Dr. Appleton's paper referred to in my original article. The theory is too lengthly to recapitulate here but the conclusions may be mentioned.

Suppose two oscillations are coupled together in such a manner that automatic synchronisation can take place, and suppose a third circuit is coupled



to them in such a way that the combined voltages produced by the two oscillators are recorded in this circuit on some indicating device, *e.g.*, Moullin voltmeter, crystal and galvo, etc., then these conditions will correspond to those described by Mr. Scroggie—his circuits being a particular case of the general form described above.

Now let observations be taken in the recording circuit when the frequency of one of the oscillators is approached to that of the other. If the voltage indeed in the recording circuit is plotted against change of frequency, a curve of the type shown in the figure will be produced.

As the frequency of one oscillator (ω_1) approaches that of the other (w_2) the recorded voltage rises till a maximum is attained as the commencement of the silent space is reached (point *A*), *i.e.*, when automatic synchronisation takes place. As the silent space is traversed the voltage drops very rapidly and reaches a minimum as the beats start again (point *D*) and thence rises to its normal value at *E*.

This voltage variation represents a changing phase difference (ϕ) between the two sets of oscillations. The phase relations go from $\phi=o$ through $\phi=\pi/2$ to $\phi=\pi$. This rapid phase change during the silent space may be accounted for theoretically if the oscillators are assumed to have characteristics of the form

$$i = f(v) = -\alpha v + \beta v^2 + \gamma v^3.$$

and this approximates to a triode characteristic. These phase changes may be observed by the Lissajon's figures produced in a suitably arranged cathode ray oscillograph.

This may explain the phenomenon Mr. Scroggie observed, only it would appear that he approached the silent space from one side and not the other, since he makes no mention of a *fall* of recorded voltage on approaching the silent space in one direction, as would happen from *E* to *D* in the figure.

If this explanation is to hold good for Mr. Scroggie's experiment, (1) the minimum recorded voltage would occur at one side of the silent space and *not* throughout, the voltage variations taking the form shown in the figure; and (2) for two oscillations of unequal voltage the drop would only be equal to "double the difference between the two" for one particular case.

However, the similarity between the phenomenon I have described and that of Mr. Scroggie is sufficiently near to warrant my putting forward the above explanation, and it might well transpire that a check of Mr. Scroggie's observations might show substantial agreement with what I have described, or else Mr. Scroggie may find an explanation for his own case in the light of what I have stated.

In any case, I should be interested to hear if Mr. Scroggie has been in any way helped by what I have had to say.

Barracks, DESMOND DE BURGH.
Mayfield, Sussex.

The Editor, E.W. & W.E.

SIR,—Referring to the phenomenon noticed by Mr. Scroggie and published in the November issue.

It is well known that the inductance of a coil is decreased when the flux of coil *A* threads coil *B*, and produces a current, this current producing a second flux which increases the reluctance of coil *A* and so decreases the inductance. If, however, the current in coil *B* is made to lead the voltage by 90 deg., the flux of coil *B* will decrease the reluctance of coil A and so increase the inductance.

An effect analogous to the above may be happening in the phenomenon referred to, that is to say, the oscillator may actually radiate waves 180 deg. out of phase with 2LO, notwithstanding the fact that 2LO is acting as a "drive oscillator."

A close study of the oscillator circuit used by Mr. Scroggie may confirm the above theory.

SAMUEL H. BROWNING, A.Rad.A.
43, Clarinda Park E., Kingstown, Co. Dublin.

Proposed Institute of Radio Engineers.

The Editor, E.W. & W.E.

SIR,—With reference to your editorial comment on my letter published in your November issue, I fear that, in turn, you may have misunderstood the object of my letter, which was not written with a view to entering into any controversy as to whether or no the Institution of Electrical Engineers properly serves the wireless engineer, but to correct certain statements made by Mr. Gambrell, which I believe to be misleading, regarding the status and training of a wireless engineer.

34, Norfolk Street, B. BINYON.
Strand, W.C.2.

Reversing Coils.

The Editor, E.W. & W.E.

SIR,—In your article on O'Keeffe Plug-in Coils in the November issue, it is stated that a good feature of these coils is their reversibility.

It should be remembered, however, that the reversal of the coil will entail the reversal of the coil connections; therefore, the direction of the lines of force will remain unchanged.

Wishing your magazine every success.

40, Wingford Road, A. W. SUMBLER.
Brixton, S.W.2.

The Australian DX Record.

The Editor, E.W. & W.E.

SIR,—A letter appears in your issue of last July under the heading of "The Australian DX Record" and signed by J. H. D. Ridley.

While congratulating Mr. Ridley on getting his short-wave signals across to Australia, he has made a mistake as to the date of the reception by me of Mr. Simmonds' transmission. This was on Sunday, 26th April, and not the 27th as stated in Mr. Ridley's letter. I cannot give the exact time of the reception as it occurred during a test period. However, it is certain that it was before 4.45 p.m., for I have a later entry in my log, time 4.45 p.m., covering two-way working with U6TS and U1CMX, on 20 metres.

Faint 20 metre signals had been heard calling me on 19th April, but although my call-sign (2CM) was distinguished there is a doubt as to the station calling. The only guide to this is, that it contained the figure 2 and the letter K. I therefore considered it to be 2KF who I knew would be calling me at this period.

The date of the first reception of the signals from my station, in England, by Mr. Partridge and Mr. Morrow was 15th April, and the date of the first two-way working between Mr. Simmonds and myself was 2nd May.

CHAS. MACLURCAN (A2CM).

4th Floor, Pratten Buildings,
26, Jamieson St., Sydney.

Station News.

The Editor, E.W. & W.E.

SIR,—May I take this opportunity of advising you that each Thursday at 10.30 p.m., and each Sunday at 11 a.m., I shall be transmitting on a wave-length of 9.2 metres for a period of half an hour, with intervals of five minutes between transmissions of a similar duration.

If you will make this announcement in your paper I can guarantee positively that these transmissions are being carried out to schedule.

Reports are welcomed.

33, Castlegate, N. G. BAGULEY (G2NB).
Newark.

The Editor E.W. & W.E.

SIR,—Will you kindly note that I shall be transmitting on wave-lengths of 163 metres and 440 metres in the course of a week or so. QSL cards welcomed, and will be answered.

"Fiveways," G. S. WHITE (G2GW).
Chippenham, Wilts.

The Editor, E.W. & W.E.

SIR—Kindly note that the QRA of this station is now: G6UG 10 watts 150/200 metres. QSL cards answered per return.

18, Albion Street, H. DEAN POULTON.
Cheltenham.

The Editor, E.W. & W.E.

SIR—I should be glad to get into touch with another amateur desirous of working phone on 150/200 metres, within a radius of 50 miles.

My station call is 6MW.

Clifton House, C. W. THOMAS.
Old Swinford, Nr. Stourbridge.

The Editor, E.W. & W.E.

SIR,—Would you be so kind as to publish the fact that I have been allotted the call 5KU in place of 2APW. This is for CW and phone on 45 and 23 metres.

Wishing E.W. & W.E. all the best.

4, Glenhurst Avenue, R. POLLOCK.
N.W.5.

The Editor, E.W. & W.E.

SIR,—Please note the address of my station, 2JP, is now "Brooklands," Follifoot, Harrogate. Transmissions are carried out on wave-lengths of 95 and 45 metres, and all reports will be welcomed.

17, Princes Street, M. C. ELISON.
Harrogate.

The Editor, E.W. & W.E.

SIR,—I should be very glad if you would be kind enough to publish my call-sign, etc., as below at your early convenience.

5KR, wave-lengths 150-200 and 440 metres, watts 10.

The Crossways, C. M. THORPE.
Rhuddlan, N. Wales.

The Editor, E.W. & W.E.

SIR,—It may be of interest to you to note that the P.M.G. has granted me an artificial aerial transmitting licence, the call-signs allotted to me being 2BCT.

I have also been granted permission for use of a transmitter using a frame aerial for remote control of a model boat.

Congratulations on the continued excellence of E.W. & W.E., and best 73's.

23, Palmer's Avenue, A. G. WILLIAMS.
Grays, Essex.

The Editor, E.W. & W.E.

SIR,—I should be glad if you would make known the fact, through the next issue of your excellent journal E.W. & W.E., that my station 5XW is now active on wave-lengths between 150 and 200 metres, and that reports on the transmissions are welcome and will be answered. Usual QRH 168 metres.

Wishing you every success.

5, Creffield Road, C. BRYANT.
Colchester.

The Editor, E.W. & W.E.

SIR,—The P.M.G. has allocated to me the call sign 6YU, and I should greatly welcome reports on my transmissions, which at present are on 45 metres.

All QSL cards acknowledged.

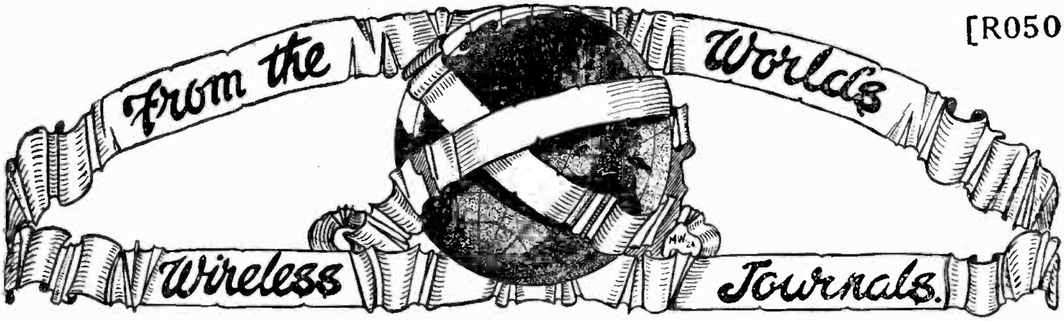
Thanking you for the pleasure and help I derive from your excellent journal.

56, Falstaff Gardens, J. HANSON.
Radford, Coventry.

A Correction.

With reference to the Radio Relative Index published in E.W. & W.E. for November, the classification for intervalve input and output couplings should be R132.1-3 and not as given.

[R050



R100.—GENERAL PRINCIPLES AND THEORY.

R113.—REPORT ON MEASUREMENTS MADE ON SIGNAL STRENGTH AT GREAT DISTANCES DURING 1922 AND 1923 BY AN EXPEDITION SENT TO AUSTRALIA.—H. J. Round, T. L. Eckersley, K. Tremellen and F. C. Lunnon of Marconi's W/T Co., Ltd. (*Journ. Inst., E.E.*, Oct., 1925).

This is a very lengthy paper read before the Wireless Section of the I.E.E. on 6th May. A short preface by Capt. Round recapitulates early signal strength measurements, and outlines the expeditions whose results are detailed. The method and apparatus used are then described. A measured local signal was introduced into either the working aerial or a dummy aerial to equal that in the receiver, the well-known "slide back" method being used for measurement. The apparatus was all carefully screened and an accuracy of 10 per cent. is claimed in the measurement of received signals under all the same exceptional conditions of atmospherics. In 1921, the apparatus was used for the measurement of American signals at Chelmsford, and also at other parts of Great Britain. Curves are given for signal E.M.F. against time (in hours). The mean daylight value measured was, for Chelmsford, of the order of 2.1 or 2.2 and that for Girvan, Ayrshire, 3.3 or 3.4 times that due to be received by calculation from the Austin Cohen formula. An interesting figure shows results at Chelmsford for four American stations reduced for comparison to the value of a 140 000 metre-ampere station. A sudden and very marked decrease is shown in the early weeks of November, the lower though increasing value holding through the winter months. A series of measurements were also made in South Africa in August-September, 1922, curves being shown for the reception of UFT and WQK. It is pointed out that the signals from European stations are approximately halved by their overland route as compared with those more wholly oversea from America.

The next sections then describe measurements made during an extensive world cruise. In January, 1922, observers left England in S.S. *Dorset*, proceeding by the Atlantic, Panama and Pacific to New Zealand. The gear was there unshipped and transported to Australia, where measurements were continued. The return journey was made in S.S. *Boonah*, *via* the Indian Ocean and Mediterranean. Curves of signal strength from various European and American stations are given for the complete journey. Measurements aboard ship are shown in the form Field Strength ($\mu V/m$) against distance from transmitter, and those for land observations in Australia in the form microvolts at 60 feet actual height against time, in hours. The text discusses the measurements and curves. A notable point is that when in the Pacific Ocean, it was detected that signals from New York stations were being simultaneously received round the world in both directions. Here and elsewhere it appeared that signals frequently preferred a longer dark route to a shorter lit path. A considerable section is devoted to atmospherics. Directional reception indicates origins of considerable distance, especially of the X's received on the longer waves. Apart from purely local thunderstorms various large areas of land in or near the tropics are shown to be productive sources, varying with season, and having a maximum about 3 p.m. local time. Between midnight and 02.00 G.M.T. S. America contributes a steady supply. Information as to the microvolts per metre necessary to read through X's is stated to have been obtained, but is not published.

The latter half of the paper gives a theoretical discussion of the results. The Austin Cohen formula is abandoned as giving inadequate information regarding the nature of transmission. A form due to G. N. Watson is suggested as suitable. This formula includes an attenuation factor depending upon the resistivity and permeability both of the earth and of the upper layer, and upon the height of the layer. This is finally simplified by the authors to a working form

$$E = \frac{120\pi h I \epsilon^{-ad/\sqrt{\lambda}}}{\lambda(d_0 R \sin\theta)}$$

Where h = effective height of transmitter (in km.)
λ = wave-length in km.
I = transmitting current.
θ = zenith angle between transmitter and receiver.
d = distance.
a being the attenuation factor and d_0 being approximately at $3H/2$, where H is the height of the layer.

Values of attenuation are tabulated for the *Dorset* voyage, the figures for the Atlantic voyage being shown separately for European and American stations, on account of the difference of their routes. The values are .001 8 and .001 42 respectively. For the Pacific portion of the cruise the value measured on European stations is given as

.000 955. For the *Boonah* return voyage the values shown in tables are .001 07 for the European and .001 24 for the American stations.

Land absorption is discussed on a basis of (*a*) Dielectric losses in surface vegetation ; (*b*) Conduction losses in various structures on the surface as well as surface vegetation. The night effect in long distance transmission—including the bi-directional transmission already referred to—is then considered, and the theory and effect of the upper layer is dealt with. It is concluded that day transmission is confined to the space between the earth and the lower conducting layer, and at night when the ionising effect of the sun is absent, the lower layer disappears, and the upper auroral layer comes into play with its much better defined reflecting surface. It can thus reflect radio waves at much greater angles than those of day time. As a consequence there is the irregular interference phenomena so characteristic of night transmissions which must be due to slight variations in the height and conductivity of the layer. Evidence from other sources is quoted in support.

Lastly, reference is made to the fact that on the data there appears to be a superiority of transmission from West to East as compared with that from East to West. It is suggested that this might be explicable by effects of electronic or ionic movement in the earth's magnetic field, but no very definite conclusion is reached.

R113.4.—Wave Propagation at High Frequencies.—Dr. A. Hoyt Taylor and Dr. E. O. Hulbert (*Q.S.T.*, Oct., 1925).

After briefly considering the process of ionisation in the upper air, the authors proceed to discuss the effect of the ionised layer at the higher radio frequencies, *i.e.*, wave-lengths of 10 to 40 metres. Reference is made to the fact that short wave signals are usually received better at a distance than near to the transmitter, while there is a "skipped distance" in between where they cannot be received. Typical "skipped distances" for various short wave-lengths are shown by a curve. This is explained by the rapid absorption of the direct and earth-bound ray, and the reflection from the ionised layer of the indirect ray to much greater distances. The authors estimate an electron density of 5.57×10^5 electrons per cubic centimetre as the value necessary to turn back these short waves, and show typical ray paths for the reflected wave according to different assumptions of the variation of electron density with height.

R113.8.—The Effect of the Solar Eclipse of 24th January, 1925, on Radio Reception.—G. W. Pickard (*Proc., I.R.E.*, Oct., 1925).

This paper, which is a communication from U.R.S.I., gives graphical results of many measurements of field strength taken in different parts of U.S.A. during the eclipse last January. The eclipse occurred shortly after 9 a.m. (American time) and many of the graphs give interesting comparisons of the eclipse effect alongside the night effect of the preceding hours on wave-lengths of 300 to 500 metres. The results are well presented by a mean graph in which the eclipse effect is superimposed on (*a*) the normal morning fall of mean field, and (*b*) the normal morning fall of the fluctuations about mean field value. The effect of the relative positions of transmitter and receiver with respect to the shadow band is considered from reference both to these and to other eclipse observations. A "Bibliography of Eclipse Effects" is appended, with a later communication by the author giving results of measurements made in New York City on the 75 metre signals from Schenectady.

R113.9.—Some Measurements on Wireless Wave Fronts.—R. L. Smith-Rose and R. H. Barfield (E.W. & W.E., Sept., 1925).

After a review of preliminary theory of wireless transmission, the authors describe the use of a straight-wire rotating aerial (Hertzian rod), and a rotating loop for the determination of the electric and magnetic components respectively of an arriving wave. Results are given of the use of this apparatus at short distances from the transmitting stations. These show practically negligible tilt of the electric component in the plane of propagation on medium waves of 2 000—7 000m. at distances up to 36 miles, and a maximum tilt of 2.7 degrees on 450m. at 12 miles. The results are used to determine the earth's conductivity at the receiving station, and further experiments with portable apparatus are described, giving similar determinations at various places. A mean resistivity of 5 000 ohms per cubic centimetre is quoted. Wave-front measurements at greater distance from the transmitting stations are then described. It is stated that waves arriving from appreciable distances (*e.g.*, up to 600 miles), and under conditions such as might give rise to d.f. errors, are not readily distinguishable (by measurement of the electric and magnetic fields) from those propagated horizontally from nearer stations. The necessity for continued work on shorter wave-lengths is indicated in conclusion. The work described has been carried out under the direction of the Radio Research Board.

R125.1—The Polar Curves of Reception for Spaced Aerial Systems.—E. Green (E.W. & W.E., Oct., 1925).

The author first considers the simplest of polar curves, *i.e.*, the circle of a nondirectional vertical aerial, the figure of eight diagram of a d.f. frame, and their combination into a cardioid or heart-shaped polar diagram, with additional reference to a cardioid with a small single pip due to inadequate vertical component. He then considers the use of two vertical aerials, spaced a fraction of a wave-length apart, and mutually led to coupling circuits in the station midway between. The use of these aerials to produce a figure of eight diagram is described and well illustrated by vectors of the phase relations. The change of phase relations by the detune of low decrement closed circuits in the station is described and illustrated by vectors to give a cardioid, as is the production of a pipped cardioid by incorrect phasing. The effect of aerial spacing is considered, one-fifth to one-sixth of a wave-length being stated to give maximum signal strength. It is also stated that the spaced aerial gives great freedom from atmospherics. The use of pairs of d.f. frames at each point, instead of the vertical aerial, is then considered, with the combination of their polar diagrams and mistune to give a cardioid. Polar diagrams obtained under various conditions are very fully illustrated. The article concludes by well-summarised instructions for the compounding of the factors involved in the construction of a polar curve.

R133.—THE VALVE AS OSCILLATION GENERATOR.—Dallas G. Bower (*Electrician*, 9th Oct., 1925).

A description is given of the use of the valve to generate continuous oscillations. Curves show the phase relations between the grid potential and the anode current and potential. Expressions are given for the efficiency of the device, and the effect of working at a bent portion of the characteristic curve is discussed.

R134.—DETECTING CHARACTERISTICS OF ELECTRON TUBES.—H. M. Freeman (*Proc. I.R.E.*, Oct., 1925).

After pointing out the advantages of the valve as a detector, the author refers to the increasing need for "special purpose" valves. He then considers the operation of a detector working with cumulative grid, giving curves of detector output derived from considerations of the static characteristics. The paper then describes work done at the Westinghouse Laboratory, East Pittsburgh, in experimental confirmation of these valves. The rectified outputs from several different valves were measured, using a "slide-back" arrangement. The work was performed in a cage shield to screen the apparatus from various local sources of disturbance (including KDKA). Experimental curves were obtained in good agreement with those calculated from static characteristics, and it is shown that the method can be used to measure the effect of variations in operating conditions on the detector efficiency. Curves are given showing the effect of such variation, as well as the variations in the detector efficiency of several similar valves worked under their normal operating conditions, explaining why considerable improvement can often be made by (as the author puts it) "juggling the tubes around."

R135.—DISTORTION IN WIRELESS TELEPHONY, AND RELATED APPLICATIONS OF THE CATHODE RAY OSCILLOGRAPH.—E. K. Sandeman and N. Kipping (E.W. & W.E., Sept. and Oct., 1925).

The September article gives a general discussion of the causes producing distortion in wireless telephony. The various types of distortion are defined, and the chief causes producing each type are stated and discussed.

The October article discussed the application of the Cathode Ray Tube to various determinations of wave form, and other purposes. Sections, with appropriate illustrations, are given on (*a*) Wave form of atmospherics ; (*b*) dynamic valve characteristics (with photographic illustrations) ; (*c*) percentage modulation (with photographs) ; (*d*) asymmetric distortion (with photographs) ; (*e*) frequency resonance curves ; (*f*) other related applications, including frequency determinations by the ordinary method of Lissajon's figures and by the method of using the source under examination to vary the accelerating voltage and deflectional sensitivity.

Appendix I. (Sept.) gives a mathematical explanation of the processes of modulation and detection. Appendix II. (Oct.) describes the use of neon lamp circuits for the production of a linear time base voltage for use with the Cathode Ray Oscillograph. A bibliography is also appended.

R138.—LIFE TESTING OF TUNGSTEN FILAMENT TRIODES.—W. C. White (*Proc. I.R.E.*, Oct., 1925).

The author points out that life testing is a subject on which little has been published, and gives reasons for the importance of the subject. The chief of these are :—

(1) To verify that no details have been overlooked conducive to a satisfactory operating life.

(2) To permit the best choice of proposed details of design.

(3) To detect marked changes in the life quality of valves regularly produced.

(4) To aid in the choice of the best raw materials.

(5) To determine the most satisfactory exhaust method.

(6) Verification of characteristics during operating life.

(7) To learn the effect on life of different combinations of operating conditions.

Extensive life tests made at the Schenectady Laboratory of the G.E.C. are then described, with information and illustrations of the apparatus and methods employed. Various tables are given showing the life-test results of different batches, with a statement of the type of valve in the batch, operating conditions, hours of life and cause of failure. In one case of a Radiotron UV 201A a life of over 11 500 hours is recorded when the valve was removed from test although it had not then failed. In the same batch two others gave 10 500 and 10 000 hours respectively, while a batch of the same model, but defective, yielded lives of 75 to 125 hours. Statistical results of many of the tests are illustrated by curves. Curves are also given showing the effect of variation of filament voltage upon the life (of a tungsten filament). The author concludes by emphasising that the life of a valve is not a constant for any particular type, but is as variable as are most of the other characteristics.

R138.—THE APPLICATION OF X-L FILAMENT TO POWER TUBES.—J. C. Warner and O. W. Pike (*Proc. I.R.E.*, Oct., 1925).

This article, written from the G.E.C. Research Laboratory at Schenectady, N.Y., describes work done on the application of the thoriated tungsten (X-L) filament to power valves. The authors discuss the general properties of the thoriated tungsten filament and its advantages over other materials (particularly over the pure tungsten filament) for use with power valves. A table gives an interesting comparison of the X-L and pure tungsten filaments used in various radiotrons named, the characteristics quoted varying between an emission of 4.5mA per watt for a tungsten filament to 118mA per watt for the thoriated filament used in the 1kW. radiotron U.V. 851. Several power valves with X-L filaments are then described with photographic illustrations of constructional details and curves of their characteristics, while the improvements in design rendered possible by the use of this filament are shown. The paper concludes with a table showing the operating constants and characteristics of five power valves with thoriated filaments and ranging from the 7.5 watts rating (U.V. 210) to the 1kW. of the U.V. 851 already mentioned.

R145.—INDUCTANCE AND CAPACITY. THE EFFECTS OF HARMONICS ON THEIR APPARENT VALUES. —P. Kemp (*Electrician*, 23rd Oct., 1925).

It is pointed out that if an E.M.F. of complex wave-form (*i.e.*, with harmonics) is applied to a simple inductance, the usual simple formula $E = 2\pi f L I$ no longer holds. It is shown that if third, fifth, etc., harmonics are present the inductance of the circuit is apparently increased in the ratio

$$\sqrt{\frac{E_1^2 + E_3^2 + E_5^2 \dots}{E_1^2 + \frac{E_3^2}{9} + \frac{E_5^2}{25} \dots}}$$

This is worked out for harmonics of amplitude up to 25 per cent. of the fundamental amplitude, and shown both in table and curves.

Similarly, it is shown that the capacity is apparently increased in the ratio

$$\sqrt{\frac{E_1^2 + 9E_3^2 + 25E_5^2 \dots}{E_1^2 + E_3^2 + E_5^2}}$$

The following table shows the higher values of increase for each case :—

Per-centage Har-monic.	Percentage increase in apparent Inductance.			Percentage increase in apparent Capacity.		
	Third Har.	Fifth Har.	Seventh Har.	Third Har.	Fifth Har.	Seventh Har.
10	0.44	0.48	0.49	3.88	11.25	21.65
15	1.00	1.07	1.10	8.44	23.62	43.39
20	1.76	1.90	1.96	14.36	38.67	68.71
25	2.74	2.90	3.02	21.27	55.30	95.54

It is then shown that if calculations are based on the relative strength of harmonics present in a known *current* wave-form (instead of the form of the applied E.M.F.) the increases shown for inductance in the case of calculation on the E.M.F. wave-form are now applicable to capacity, and *vice versa*.

R200.—MEASUREMENTS AND STANDARDS.

R271.—NOUVELLE CONTRIBUTION A L'ETUDE DE LA PROPAGATION DES ONDES.—M. Lardry (*Onde Elec.*, Oct., 1925).

A continuation of the paper in *Onde Electrique* of Sept., 1925 (abstract in E.W. & W.E., Nov., 1925).

The author's measurements were continued on 50 metre stations, including the S.S. *Jacques Cartier*, on a voyage from Havre to the Gulf of Mexico and back. Curves are given of the readings taken on different stations. These show general similarity to the previous results on 450 and 115 metres. Measurements were also made on emissions of 48 and 50 metres sent out simultaneously from the same station. The results are similar as regards the mode of variation, but the 48-metre curve is two or three hours ahead of the 50-metre curve in details of variation.

The results are summed up as showing two distinct phenomena, (1) rapid fluctuations sometimes cutting signals down to unintelligibility; (2) longer period variations with a daily maximum and minimum, which the author compares to a tidal effect.

R300.—APPARATUS AND EQUIPMENT.

R342.6—SELECTIVE AMPLIFIERS.—P. K. Turner (E.W. & W.E., Oct., 1925).

The paper gives detailed consideration to the fundamentals of design of one or more stages of H.F. amplification to give a correct degree of selectivity. The familiar tuned anode circuit is illustrated and reduced to "equivalent circuit form." Symbols are assigned to the chief relationships of the circuit, and their general effect considered. The following curves are given to assist in the choice of circuit constants for any particular design, (*a*) efficiency against tune (*i.e.*, resonance curves) for different values of the ratio of anode resistance to coil reactance, (*b*) efficiency against this ratio for stages from 1 to 6, (*c*) efficiency against tune for stages from 1 to 6, (*d*) efficiency against frequency and/or wave-length for different values of a steady modulating frequency, (*e*) efficiency against ratio of anode resistance to coil reactance for 1, 2 or 3 stages and for different values of tuning ratio, (*f*) capacity against frequency and/or wave-length for different values of anode resistance. The use of the curves as aids in design are neatly summarised, while two appendices give details of the formulæ involved in the curves.

R342.6—A TRUE CASCADE R.F. AMPLIFIER.—Dr. L. M. Hull (*Q.S.T.*, Oct., 1925).

The author considers the question of obtaining a true cascade effect at radio frequencies, *i.e.*, a number, n, of stable stages, each yielding a voltage gain of A, so that the overall voltage gain is A^n. A brief description is given of such an amplifier (for about 400 metres), developed at the Radio Frequency Laboratories, Boonton, N.J. Each stage is copper-shielded, and casual reactions minimised. Specifically introduced reaction between the anode and grid circuits of *one* particular wave—the second in the cascade was actually used—was found not to be detrimental to true cascading, but two such reactions actually led to a net loss. Photographs and a circuit diagram are given of an amplifier to this pattern, four stages of H.F. amplification being followed by three audio stages.

R360.—SHORT WAVE RECEIVERS.—R. R. Batcher (*Q.S.T.*, Oct., 1925).

The author gives some notes on the design of parts for a short-wave receiver, devoting special attention to the coils and their sources of loss. A graph is given for the calculation of inductance, with a nomogram for inductance capacity and wave-length or frequency. Illustrations and a circuit diagram of the Grebe C.R.-17 short-wave receiver are given. The aerial is joined to the tuner through a small fixed condenser of $5\mu\mu$F.

Rectification occurs at the first grid, followed by an L.F. stage. Reaction (from the first anode to the aerial) is controlled by a 1 000$\mu\mu$F condenser shunted by a resistance of 25 000O joined in series between the H.T. + and the reacting coil.

R384.1. — PRESENTATION D'UN ONDEMÈTRE HETERODYNE.—E. Fromy (*Onde Elec.*, Oct., 1925).

It is pointed out that in an ordinary oscillating valve circuit, variation of operating conditions, especially of the L.T. and H.T. voltages, cause sufficient variation in frequency to render the arrangement unreliable as a wavemeter. These effects are shown to be due in the greater part to changes of phase in the different circuits. This can

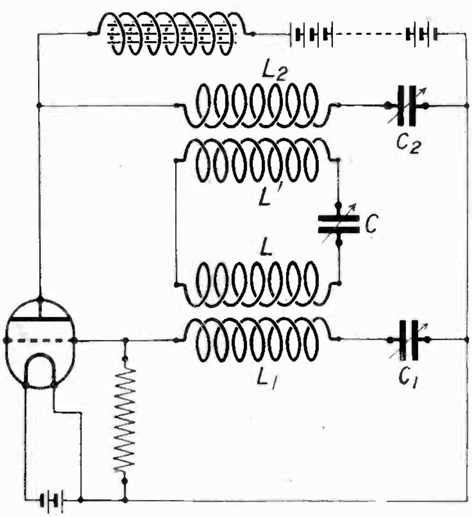


Fig. 1.

be overcome by the arrangement shown in Fig. 1 (redrawn from Fig. 2 of the paper). L_1 and L_2 have no mutual coupling, and the condensers C_1 and C_2 should be the order of C. Oscillations of very constant frequency can then be obtained in the $L L^1 C$ circuit, a curve experimentally obtained showing a variation of less than 1 in 100 000 over a wide range of working voltages. Differences in interelectrode capacities prevent a fixed calibration allowing for changes of valve, but it is pointed out that this can be overcome by a very small variable condenser from anode to grid, readjusted to maintain a constant total capacity.

R386.—FILTERS: A SUPPLEMENTARY NOTE.—P. K. Turner (E.W. & W.E., Oct., 1925).

A supplement to the author's paper on "Filters" in E.W. & W.E. of August, 1925. Band Pass and Band Stop Filters are illustrated, and the expression for each given. Distinction is drawn between "width of band" and "sharpness of cut off," and the factors governing the former are considered.

R388.—DISTORTION IN WIRELESS TELEPHONY AND RELATED APPLICATIONS OF THE CATHODE RAY OSCILLOGRAPH.

See abstract under R135.

R600.—STATION EQUIPMENT, ETC.

R616.5.—BIRMINGHAM BROADCASTING STATION.—E. M. Deloraine (*Electrician*, 9th and 16th Oct., 1925).

The whole of the first article is devoted to theoretical considerations of the conditions to be fulfilled at transmitter and receiver for the best reproduction. The requirements of the human ear are first considered and illustrated graphically, as are the frequencies characteristics of speech as regards both energy and importance for intelligibility and the sound spectra of various musical tones from voice, piano, violin, clarinet and organ. The author discusses the possibility of arranging that the wireless transmitter should, over all, discriminate against low frequencies, leaving the receiver to discriminate against the higher audible frequencies, to secure a final balance in reproduction, but decides that the best system is one where the various frequencies are given their normal weight in the spectrum of sound energy. The second article considers the loudness of sound and range of variation to be transmitted and reproduced, and shows the necessity for a certain amount of control of level, *i.e.*, modulation amplification at the transmitter. The equipment of the new Birmingham Station is then described. A graph shows the frequency characteristics of (*a*) the carbon microphone, (*b*) the amplifiers and (*c*) the overall transmitter. Photographs are given of the speech input equipment, the radio transmitter panel, and microphone. Carbon and electrostatic microphones are both installed, three stages of amplification being used with the former and five with the latter. The transmitter is designed to deliver 1kW of unmodulated high frequency energy to the aerial.

Amateur Work in Egypt.

A FEW weeks ago the "Union of Greek Wireless Amateurs of Egypt" was formed, with headquarters in Alexandria and a membership of thirty.

At an electoral meeting Mr. L. P. Sclaoounos, who has been known to us for some time as an amateur, was elected President of the Union, and Mr. E. Brouzos and Dr. Glyki were appointed Secretary and Cashier respectively.

A laboratory has already been equipped and a high-power receiver installed, while permission is awaited from The Egyptian Government to erect a low-power transmitter. In addition, frequent lectures are given by the President.

We are confident that our readers will wish this new body every success and will be glad to co-operate with its members as much as possible. The address of the laboratory and offices is: Memphis Street, 24 (Camp de César), Alexandria, Egypt.

Some Recent Patents

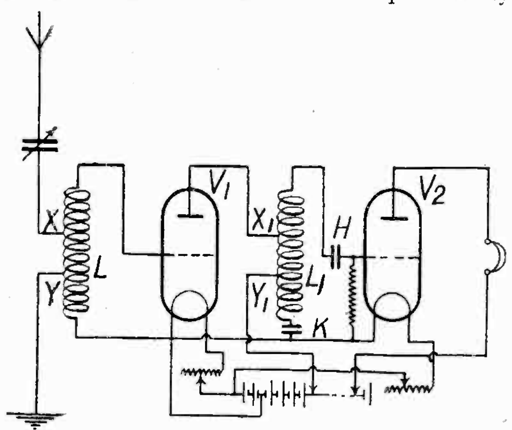
(The following notes are based on information supplied by Mr. Eric Potter, Patent Agent, Lonsdale Chambers, 27, Chancery Lane, W.C.2.)

[R008

AN INTERVALVE COUPLING.

(*Application date*, 13*th March*, 1924. *No.* 235,312.)

An intervalve coupling in the form of a step-up transformer is described by K. D. Rogers and G. V. Dowding in the above British Patent. The invention is very simple in its nature, and lies in providing a step-up transformer of the auto-coupled variety.



This consists of a coil L provided with tappings at X and Y. The portions between one end of the coil and X and the other end of the coil and Y are identical and the points X and Y are connected with the aerial and earth respectively, while the outer ends of the coil are connected between the grid and the filament of the first valve, $V1$. A similar device is used to couple the amplifier valve to the detector valve $V2$. In this case the tapping points X_1 and Y_1 are connected respectively to the anode and the high tension battery, and one of the outer ends of the coil is connected to the grid, through the condenser H, while the other is taken to a small condenser K, which serves to isolate the high tension voltage from the filament. It will be noticed that neither the primary nor the secondary of the intervalve coupling is shown tuned. The device is presumably semi-aperiodic.

DULL EMITTER FILAMENTS.

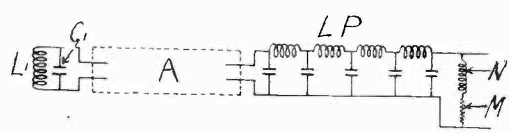
(*Application date*, 26*th March*, 1924. *No.* 236,615.)

A rather interesting method of manufacturing dull emitter filaments is described by E. Y. Robinson in the above British patent. It is pointed out in the specification that the coating used for dull emitter filaments is more easily applied to platinum and iridium alloys. Unfortunately alloys of this nature are not altogether satisfactory, as the tensile strength is not sufficiently great to enable them easily to be stretched between filament supports. According to the invention a core of tungsten or molybdenum wire, coated with platinum, is used. The coating may be deposited electrolytically, or in the form of platinum black, using a 3 per cent. solution of platinum chloride containing a trace of lead acetate. When the platinum has been deposited, the composite base is coated with the usual oxides in any convenient manner, such as mixing the oxides with wax or resin and burning off the carrier by heating the filament. The same method of construction is also mentioned in connection with equi-potential cathodes, in the form of coated cylinders, which are electrolytically or otherwise coated with platinum.

AN INTERESTING SYSTEM OF RECEPTION.

(*Application date*, 26*th January*, 1924. *No.* 233,024.)

A rather interesting system of reception is described in the above British Patent, which is granted to G. M. Wright. The object of the invention is to overcome the difficulty which is experienced in high speed signalling of the rounding off of the morse signals and the accentuation of the atmospherics. Briefly the idea consists in passing rectified currents due to incoming signals through a low pass filter and then through two impedances.

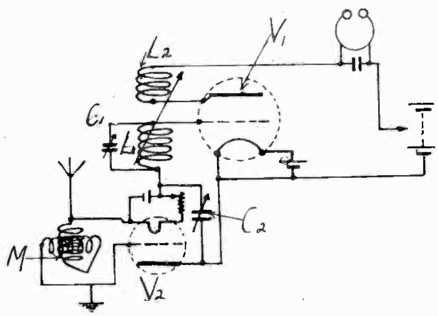


One impedance is such that the E.M.F. produced in it is proportional to the amplitude of the current giving rise to its E.M.F., while the other is such that the E.M.F. produced is at all instants proportional to the rate of change of the amplitude of the current. A recording device of some description is connected to the output of this arrangement, so that it is operated by the algebraic sum of the two E.M.F.s produced across the two impedances. The arrangement is shown schematically in the accompanying illustration. The input circuit consists of an ordinary tuned circuit L_1, C_1 of exceedingly low damping. This is connected to an amplifier A, the output of which is connected to a low pass filter LP, comprising the usual arrangement of series inductances and shunt capacities. The two impedances N and M are connected to the output of the low pass filter. The impedance M is an ohmic resistance, in which the voltage produced is proportional to the current amplitude giving rise to the E.M.F., while the other is an inductance having substantially no ohmic resistance, in which the potential produced is at all instants proportional to the rate of change of the amplitude of the current. The recording device, of course, is simply connected across the two impedances. If it is assumed that damping of the input circuit L_1, C_1 is such that frequencies of 100 cycles on either side of the tuned point are very much reduced, it will be seen that morse signals received at the rate of perhaps 30 words a minute would be very much rounded off, a "hanging-on" being produced. Now the square modulation required in morse signals is given in the receiver by the combination of the interference tones produced by the rectifier. When the side frequencies are reduced, the correct blending of the tones to get the original modulation cannot occur, with the result that the signals are rounded. But it can be shown that by passing the mixture of interference tones through impedance of the type indicated in the diagram, the original square modulation effect will be reconstructed. It is further claimed that greater ease in reception is obtained for the following reason: If it is supposed that the low pass filter cuts off at 150 cycles, harmonics after rectification of the interference tones comprising the morse modulation will have frequencies greater than this figure, and will be heavily attenuated by the filter and may be neglected. The inverse of this, of course, is true.

A NOVEL SQUEGGER CIRCUIT.

(*Application date*, 11*th March*, 1924. *No.* 238,261.)

A rather novel squegger circuit is described by J. Robinson and T. H. Kinman in the above British Patent, one arrangement of which is shown in the accompanying illustration. The squegger

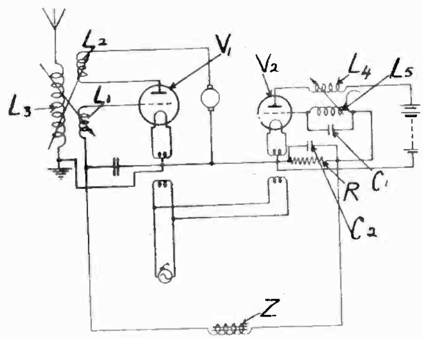


circuit, it will no doubt be remembered, consists in causing a valve to oscillate at a radio frequency and introducing into the grid circuit a resistance and a capacity, the time constant of which is adjusted so that it interrupts the production of continuous oscillations, thereby causing an audible note in the telephones. The incoming signals are caused to vary the time constant of the squegger device, thereby altering the resulting note. The novelty of the invention lies in replacing the fixed or variable resistance by means of the filament-anode impedance of a valve. Such an arrangement is shown in the accompanying illustration, in which it will be seen that the valve is caused to generate oscillations by the coupling between the grid circuit, L_1, C_1, and an anode coil L_2. The resistance-capacity combination of the squegger device comprises a capacity C_2 and the filament-anode impedance of the valve V_2. In the normal arrangement the aerial circuit is connected in shunt with the grid circuit of the valve oscillator, but in the embodiment shown in the illustration a very much greater effect is obtained by connecting the aerial circuit between the grid and filament of the valve V_2. Thus it will be seen that the aerial circuit is tuned by a variometer M which is connected between the grid and filament of the valve V_2. Several other modifications are shown in the specification in which the squegger frequency is made supersonic, and also in which a reflex action is obtained. In this case the valve V_2 is used to amplify the low frequency beat change from the anode circuit of the valve V_1, the telephones, of course, being included in the anode circuit of the valve V_2.

A GRID BIAS SCHEME.

(*Application date*, 11*th June*, 1924. *No.* 239,299.)

A method of obtaining grid bias for a valve oscillator is described in the above British Patent

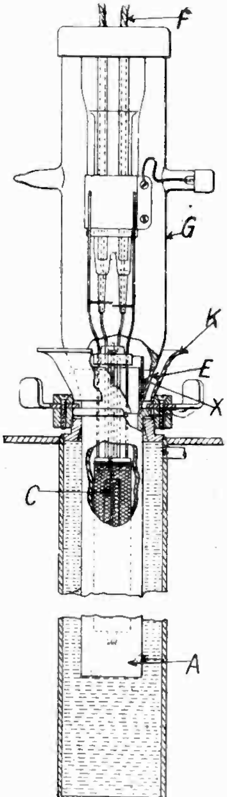


by E. Y. Robinson and Metropolitan-Vickers Company, Limited. Briefly the invention consists in causing an auxiliary valve to generate oscillations either at radio or audible frequency, rectifying the oscillations so produced, obtaining a potential drop across the resistance in the circuits associated with the auxiliary oscillator, and applying this potential drop to the grid of the main oscillator. One simple arrangement is shown in the accompanying illustration, in which it will be seen that the valve V_1 generates radio frequency oscillations in the normal way, *i.e.*, by the coupling between the coils L_1 and L_2. Each in turn is shown coupled to the aerial circuit L_3. The auxiliary valve V_2 is also arranged to produce oscillations by virtue of the coupling between an anode coil L_4 and a tuned grid circuit L_5, C_1. The grid circuit of this valve also contains a resistance R which is shunted by a capacity C_2. The lower end of the grid coil of the main oscillator is not taken directly to the filament, but to the high potential end of the resistance R, thereby obtaining a steady negative potential. To prevent any interaction between the two valves a choke Z is included in this lead. The rest of the circuit is quite normal, alternating current being used for heating the filament, a generator being used for obtaining the high tension supply to the main oscillator, and a small battery for the local oscillator. The object of the scheme, of course, is to eliminate the usual high voltage and rather bulky grid battery which is normally employed.

A PROTECTED WATER-COOLED VALVE.

(*Convention date, U.S.A., 13th November,* 1923. *No.* 224,906.)

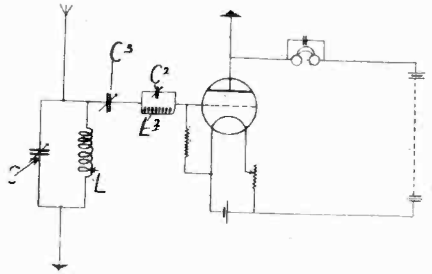
A form of protective construction for a water cooled valve is described in British Patent No. 224,906 by The British Thomson-Houston Company, Limited and H. J. Nolte. It is pointed out in the specification that arc discharges are liable to occur in high power valves, and very frequently the seal breaks down. The construction, which is shown in the accompanying illustration, is designed to overcome this difficulty. It will be seen that the valve is of the normal water-cooled anode variety, in which the anode A consists of a metal tube sealed to a glass stem G. The filament leads are shown at P and grid at C. The anode is sealed to the glass stem by means of an extension E, consisting of a copper coated and nickel-iron alloy having substantially the same expansion coefficient as that of glass. This seal is shielded by means of the extension of the anode X and the conical shaped portion K, which is extended to the glass tube. Thus it will be seen that the seal is completely between the portions X and K, with the result that all electrostatic stresses or actual arc discharges are eliminated, thereby preventing the tube from breaking down.



A RECEIVING SYSTEM.

(*Application date, 8th May,* 1924. *No.* 238,003.)

The accompanying diagram illustrates a form of receiver which is claimed by M. M. Melinsky in British Patent No. 238,003. It is stated in the specification that the arrangement produces an extremely sensitive and selective circuit, and a comparative freedom from undesirable noises such as atmospherics. We fail to see, however, how the system shown in the diagram can lessen the effect of atmospherics to any material extent.

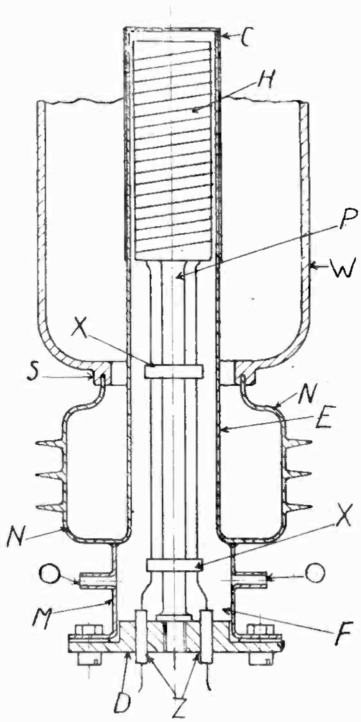


Increased selectivity is, however, obviously obtained. Briefly the invention consists in using an ordinary aerial circuit L, C, including another tuned circuit in series with the grid lead and earthing the anode of the valve instead of the filament. Thus in the accompanying illustration it will be seen that between the output of the aerial and the grid a tuned circuit L_2, C_2 is included, a third condenser C_3 of the order of $0{\cdot}001\mu F$ being included. The anode is earthed at E. The novelty of the scheme obviously lies in the combination of these ideas, each of which, of course, is not new in itself. Several modifications of the idea are shown in the specification, but a 2-valve arrangement is not altogether clear to us. The anode of the first valve is coupled to the grid of the second through another series circuit similar to L_3, L_2, C_2, but the anode of the second valve and the end of the tuned anode circuit of the first valve are both earthed, and the telephones are included in the common high tension lead. This arrangement obviously introduces a new feature into the scheme, whereas in another 2-valve arrangement, which is shown for low frequency work, the telephones are shown connected in the normal manner.

AN INTERESTING HIGH POWER VALVE.

(*Application date, 12th April,* 1924. *No.* 236,992.)

A high power valve with a rather unusual cathode is described by P. D. Tyers in the above British Patent. The valve is of the equi-potential type, the novelty of the invention lying in the construction of and method of heating the cathode. The accompanying illustration shows one form of the construction. The cathode consists of a cylinder C provided with an extension tube E, which is bent backwards at N and sealed at S to the walls W of the discharge chamber. In other words, the cathode, or rather an extension of it, forms a re-entrant tube. The cathode is heated by a heater element H, which is fixed to a support P which also carries cross-members X supporting the leads from the heater. The end of the re-entrant tube is closed in by a "heater chamber" *F*, which simply comprises walls *M* closed by a plug *D*. The leads from the heater pass through

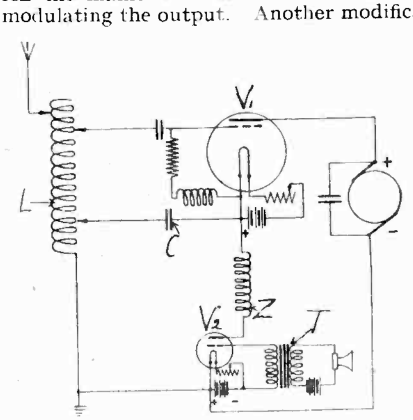


the plug at *Z*. The seal *S* between the re-entrant tube and the walls of the discharge chamber is an ordinary type of valve wall, and is intended to work at high vacuum. The seal *Z* through which the heater wires pass is a low vacuum seal. The valve is exhausted in the normal manner, and the cathode is heated by passing the current through the heater element. Owing to the boundary of the discharge chamber comprising the heater chamber, hydrogen and other similar gases in the atmosphere might pass through the heated metal, thus lowering the vacuum in the discharge chamber. In order to overcome this difficulty the space between the heater element and the plug is maintained at a low vacuum. The plug *P* is simply screwed on to the base of the walls *M* with an ordinary gasket. Outlets *O* are provided for producing a low vacuum, such as can be obtained from a small oil pump. It is claimed that the advantage of this type of construction enables a valve to be produced having an exceedingly long life owing to the very large active emission area of the cathode. It will further be seen that should the heater coil burn out, it can instantly be removed by unscrewing the plug and withdrawing it from the cathode tube. It is further pointed out in the specification that the valves allows a very rigid type of construction, in which the grid, for example, can be placed very near to the cathode, while, in addition, alternating current can be used for energising the heater coil; also there is no necessity to make a high current vacuum seal, the heater walls merely being of the ordinary low vacuum type. The cathods, of course, is coated, in order to increase the emission.

A SERIES MODULATION SYSTEM.

(*Application date*, 18*th June*, 1924. *No.* 239,309.)

A series modulation system is described in the above British Patent Specification, which is granted to G. W. Hale and Radio Engineering Company, Limited. The modulation system shown is of the type in which the anode-filament impedance of a valve is connected in series with some part of the oscillation circuit, and is varied by impressing speech voltages between the grid and the filament, thus modulating the output. The circuit shown in the accompanying illustration is comparable with several modifications described in the specification. We think, however, there must be some error in this circuit, as we fail to see exactly how the valve oscillates, since the anode circuit contains nothing other other than the voltage directly between the anode and earth, although in the specification it is stated that the anode is connected to the main aerial inductance *L*. Assuming, however, that the valve would generate oscillations, it will be seen that the filament is connected across part of the aerial inductance through a condenser *C*, and also across part of it, *i.e.*, through earth to a valve *V*2. A high frequency choke *Z* is included between the filament of the valve *V*1 and the anode of the valve *V*2. The filament of the valve *V*2 is thus connected to earth and also to the negative side of the high tension supply. A modulation transformer *T* is connected between the grid and the filament of the valve *V*2. The speech voltages impressed upon these vary its internal impedance, and alter the resistance path between the filament of the valve *V*1 and earth, thus modulating the output. Another modification



of the invention shows a similar arrangement in which the filament of the valve *V*1 is heated by passing the current through a choke and through part of the aerial inductance. The modulation valve *V*2 is then connected as before in series with the high tension supply. There appears to be very little difference between this arrangement and the more normal one of simply including a modulator valve in series with the low potential side of the high tension supply. This arrangement, of course, was in use about 1921 or 1922.