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Editorial.

The B.E.S.A. Glossary of Terms used in Electrical Engineering.

ON page 612 of this issue will be found a brief review of this publication and particulars as to price, etc. In a paper read before the Engineering Section of the British Association at Oxford, on Wednesday, 11th August, we made a vigorous protest against the unmerited slur which the British Engineering Standards Association has cast upon the fellow countrymen of Faraday, Clerk-Maxwell and Kelvin by giving its authoritative imprimatur to the publication of such a collection of definitions as are to be found on pages 11 to 18 of this book, and we expressed the hope that the Association would take immediate steps to recall it and issue a note asking those who had purchased copies to delete these pages pending their revision. The outcome of this has been the appointment by the British Association of a committee to co-operate with the B.E.S.A. in the revision of the definitions. We cannot here go into the definitions seriatim* but we may indicate briefly the sort of confusion which exists among the definitions of even the most fundamental magnetic and electric terms. Electrostatic Flux is defined as "The number of unit electrostatic tubes of force traversing a given surface. The total flux over a surface enclosing a charge is equal to the charge." Here we have a hopeless confusion between two different things, viz., the electric force and the flux or displacement produced by the force. In a condenser, for example, if the P.D. is fixed, the electric force is fixed, but the flux or charge depends on the dielectric constant or permittivity of the medium. How then can the electrostatic *flux* be defined as the number of tubes of *force*? Exactly the same confusion occurs in the magnetic units, for Magnetic Flux is defined as the number of unit magnetic tubes of *force* traversing a given surface. The impossibility of this definition is obvious from the fact that when magnetic flux passes from iron to air the magnetic force undergoes an enormous change; in fact, another definition tells us that permeability is the ratio of the magnetic flux produced by a given magnetic force in the material or medium to the magnetic flux which would be produced by the same magnetic force in a perfect vacuum. How can the ratio change if *flux* is defined as the number of tubes of force? The reason for the muddle is to be found in the failure to distinguish between cause and effect, between the force and the resulting displacement, between the stress and the resulting strain.

There is another trouble, however, which is caused by a real difficulty, although to judge from the definitions, those who drew

*The paper was published in full in the *Electrician* of 20th August, and in *Engineering* of 20th August.

them up were not aware of the difficulty. The term "potential difference" is based on the potential theory, and is only strictly applicable to fields in which the work done in moving unit charge or pole from one point to the other is independent of the path followed. In such a field the work done in moving round any completely closed curve must be zero. Now when the magnetic flux through any closed curve is changing, the work done in moving unit charge around the curve is not zero, but is equal to the E.M.F. induced in the path. Strictly speaking, therefore, the potential theory is not applicable to alternating current circuits, but in the majority of practical cases it can be applied with little ambiguity. When one speaks of the P.D. between two transmission lines one assumes that the voltmeter wires by which it is measured ran approximately from one line to the other by the shortest path, and not via the power station and the stator slots. In radio-telegraphy and all high frequency work, one has to be very careful about the voltmeter leads when measuring the so-called P.D. between two points, although if the P.D. were equal to the work done in moving unit charge from one point to the other, irrespective of the path followed, such precautions would not be necessary. As an example of the confusion caused by the misapplication of the potential theory, we may choose an example which will appeal to our least mathematical reader. Electromotive Force is defined as "an electric condition tending to cause a movement of electricity in a circuit. It is measured by the sum of the potential differences from point to point round the circuit." One of the first things we do in teaching students the principles underlying electrical engineering is to try to get them to distinguish clearly between electromotive force and potential difference, but in this definition the two are mixed up together. If one makes a closed ring of copper wire and suddenly plunges the pole of a bar magnet into the centre of it, a current is produced around the ring because an E.M.F. is induced in it, but from considerations of symmetry every part of the ring is at the same potential; there is an E.M.F. but there are no potential differences. One cannot therefore define the E.M.F. as the sum of a lot of non-existent potential differences.

These few examples will serve as a warning to those readers who may turn to the Glossary for enlightenment on fundamental magnetic and electric terms. They may even serve a more useful purpose by causing many readers to look to their own foundations and see if they have clear conceptions of the meanings of these fundamental terms which occur on every page of electrical literature.

The Thermionic Voltmeter.

By W. B. Medlam, B.Sc., A.M.I.E.E., and U. A. Oschwald, B.A.

[R261

THE thermionic voltmeter has become a very powerful weapon in various H.F. measurements, and little information concerning the operating conditions of the various forms of the voltmeter appears to have been published since the introduction of the direct deflection voltmeter by E. B. Moullin.* The present paper gives the results of an experimental investigation of the performance of five different types of thermionic voltmeter from the points of view of :—

(*a*) Sensibility and range.
(*b*) Possible frequency error.
(*c*) Wave form error.
(*d*) Input load.
(*e*) Stability of calibration.

Type 1.—Deflection Type, Rectifying on Curvature of the Anode Characteristic.

The essential connections of this well-known type of voltmeter are given in Fig. 1. The rectified current through the micro-ammeter *G* will vary with the A.C. voltage

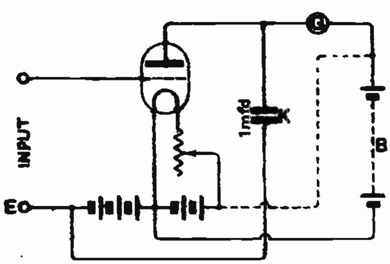


Fig. 1. *Connections of deflection voltmeter, Type I, rectifying on curvature of anode characteristic.*

applied across the input terminals, and the scale of the instrument may be calibrated to give a direct reading of the input voltage for given values of the filament current, steady bias voltage, and anode voltage due to the battery *B*.

* *I.E.E. Journ.*, Vol. 61.

The voltmeter will function without the anode battery *B* if the galvanometer lead is taken to L.T.+ as shown by the dotted connection, but a certain amount of extra anode voltage is a decided advantage as is shown later. The condenser *K* (of the order of 1μF) prevents losses due to H.F. currents flowing through the galvanometer and anode battery. It also steadies the reading of the instrument when the input voltage carries a varying modulation. To put the voltmeter into operation its input terminals are shorted, and the filament resistance is adjusted until the reading of *G* is a definite value, taken to be the zero of the voltage scale.

(*a*) *Sensibility and Range.*

The smallest voltage which can be read with this type of voltmeter depends upon the values of anode voltage and negative grid bias. The value of the latter is more or less definitely determined by the maximum voltage it is desired to measure on the voltmeter. In order to avoid grid current the bias should be about one volt greater than the peak value of this maximum voltage. Using this bias, the lowest voltage readable on a microammeter will be about two volts less than the maximum voltage. That is, the scale of the voltmeter covers a range of about two volts, commencing at any desired voltage that may be safely applied to the grid, say 100 volts or so. From this it will be seen that the sensibility decreases continuously as the negative bias is increased. This point is illustrated in Fig. 2 which shows a series of calibrations for values of the bias between —2 volts and —6 volts. For example, suppose the voltmeter is to measure up to 5 volts (peak value), the bias would be fixed at —6 volts. With this bias the change of deflection becomes too small to read with less than 1.41 volts peak, giving an effective range from 1 to 3.53 volts (R.M.S.). To read inputs of the order of 1 volt (R.M.S.) more accurately the bias may be altered to —3 volts, changing the effective range to 0.2 to 1.4 R.M.S. volts, and so on. To measure very small voltages most accurately no negative bias should be used, but in this

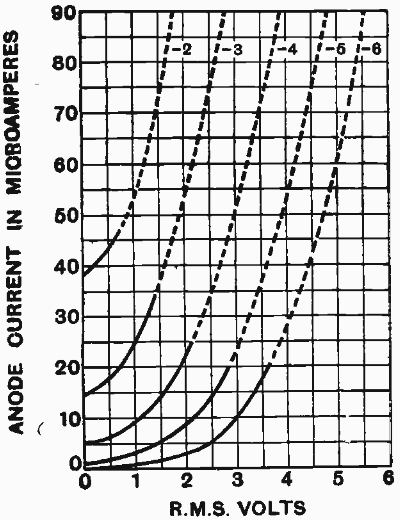


Fig. 2. *Calibration curves of deflection voltmeter, Type I.*

case the range should be restricted to the measurement of a few tenths of a volt only, owing to the increasing load produced by grid current as the A.C. voltage is raised. The lowest voltage measurable with this type of voltmeter and a microammeter is of the order of 0.1 volt. It may be mentioned that a different calibration is necessary for each range. The calibrations may be conveniently arranged in linear form, on a postcard, as shown in Fig. 3. The A.C. volts corresponding to any anode current may be read

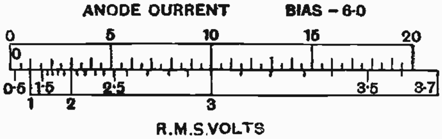


Fig. 3. *A convenient method of recording voltage calibrations of a microammeter scale.*

directly from the lower of the two scales corresponding to the particular bias in use.

The general effect of anode voltage on the sensibility is illustrated in Fig. 4, in which the relation between anode current and anode voltage is shown, for zero applied voltage by curve *A*, and for a certain constant A.C. voltage by curve *B*. The change in anode current (*i.e.*, the vertical difference between curves *A* and *B*) is shown to an enlarged scale by curve *C*. In this particular case,

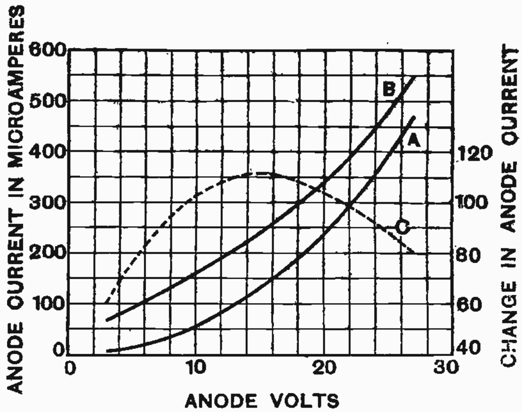


Fig. 4. *Effect of anode voltage on the sensibility of the Type I voltmeter.*

in which no grid bias was used, the best H.T. was 15 volts. The best value, however, increases with the bias. Thus, although the voltmeter may be used with the anode instrument connected direct to L.T.+, the

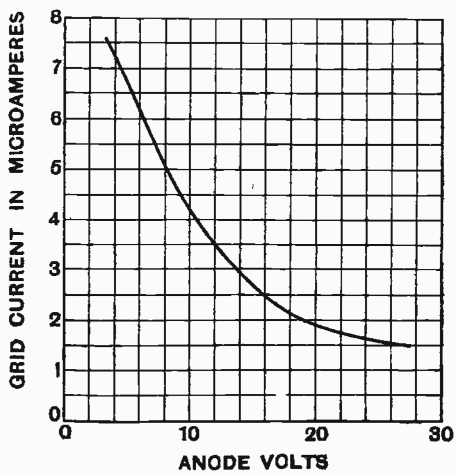


Fig. 5. *Effect of anode voltage on grid current.*

sensibility is considerably increased with a certain amount of extra anode voltage, particularly when the grid is given a steady negative bias. This extra voltage is also beneficial in another respect: it reduces the possibility of grid current to some extent, as shown by the curve in Fig. 5, which refers to the same valve with zero grid bias.

(b) Frequency Error.

There does not appear to be any appreciable frequency error in this type of voltmeter up to a frequency of 2×10^6 cycles. A calibration at this frequency agreed within the limits of experimental error with one at 40 cycles,* and further, the A.C. calibration under any given conditions is calculable exactly from a static characteristic of the valve. Fig. 6 shows how close is the agreement between a calculated and observed

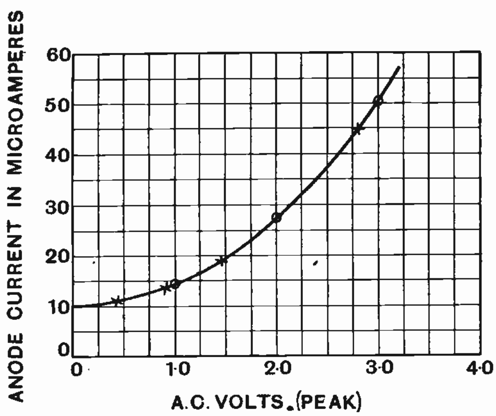


Fig. 6. *Close agreement of a calculated and observed calibration curve. (See Table IIIa.)*

calibration. The points on the curve located by ×'s were obtained from an A.C. test, those shown by circles were calculated from the static characteristic. The calculations are given in detail in the Appendix.

(c) Wave Form Error.

Errors may arise if the instrument is used to measure voltages having a wave form different from that on which it is calibrated. The. errors become more serious as the amplitude of the voltage is increased, *i.e.*, as the instrument reads nearer the top of its scale. The lower part of the scale follows a square law approximately and no wave form error occurs where this law holds, but over the middle and upper parts of the scale the calibration approximates more to a linear law and large errors may be introduced on a distorted wave. To give some idea as to the magnitude of these errors the results of a comparative test are given in Table I. and

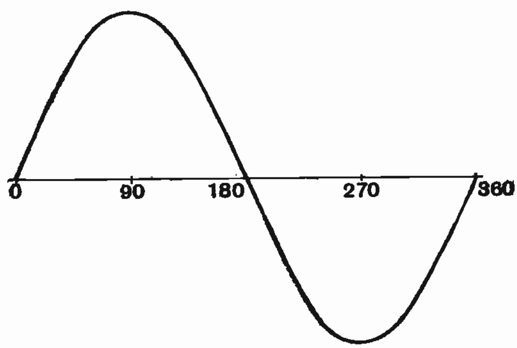


Fig. 7. *Wave form* (A)—*a sine wave.*

Fig. 10 for (*a*) a sine wave, (*b*) a wave with a pronounced third harmonic, and (*c*) a wave with a second harmonic. The wave forms are given in Figs. 7, 8 and 9 respectively. The equations to these wave forms, neglecting unimportant higher harmonics, are :—

(*b*) $E = \sin \omega t - .31 \sin 3\omega t + .05 \sin 5\omega t$

(*c*) $E = \sin \omega t + .26 \sin\left(2\omega t + \frac{\pi}{2}\right)$

In (*b*) the ratio of peak value to R.M.S. is 1.83, and in (*c*) the ratio peak/R.M.S. is 1.05 for the flat half and 1.77 for the reverse half of the wave, the ratio of the peaks being 1.7. The errors in the last three columns of Table I. were deduced from the sine wave calibration.

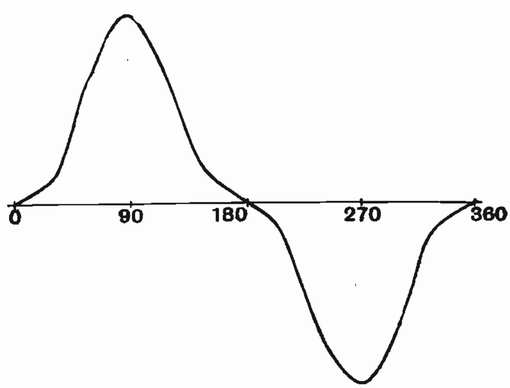


Fig. 8. *Wave form* (B)—*has third and fifth harmonics.*

* Care was taken to eliminate harmonics in the wave forms.

The results in Table I. show that the large third harmonic (*b*) increases the reading about 2 per cent., the flat half of the second harmonic (*c*) produces a more variable and rather larger error, and the peaky half of (*c*) produces unexpectedly large errors of the order of 22 per cent. for readings greater than 1 volt.

TABLE I.

H.T. = 18 volts. Grid bias —3.0 volts.

R.M.S. volts.	Anode current (μA) with wave forms.				Per cent. error.		
			c			*c*	
	a	*b*	Peaky half making grid +	Flat half making grid +	*b*	Peaky half +	Flat half +
0	14.5	14.5	14.5	14.5	—	—	—
0.5	17.5	17.7	17.8	16.8	+0.5	+ 0.6	−16.0
1.0	24.0	25.3	28.0	24.5	+7.0	+22.0	+ 2.0
1.5	35.0	37.7	47.3	37.1	+6.0	+25.0	+ 5.3
2.0	52.4	54.0	71.0	55.7	+2.0	+21.0	+ 3.2
2.5	75.0	77.0	101.5	78.5	+2.0	+21.0	+ 3.2
3.0	100.0	101.4	137.0	105.0	+0.8	+23.0	+ 3.3

These wave form errors are great enough to indicate the necessity for care in the use

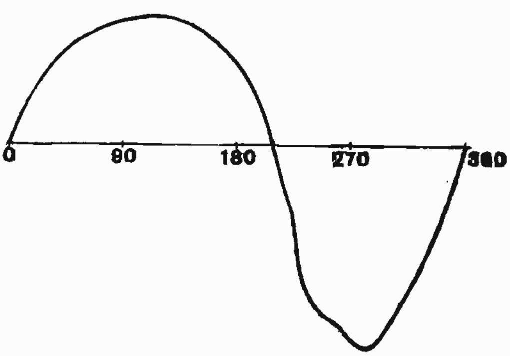


Fig. 9. *Wave form* (c)—*has a second harmonic.*

of a valve oscillator, the supply from which contains both even and odd harmonics. Such a supply may be effectively filtered by picking up through a tuned circuit loosely coupled to the oscillator. For instance, the E.M.F. wave (*b*), Fig. 8, was applied across an inductance loosely coupled to a circuit tuned to the fundamental. The wave form of the voltage across the condenser of this tuned circuit did not differ perceptibly from a sine wave.

(*d*) *Input Load.*

The power factor of this type of voltmeter can be reduced to a fairly low figure when the voltmeter is operated under proper conditions as regards the value of the steady bias in relation to the peak value of the A.C. voltage, and with a moderate value of H.T. voltage. The power factor, however, rises very rapidly once the grid is allowed to attain a positive potential during any part of the cycle of the input voltage. A typical set of power factor measurements on an "R" type valve are given in Table II. In this table the second column shows the input

TABLE II.

Conditions.	Capacity. ($\mu\mu$F)	Power factor.	Relative power lost.
A	1.4	.011	1
B	5.7	.019	7
C	8.0	.025	13

capacity, and the fourth column the power lost expressed as a ratio to that lost under conditions (A). The conditions are as follows :—

(A) Voltmeter panel with valve holder, terminals, and all internal wiring. Excluding the valve and external connections to H.T. and L.T. batteries.

(B) Same as (A), but with the valve in its holder.

(C) Voltmeter under working conditions, with an input of 2 volts R.M.S. at $\lambda =$ 480 metres. Bias —3.3 volts. H.T. 25 volts. Mica condensers of .02μF connected across the bias and from anode to L.T.—.

From the above results it will be seen that half the total loss with the voltmeter working near the top of its scale is due to losses in the dielectrics used in the construction of the valve. These losses vary considerably in valves produced by different firms and if one has a number of suitable valves to choose from, it is worth while making a preliminary test of their relative losses. The test necessary to classify the valves in their order of losses is a very simple and rapid one. On high frequencies a condenser connected as shown in Fig. 1 may materially reduce the power factor.

(e) Stability of Calibration.

Error due to some internal change in the valve itself appears to be very small. For example, one valve used continuously for 12 months showed no appreciable change in

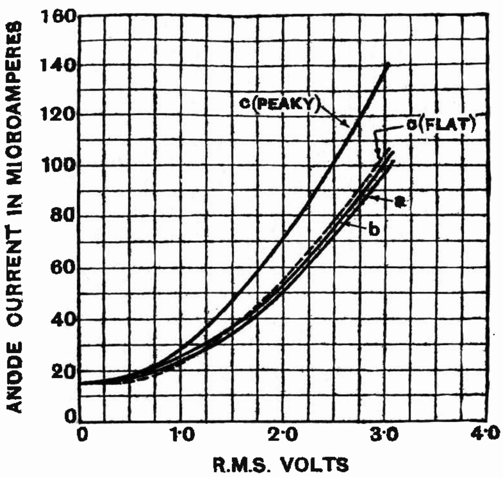


Fig. 10. *Calibration curves of the Type I voltmeter on wave forms* (A), (B), *and* (C).

calibration over this period. In fact, any internal change is very largely compensated for when the voltmeter is operated by adjusting the filament current to produce a constant value of anode current with no A.C. volts on the grid. This method also partially

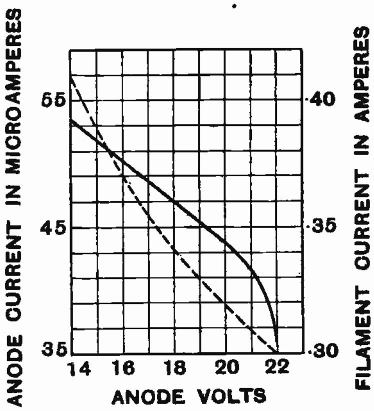


Fig. 11. *General effect of a change in anode voltage on the calibration of the Type I voltmeter.*

compensates for changes in anode voltage and grid bias, but serious errors may arise if these voltages differ much from their original values.

The effect of change in anode voltage is shown in Fig. 11 by the full line curve, which was obtained under the following conditions with a 235-type valve: Constant grid bias — 2.8 volts, constant anode current with no A.C. volts 10μA (the filament current necessary to give this reading with various anode voltages is shown by the dotted curve). Constant input of 2 volts R.M.S. Curves obtained under other conditions were of similar shape, showing increasing slope as the H.T. was increased and the filament current reduced.

Unless the filament current is low the anode current rises linearly as the anode voltage is reduced. The slope of the curve in Fig. 11 is such that 1 volt (say 5 per cent.) change in H.T. alters the anode current by 1.65μA.

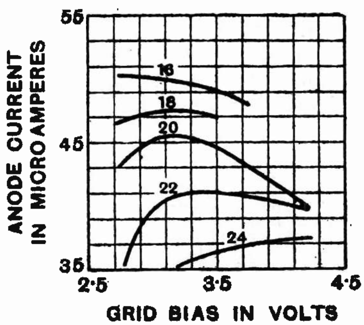


Fig. 12. *General effect of a change in bias voltage on the calibration of the Type I voltmeter.*

From a calibration curve it was found that this change in anode current corresponded to a change in A.C. volts of .04 volt, *i.e.*, from 2.00 to 2.04 volts, or 2 per cent. Thus near the top of the scale the voltmeter reads 1 per cent. high when the anode volts drop 2.5 per cent. With low filament currents the error becomes greater.

The effect of a change in steady grid bias is shown in Fig. 12 for the same valve with the same anode current with no A.C. volts and with a constant input of 2 volts as before. The anode current with the A.C. voltage applied was noted for a series of values of the bias (after adjustment of the filament current to give the same "zero" of 10μA). The results for five different values of the anode voltage from 16 to 24 volts are as shown in Fig. 12. It will be noted that the general slope of these curves is very much less than is the case in Fig. 11

(horizontally they cover about the same percentage change in voltage) indicating, in general, a much smaller error due to a change in the bias than is produced by the same percentage change in anode voltage. Fig. 12 shows that as the bias is reduced the curve may rise, keep level, or fall, according to the operating conditions; thus these may be chosen so that little error is produced by, say, a 20 per cent. fall in bias voltage.

Type II.—Deflection Type with Leaky Grid Rectification.

The connections of this type of voltmeter are shown in Fig. 13. In this type the galvanometer reading decreases as the input voltage is increased. Its obvious advantages over the former type are that it does not require a closed input circuit, *i.e.*, it can be used to measure the voltage across one of two condensers in series, and it is not affected

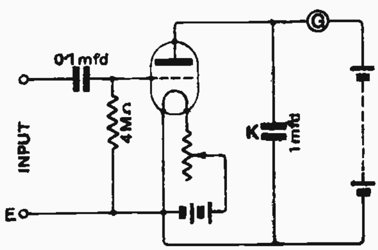


Fig. 13. *Connections of the deflection voltmeter, Type II, with leaky grid rectification.*

by any D.C. voltage across the input provided the grid condenser has an insulation resistance very much greater than the resistance of the leak. The importance of high insulation resistance in the grid condenser cannot be emphasised too strongly. To take an extreme, but quite practical case, suppose one wishes to measure the A.C. voltage across an anode resistance of 50,000 ohms in a resistance-coupled amplifier, and suppose the A.C. voltage to be measured is of the order of 1 volt. The anode current (D.C.) may be of the order of 2 milliamps, giving a D.C. drop on the resistance of 100 volts. A simple calculation will show that a D.C. voltage exceeding 1 per cent. of the A.C. voltage will be applied to the grid unless the insulation resistance of the grid condenser exceeds the huge figure of 20,000 megohms, with a grid-leak of 2 megohms. The necessary insulation resistance of the condenser increases with the leak resistance.

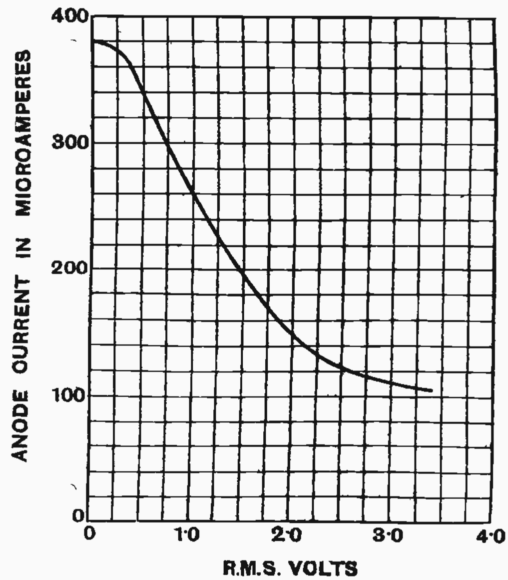


Fig. 14. *Specimen calibration curve of the Type II voltmeter.*

(*a*) *Sensibility and Range.*

A specimen calibration for a voltmeter of this type is shown in Fig. 14. From this curve it is evident that the sensibility is greatest between the limits of 0.5 and 2 volts, and falls rapidly for voltages exceeding 2.

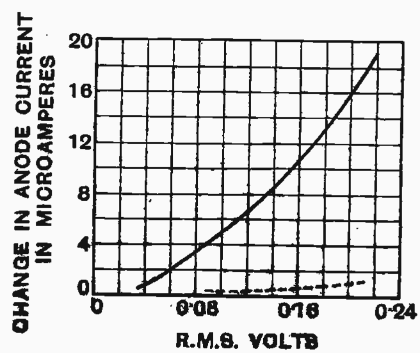


Fig. 15. *A low voltage calibration curve of the Type II voltmeter.*

Thus the range is restricted to the measurement of not more than about 3 volts, and we have not been able to devise any simple way of extending the range, such as can be done in the first type by adjustment of the grid bias.

A low voltage calibration is shown in Fig. 15 by the full line curve. For comparison a calibration over the same range for a Type I. voltmeter is shown by the dotted line. The grid-leak type appears about three times more sensitive than the other, and reads down to about .04 volt with a microammeter. Owing to the large steady anode current with no applied voltage it is usually necessary to balance out this current in order to avoid having to shunt the microammeter and thus lose entirely the extra sensibility of this method. The usual balancing arrangements are shown in Figs. 16 and 17. A low resistance potential divider is connected across the filament accumulator (Fig. 17) or separate accumulators (Fig. 16). Current through the galvanometer from the potential divider is

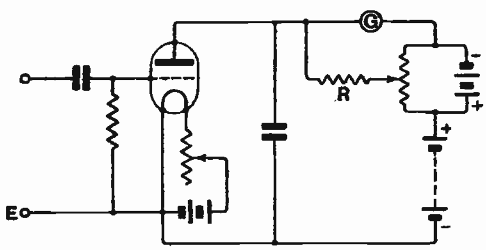


Fig. 16. *A method of balancing out the steady component of anode current.*

in the opposite direction to the steady anode current, and may be made equal and opposite to it by adjusting the potential at the tapping end of the resistance *R*. The resistance *R* should be made large compared with that of the instrument and potential divider to minimise loss of sensibility due to its shunting effect. The multiplying power of the shunt has usually to be determined from a separate calibration.

Unlike the first type of voltmeter, the leaky grid type will not operate when the anode voltage is below a certain value. With low anode voltages rectification on the lower bend of the characteristic occurs and the anode current rises—instead of falling—with increased applied volts. It is, in fact, possible to adjust the H.T. so that no change in anode current occurs when a voltage is applied to the grid. These points are well shown in Fig. 18, in which the full line curves show how, in an actual test, the anode current varied with the H.T. with (*a*) no voltage applied to the grid and (*b*) an alternating voltage of R.M.S. value 1.61 volts was applied. The change in anode current due to the A.C. voltage is shown to an enlarged scale by the dotted curve.

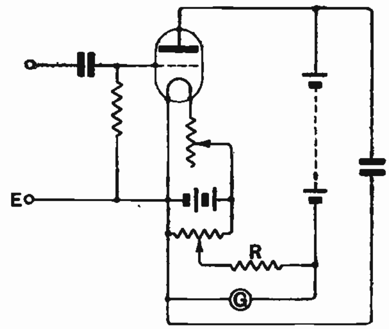


Fig. 17. *Another method of balancing out the steady component of anode current.*

The best potential to be applied to the filament end of the grid-leak has to be determined by trial, but it may be mentioned here that any gain in sensitivity due to a positive potential on the leak may be more than offset

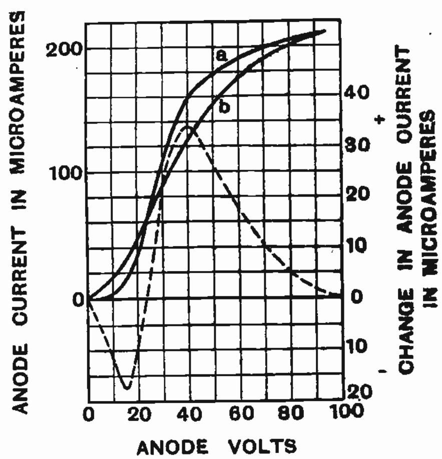


Fig. 18. *Effect of anode voltage on the sensibility of the deflection types of voltmeter.*

by the rise in power factor of the voltmeter due to this positive connection, and by the possibility of a change in calibration due to alteration of this potential as the cells run down.

(*b*) *Frequency Error.*

This type of voltmeter is not entirely free from frequency errors, although these may be made small by suitable choice of values for the grid capacity and leak resistance. For present purposes the voltmeter is equivalent to the arrangement shown in Fig. 19, in which R is the leak resistance, K_1 the grid condenser, and K_2 the sum of the grid-filament and grid-anode capacities, including the capacities of the leak and wiring. K_2 will be of the order of $10\mu\mu$F, having a reactance of 20,000 ohms at a wavelength of 377 metres, rising to 300 megohms on about 50 cycles. As the leak resistance R will be between the limits of 1 to 10 megohms it is evident that at high frequencies the effect of R is negligible, whereas at very low frequencies that of K_2 is negligible.

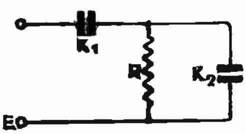


Fig. 19. *Equivalent input circuit of the Type II voltmeter.*

Thus we have to make the reactance of K_1 small compared with that of K_2 at high frequencies and also small compared with R at low frequencies. The first condition can be met by making K_1 say, 1,000 times K_2, or about $.001\mu$F, but this value is not large enough to satisfy the second condition. Suppose we wish to limit the error on 50 cycles to 0.25 per cent. using a 4-megohm leak, then the minimum value of K_1 may be calculated from the formula

$$K_1 = \frac{10^7}{\omega R\sqrt{2e}}\ \mu\text{F},$$

in which e is the percentage error assumed to be small. In this case $e = .25$. As $\omega = 2\pi \times 50 = 314$, and $R = 4 \times 10^6$, the value of $K_1 = .011\mu$F. If the leak resistance is reduced to 2 megohms., K_1 becomes 0.022μF, and for a 1 megohm leak K_1 rises to 0.045μF.

The final choice of grid-leak resistance value will be determined from the four following considerations: (1) The resistance must be high to minimise frequency error with a reasonable capacity in the grid condenser; (2) The D.C. resistance must be high so as not to add very appreciably to the power factor of the voltmeter.* From this view-point it should not be less than 2 megohms; (3) It should not be so high that the grid takes appreciable time to steady down to its steady potential. With 10 megohms the grid becomes sluggish, and the value should be below this figure; (4) It should be as low as possible to prevent error due to D.C. potentials leaking through the condenser insulation, as has already been mentioned above. In view of the last two considerations the leak should lie between 2 and 4 megohms.

(*c*) *Wave Form Error.*

In order to make a direct comparison with Type I. of the effect of wave form on the calibration of the Type II. voltmeter, the leaky-grid type was tested on exactly the same wave forms and over the same range as described above in connection with Type I. The results are collected in Table III., the letters (*a*), (*b*) and (*c*) having the same meaning as before. These calibrations are shown graphically in Fig. 20.

The errors are enormously greater in the Type II. voltmeter than in Type I. In fact there is only one single observation in Table III. with an error less than 20 per

TABLE III.

R.M.S. volts.	Anode current (μA) with wave forms.				Per cent. error.		
	a	*b*	*c*		*b*	*c*	
			Peaky half making grid +	Flat half making grid +		Peaky half +	Flat half +
0	230	230	230.0	230.0	—	—	—
0.5	188	180	176.0	200.0	+14	+24	—22
1.0	150	130	136.0	170.0	+45	+30	—30
1.5	128	100	107.0	154.0	+75	+47	—37
2.0	112	82	93.0	143.5	>100*	+70	—43
2.5	102	72	87.5	136.8	>100*	>100*	—49
3.0	96	66	84.0	132.8	>100*	>100*	—54
3.5	92						
4.0	90						
4.5	89						

* Outside the range of the sine wave calibration.

* This must be distinguished from the A.C. resistance, associated with the self-capacity of the leak, which is in parallel with the D.C. resistance. The former resistance causes most of the losses on high frequencies unless the D.C. resistance is quite low.

cent. Some of the errors are too great to be evaluated on the sine wave calibration. For example, with 3 volts R.M.S. the anode current with the third harmonic wave *b*

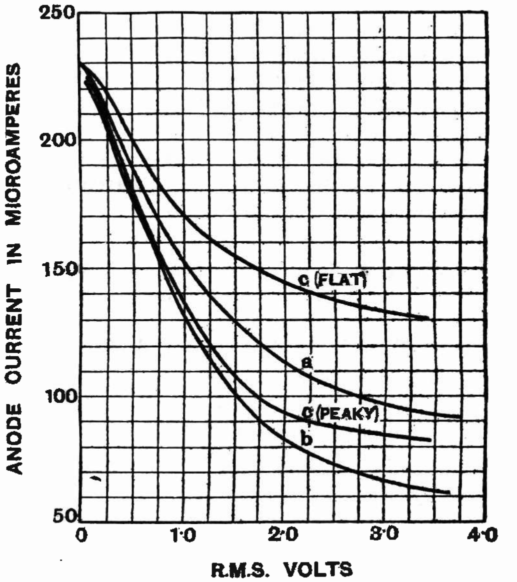


Fig. 20. *Calibration curves of the Type II voltmeter on wave forms* (A), (B), *and* (C).

is 66. The sine wave calibration cannot usefully be continued down to this anode current as it flattens out in the region of 4 volts and 90μA.

In the above test the frequency was 82 cycles, the leak resistance 3 megohms, and the grid condenser 0.3μF.

(*d*) *Input Load.*

The power factor of this type of voltmeter is very considerably higher than that of the first type. This is due partly to the grid current necessary for the action of the voltmeter, and partly to losses in the leak resistance. Some typical results are given in Table IV. These results were obtained with the same valve mounted on the same panel and with the same input conditions as for the results shown in Table II. so that a direct comparison of the two sets of results may be made. The power lost (Table IV.) is relative to *A* (Table II.). The results are shown for the same voltmeter, using three different leaks (connected to a potential of + 2 volts), and the results for the leaks alone are given separately.* The resistance element in the case of leak *D* was a plastic compound, the D.C. resistance being 4 megohms. Readjustment of this resistance to about 10 megohms did not affect the A.C. losses appreciably. Leak *E* was a piece of some ebonite substitute sold for use as panels in wireless sets. The D.C. resistance was 4 megohms. Leak *F* was made from sodium silicate which was contained in an ebonite tube carrying a terminal at each end. The D.C. resistance

TABLE IV.

Conditions.	Capacity. ($\mu\mu$F)	Power factor.	Relative power lost.
Grid-leak D	1.0	0.19	12.0
Grid-leak E	2.0	0.52	68.0
Grid-leak F	0.4*	0.41	11.0
Grid-leak G	1.2	0.12	9.0
Voltmeter with leak D	9.0	0.066	39.0
Voltmeter with leak E	10	0.13	85.0
Voltmeter with leak F	8.4	0.066	36.0

* Estimated value.

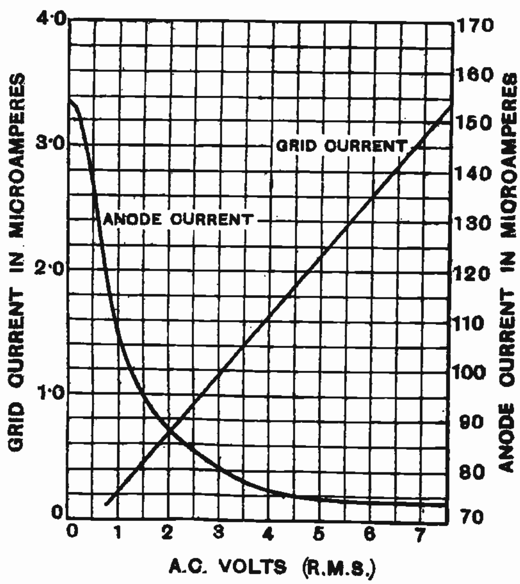


Fig. 21. *Effect of input voltage on grid current in the Type II voltmeter.*

* If the leak behaved on A.C. as a pure ohmic resistance of 4 megohms, the power lost in it would have been represented by the low figure of 2.7.

was 3 megohms. Leak *G* was a pencil line on ebonite. The D.C. resistance was 3 megohms. The power factor of the voltmeter appeared to be practically independent of the input voltage. Any change due to change in grid current was probably swamped by the large constant losses in the circuit. The manner in which the grid current varies with

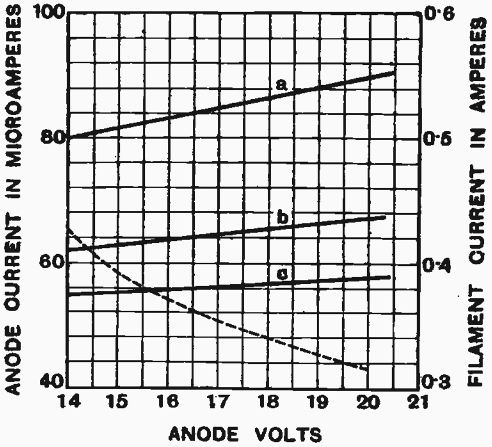


Fig. 22. *General effect of a change in anode voltage on the calibration of the Type II voltmeter.*

the input voltage is shown by the straight line in Fig. 21. The curve shows the anode current calibration obtained at the same time.

(*e*) *Stability of Calibration.*

The calibration of this type of voltmeter may alter due to a change in (1) the valve itself, (2) the anode voltage, (3) the resistance of the grid-leak, (4) the potential applied to the end of the leak when this is not connected to L.T. —.

Regarding (1), we have no definite experimental results, but it appears probable that internal changes are practically compensated for by the initial adjustment of the filament current to give a definite false zero of anode current. The general effect of change in anode voltage is shown in Fig. 22. These results were obtained by adjusting the filament current, for each value of the H.T., until the same anode current (120μA) was obtained with no A.C. volts. The anode current with A.C. volts on the grid was then noted. It is the relation between this anode current and the H.T. which is plotted in Fig. 22, for the following A.C. inputs (*a*) 0.83 volts, (*b*) 1.64 volts and (*c*) 2.44 volts. The dotted curve shows the corresponding variation of filament current. The valve was of the 235-type. A change in H.T. of 1 per cent., causes an error of about 1 per cent. in the reading at 1 volt input, under the conditions of this particular test.

The effect on the calibration due to a change in leak resistance varies considerably with the type of valve and the conditions under which it is operated. A typical set of results is shown in Fig. 23, from which it will be seen that with leaks less than 4 megohms the calibration changed much more rapidly than it did with leaks greater than 4 megohms. The calibration in the region of 2 volts R.M.S. changed 1 per cent. when the leak changed 1.3 per cent. when set at 1.5 megohms, and 6 per cent. when set at not less than 4 megohms. In the test to

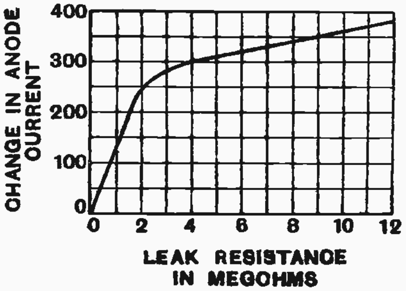


Fig. 23. *General effect of a change in leak resistance on the calibration of the Type II voltmeter.*

which these figures refer the anode current with no input was maintained at a fixed value, as the leak was varied, by adjustment of the filament current. The A.C. input was kept constant at 2.19 volts R.M.S.

If the leak is connected to L.T.+ there may be a further change in calibration as the accumulators run down.

(*To be continued*).

A High-Tension Rectifier for a Low-Power Transmitter.

By T. S. Skeet. [R355.51

THE apparatus about to be described works from 200V, 50 cycle A.C., and delivers smooth D.C. at approximately 620V and any current up to 60 milliamps.

Other voltage and current loads may be obtained as required; the output at high voltage being limited by the flash-over point of the commutator and by the voltage which can safely be applied to the smoothing condensers.

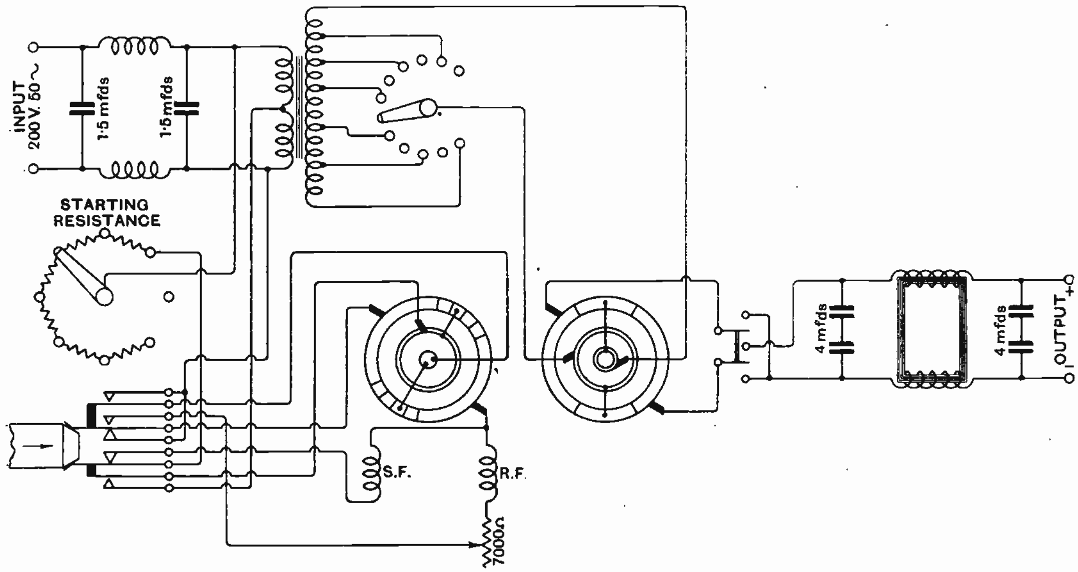
The apparatus consists of (*a*) A ½kW house lighting transformer suitably re-wound; (*b*) A small 100V A.C. motor converted to a synchronous motor and fitted with separate rectifier commutator; (*c*) Starting switches; and (*d*) A smoothing unit.

The transformer and smoothing unit were used for a considerable time with chemical rectifiers, but a device whose voltage output was less dependent on load current was desired, and the synchronous rotary rectifier was evolved.

The circuit arrangement of the outfit is as shown in the diagram, and the photographs give a general idea of the equipment.

The motor, which is a two-pole machine wound for 100V (A.C.) was first fitted with ring oiler bearings, the particular form of hollow pedestal casting being very suitable for this alteration.

A light slip ring made from the shade carrier ring of a lamp-holder was next carefully forced over the armature, empire cloth being used for insulation. The ring was connected to one commutator segment and the diametrically opposite segment was connected to the shaft. To ensure that the currents shall not flow through the bearings, a steel ball was placed in the shaft centre hole, and a piece of brass rod with spring tension is pressed on to the ball, the frame connection being made to this spring contact. The other end of the shaft has a thrust bearing, so that the armature is not displaced



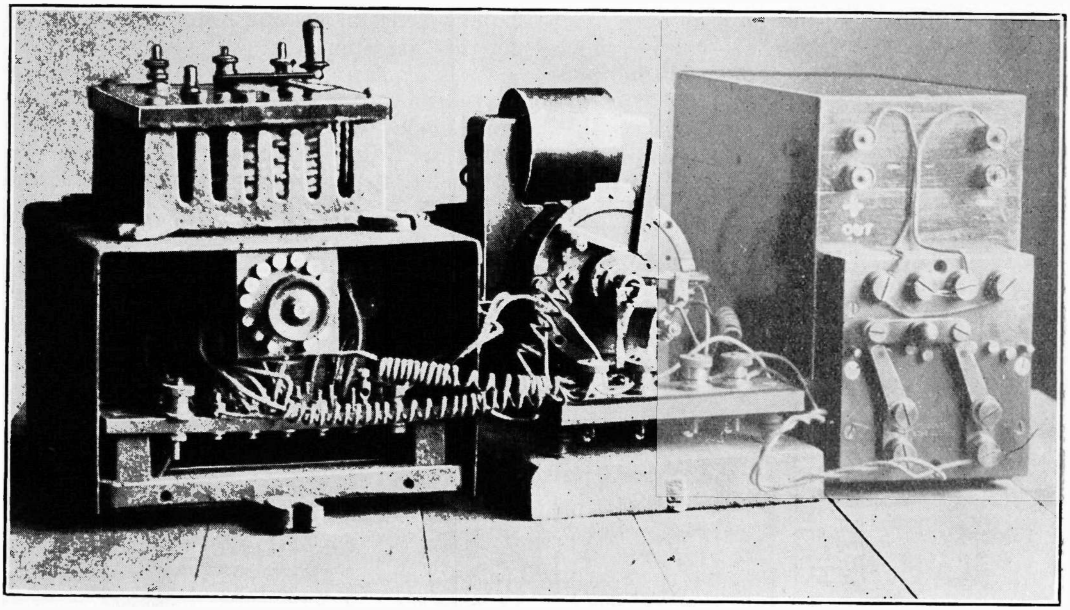
Circuit arrangement of the H.T. rectifier described in this article.

by this end tension. The various experiments with the machine occupied several months of spare time, and it may be advisable to describe briefly the ideas which were tried, and the mistakes which were made.

The field was first rewound for separate excitation from 2V, the field input being about 1½ watts. This necessitated D.C. being used for running up to synchronous speed; the D.C. was obtained from the 200V A.C. by means of a full-wave 8-cell aluminium-lead rectifier, with a solution of borax as the electrolyte. The curious beat note given out by the machine indicates approximately when synchronous speed is reached, and at this instant the plunger switch is operated which applies the 100V A.C. to the slip ring and frame connection. After a little practice it is quite easy to make the machine synchronise. This arrangement was quite satisfactory in practice, but the additional accumulator and bulky chemical rectifier were objectionable. The next move, therefore, was to eliminate the accumulator. Once the machine was started, the brushes on the commutator were idle, and as a D.C. voltage of approximately 130 could be obtained from them, the field was rewound to absorb about 2 watts at this voltage. This alteration necessitated a re-arrangement of the switching system, and the plunger switch which had originally only six contacts now has nine.

The new system also necessitated D.C. for starting, and as the chemical rectifier was not available at this period, the current was obtained from the receiving H.T. battery (accumulators, home-made, of approximately 0.1 A.H. capacity), the machine was found to synchronise quite as readily as when separately excited.

The necessity for starting up from the very small H.T. battery was the next objection, and efforts were made to start up from A.C. A separate winding of comparatively few turns of 38 gauge wire (D.S.C.) was put on the field, and attempts made to start up as an A.C. motor. Great difficulty was experienced in getting the motor to run up to speed, and the first starting winding was burnt out in the attempt. The reason for the difficulty was not obvious and occupied considerable time in finding.



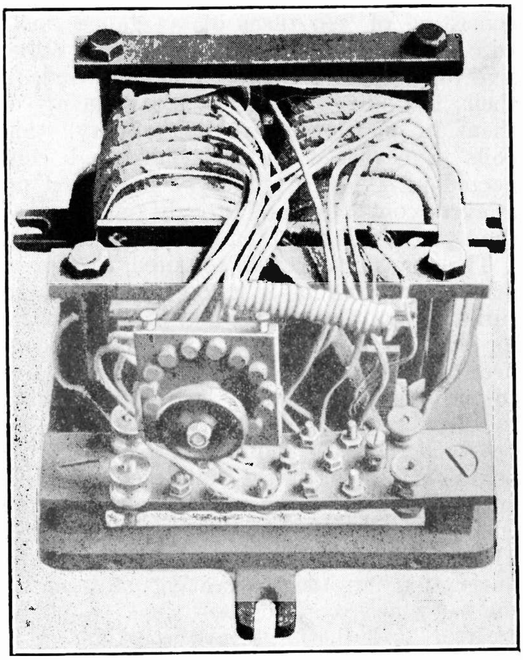
The complete apparatus.

The machine has laminated fields and a very small air gap, and is therefore a fairly efficient transformer. The running winding has sufficient turns to give an induced E.M.F. of 3,000V when 200V are applied to the armature and starting windings. The ends of this running winding were connected to a switch contact on the slate base and a terminal mounted on a fibre strip on the machine frame, and whilst this insulation was quite O.K. for 130V D.C., it was useless for 3,000V. The effect of the leakage current was practically to short circuit the running winding, and therefore to reduce the field flux to a very small amount. Increase of starting current merely increased the leakage and resulted, as before stated, in a burnt-out starting winding. After the insulation was improved the motor started up and synchronised without further trouble. It was thought that all trouble was now over, and that it would merely be necessary to fit a commutator and slip rings to the shaft to enable loads at any voltage to be taken from the rectifier.

An account of the further failures may prevent other experimenters holding the same absurd ideas. A four-part commutator was first constructed, the live segments being about two-thirds the length of the dead segments. Gauze brushes were used for the slip rings, and carbon brushes in carefully made boxes for the commutator. This arrangement was quite satisfactory for accumulator charging, particularly when graphite brushes were used, but was hopeless for high-tension rectification, anything above 250V causing violent flash-over, with consequent shorting of the transformer. Gauze brushes were next tried, and whilst matters improved, results were anything but satisfactory.

A 14-part mica insulated commutator, with three live segments connected to each slip ring was next tried, and as this gave five separate and somewhat thick mica sections between the live portions, considerably greater success was obtained. Foliated copper brushes were next substituted and these seem far superior to anything yet tried. It is presumed that a commutator, with live segments let into an insulating disc or cylinder, would be ideal, but such an arrangement would not be particularly sound mechanically, and would be subject to rapid wear. The present arrangement has been tested with a smoothed output of 700V 30 mA and 530V 70 mA. Larger output at 700V was not tried on account of lack of suitable artificial load, and an output of 800V gave occasional flash over.

As the input from the mains to the transformer never exceeds 100 watts, a 0.5kW transformer is altogether out of proportion, the transformer was, however, obtained from a lighting contractor for 7s. 6d., and had the core size been reduced, a greater length of wire would have been needed, and the cost of the wire was of course much greater than the cost of the transformer. The transformer when obtained was "auto" wound, and as the wire occupied the whole of the winding space, it was necessary to remove



The rewound transformer.

the original 200V winding and rewind with smaller gauge wire to make room for the high voltage secondary. The transformer in question is of the "core" type, the core being composed of rectangular plates. In taking the transformer apart, only the end plates should be removed, the portions inside the coils being carefully preserved in their staggered formation by tying with tape, this will save considerable time during reassembling.

It has been observed that 3 turns per volt is a standard winding for 50 cycle transformers having iron of 3 sq. in. cross section, so that should the core be reduced the turns must be increased proportionately, and a little consideration will show that the actual length of wire required will be greater than for the larger core. The transformer under discussion was rewound with 300 turns of 22 gauge D.C.C. on each limb, and the winding taped and varnished. A rectangular former was now constructed approximately $\frac{1}{8}$ in. long, and the same size as the outside of the primary winding, the removable metal cheeks were slotted to take four threads for tying up the coils preparatory to taping and to facilitate the removal of the coils from the transformer. Twelve coils were wound, each consisting of 340 turns of 35 gauge D.S.C. wire, and were thoroughly taped with adhesive tape. The coils were not varnished, as their flexibility assists in the placing of them in position over the primary. Six coils were placed on each limb and connected in series, a tapping being taken off at every connection and brought out to one of the 13 terminals mounted on the transformer.

The transformer was required to give a maximum voltage of 1,200, the extra 40 turns for coil being included to compensate for voltage drop on load. The centre connection of the 200V winding is brought out to provide the necessary 100V for running the synchronous motor.

Whilst the set is running on load, with the field at full strength, the voltmeter and milliammeter needles have a beat swing in step with the beat note given out by the machine. This beat effect is believed to be due to some fluctuation at the generating station, as the same note can be heard in a telephone receiver by induction from the mains. This beat trouble can be cured by mechanically loading the motor, *i.e.*, by applying friction to the shaft, but as this is very undesirable, the adjustable 7,000 ohm resistance shown in series with the running winding is varied until the beat ceases and the output is steady. The actual beat is caused by the armature changing its position periodically with respect to the phase of the supply; this fact was proved by inspecting the running machine by the light of a Neon lamp ("Osglim" type) lighted from the same supply main. The armature, when so inspected, appeared to be merely rocking backwards and forwards at the beat frequency, but the writer is unable to explain the reason for such behaviour.

The change-over switch shown on the smoothing unit is for the purpose of reversing the connections to the output circuit, this change over being often necessary owing to the fact that the direction of the D.C. depends on chance, *i.e.*, upon the manner in which the motor synchronises.

The smoothing unit employs Mansbridge 2μF paper condensers, eight of which were purchased for 12s. (Ex. Govt.). These condensers, as purchased, are useless for any purpose, except as variable (very) grid-leaks, and special treatment is required before they can be used as smoothers. The eight condensers referred to were placed upright in a large iron vessel and molten wax poured in, until the condensers were covered. The wax was then maintained at a temperature of 330°F. until all bubbling ceased (this took five hours). The wax was allowed to cool, fresh wax being added to make up for that drawn into the condensers. When quite cold the condensers can easily be broken out of the wax, particularly if they are tied together before boiling. The writer has treated many faulty condensers in this manner, and finds that they stand up to severe treatment far better than new condensers of similar make, owing, no doubt, to the fact that they are truly hermetically sealed, provided that they are totally immersed in the wax during the cooling process. The eight condensers are grouped as shown in the diagram, giving an effective capacity of 2μF across each end of the smoother, with the voltage of the supply divided between the two capacities in series. The smoothing choke is of original design, and has a closed core of $\frac{5}{8}$ in by $\frac{3}{4}$ in. cross section.

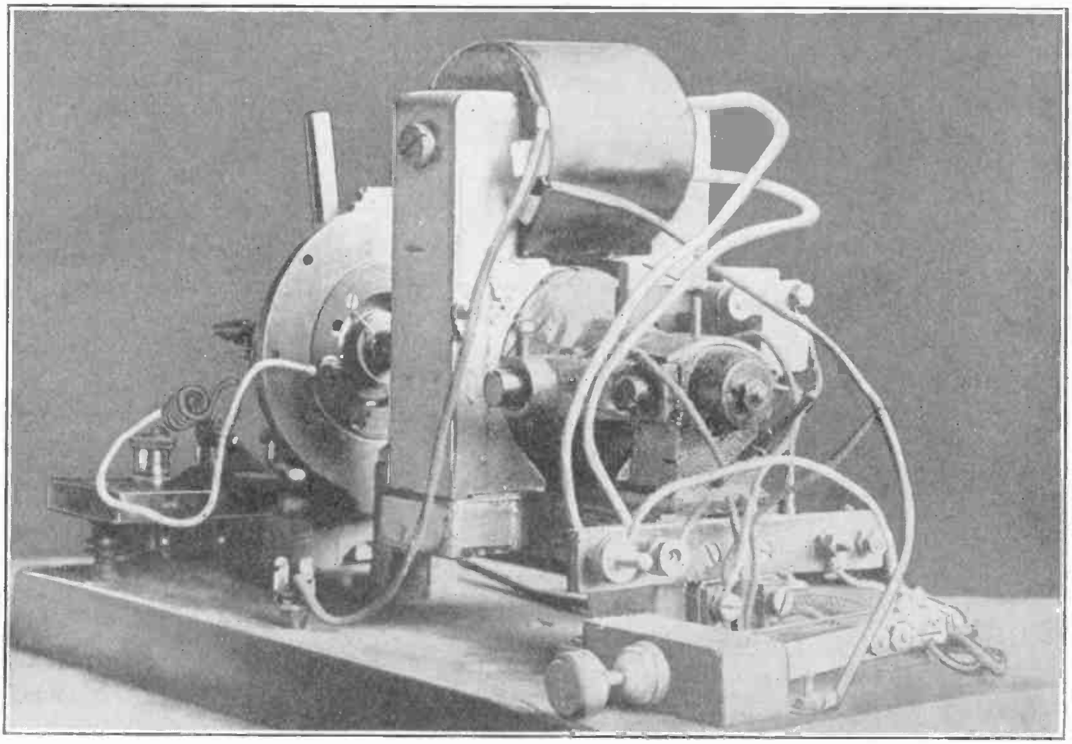
Two windings are used, each consisting of 8 ozs. of 34 gauge enamelled wire. The closed core is of rectangular form, and one winding is placed on each of two opposite limbs. One coil is connected in each leg of the supply and smoothing is very effective; in fact this type of smoothing choke with two windings is the only type which the writer has found satisfactory, either for transmission or reception H.T. supply. The fact that the core is closed and of liberal cross section, enables smoothing to be effected with comparatively few turns of wire, and consequently limited voltage drop.

The unit described above has not yet been used for transmission purposes, but it was learned that reception of Daventry on a neighbour's crystal set was seriously impaired whilst the rectifier was running on load in the workshop.

As it is desired to run the machine for test purposes, and for work with a non-radiating aerial during broadcast hours, this interference had to be eliminated. The starting and running of the machine did not cause the trouble, which only occurred whilst the rectifier was on load, it was assumed therefore that shock excitation of some portion of the apparatus was responsible.

A case lined with tinned iron was made to accommodate the whole of the apparatus, and the joints soldered, except, of course, the door joints. The apparatus was enclosed and the lining earthed, the machine was put on load and the interference was considerably increased, but with the earth connection removed there was a slight improvement over the original arrangement.

It was noticed (on a test receiving circuit) that the interference varied with the sparking of the rectifier, and after considerable running of the commutator, previously described, it was found that the flash-over voltage was reduced, and with the commutator at rest the flash-over occurred at 800 (R.M.S.) V, due to the copper dust embedded in the mica. It was probable that the minute sparks due to this leakage were accentuating the shock excitation, and in spite of previous remarks, it was decided to construct on ebonite commutator, with brass segments let into the surface.



The synchronous motor (running end).

This new commutator does not flash-over, and is far more satisfactory than the other types, but it is early to judge of its wearing qualities. The result of this latter alteration was a further slight diminution of the interference.

From the results obtained by earth connecting the screen, it was deduced that the excitation was being induced into the lighting system, the outdoor cables for which run overhead between the houses, and the next step was to provide H.F. chokes in the supply leads.

A coil of approximately 130 turns of 24 gauge wire on a $3\frac{1}{2}$ in. diameter former was included in each leg of the supply, and the interference was eliminated so far as the crystal set was concerned, but was still audible on the writer's valve set, the H.T. for which is obtained from the mains.

A $1\frac{1}{2}\mu F$ condenser was next placed across the mains at each end of the chokes, and the trouble was completely cured. The energy supplied to the transformer with the secondary on open circuit is only 9 watts, so that the condensers are causing very little loss.

The excitation should be equal in either leg of the supply leads, and therefore the condensers should not make any difference, but the slight improvement noticed is probably due to the fact that one main is earthed at the sub-station transformer, with consequent inequality of the currents induced.

The casting carrying the brush-rocker disc, which may be seen in the photographs, may be recognised as the frame of an old Blake transmitter, of the carbon button and platinum contact type which saw service many years ago in the early days of telephony.

If this article has pointed out some of the errors to be avoided in the construction of a rectifier system, its object will have been achieved.

A Method of Calibrating Microphones and Loud-Speakers.

By H. J. Round, M.I.E.E. [R290

CONSIDERABLE difficulties occur in the calibration of microphones. A constant sound pressure over wide ranges of frequency is difficult to obtain, and reference is usually made to some theoretical basis for the purpose.

I have not seen the following method described before. It is comparatively simple, and avoids a good many of the usual difficulties, and is applicable to almost any type of microphone which employs a diaphragm. I have recently used it extensively to study the action of various microphones. In general the idea is to apply the necessary force to the diaphragm by an electrostatic force instead of an air force.

The microphone diaphragm, if not metallic, is first coated with aluminium leaf, which leaf is extended all over the microphone, and well earthed.

If the microphone has a metallic diaphragm fixed in a metallic case, there will be no necessity to do this if the case can be earthed. (The W.E. electrostatic microphone is an example of this.)

Near the diaphragm surface is placed a solid flat-faced metallic block, the flat face of which can be brought to about 2 mm. from the diaphragm surface. Various shapes of block may be used to check whether any air pocket resonance is present.

If the block be now statically charged to a high voltage (from 600 to 1,500 volts I find convenient), a force is applied to the diaphragm, and if now superimposed on this

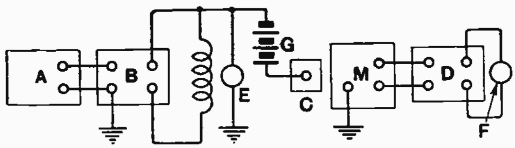


Fig. 1.

voltage an alternating E.M.F. of any frequency is applied—the E.M.F. of which can be measured—the alternating component of the force produces a current in the microphone circuit which can be measured and plotted against the applied force.

Fig. 1 is an overall representation of the apparatus used.

A is a musical note producer, which will be described later.

B is a resistance amplifier using a plate voltage of 300 volts to get large undistorted amplitudes.

C is the solid metallic block.

M is the microphone, modified if necessary as described above.

D is the microphone amplifier.

G is a polarising battery.

E and *F* are A.C. voltmeters of the slide back type placed where indicated, and the curve is plotted between their readings.

This curve can be taken as the curve between air pressure at the diaphragm surface and output open circuit volts. Absolute values can, of course, be obtained.

It may be of interest here to give a more detailed description of the note producer and amplifiers (Fig. 2).

A weak 3,000 meter fixed oscillator *O*, fitted in a shielding box, is fed through one loosely-coupled circuit—to remove harmonics —to a valve *V*, and thence induces into a rectifier *R*.

Another more powerful oscillator *P*, the frequency of which is variable and without a coupled circuit attached also induces into the circuit attached to the rectifier valve *R*.

The resulting beat tone in the plate circuit of the rectifier *R* is fairly pure and free from harmonics. A filter circuit *F*, to remove all H.F., is then inserted, and the purified beat tone, magnified up to the value desired, is of almost constant amplitude, and, in fact for rough experiments, can be assumed constant.

Calibration of note frequency is done on the condenser of the second oscillator and must be done frequently by means of one or two tuning forks. Fortunately the frequency scale is nearly linear.

The resulting beat tone is magnified up by means of a carefully constructed resistance amplifier. Harmonics are, of course, introduced, and for very accurate work must be removed by cut-off filters after the last stage

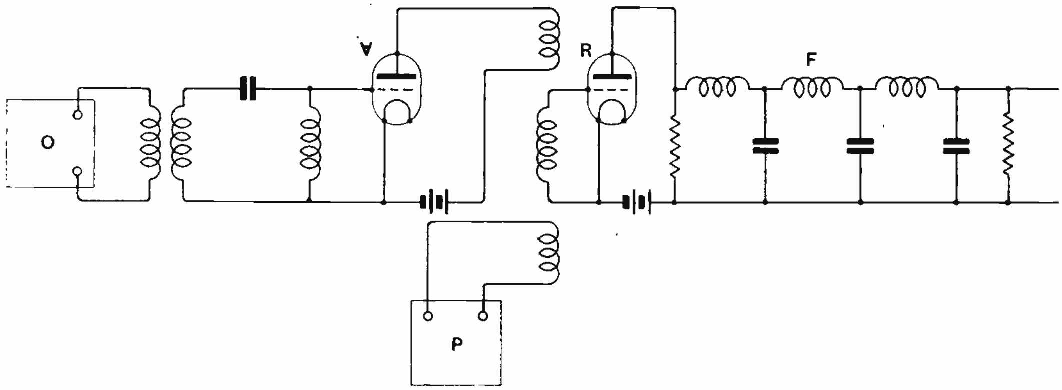


Fig. 2. *Circuit arrangement of the note producer and amplifiers.*

of amplification, but for a lot of work they can be neglected.

The above method for producing notes of constant amplitude was suggested to me by Mr. Norman Lea, and the arrangement of apparatus, including the addition of a coupled circuit for one of the H.F. oscillators, was made by my assistant Mr. N. M. Rust.

The idea of this coupled circuit is very interesting. If two oscillators are beating together and being rectified, and both produce harmonics the resulting beat tone will have similar harmonics, but if only one set of harmonics is removed the result is a freedom from harmonics in the beat tone.

A modification of the test with which I am now experimenting, is to balance the input and output in a bridge system which will give the phase angle as well as the amplitude curve.

Recent Developments in Short-Wave Wireless Telegraphy.[1]

By H. Rukop

(*Telefunken Company*).

[R401

I.—Previous History.

THE technics of wireless telegraphy throughout the whole world have experienced a great surprise during the past two years as the result of the unanticipated effectiveness of short waves for Transoceanic traffic. In this connection, waves of about 100 metres and less are to be understood as short waves, *i.e.* electrical oscillations of frequencies of about three million cycles per second and over, which have produced quite extraordinary results over great distances.

Although wireless telegraphy can now look back upon a lifetime of 25 years, it must nevertheless, as compared with other industries and branches of technology, be accounted a very young industry, in which development has proceeded with extraordinary rapidity and constant change, but one which has in no way reached a state of equilibrium. There does not yet exist any generally recognised best system of transmission, and in reception also there are still countless variations, even although, in the fundamental principles of wireless telegraphy, in the electro-dynamic action in the apparatus itself, as well as in the process of radiation and reception with aerials, there are hardly any differences of opinion worthy of mention. The explanation of the propagation of the waves over our earth has, however, always proved an extremely difficult matter. This propagation has been extensively dealt with in exhaustive theoretical and practical investigations from the very first years of wireless telegraphy (J. Zenneck, A. Sommerfeld, H. Poincaré, J. W. Nicholson, L. W. Austin, V. Rybczinski, L. F. Fuller, W. H. Eccles[2]), and there is no doubt that the true conditions have been depicted with approximate correctness by the formulæ of the respective authors. The formulæ ascertained by methods of calculation relating to the propagation along the surface of the earth take account of numerous factors: the properties of the waves themselves, the conductivity and dielectric properties of the earth's surface, the divergence of the radiation away or "Dispersion" from the earth in consequence of the spherical form ot the latter, but they do not contain at the outset any terms which take account of the absorption, reflection or refraction on the earth itself or in the atmosphere. Now, if it is desired to express the intensity of the electrical field prevailing at a certain distance from a known transmitter and proceeding from its radiation, one uses for the purpose preferably the Austin - Cohen formula:

$$E = 120\pi \frac{J_s h_s}{\lambda d} \sqrt{\frac{\delta}{\sin d}}\, e^{-\frac{0{,}0015 d}{\sqrt{\lambda}}} \text{ microvolts per metre,}$$

which, as compared with the calculated formulæ of the above-mentioned authors, contains a small correction ascertained by measurements. In this formula, J_s signifies the intensity of current in the transmitting aerial, h_s its effective height of radiation, λ the transmitted wavelength, d the distance of the place of reception from the transmitter measured along the greatest circle of the sphere, all in km., δ the angle subtended at the centre of the earth by the two stations, and E the electrical field

[1] Translation of a paper read at the meeting of the Deutsche Gesellschaft für Technische Physik, Danzig, in September, 1925, published in the *Telefunken Zeitung*, January, 1926.

[2] For publications on this subject see: J. Zenneck and H. Rukop, *Lehrbuch der drahtlosen Telegraphie*, 5th Ed., p. 294; A. Hund, *Hochfrequenz-Messtechnik*, p. 204 and following; J. Zenneck, *E.u.M.*, 43, 1925, p. 593; G. J. Elias, *E.N.T.*, 2, 1925, p. 351.

strength at the place of reception, in microvolts per metre. If, now, it is desired to estimate the dependency of the receiving field strength upon the wavelength for two given points, special conditions regarding the transmitter must also be added, for example, that with a given aerial a certain number of kilowatts are available, or that the aerial is being utilised to the limit of permissible voltage. If one combines such conditions with the Austin-Cohen formula, a function is obtained which has approximately the form of curve 1 in Fig. 1.

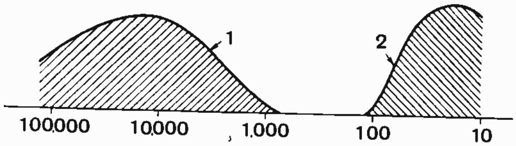


Fig. 1. *Received field strength on various wavelengths at a distance of about 6,000 kilometres.*

Now, this function is generally found to be confirmed in practice with approximate correctness. One finds in fact an optimum with certain medium wavelengths, which as a rule are about the 500th part of the distance between the two stations, that is to say, at a distance of about 6,000 km. (Nauen—New York) a wave of 12,000 metres has been found to be very satisfactory. If much longer waves are used, it is found that the strength of reception drops very considerably in consequence of reduced radiation. It is likewise found that when much shorter waves are used, there is also a greater diminution in the intensity, notwithstanding the increased radiation, this being due, as is known, to failure to bend round the globe (dispersion) on the one hand, and to absorption on the other hand. In fact wavelengths below about 1,000 metres are found to be very unsuitable for Transoceanic communications, for which reason, during the last decade, one has been enabled safely to conclude that curve 1 shown in Fig. 1 reproduces the true conditions with absolute correctness, and no technician who cared about his scientific or technical reputation would have ventured, in connection with ranges of 10,000 km. or similar ones, to speak of wavelengths far below 100 metres. And this is precisely what has now become the accomplished fact!

The discovery of the extraordinary effectiveness of these short waves was made accidentally, namely, by the fact that in the United States of North America there were allotted to amateurs, who also wished to devote their attention to transmitters, regulation wavelengths under 125 metres, regarding which it was assumed that they would not cause further interference to anybody. It was very soon found, however, that such short-wave transmissions were received at quite considerable distances, in Europe for example, whereupon the attention of all wireless technicians was immediately focused upon this remarkable phenomenon.

The question will now at once be asked how it was that so important a fact could remain concealed for so long. The explanation of this can easily be deduced from the history of wireless telegraphy.

There can be no doubt at all that the newly found good results with short waves are to be attributed solely to the era of the valve transmitter and valve receiver, since, in principle, transmission with so short waves is in no way a novelty. It should be recalled that in the early days of wireless telegraphy, Righi oscillators were used, and, as a general rule, these were of such dimensions that they were only able to give wavelengths of a few metres at the most. At least, it was the intention at that period to work with such oscillators and such wavelengths, even if, in fact, much longer wavelengths resulted when the aerial was coupled direct to the Righi oscillators.

There is no doubt that at that time the technical means available, and especially the receivers, were too inadequate for such results to be even thought of, as can now be witnessed with short waves.

A few years later, during the era of the musical note transmitter, such waves could perhaps have been conceived, from the standpoint of the transmitter. But even then no results would have been obtainable as regards reception, since there was not a fully elaborated receiving and amplification technique as would have been necessary for the purpose. The Poulsen arc and machine transmitters were quite unsuitable for the production of such short waves.

It was only after the elaboration of transmitting valves, when the production of undamped oscillations for wavelengths down to about 1 metre was made comparatively easy, that trials with short waves were again made. In fact, it was not until about 1916 that the technical auxiliaries, such as transmitting valves of suitable output, heterodynes, and all the necessary receiving and amplification circuits were developed far enough to lead to the discovery and utilisation of the singular qualities of short waves. But meanwhile theory and experience had apparently shown unanimously that propagation over the earth is subject to the laws represented by Fig. 1, curve 1. As however this representation is absolutely correct, even now, down to about $\lambda=150$ metres, and as not even a trace of deviation or exception has ever been found, it was logically held to be correct for still shorter waves, and it would have been a waste of time to go still lower with the wavelength. Only for special purposes, such as directional transmission with reflectors at shorter distances, did the short waves seem likely to be successful and attempts were in fact often made to use them.

Special mention should here be made of the series of experiments on a large scale that were carried out by C. S. Franklin and the Marconi Company, about the year 1919 and succeeding years.[3] Nevertheless, owing presumably to the lack of other receiving observation stations for these wavelengths, these experiments did not reveal the enormous importance of short waves, although all the requisite conditions were present in the transmitting apparatus of C. S. Franklin. Even the Marconi Company's receiving stations, at the time when the fabulous ranges of short waves had been discovered elsewhere, had not yielded corresponding results, so that the fame for this discovery was lost to it in consequence of the results that had been secured accidentally by amateurs.

Therefore, when the first signs of the extraordinary ranges of short waves had been justified by observations in several quarters, interested circles directed all their energies to the elaboration of this important new branch of high-frequency technics.

The "Telefunken-Gesellschaft für drahtlose Telegraphie," which together with the "Transradio - Gesellschaft für drahtlosen Uberseeverkehr" is interested in the transmission of messages by wireless telegraphy over the greatest ranges, proceeded immediately with the study of these problems and, by building and putting into operation several valve transmitters for short waves between 100 and 10 metres, for communications between Nauen and far-distant receiving stations, such as Buenos Aires (12,000 km.), Bandoeng, Java (11,000 km.), Osaka, Japan (9,000 km.), has achieved important results and progress, and acquired extremely valuable experience. Further, in several other quarters connected with the high-frequency industry, as well as in the State laboratories of various countries, important results have been obtained and published. Furthermore, amateurs, and especially those of the United States of North America, have obtained important data on the propagation of short waves, and the effect of such variable factors, as the time of the day, time of the year, wavelength, etc. One can therefore form a provisional picture of the strange phenomena of short-wave wireless telegraphy.

Before I proceed to the chief theme of the present paper, namely, the results which the Telefunken Company in co-operation with the Transradio Company has obtained in the attempt to bridge long distances by wireless, it is necessary, for a better comprehension of the subject, to explain those physical phenomena which form the basis of the action of short waves, as contrasted with long waves, as far as they appear to be known at present.

II.—Method of Propagation.

The propagation and transmission of short waves, as compared with long waves, shows some striking differences, which have already been partly described by A. Meissner[4] and A. Esau.[5] In tfhe case of short waves, the ollowing properties are especially noticeable: Fading, *i.e.*, sudden strong fluctuations of intensity, as, for example, are represented in Fig. 12; the great differences between the day and night signal strength; the existence of suitable

[3] See, for example, under G. Marconi, *Jahrb. drahtlose Tel.*, 21, 1923, 58.

[4] A. Meissner, *Zeitschrift f. Tech. Phys.*, 5, 1924, 485.

[5] A. Esau, *Zeitschrift f. Tech. Phys.*, 5, 1924, 538.

wavelengths in the immediate neighbourhood of which very unfavourable wavelengths may lie; the variation of the favourable wavelengths with the time of the day and year, and finally the so-called dead zones. Before I go into details, it must first of all be shown how the earlier laws (curve 1, Fig. 1) have been modified by the new discoveries.

According to the results obtained up to the present, there is no doubt that, in addition to the range of wavelengths of Curve 1 in Fig. 1, there exists a further favourable range, somewhat as shown in curve 2, Fig. 1, of wavelengths of about 100 metres and below, but that between these two ranges there is a range which is useless for Transoceanic distances. That curve 2 is not given by the above-mentioned formulæ is due to the fact that the latter are only calculated for a direct transmission along the earth's surface, and that Austin's experimental results were only obtained on longer waves, whilst the effect of the short waves—as can now be maintained with the greatest certainty—is an indirect one. By this it should be understood that the short waves travel, on the one hand, along the surface of the earth, but that the energy which is measured at distances of several thousand kilometres does not proceed from a propagation along the earth's surface, but has returned from the higher layers of the atmosphere. The reasons of this assumption are justified by various experimental results of the past year.

One of the most important reasons which can now be adduced for this is the so-called "dead zone" which occurs in certain cases which are more fully described below. The strength of reception, in fact, has often a remarkable distribution around a transmitter, in that, first of all (see Fig. 2(*a*)) there is around the transmitting aerial (*S*) a zone of considerable intensity (*A*). Beyond this zone is found a second one (*B*) in which the receiving strength is exceedingly small, whilst at a certain distance a zone of increased receiving strength (*C*) is again perceptible, and this may be of enormous extent. The simplest explanation of this, then, is that zone *A* is that of direct transmission of surface waves, which the Austin-Cohen formula represents, and that these surface waves at the beginning of zone *B* have so diminished in their intensity by absorption and reflection that they can no longer be detected. A considerable amount of radiation energy has, however, directed its course obliquely upwards and, in consequence of physical conditions to be explained later, returns again to the earth, where it becomes perceptible in zone *C*.

As regards the existence of the dead zones, exhaustive statistical investigations have been reported by J. L. Reinartz[6], and also by A. H. Taylor and E. O. Hulbert.[7] Exact data regarding this are given in the latter paper, from which it appears that dead zones do not occur generally in wavelengths above 50 metres, that in the neighbourhood of 40 metres they may first of all assume breadths of about 100-200 km. and that their breadth down to a wavelength of 15 metres increases extraordinarily and may reach far beyond 1,000 km.

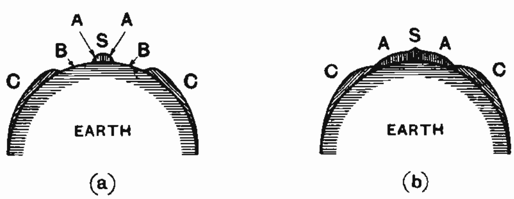


Fig. 2. *Distribution of the receiving intensity around a short-wave transmitter.*

The direct receiving zones *A*, Fig. 2(*a*). which are obtained with various wavelengths, may, depending on the conditions, vary in width from a few kilometres (occasionally estimated at less than 10 km.), to 100 or 200 km., and the direct zone is in fact probably reproduced with sufficient correctness by the original Austin-Cohen formula.

But even where there is no dead zone, there is direct as well as indirect transmission. This means that with the longer waves of range 2 (approximately 60 to 100 metres) the direct range is so large that it overlaps the zone of the indirect range.

[6] J. L. Reinartz, *Q.S.T.*, 9, 1925, No. 4, p. 9.

[7] A. H. Taylor and E. O. Hulbert, *Q.S.T.*, 9, 1925, No. 10, p. 12; A. H. Taylor, *Proc. I.R.E.*, 13, 1925, 677.

There then results, instead of the distribution shown in Fig. 2(*a*), a distribution as shown in Fig. 2(*b*), and the signal strength in a receiver, at increasing distances from the transmitter would, in the case of the distribution shown in Fig. 2(*a*), be represented by curve *a* in Fig. 3, whereas in the case of the distribution shown in Fig. 2(*b*) it would be given by curve *b*. The former (curve *a*), would, therefore, be expected with wavelengths of less than 40 metres, the latter (curve *b*) with waves over 60 metres. It would appear that the fading phenomena are especially great at those places where the direct range overlaps the indirect. On the other hand, they are in no way limited to this zone, since even at distances of 10,000 km. and over, where indisputably only the indirect rays are concerned, they are also very pronounced. A further reason for the assumption that short waves do not go

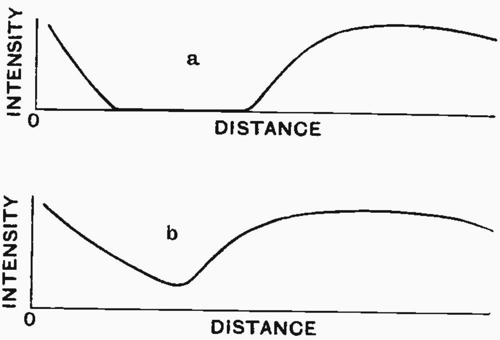


Fig. 3. *Variation of signal strength with distance of the receiver from the transmitter.*

by a direct route over great distances is the fact that when bearings are taken along the route, either they are extraordinarily lacking in sharpness or it is completely impossible to effect them, the received waves being of a muddled or diffuse character.

A very interesting discovery regarding the return of waves from the upper atmosphere has been made by E. V. Appleton[8] who found, by means of a receiving set some 150 km. distant from the transmitter, that at the respective point of reception there were both direct and indirect rays, since interference between the two could be demonstrated. He likewise found, on varying the wavelength, that there were very close maxima and minima of reception, from which he was able to deduce that there was a difference of path between the two rays amounting to about a hundred wavelengths. From the distance of the station and the different length of path (about 80 km.), he was able to conclude that the indirect ray returned from a height of 80–90 km., a height at which, from our knowledge of meteorological conditions, a considerable conductivity is extremely probable.

If we assume that the radiation returns from the upper layers of the atmosphere, the conditions for the realisation of this phenomenon must be very complex. Several explanations are possible. A simple assumption would be that the electrical waves are totally reflected at the naturally not very sharp limit between the atmosphere and the space which is either empty or interspersed with frozen gas dust. It can, therefore, be easily deduced, from the configuration of the atmosphere and the earth, that the rays in order to traverse a route such as that from Nauen to Buenos Aires *i.e.*, about 100 degrees, would necessarily undergo numerous total reflections. It is manifest that this explanation is not adequate, however, since if it were only a question of the dielectric properties of the atmosphere, there would be no reason why waves of from 100 metres up to the longest are not also totally reflected to the same extent. This would necessitate a dispersion, which is in nowise inherent in the air.

Instead of a total reflection, on passing from the air-space (atmosphere) to the empty space, one can secondly assume a reflection at the much discussed Heaviside layer, *i.e.*, a layer which, as compared with the air layers on the earth's surface, is said to possess a considerably increased conductivity in consequence of ionisation. The same here applies as has been said in the, previous case, regarding the necessary manifold reflection.

The possibility both of reflection and of selective reflection for short waves of only a definite range, is here present. The physical bases of this assertion will also be discussed below when treating of the fourth

[8] E. V. Appleton, *Tidj. Ned. Rad. Gen.*, 2, 1925, 115.

possible explanation. In any case, the explanation just given is to be counted among the more probable ones, even if preference is now given to the fourth explanation set forth below.

A third possible explanation is refraction, *i.e.*, such a bending of the rays in the upper layers of the atmosphere that they follow a path parallel to the curvature of the earth, so that when the waves have once reached certain heights, they now direct their course without reflections to distant points of the earth, and the energy, less what is lost on the way, returns to the earth. The only physical prerequisite for such a curved route is that the speed of propagation in the upper air layers must be somewhat greater than in the lower ones, namely, of course, to such an extent that the curvature of radiation is approximately the same as the curvature of the earth. Here also one might at first assume purely dielectric differences. For this, the dielectric constant of the lower air layers, in comparison with that of the upper ones, would have to be greater than that actually caused by the difference of density, and one would be compelled to have recourse to the aqueous vapour in the lower layers or something similar, as has already been suggested by the above-mentioned authors. But, here again we should be in a dilemma in that we should have to assume, with a purely dielectric explanation, a dispersion of the air layers, in order to explain the extraordinary difference in the propagation of the short waves as compared with the long. This explanation seems therefore to be as little tenable as that of total reflection.

A fourth explanation is now chiefly held to be the correct one, namely, that a curvature of the wave rays takes place, therefore not reflection but refraction, and that this curvature is effected by the effective dielectric constant being diminished in the upper layers by conductivity, and the speed of propagation consequently increased. The existence of such a conductivity cannot, of course, be held to be contrary to physical laws, and it seems entirely justified to assume a " Heaviside Layer " of such conductivity, so long as nothing better is known to explain the peculiar facts. The assumption of O. Heaviside is to the effect that in the upper atmosphere there are found layers with considerable ionisation and therefore of considerable conductivity, and that the divergence of the electrical waves from the earth and their radiation into universal space is thereby prevented, and the receiving intensity is increased far beyond that given by the ordinary diffraction formula. Now, whether this conservation of radiation is effected by reflection or refraction, would probably matter but little as regards the designation " Heaviside Layer." It can in any case be maintained that the great scientist, with intuitive glance, at once realised the favourable influence of atmospheric conductivity on the propagation of electrical waves, even if his explanation should not be found to be correct to a full 100 per cent.

The assumption of a radiation curvature due to diminution of the dielectric constant of the upper layers, in consequence of conductivity, is not only capable of explaining the extraordinarily favourable ranges and the conservation of the radiation energy, but also the difference in the propagation of short waves, as compared with the long ones. Even before the discovery of the short-wave phenomenon, it had already been pointed out from many quarters that, if the effective dielectric constant of the air is lessened by ionisation or conductivity, it must become noticeable in wireless telegraphy (H. W. Eccles, J. Salpeter, B. van der Pol, etc.).[9] The assumption which has to be made regarding the density of ionisation in the upper layers, in order to obtain a suitable variation of the dielectric constant by conductivity, is exceedingly probable and agrees with what is believed regarding the ionisation produced in the upper atmosphere by ultra-violet light, Cathode rays, α rays, penetrating radiation, etc. It may, however, be further stated that such a diminution of the dielectric constant without considerable losses in the respective layers, can only take place if the ionised particles are able to follow sufficiently freely the electric field of the oscillations. An examination of these

[9] H. W. Eccles, *Proc. Roy. Soc. A*.. 67, 1912, p. 79 ; *Electrician*, 79, 1912, 1015 ; *Jahrb. Drahtl. Tel.*, 8, 1914, 253, 282. J. Salpeter, *Phys. Zietschr.*, 14, 1913, 201 ; *Jahrb. Drahtl. Tel.*, 8. 1914 ; B. van der Pol. *Dissertation*, 1920, Utrecht.

conditions has recently been made by J. Larmor,[10] who has shown that in this direction the results are quite satisfactory. As will easily be seen, the dielectric constant in the ionised air is in itself dependent upon the frequency, since the phase of the electrons in the electric field is dependent upon the frequency. According to this, the dielectric constant for the shortest waves ought to show the smallest decrease, and for longer waves a greater decrease, *i.e.*, the radiation of the shortest waves will be less curved than those of the longer waves. How far this is in accordance with the facts is not yet exactly known, but in any case A. H. Taylor and E. O. Hulbert[7] have maintained that with wavelengths shorter than 10 to 15 metres a return of the radiation from the upper atmosphere hardly takes place. In the case of waves over 15 metres one would obtain, according to knowledge gained hitherto, a sufficient curvature by the conductivity in order to be able to explain the great ranges. Furthermore, in the direction of longer waves, there is found a limit which, as is shown by Fig. 1, lies in the neighbourhood of a wavelength of about 125 metres, after which favourable propagation decreases. This is to be explained by the fact that, from these frequencies downwards, the ions and electrons respectively, in the time between two collisions with gas molecules, no longer have time to follow these relatively slow oscillations in such a way that a curvature of the ray can take place without loss, *i.e.*, for wavelengths beyond a certain value the energy not only returns towards the earth too early in consequence of greater curvature, but also is consumed by the collisions of the ions, so that large ranges cannot be obtained.

[10] J. Larmor, *Phil. Mag.*, 48, 1924, 1025. See also *Jahrb. Drahtl. Tel.*, 25, 1925, 141.

(*To be continued*).

Book Review.

THE B.E.S.A. GLOSSARY OF TERMS USED IN ELECTRICAL ENGINEERING.—Published by Crosby Lockwood & Son for the British Engineering Standards Association, pp. 263. Price 5s.

This Glossary was prepared by a Sectional Committee, a sub-Committee, and a number of panels; it was finally adopted by the Sectional Electrical Committee, which is the British National Committee of the International Electrotechnical Commission in January of the present year. The objects in view are stated to have been (*a*) to standardise and co-ordinate the electrotechnical terms used in the British Empire, and (*b*) to provide a basis for the British portion of an International Vocabulary, in course of preparation by the International Electrotechnical Commission. It is divided into eleven sections, two appendices, and an alphabetical index. Each section is subdivided into a number of sub-sections, for example: Section X., Radio Communication, is sub-divided into seven sub-sections under the following headings: Ether and Ether Waves; Aerials and Aerial Construction; Transmission; Reception; Valve Construction and Properties; Circuits and their Properties; Amplifiers and Relays. Appendix I. gives a table of symbols for quantities and units; Appendix II. classifies the contents in the order of the international decimal classification. An attempt has been made to standardise as far as possible the termination "or" for pieces of apparatus or machines for accomplishing a certain purpose, leaving the termination "er" for the person who carries out an operation, but the scheme could not be carried right through. The Committee adopted "divertor" and even "startor" but drew the line at such things as "milkor," "feedor" and "voltmetor."

The most unsatisfactory sections in our opinion are those dealing with fundamental electrostatic and magnetic terms. These appear to be very confused and we cannot understand how they reached the stage of publication. G. W. O. H.

Mathematics for Wireless Amateurs.

By F. M. Colebrook, B.Sc., A.C.G.I., D.I.C. [510

(*Continued from page 563 of September issue.*)

5. Logarithms.

(A) *Preliminary Note on Functions, and their Graphical Representation.*

ANY algebraic letter symbol can be considered to stand for any positive or negative number or fraction. Starting with some such symbol, x for instance, other numbers can be built up the magnitude of which will depend in some specified way on the magnitude of x. The number $3x+4$ is a simple instance of such a built-up number, and, being a number, it can be represented for convenience by some other single symbol, such as y. This number y is then defined by the statement (or equation)

$$y = 3x + 4$$

In such a connection the number x is termed an "independent variable," the idea being that it is at liberty to wander at its own sweet will over the whole range of magnitude.

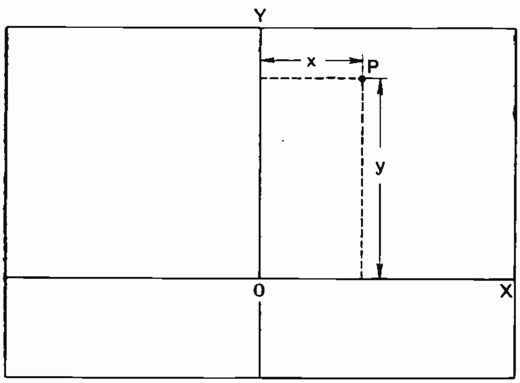


Fig. 7.

The number y on the other hand has no will of its own and has to go where x tells it. This is expressed rather grandiloquently by the phrase "y is a function of x." In mathematical shorthand this is written

$$y = f(x)$$

Notice that the letter symbol f does not in this instance represent a number, but expresses a functional relationship between y and whatever symbol is written inside the brackets. Different functional relation ships can of course be represented by other letters, *e.g.*, $F(x)$ or $\phi(x)$. Once a particular functional relationship has been specified the same letter should be used throughout any piece of work for that function.

The dependence of y upon x can be emphasised by assigning various values to x and finding the corresponding value of y. Such values can be tabulated thus:—

x	y
—2	—2
—1	1
0	4
1	7
2	10

An extensive set of tables could be drawn up in this way, but such tables would not reveal the distinctive character of the dependence of y on x. This, however, can be made quite clear by means of a method of graphical representation invented by the philosopher Descartes while he was lying in bed one morning (which just shows the unwisdom of too early rising).

Draw two lines OX and OY at right angles (Fig. 7). Any related pair of numbers x and y can now be represented by a point such as P, which is situated x units of length perpendicularly to the right (if x is positive) or left (if x is negative) of OY, and y units of length perpendicularly up (if y is positive) or down (if y is negative) from OX. (There is no need for the units of length to be the same in the two directions.) The numbers x and y are called the "co-ordinates" of the point P, which can be referred to as the point (x,y).

In Fig. 8 are shown all the points represented by the pairs of numbers listed in the above table. A new aspect of the matter is at once revealed. All the points are seen to lie on a straight line. Moreover, it will

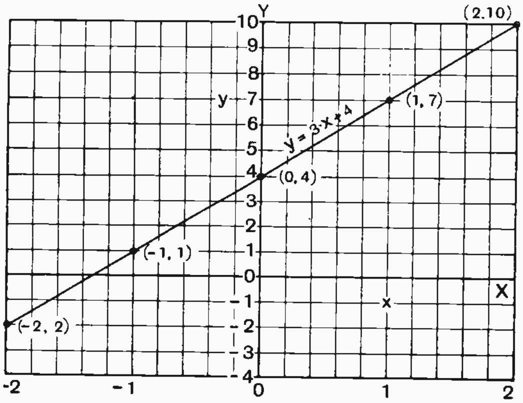


Fig. 8.

be found that any other related numbers belonging to this set will give rise to points which also lie on this straight line. The straight line can therefore be regarded as a complete representation of the function

$$y = 3x + 4$$

since all the points of the function will be found somewhere on this line. Conversely, any point on the line satisfies the functional relationship, and the value of y for any given value of x could be read off the diagram or a suitable extension of it. For $x = 1.7$, for instance, the corresponding value of y is seen to be 9.1.

The idea of functional form can now be described. There is no special magic about the numbers 3 and 4 in the above function, so it is inherently probable and is true in fact that any other pair of numbers a and b would give rise to a similar picture for the function, *i.e.*, a straight line. The function

$$y = ax + b$$

is for this reason called a straight line function of x.

Obviously much more complicated numbers than this could be built up out of x and other constant numbers. For instance

$$y = 3x^2 + 4x + 5$$

or more generally

$$y = ax^2 + bx + c$$

The points of any such function for given values of a and b could be similarly plotted on a diagram as in the above simpler case. It would be found that the points do not lie on a straight line for this rather more elaborate function. Nevertheless by plotting a sufficiently large number of points close together a dotted line will be produced through which a smooth curve can be drawn, and it will be found that any other points of the function within the range of the diagram will lie on or very close to this curve, and the greater the number of points calculated and plotted, the more nearly will any other points be found to lie on the curve.

(B) *The Exponential Function.*

The above is no more than a very brief introduction to the idea of functions and their graphical representation. From this point there will be considered a particular function closely related to the subject matter of Section 4, namely

$$y = a^x$$

where a is some constant number.

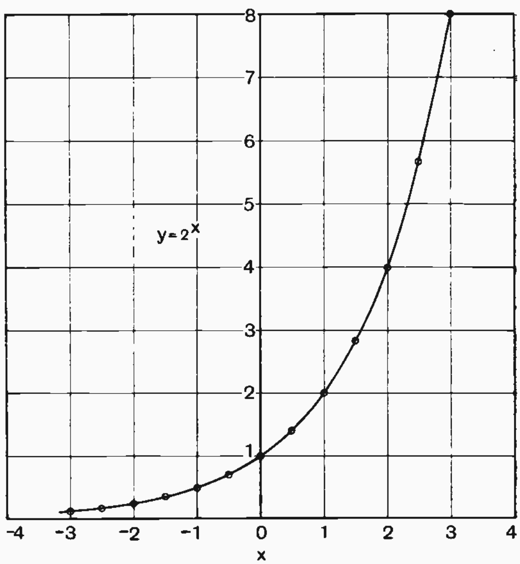


Fig. 9.

To fix ideas, let a have some simple value, such as 2. That is

$$y = 2^x$$

The first thing to notice is that x can have any positive or negative fractional or integral value, for the significance of such a general index has been determined. For instance, if $x = .5$

$$y = 2^{.5} = 2^{\frac{1}{2}} = \sqrt{2} = 1.414$$

and if $x = -.5$,

$$y = 1/x^{.5} = 1/1.414 = .707$$

Proceeding in this way, it will be possible to draw up a table of related values of x and y covering any desired range. For instance,

x	y
—3.0	.125
—2.5	.177
—2.0	.250
—1.5	.355
—1.0	.500
0	1.00

x	y
1.0	2.00
1.5	2.83
2.0	4.00
2.5	5.66
3.0	8.00

These and similar values can be plotted on a diagram and a curve drawn. The curve is shown in Fig. 9.

From such a curve any other corresponding pair of numbers within the given range can be determined fairly accurately (to about 1 per cent. or so). For instance, for the point on the curve for which $y=4.8$, x is seen to be 2.26, so that

$$4.8 = 2^{2.26}$$

(This illustrates a very useful application of the graphical representation of functions. Given that

$$4.8 = 2^x$$

the determination of x by any method of direct calculation would be a troublesome business, and would puzzle most people.)

Theoretically the above curve could be extended indefinitely beyond the limits shown in either direction, and it would be found to be a smooth continuous curve. This means that for any finite value of y it will be possible to find a value for x such that

$$y = 2^x$$

There is no special magic about the number 2 which has been used for a in these calculations, and it may therefore be said that in general, for any finite positive value of a, and any finite value of y, it will be possible to find a value for x such that

$$y = a^x$$

[Notice that a must be positive. The reader is recommended to try to tabulate a set of related values for y and x similar to the above for

$$y = (-2)^x$$].

(c) *Logarithms.*

When x, y, and a are so related that

$$y = a^x$$

x is called the logarithm of y to the base a, and is written

$$x = log_a y$$

The two statements

$$y = a^x$$

and

$$x = log_a y$$

therefore mean the same thing. The number corresponding to a given logarithm is called the antilogarithm of the given logarithm. Thus in the above y is called the antilogarithm of x. (These, by the way, are the full ceremonial titles. Log and antilog are what one actually says.)

Having now shown that the logarithm of any number to the base a exists, and having indicated the possibility of determining it by simple arithmetic and drawing, it will be assumed that there is available a set of tables or curves recording the logarithm of all numbers to the given base a, the intervals between whole numbers being subdivided to any desired degree of fineness. For reasons to be given later, 10 is the base chosen in practice, and tables of logarithms and antilogarithms to the base 10 are easily obtainable. What, now, is the use of such tables?

Suppose it is required to find the product of two numbers y_1 and y_2. The logarithms of these numbers can be found in the tables. Call them x_1 and x_2. Then

$$y_1 = a^{x_1}$$

and

$$y_2 = a^{x_2}$$

so that

$$y_1 \times y_2 = a^{x_1} \times a^{x_2} = a^{(x_1+x_2)}$$

This means that (x_1+x_2) is the logarithm of $(y_1 \times y_2)$, or that $(y_1 \times y_2)$ is the antilogarithm of (x_1+x_2). To find the product $(y_1 \times y_2)$, therefore, it is only necessary to find the logarithms of y_1 and y_2, add these together and find the antilogarithm of this total. For instance

$$\begin{aligned} log_{10}\, 3.412 &= .53300 \\ log_{10}\, 796 &= 2.90091 \\ \text{Sum} &= 3.43391 \\ antilog &= 2715.8 \end{aligned}$$

Therefore

$$3.412 \times 796 = 2715.8$$

Thus multiplication is reduced to a simple operation of addition. In a similar manner, division can be simplified to subtraction, for, by an obvious modification of the above proof it can be shown that

$$log\, a(y_1/y_2) = log_a y_1 - log_a y_2$$

Thus to divide 796 by 3.412,

$$\begin{aligned} log_{10}\, 796 &= 2.90091 \\ log_{10}\, 3.412 &= .53300 \\ \text{Difference} &= 2.36791 \\ antilog_{10} &= 233.29 \end{aligned}$$

Therefore

$$796/3.412 = 233.29$$

Again, since

$$log_a(y_1 \times y_2) = log_a y_1 + log_a y_2$$

it follows that

$$\begin{aligned} & log_a(y_1 \times y_2 \times y_3 \ldots\ldots y_n) = \\ & \quad log_a y_1 + log_a y_2 + log_a y_3 \ldots\ldots log_a y_n \end{aligned}$$

and if

$$y_1 = y_2 = y_3 = y_4 \text{ etc.} = y$$

this becomes

$$\begin{aligned} & log_a(y \times y \times y \ldots\ldots n \text{ factors}) = log_a(y_n) \\ & = log_a y + log_a y + log_a y \ldots\ldots n \text{ terms} \\ & = n \times log_a y. \end{aligned}$$

Thus a number can be raised to any integral power by simple multiplication. For instance

$$\begin{aligned} & log_{10}\, 3.412 = .53300 \\ & log_{10}\, 3.412^5 = 5 \times .53300 = 2.66500 \\ & antilog_{10}\, 2.66500 = 462.38 \end{aligned}$$

Therefore

$$3.412^5 = 462.38$$

Furthermore, the general formula

$$log_a y^n = n \times log_a y$$

proved above for an integral index, is true also for a fractional index. Let $n = p/q$, where p and q are integers. Then by the definition of a fractional index,

$$(y^{\frac{p}{q}})^q = y^p$$

Therefore

$$log_a\,(y^{\frac{p}{q}})^q = log_a y^p = p \times log_a y$$

But

$$log_a\,(y^{\frac{p}{q}})^q = q \times log_a(y^{\frac{p}{q}})$$

Therefore

$$q \times log\,(y^{\frac{p}{q}}) = p \times log_a y$$

or

$$log_a\,(y^{\frac{p}{q}}) = (p/q) \times log_a y$$

In particular the nth root of any number can be calculated by logarithms, for

$$\begin{aligned} log_a \sqrt[n]{y} &= log_a y^{\frac{1}{n}} \\ &= (1/n) \times log_a y \text{ or } (log_a y) \div n \end{aligned}$$

Thus, to find the fifth root of 796,

$$\begin{aligned} log_{10} 796 &= 2.90091 \\ log_{10} \sqrt[5]{796} &= 2.90091 \div 5 \\ &= .58018 \\ antilog_{10} &= 3.8037 \end{aligned}$$

Therefore

$$\sqrt[5]{796} = 3.8037$$

Here an arithmetical process which is too complicated to be admitted into ordinary text-books is reduced to a simple matter of division.

The full advantage of the logarithmic method of calculation is seen in the determination of a more or less complicated number such as

$$y = \frac{2.43^3 \times 191 \times \sqrt[2]{347}}{\sqrt[4]{1.519^3}}$$

The determination of this by direct calculation would be a weariness to the flesh, for which weariness the flesh would probably retaliate by slipping into error. Logarithmically, however, the calculation is simplified to

$$\begin{aligned} log_a y = 3 \times log_a 2.43 + log_a 191 \\ + \tfrac{1}{2} log_a 347 - \tfrac{3}{4} log_a 1.519 \end{aligned}$$

The whole of the foregoing propositions with regard to the application of logarithms are independent of the particular base to which the logarithms are referred. The choice of the base to be used in practice is merely a matter of convenience. As stated above the base 10 is actually used for the following reason. Any whole number or decimal can be expressed as some number between 1 and 10 multiplied by some power of 10. For instance

$$.143 = 1.43/10 = 1.43 \times 10^{-1}$$
$$3179.8 = 3.1798 \times 1000 = 3.1798 \times 10^3$$

and so on. Thus any number can be expressed in the form

$$y \times 10^n$$

where n is a positive or negative integer and y is some number or fraction between 1 and 10. Now

$$log_{10} y \times 10^n = log_{10} y + log_{10} 10^n$$
$$= log_{10} y + n$$

Thus all that is needed in a table of logarithms to the base 10 are the logarithms of all numbers between 1 and 10, subdivided decimally to any desired degree. (Five figures are generally quite sufficient for experimental work.) Such logarithms will all lie between 0 and 1, *e.g.*,

$$log_{10} 2 = .30103$$

The whole number to be placed in front of the decimal point will be n, determined as shown above. Thus $log_{10} 200$ would be 2.30103, and $log_{10} .002$, *i.e.*, $log_{10} 2 \times 10^{-3}$ would be $\bar{3}.30103$. In practice the negative sign is put as a bar over the whole number, as in this example, to show that it refers only to the whole number and not to the decimal part which follows. It is more convenient to keep the decimal part positive. Thus $\bar{2}.30103$ is the same as $(-2 + .30103)$, *i.e.* (-1.69897), but the first form is always used in computation.

Logarithms calculated to the base 10 are called Common Logarithms, and the base is not expressed. Thus if no other base is specified, it is always assumed to be 10.

There is another set of logarithms which is in occasional use. These are calculated to the base 2.71828, for which apparently arbitrary number the symbol e or the Greek ϵ is always used. There is method in this apparent madness. So much so, in fact, that such logarithms are called "natural logarithms," though at first sight nothing could appear less natural. The natural logarithm of y is written $log_\epsilon y$. Actually the use of this other system of logarithms will not necessarily involve a new set of tables, for a logarithm to any one base can be readily converted to the logarithm to some other base in this way. Suppose

$$log_a y = m$$
$$log_b y = n$$

i.e., $$y = a^m = b^n$$

Suppose further that the logarithm of b to the base a is k,

i.e., $$b = a^k$$

Then

$$y = b^n = (a^k)^n = a^{kn}$$

and since also

$$y = a^m$$
$$m = kn$$

so that

$$log_a y = log_a b \times log_b y$$

In particular

$$log_e y = log_e 10 \times log_{10} y$$

and since $log_e 10$ is a constant number (2.3026) the conversion reduces to

$$log_e y = 2.3026 \times log_{10} y$$

i.e., Natural Log. = Common Log. × 2.3026.

If the foregoing description of logarithms and their application is thoroughly understood, the reader should have no difficulty in using this method of computation. It does not pretend to be a complete set of working instructions for the manipulation of log tables, but if the theory is really appreciated, the reader should be able to follow the detailed instructions which are generally included with any such tables. (To guard against any misconception on this point, it should be made clear that the tabulated logarithms found in the usual published tables have not actually been determined by the method described in this article, which would not be nearly accurate enough. The actual method of calculation will probably be encountered later in this series.)

Finally, one practical point. The logarithmic method can only be applied to any expression which consists exclusively of products, quotients, and powers. Therefore, before setting out on any series of calculations it is well to arrange them as completely as may be in a form suitable for logarithmic computation. An instance which may frequently occur in connection with alternating current problems is the difference of two squares, *i.e.*, $a^2—b^2$, where a and b have certain specified numerical values. The form $a^2—b^2$ is not suitable for the use of logarithms, but, as already shown (see Examples, p. 450, July issue),

$$a^2 - b^2 = (a - b)(a + b)$$

and the form on the right hand side, consisting of the product of two factors, is better adapted for calculation. For example,

$$874^2 - 27.8^2 = (874 - 27.8)(874 + 27.8)$$
$$= 846.2 \times 901.8$$

No general rules can be laid down, but the exercise of a little ingenuity in this matter will often save a great deal of time and labour.

Examples.—Logarithms.

1. Given that $log 2 = .30103$, show that $log 5$ is .69897.
2. $Log 3 = .4771$. Show that

$$log 1/3 = \bar{1}.5228$$
$$log\ 81 = 1.9084$$
$$log 3\tfrac{1}{3} = .5228$$
$$log 3^{30} = 14.313$$

3. What are the whole numbers in the logs of 21, .021, 99918, .00073 ?
4. Show that 2^{100} is a whole number of 301 figures.
5. Show that $log\,(log 10^{10^x}) = 1 + x$.
6. Show that $log_a 1 = 0$ for all finite values of a.

(*To be continued.*)

Note on a System of Atmospheric Elimination.

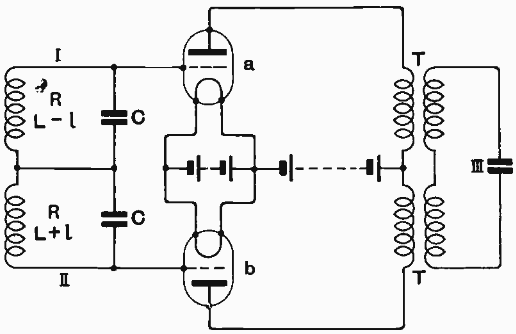
By S. Butterworth. **[R431**

(*Admiralty Research Laboratory, Teddington.*)

IN a recent patent specification* M. L. Levy has described a circuit which is intended to eliminate atmospheric or similar parasitic shock excitations. Some eight years ago the present writer had occasion to study a very similar circuit which had been suggested to him for the same purpose, and came to the conclusion that a circuit of this type was incapable of eliminating disturbances due to shock excitation of any kind.

As the circuit has been once more put forward, and as the arguments in its favour seem very plausible, it may be of interest to your readers to point out why it does not eliminate atmospheric disturbances, and why it is inefficient in regard to increasing selectivity between two continuous wave signals.

The circuit in question is essentially as shown in the figure. Two resonant circuits, I and II, receiving equal E.M.F.s from the required station, are slightly detuned, so that I resonates at a frequency slightly above, and II at a frequency slightly below, the frequency of the incoming signal. Because of the rapid reversal of phase as we



pass through resonance, it is clear that for any frequency in the band lying between the resonances of I and II the potentials of the grids of the valves a and b will tend to be in antiphase, while for any frequency outside

* British Patent No. 225,570, described in *E.W. & W.E.*, June 1926, p. 398.

this band they will tend to be in phase. Hence, if we couple the anode circuits of these valves to a third resonating circuit III, which is tuned to the required signal, we can so arrange that while the induced E.M.F.s in circuit III. due to the wanted signal, are helping, those due to unwanted signals are in opposition. From this argument it appears, therefore, as if we can eliminate everything but the required signal.

We will first deal with the fallacy in the reasoning when the unwanted disturbance is due to shock excitation. A little consideration will make it clear that when a resonant system is subject to shock, the resulting disturbance does not merely repeat the shock, but there is also set up a damped oscillation having the same period as that of the resonant system. In the case of sound, of course, this principle is made use of in the construction of all stringed instruments. Thus in the case of the present circuit system we see that an atmospheric disturbance will cause circuits I and II to "ring" each at its own frequency. Hence, the net E.M.F. induced in circuit III by an atmospheric will consist of two damped E.M.F.s of slightly different frequencies, and these, by virtue of their rapid alternation in relative phase from assisting to opposing, will produce a damped beating effect in circuit III. This effect will have longer and longer duration as the efficiency of the circuits I and II is increased. The circuit is thus useless in so far as elimination of atmospheric disturbances is concerned.

We now consider the selectivity of the circuits in regard to continuous waves. Let the circuits I and II have equal capacities C, equal resistances R, and inductances $L-l$ and $L+l$ respectively. Let similar E.M.F.s, each of value E, be impressed on the circuits, the frequency being $\omega/2\pi$. Then, assuming equal transformers T linking the valves with the circuit III, and taking the common overall voltage amplification (valve+transformer) as m, the net E.M.F. impressed on circuit III is

$$E_c=\frac{mE}{j\omega C}\left[\frac{1}{R+j\left\{\omega(L-l)-\frac{1}{\omega C}\right\}}-\frac{1}{R+j\left\{\omega(L+l)-\frac{1}{\omega C}\right\}}\right]$$

$$=\frac{mE}{j\omega C}\cdot\frac{2j\omega l}{\left[R+j\left\{\omega(L+l)-\frac{1}{\omega C}\right\}\right]\left[R+j\left\{\omega(L-l)-\frac{1}{\omega C}\right\}\right]}$$

the usual vector notation having been employed.

Hence the R.M.S. value of the E.M.F. is

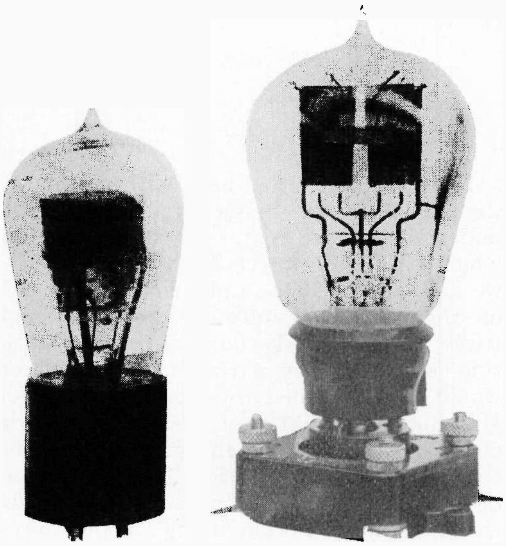
$$(E_c)=\frac{2(mE)l}{C\sqrt{\left[R^2+\left\{\omega(L+l)-\frac{1}{\omega C}\right\}^2\right]\left[R^2+\left\{\omega(L-l)-\frac{1}{\omega C}\right\}^2\right]}}$$

If we are concerned only with stations of slightly different frequency, the quantity under the square root sign is the only one which changes appreciably with ω. But if we had employed the same circuits I and II on the input and output sides of a single valve, using a weak coupling on the output side, the frequency variation of the system would be governed by the same factor. It is concluded that the same circuit material could be used to give the same C.W. selectivity in a far more efficient manner without departing from common practice. In addition the small factor l occurring in the numerator of the expression for the E.M.F., acting on circuit III, reduces the intensity of the required C.W. signal, while in the case of the atmospheric disturbances it merely governs the rapidity of the beats. This consideration immediately shows that the system increases, instead of diminishing, the relative importance of the atmospheric disturbances.

The National Radio Exhibition. [R064

Review of Components and Accessories of Special Interest to our Readers.

AFTER a careful examination of the new apparatus to be seen at the first National Radio Exhibition held this year at Olympia, one is ready to admit that the wireless industry has already passed through its infancy. There has probably been more real progress made in the design of broadcast receivers and their associated components and accessories during the past twelve months than during any other year since broadcasting commenced. It must not be thought from these remarks that apparatus embodying fundamentally new ideas has been evolved, but progress has essentially been made in regard to refinements in design which are the outcome of a better understanding of the underlying principles.

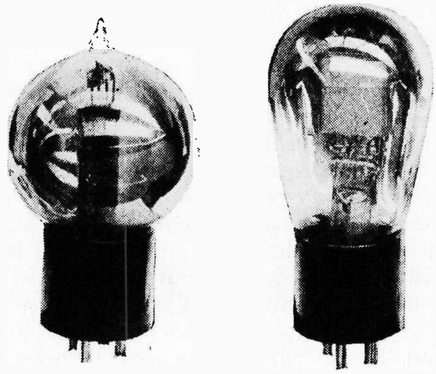


Osram gas discharge tube giving full wave rectification for use in an A.C. mains battery eliminator.

The Osram U5 full wave rectifier.

The New Valves.

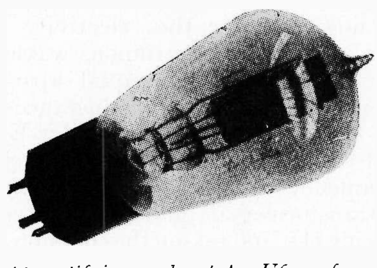
Many new valves have been introduced specially designed to suit the requirements of various amplifying circuit arrangements, as well as others for use in connection with rectifying equipment. In the 2-volt group of Mullard PM valves there are now three types, the PM1 H.F., PM1 L.F., and the PM2. Each of these valves is operated with a filament potential of 1.8 volts, the PM1 type passing a current of 0.1 ampere and the PM2 0.15 ampere. The high impedance PM1 H.F. has an amplification factor of 13.5 with an impedance of 20,000 ohms, showing the mutual conductance to be 0.48mA per volt. The low impedance L.F. valve has an amplification factor of 8.9 with an impedance of 18,000, the mutual conductance being 0.5mA per volt. The PM1 H.F. is suitable for use in high-frequency and resistance-coupled amplifiers, and the PM1 L.F. is intended for transformer-coupled low-frequency stages, whilst the PM2, which has an



B.S.A. power valves types P425 and P612.

amplification of 5.4 with an impedance of 8,750, is suitable for the last L.F. stage where a larger grid bias is required.

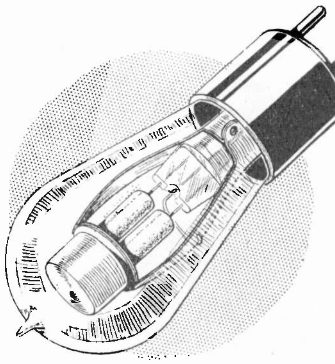
Another new Mullard valve is the DP425 which is a dull filament power amplifier, and especially designed for use with loud-speakers. The filament requires 0.25 ampere at 3.8 volts, and it has the very low impedance of 3,500 ohms with an amplification of 3.15, giving a mutual conductance of 0.9mA per volt, with an anode voltage of 100. The available grid swing is approximately 30 volts,



Burndept rectifying valve type U695 for charging H.T. accumulators from A.C. supply.

so that a grid bias of at least 15 volts can be used. With this grid swing of plus or minus 15 volts and a mean anode current of 12 milliamperes at 100 volts, the largest loud-speakers can be operated with a minimum amount of distortion.

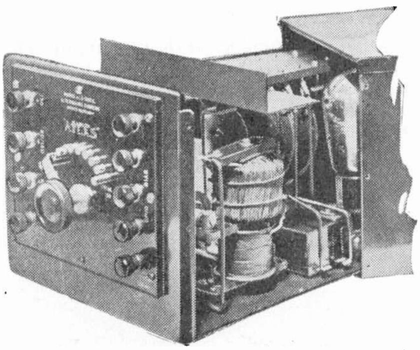
Two new valves have been added to the Cosmos short path series, the SP55R and the SP55B. The former is a power valve having an impedance of 3,500 ohms with an amplification factor of 6, giving an exceptionally high mutual conductance of approximately 1.7mA per volt. The filament voltage is 5.5 and the current is 0.25 ampere. The new SP55B is a moderately high impedance valve having the exceptionally high amplification factor



The Burndept Ethotron gas discharge rectifier for use in an A.C. battery eliminator.

of 35 and a mutual conductance of 0.65mA per volt, the impedance being 55,000 ohms.

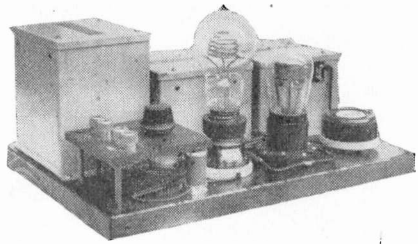
Amongst the range of "Cossor" valves should be mentioned three of the type which are of recent construction. These are 2-volt valves, designed as detector, H.F. amplifier, and for power use



The Atlas full-wave rectifier for obtaining H.T. supply from alternating current mains. Grid biasing potentials are also provided.

respectively. The power valve filament takes .15 ampere and the detector and H.F. valves .1 ampere. A point of interest in the construction of these valves is the shock-proof filament suspension system. The filament is arched and is held in position by a fine wire but is not under tension as is the case with other types. It is claimed that as a result the filament will withstand shocks without risk of breakage.

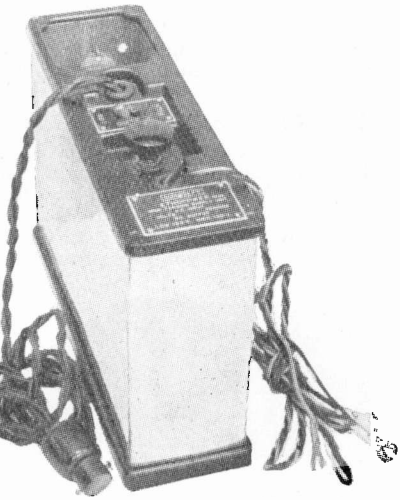
B.S.A. Radio, Ltd., have now entered into the field of valve manufacture. A number of new valves with heavy strip filaments operating at low temperatures were shown. The type P425 is a power valve with a 4-volt filament consuming 0.25 ampere and capable of handling large input voltages with a moderate high tension potential. The impedance is given as 5,000 to 7,000 ohms with an amplification factor of 6.4 to 6.8. Another new valve, the PE612, has very similar characteristics, and is fitted with a filament consuming only 0.12 to 0.14 ampere at approximately 6 volts. Like the new type Mullard valves, the B.S.A. Standard valves (produced jointly by B.S.A. Radio, Ltd., and Standard Telephones & Cables,



G.E.C. battery eliminator fitted with gas discharge full-wave rectifier and neon lamp.

Ltd.) are fitted with pins of unusual construction. A slot is cut through the pin not quite reaching to the ends so as to give a slight expansion about the middle and produce a reliable spring contact with the socket.

Among Marconi and Osram valves those of special interest are designed for use as rectifiers in H.T. battery eliminators. For single-phase rectification the U4 has been produced, which is a two-electrode dull emitter, operated at an applied A.C.



Burndept Ethopower A.C. unit.

voltage to the anode of 220 volts maximum (R.M.S.). For biphase rectification the U5 is available, which is fitted with a dull emitting filament rated at 5 volts 1.6 amperes. This valve will withstand an applied anode voltage of 250+250 (R.M.S.)

maximum, and will provide a direct current up to 50 milliamperes.

A new single-wave rectifying valve has been produced by Burndept intended particularly for use in charging high tension batteries from alternating supply mains. It is styled the U695, passing

Single-wave rectifier for charging H.T. batteries from A.C. supply.

a current of 0.95 ampere at 6 volts and is capable of being used for charging accumulator batteries up to 120 volts with a maximum charging rate of 60mA.

Full Wave Gas Discharge Rectifiers.

Gas discharge rectifying valves have been produced by both Osram and Burndept for use in apparatus for obtaining D.C. supply from A.C. mains. They are full-wave rectifiers and possess the outstanding merit that they can be overrun and having no filament will give prolonged service.

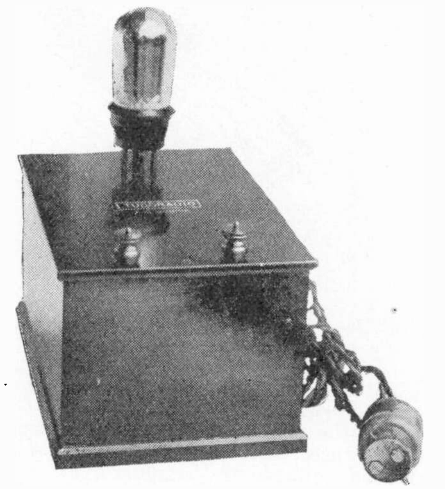
Fellophone A.C. battery eliminator.

Valves of this type become heated in operation, while compared with the thermionic rectifier give a wave form that necessitates the use of large reservoir condensers in the smoothing equipment.

Conspicuous at the Exhibition was the variety of battery eliminating sets for use on A.C. and D.C. supply.

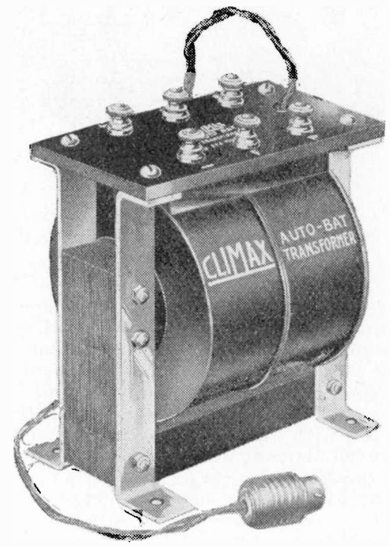
A.C. Battery Eliminators.

The Atlas H.T. battery eliminator produced by H. Clarke & Co., of Manchester, is designed to provide full-wave rectification with the use of either half or full-wave rectifying valves. Its power transformer is of large size with obviously good insulation between the sections, mid-point



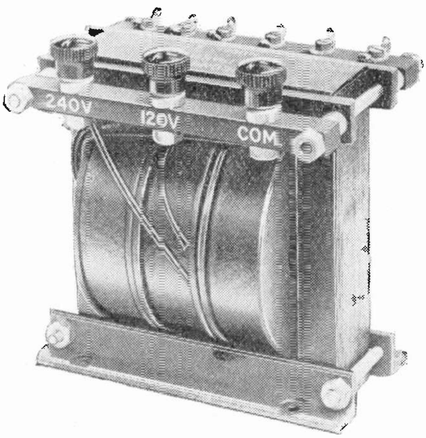
The half-wave single output rectifier of Tudoradio Co., Ltd.

tappings being provided at both output windings. Mullard DU5 or DU10 valves are used as rectifiers and smoothing is accomplished by the usual chokes and condensers though it is interesting to note that both open and closed core chokes are



Climax power transformer for use in the construction of battery eliminators.

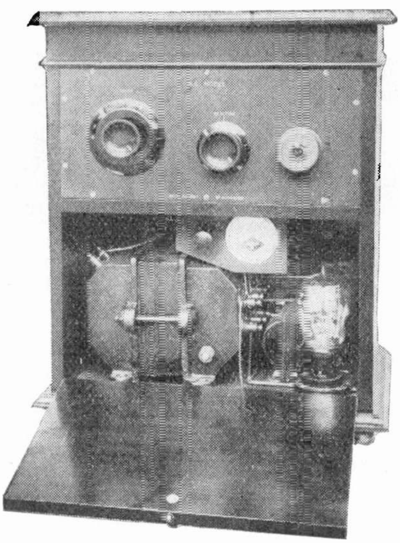
fitted and series connected. Several voltage outputs are produced by shunting the rectified output across a potentiometer and two fixed tappings are made to give approximately 60 and 150 volts. A third output voltage is controlled



The Marconiphone power transformer with tapped primary so that it can be used on 100/120 volt or 200/240 volt supply.

by a multi-contact switch which gives any potential in small steps up to the maximum of 150 volts. Four taps are also provided to give grid biasing potentials of 4, 8, 12 and 16 volts. The entire outfit is accommodated in a steel box.

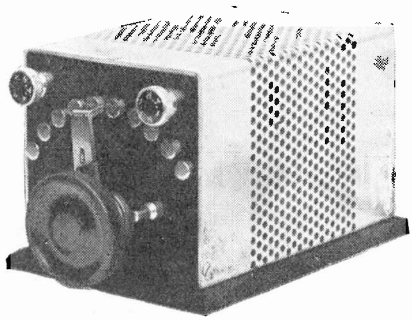
The General Electric Company also produce battery eliminators for use on A.C. and D.C.



Gambrell set operated entirely from A.C. supply. The filaments which pass a current of 0.06 ampere are series connected.

mains, though it is the A.C. instrument that is of particular interest as it makes use of a full-wave gas discharge rectifying valve. Owing to the particular wave-form obtainable with this type of rectifier a very liberal smoothing equipment is necessary which is augmented in this instance by the use of a neon tube the non-uniform conductivity, properties of which assist in providing a smooth output.

The Ethopower H.T. unit of Burndept also makes use of a gas discharge rectifier and includes a very

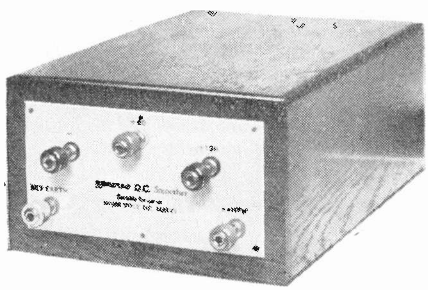


Cable H.T. unit for use on D.C. supply. A single variable output is obtainable.

liberal smoothing equipment. To provide more than one voltage output a lead is taken from the maximum voltage terminal and the potential is dropped through a resistance shunted with a by-pass condenser.

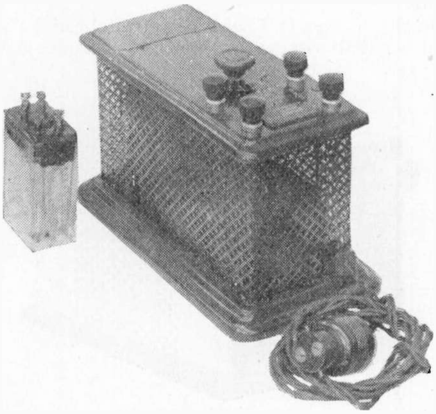
Although the use of rectifying equipment suggests the entire elimination of H.T. primary or secondary batteries there are many who would prefer to retain their accumulator source of H.T. supply. For use on A.C. mains Burndept Wireless, Ltd., offer a useful unit which will provide the necessary slow charging rate making use of a thermionic valve rectifier. A pilot lamp according to its brightness indicates the value of the charging current, a visible glow being obtained at 35 mA.

Among the many battery eliminators making use of half-wave rectifiers are the units made by the Fellows Magneto Company and the Tudoradio Company. The particular merit of the Fellophone high tension unit is that in overall shape and dimensions it can replace a dry cell high tension battery.



Wates, Bros., D.C. battery eliminator.

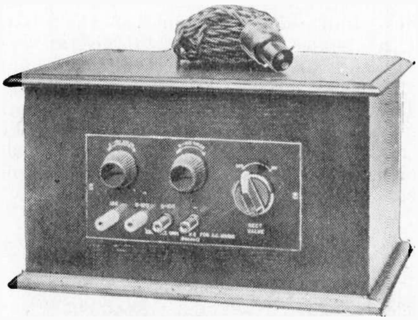
A number of parts are available for the construction of battery eliminators working from A.C. supply, the power transformer being the component which it is not always convenient to construct. Both Climax Radio Electric, Ltd., as well as the Marconiphone Co., Ltd., have produced suitable transformers for use in full-wave rectifying



The Rectalloy electrolytic battery charger for 2, 4 or 6-*volt L.T. accumulators.*

circuits supplying both filament and anode potentials. The anode circuit winding of the Marconiphone transformer is intended to give 160+160 volts, whilst the transformer is tapped so that it can be used on voltages between 100 and 240.

Other auxiliary apparatus for use in battery eliminator construction includes the "Climax" smoothing choke and potential divider, the latter being wire wound to a resistance of 20,000 ohms and tapped in ten sections.



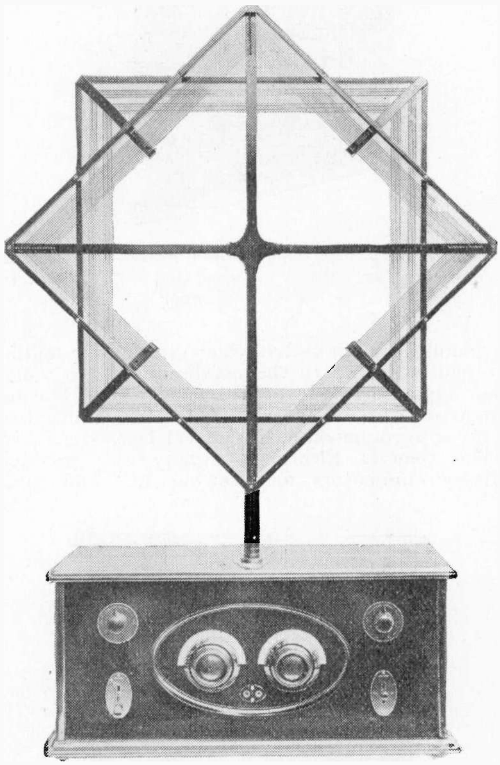
Ecko mains unit giving one fixed and two adjustable output potentials.

Deriving Filament Supply from A.C.

The incorporation of a battery eliminator in a receiver is carried out by Gambrell Bros., the set being of special interest, for both filament heating as well as anode current supply are obtained from A.C. mains. The rectifier makes use of an Osram U5 type valve, the filaments of the receiving valves being series-connected and heated from the rectified output. This arrangement is entirely new and is of special interest particularly as it is used with sets fitted with 1, 2, 3 or 4 valves.

D.C. Potential Dividers.

Battery eliminators for use with D.C. supply have been produced by many manufacturers, and consist essentially of a resistance bridging the main leads as a potential divider, the output being smoothed with the aid of condensers as well as chokes in some instances.



Ethodyne seven-valve superheterodyne receiver. The double wound frame is to eliminate long wave interference.

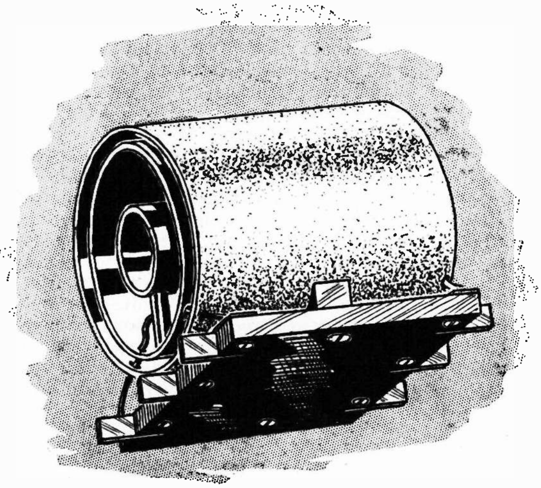
In several of the models provision is also made for obtaining grid biasing potentials, though in such cases it is essential in order to eliminate mains noise to entirely free the grid circuit of ripple. In a well-designed D.C. eliminator, however, fluctuations of potential in the grid circuit may be used to compensate for fluctuations of anode potential. Voltage regulation by means of series resistances are to be found in some of the D.C. sets, and variable high resistances are sometimes fitted to provide a critical control of H.T. potential, so that the voltage drop can be regulated according to the resistance of the anode circuit.

Almost every manufacturer of complete sets has produced a portable receiver, in many cases incorporating batteries and loud-speaker. The majority of these sets are superheterodynes, and it is interesting to consider the circuit arrangements adopted.

Superheterodyne Designs.

There were at least twenty superheterodyne sets shown, and only in a single instance was the detector valve arranged to function also as an oscillator. The use of a separate oscillator valve seems to have become standard practice.

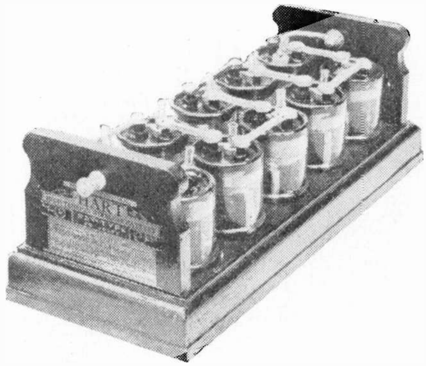
As to the intermediate amplifier, there is a tendency to employ only two high-frequency stages, while in many of the sets transformers having iron cores are used. It was not easy to examine the internal construction of these transformers, though it would appear that in no single



Interchangeable oscillator coupling unit fitted to the B.S.A. standard superheterodyne.

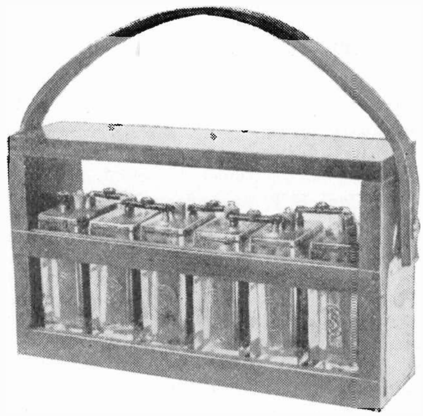
instance was the iron core completely closed. Several of the couplings were wound in grooved spools and fitted with cores of iron wire. It would seem that transformers are matched not by individual adjustment, but by manufacturing so that the windings are physically identical. Although it was suggested in some instances that matching was effected by adjusting the windings, and in others by altering the amount of iron used for the core, it would seem that both of these methods are rather inapplicable when the windings are subsequently enclosed in a metal screening box. In order that the spools may be of identical inductance, machine methods of winding have been adopted in one or two instances in preference to running on the required number of turns into a given space. No information is available as to the winding ratios, though it would seem from the space occupied by the windings that step-up ratios, perhaps as high as four to one, had been adopted.

Many new features of outstanding merit will be found in the Ethodyne intervalve couplings. In this set, two stages provide the required amplification, and the so-called filter circuit is abandoned, both stages being designed to tune over the required, though limited, frequency band.



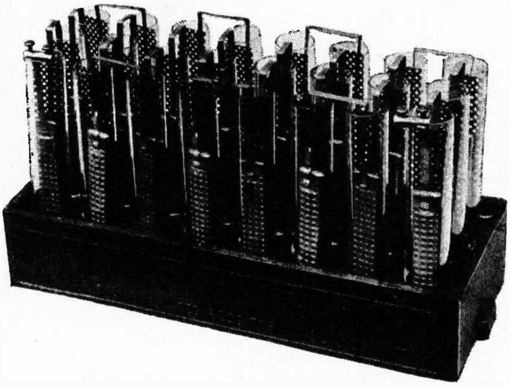
20-volt Hart H.T. accumulator unit.

Stabilising the intermediate amplifier is invariably carried out by means of a grid potentiometer, excepting in the well-known Igranic set where stability is produced by neutralising stray capacities. By using suitable valves and correctly designed transformers, higher amplification per stage is now being obtained, with the result that in many of the sets only two intermediate stages have been employed. The majority of the sets made use of frame reaction, and as regards L.F. amplification there is a trend towards using a resistance-coupled stage followed by a second, which is transformer coupled, a switch being sometimes provided for cutting out the resistance amplifier.



Ediswan "Hylo" 12-volt H.T. section.

Many of the superheterodynes were tunable only over the broadcast band, though in the sets shown by L. McMichael Ltd., and the B.S.A. Radio, interchangeable oscillator coupling units were fitted. As to tuning the frame, the G.E.C. set includes a multi-contact switch which adds the necessary loading and at the same time changes over the connections to the oscillator so that the wavelength of 300 to 3,000 metres is continuously covered.



The new nickel steel alkaline battery for H.T. supply by Batteries Ltd.

Among receiving sets employing other circuit systems the Pye 5-valve set is of special interest, for being designed to receive from the Daventry station only the tuning of the two high-frequency stages once being accurately adjusted operates without the provision of control knobs. The two H.F. stages are stabilised by neutralising the effects of stray capacity and the detector valve which is an anode bend rectifier, is followed by two L.F. stages. It is interesting to note here the decline in the use of the leaky grid condenser for rectification, particularly in sets embodying one or more stages of H.F. amplification. The Pye set, which is entirely self-contained, is fitted with three simple controls, one of which disconnects an L.F. amplifier, the second is a continuously adjustable volume control and the third is a vernier condenser connected across the frame and used to correct for small differences of tuning. The majority of the portable sets are fitted with centre tapped frames.

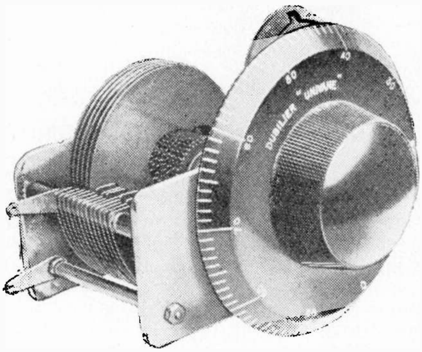
Hart H.T. Secondary Batteries.

The increased use of secondary batteries for H.T. supply is evidenced by the considerable number of H.T. accumulators shown during the Exhibition. The Hart battery, which is of new design, is made up in 20-volt units, the individual cells being in cylindrical glass containers with sealed tops and rubber plugs fitted with glass vents. A wooden rack is arranged so that the sections can be assembled one on top of the other, thus effecting a considerable economy in space.

A novel feature was to be found in the D.P. battery, inasmuch as each individual cell was completely sealed with a thick rectangular rubber plug which permits of the plates being withdrawn and the cell easily cleaned out without the need for breaking open the cells as in the case when bitumastic or other material is used for sealing. The D.P. Battery Co., Ltd., have also introduced an entirely new form of high tension battery, the principal feature of which is the provision of a large barrel type switch extending the full length of each bank of 20 cells which when rotated gives 24, 6 or 2 volts at the output terminals.

The use of glass containers is now standard practice at least for H.T. battery construction and the Edison Swan Electric Company, in their new " Hymeg " battery, in addition to the use of glass containers, fit glass lids. The glass boxes are ribbed externally to provide spacing between the cells, and in general the battery, which is carried in an acid proof wood case, will be found to be clean and comparatively free from acid spray in use.

The introduction of the steel plate battery for H.T. supply by Batteries Ltd., of Redditch, will undoubtedly develop. The cells are constructed on the lines of the well-known " Nife " nickel steel alkaline cell which has proved so successful in a number of applications where skilled and constant attention are not available. The disadvantage of using cells of this type is that on discharge the voltage slowly falls, whereas with the lead plate battery the voltage remains practically constant during discharge. This is perhaps no serious disadvantage as regards H.T. supply while many advantages are gained. The cells are practically foolproof and require no attention beyond the occasional addition of distilled water and will not deteriorate if left unattended as compared with the sulphating that sets in in the case of the lead battery. The steel plates cannot buckle and the steel containers cannot crack while the battery can be short circuited or even charged in the reverse direction without damage. The charging rate for a given ampere-hour capacity is higher than the lead battery but the most important merit is its long life in spite of indifferent treatment.

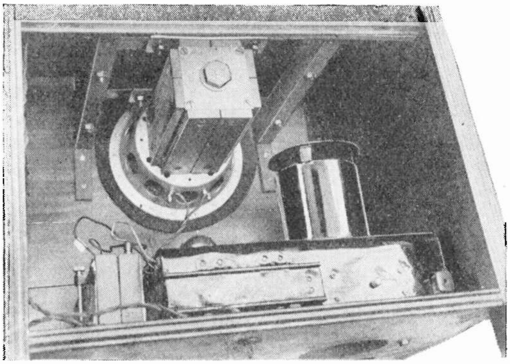


Dubilier Univane condenser in which the moving plates are propelled singly from the position of minimum to maximum capacity.

Components.

Among components mention might be made of the new Cosmos resistance-coupled L.F. amplifying stage in which the condenser and resistances are enclosed in a moulded sub-base which carries the valve holder.

As regards variable condensers progress has essentially been made in the methods adopted for supporting the plates, the provision of good bearings and a general improvement in finish. The Dubilier "Univane" condenser by an exceedingly ingenious arrangement gives a critical adjustment of capacity without the use of gearing. Each moving plate is separately controlled and by rotating the dial the plates are picked up in turn and carried from the position of minimum to maximum capacity. Apart from the scale on the dial an auxiliary indicator shows the number of plates carried over to the position of maximum capacity.



Exterior of the B.T.-H. loud-speaker. It has a moving coil movement driving "free edge" cone.

A useful buzzer wavemeter was shown by Gambrell. The type "D" instrument covers a wavelength range of from 50 to 500 metres and is fitted with a reliable form of buzzer giving a constant note and it is claimed a constant amplitude in the trains of oscillations.

The buzzer contact, instead of being rigidly mounted, is a spring and this form of construction probably accounts for the high note which is a distinct feature of the instrument. Two Gambrell coils are supplied together with the necessary calibration charts.

Changes in Loud-Speaker Design.

The decline in the popularity of the horn type loud-speaker, which is being replaced by models of the cone type, was evidenced at the Exhibition, some of the newer models being fitted with cones having "free edges." The principle of using a moving coil in a magnetic field is not new in loud-speaker construction, but the objection to this system has been the need for providing the polarisation current for the permanent field thus creating an extra drain on the current supply from the batteries.

The new B.T.-H. loud-speaker model R.K. is a moving coil instrument with a conical diaphragm practically unsupported at its edges. It is understood that an air-tight barrier is, however, fitted round the edge to prevent interaction between the sound waves set up from opposite sides of the diaphragm, and with this same purpose in view the diaphragm is mounted in the centre of a large cabinet so that the entire front board assists in preventing interaction, which would have the result of considerably reducing the volume of sound produced. A polarising field is set up by four pairs of permanent magnets, roughly 8 in. in length by 1¼ in. wide and nearly ½ in. in thickness, and arranged in pairs. An original feature also is that of incorporating a power amplifier in the loud-speaker cabinet.

Simple Testing Equipment.

At several of the stands testing sets were exhibited principally for examining valves, making continuity tests in high and low resistance circuits, and for resistance and capacity measurements.

Peter Curtis, Ltd., exhibited a testing set suitable for making all the usual tests and measurements met with by the retailer or small manufacturer.

Cleartron Radio, Ltd., now produce a simple valve testing set which they supply to retailers who handle their valves, roughly revealing filament and anode characteristics.

The Liberty Radio tester manufactured by Radi-Arc Electric Co., Ltd., is fitted with a two-range voltmeter and change-over switch for making battery tests, as well as a neon lamp which, when connected to the lighting mains, may be used for continuity and insulation tests.

The Liberty testing set for voltage measurements, continuity and insulation tests.

To the transmitting amateur probably the most interesting exhibit at the Exhibition was the experimental quartz-controlled oscillator shown by Mr. A. Hinderlich, M.A., who has apparently conducted considerable investigation work on the properties of quartz crystal by means of a valve oscillator. He demonstrated in a very simple way the use of a crystal for controlling frequency.

An Examination of the Properties of Audio-Frequency Amplifiers by Means of the Duddell Oscillograph.

By W. Baggally. **[R132**

As there appear to be very little if any data available on the nature and magnitude of waveform—as distinct from amplitude-distortion produced by audio-frequency triode amplifiers as commonly utilised in the reproduction of broadcast telephony and also for public address purposes,—an investigation was undertaken into the properties of such an amplifier.

The diagram of the instrument is shown in Fig. 1 and is quite orthodox; the coupling is by means of "Radio Instruments" standard pattern audio-frequency intervalve transformers, Marconi-Osram LS5 valves being normally used.

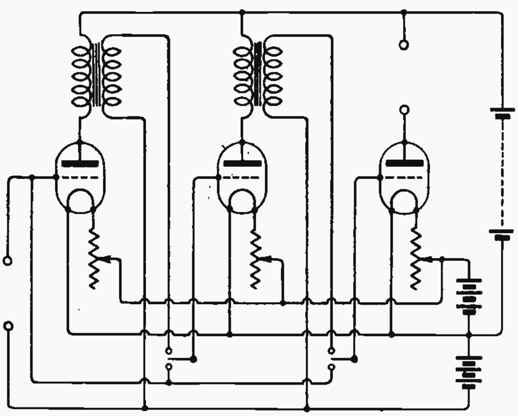


Fig. 1.

The Duddell oscillograph suggested itself as a possible instrument for use in the present investigation, and although widely known and used, a short description may not be out of place here.

The basic principle involved is that of the moving-coil galvanometer, but in the oscillograph the coil is replaced by a single tightly stretched loop of phosphor-bronze strip, the length of the vibrating portion of the loop being defined by bridge pieces in a similar manner to the strings of a violin.

Bridging this loop midway between the two bridge pieces is a very small mirror which reflects a beam of light from an arc lamp on to a photographic plate which is falling freely under the influence of gravity.

This assemblage is immersed in oil and placed between the poles of a powerful magnet, the object of the oil being to damp the vibrations and render the apparatus aperiodic.

On passing an alternating current through the loop, a couple is set up which causes the mirror and its reflected beam to oscillate, so recording the time graph of the A.C. on the falling plate.

The whole vibrating system is so small and tightly stretched that the period undamped is of the order of .0001 second, so that no difficulty from resonance effects is experienced at moderate frequencies, especially in view of the oil immersion.

In the actual oscillograph, two independent vibrators and a fixed mirror to give a zero line are immersed in the same oil bath and supported between the poles of the same magnet.

Having described in brief the action of the oscillograph, an account may be given of the actual work undertaken.

The apparatus of Fig. 2 was set up, after having calibrated the vibrators on D.C.; a previous experiment had shown that the impedance was equal to the D.C. resistance at the frequency used in the experiments, viz., approximately 480.

It will be realised that the amplitude of swing of the reflected beam gives the peak value of the current passing through the oscillograph vibrator.

Owing to various visual difficulties, such as the width of the spots of light. readings could only be estimated to 0.5 divisions on the scale used when calibrating the oscillograph, so that numerical results probably do not attain a greater accuracy than 10 per cent.

The method of examining amplifiers to be described is capable of furnishing the following information, all referring, of course, to the particular frequency chosen :—

1. An indication of the nature and extent of the waveform distortion produced by the amplifier under working conditions.

2. The total voltage amplification obtained with specified output conditions.

3. The peak voltage on the first grid, and hence the maximum permissible voltage consistent with absence of overloading and consequent distortion.

4. The best working adjustments for the amplifier.

Let us consider the methods of obtaining these results in the order given.

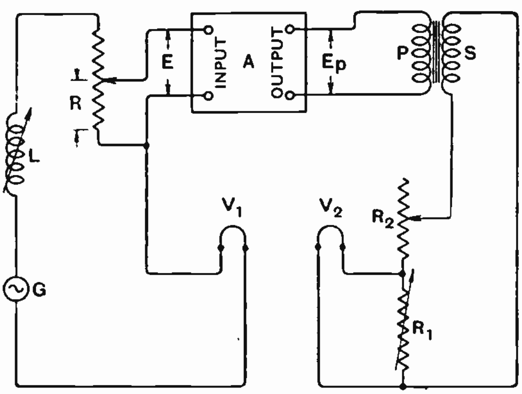


Fig. 2.

1. For this experiment, it is merely necessary to adjust the amplifier to the conditions under which it is desired to take graphs, at the same time noting that V_1 and V_2 are giving convenient deflections.

A photographic plate is allowed to fall in front of the vibrating light spots and on development the input and output graphs will be found superimposed and may be examined at leisure, when the nature and often also the cause of any distortion present will become evident.

2. Referring to Fig. 2, G is the alternating current source ; L, a choke coil for the purpose of purifying, as far as possible, the waveform of the current delivered by G ; V_1 and V_2, the vibrators of the oscillograph ; R, R_1 and R_2, non-inductive resistances ; PS, a stepdown transformer ; and A, the amplifier under observation.

Let the sensitivity of the vibrators be adjusted to equality and be S divisions of the scale per ampere.

Let V_1 and V_2 be the amplitudes of swing of V_1 and V_2 respectively, measured in scale divisions.

Let I be the peak value of the current in the circuit $G L R V_1$.

Let E be the peak value of the amplifier input E.M.F.

With A removed, let the primary terminals of PS be connected across R, also let R_1 be removed and R_2 short-circuited, and with the alternator running let R be adjusted until $V_1 = V_2$; let this value of R be denoted by K, the shunt effect of PS being in general negligible.

Let N be the ratio of the peak value of the current in the circuit $S\ R_1\ R_2$ to the peak value of the current in the circuit $R_1\ V_2$.

Let M be the voltage amplification of A with PS in the output circuit, the secondary of PS being loaded with a resistance V, where V is the resistance of V_2.

Then with the amplifier removed as above, $M=1$, also $N=1$, $V_1=V_2$ and $R=K$.

Now keeping all other conditions unchanged, let A be introduced into the circuit, then we have

$$E_p = ME$$

where E_p is the peak voltage across the primary terminals of PS.

Therefore $$V_2 = MV_1$$

or $$M = \frac{V_2}{V_1}$$

Now assume K changed to some other value R, then since E changes in the same ratio without affecting V_1 we have

$$M = \frac{KV_2}{RV_1}$$

Now let R_1 and R_2 be introduced and we obtain

$$M = \frac{NKV_2}{RV_1} \quad \ldots \quad (1)$$

Now in order to obtain N we can proceed as follows :—

It is necessary that the load on PS be kept constant throughout the experiments and equal to the resistance of V_2 alone, so that we have

$$R_2+\frac{1}{1/R_1+1/V}=V$$

which becomes

$$V^2=R_2(R_1+V) \quad \ldots \quad (2)$$

also from the theory of shunt circuits we have

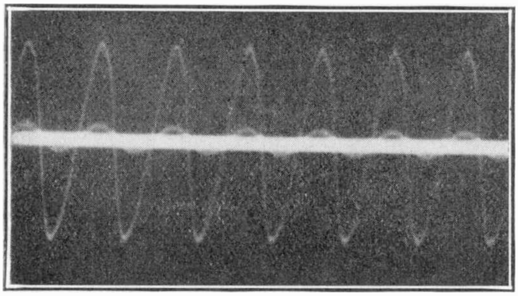
$$R_1=\frac{V}{N-1} \quad \ldots \quad \ldots \quad (3)$$

substituting for R_1 in (2) we obtain

$$V^2=R_2\left(V+\frac{V}{N-1}\right)$$

transposing we have

$$R_2=\frac{N-1}{N}V \ldots \quad \ldots \quad (4)$$



Oscillograph 1.

It will thus be seen that by making measurements of the amplitudes cf swing of the oscillograph vibrators, at the same time noting the values of the various resistances, the amplification obtained at the frequency used is at once obtained by the above simple formula.

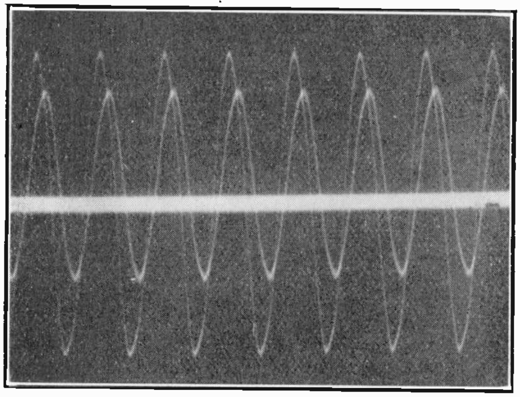
Of course, when the amplifier is removed from the circuit, an oscillogram may be taken and will show up any waveform distortion occurring in *PS*.

3. The peak voltage impressed upon the first grid is obtained from the relation

$$E=\frac{V_1R}{S} \quad \ldots \quad \ldots \quad (5)$$

which is obvious and requires no proof.

4. If a rotating mirror is available, the reflected beams from the oscillograph may be allowed to fall upon a small white screen, the screen being viewed by reflection in the revolving mirrors, when the waveforms will be visible; the adjustments of the amplifier are then varied until the distortion is reduced to a minimum.

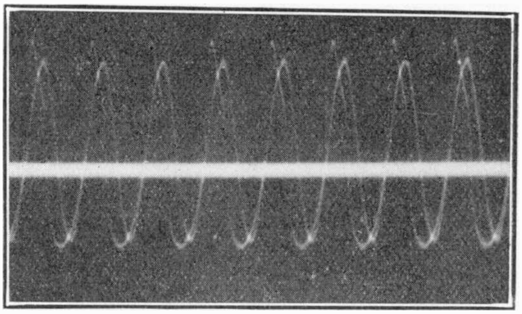


Oscillograph 2.

The following tests were conducted on the amplifier in order to illustrate the method :—

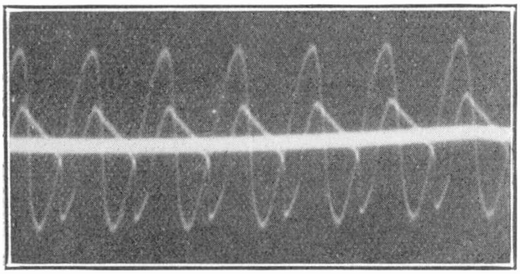
E was adjusted to a value of 1 volt peak, as probably representing average conditions, the frequency of the generator being, as previously mentioned, about 480 cycles per second.

Oscillograms 1-4 were then taken on the amplifier with one, two and three stages, using LS5 valves, and with three stages using R4 valves respectively; the operating details are shown in the table.



Oscillograph 3.

Oscillograms 5 and 6 are included as examples of what may happen to the output waveform if the amplifier is wrongly used; No. 5 shows the effect of excessive overloading, while No. 6 was taken while the valves were oscillating at a frequency of the order of 10^4 cycles per second and is a tribute to the facility with which the oscillograph follows rapid and complex current fluctuations.

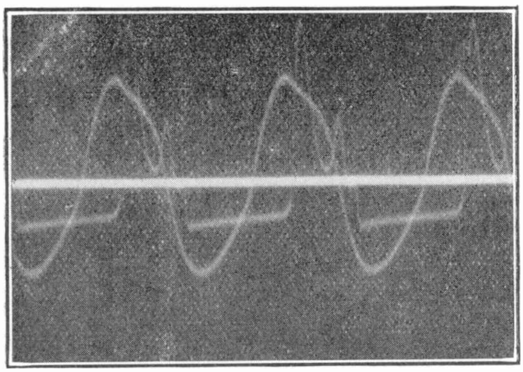


Oscillograph 4.

No precise details are available concerning these last two graphs, as they were obtained in the course of preliminary work.

It can easily be shown that a triode possessing the constants of the LS5 requires an anode voltage of about 300 and a negative grid potential of about 30 volts in order to take full advantage of its characteristics. (It will be noticed from oscillogram 3 that the last valve is overloaded when the anode and grid voltages are 120 and 10 respectively.)

In order to determine the maximum permissible peak voltage on the first grid under the best working conditions, a potential of 300 volts was applied to the



Oscillograph 5.

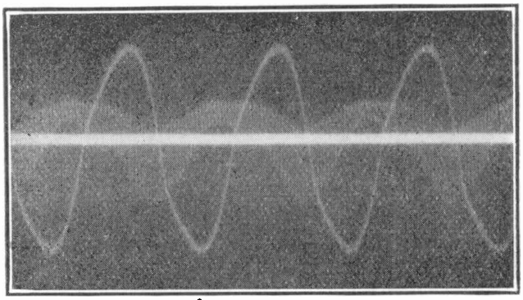
anodes, the immediate result being the breakdown of one of the intervalve transformers, which were of the old (non-sectional) type manufactured by Messrs. Radio Instruments, Ltd.

These were replaced by the new (sectionally wound) type by the same firm and the amplifier again connected up.

The instrument was now found to be oscillating at a frequency of about 16 periods per second, and in order to stabilise it, it was necessary to connect a (nominal) 0.1 megohm leak across the secondary of the first transformer and reduce the anode potential to 230 volts.

The output wave was then examined in a rotating mirror while the input voltage was increased until the first signs of distortion appeared, and then decreased until the distortion just disappeared.

The value of input voltage was calculated and found to be 0.49 volt, the amplification being 216, the steady grid potential 30 volts and the anode voltage 230.



Oscillograph 6.

Keeping the grid and anode voltages constant, the amplification with two stages was 40 and with one stage 4.

These figures, and those in the table, giving the amplification produced by the

TABLE.

E.M.F. on first grid = 1 volt peak.
Anode volts = 120.
Grid volts = 10.
LS5 valves, filament current normal.

Oscillogram No.	No. of stages.	Loud-speaker.	Voltage amplification.
1	1	Very weak	3.2
2	2	Moderate	40
3	3	Loud	150
R valves, anode volts 65, grid volts 1.5, filament current excessive			
4	3	Weak	15

various combinations of stages, call for some comment, and further research along these lines is probably indicated.

It may be said at the outset, that there are no mechanical faults in the amplifier, as the valves and transformers have been changed and all tested separately, also the individual complete stages, in their places on the ebonite panel.

The low amplification given by the first stage is explained by the fact that this figure does not include the step-up of a transformer, which is included in the values for the other stages.

It will, however, be observed that the total amplification given by the three stages working together should be $4 \times 10 \times 10 = 400$, whereas that actually obtained is about one-half this number.

Pending further experiments, the writer is inclined to think that the cause may be reverse reaction effects between the stages, as it is found that on reversing the connections to primary or secondary of either of the intervalve transformers, the instrument oscillates violently, thus demonstrating the presence of reaction effects which, when shifted in phase by 180 degrees, may lower the amplification.

It was also found on one occasion that merely reversing the connections to the primary of the output step-down transformer caused the amplification to change from 75 to 172, thus showing that large variations in the amplification attained under slightly differing conditions are to be expected.

The loud-speaker results given were obtained by changing over the amplifier output from the oscillograph and its auxiliary apparatus to a large "Magnavox" loud-speaker and are merely intended to act as a very rough guide as to what may be expected under the conditions quoted.

It is to be noted that the frequency (about 480) is somewhat low for a loud-speaker, so that it is probably not working to the best advantage; however, the loud-speaker tests are interesting when comparing the oscillograms.

The loud-speaker strength when using three stages with 230 volts on the anodes and an input of 0.49 peak volt, was about the same as with 120 volts on the anodes and an input of 1 peak volt, although in the former case distortion was absent and in the latter, quite marked; this is an excellent example of the enormous advantage, both in purity and volume, to be derived from the use of sufficient anode potential to bring the straight portion of the characteristic to the negative side of the axis of anode current.

The writer draws the following conclusions from the experiments, but in what follows due allowance must be made for the preference generally evinced by loud-speakers for the higher frequencies.

1. An average general purpose receiving valve operating a loud-speaker, however weakly, using average values of anode voltage (*e.g.*, 65) and grid potential (*e.g.*, 1.5), will in general be overloaded.

2. A power amplifier valve of the LS5 class, using the values of anode and grid potential usually to be found in loud-speaking broadcast receivers (*e.g.*, 120 and 10, say), will produce a moderate volume of sound sufficient to fill a fair-sized room without overloading, but no more.

3. A similar valve, whose anode and grid potentials have been so raised as to make use of the whole of the linear part of the characteristic curve, is, with a suitable loud-speaker, capable of producing a considerably greater volume.

Statements such as the above are of necessity of a vague general nature, owing to the difficulties of estimating sound intensities, etc.

It is almost certain that quite a large amount of distortion may pass unnoticed owing to the tolerance of the human ear, but it nevertheless may be perceived subconsciously, so that every effort should be made to reduce it to the absolute minimum.

Calibration of Ultra Short Wavelengths.

F. Aughtie, B.Sc. (G6AT). [R213

THE usual way of calibrating a circuit for short wavelengths is to employ a calibrated oscillator, which is rich in harmonics, and by taking readings of successive "chirps" determine the order of the wavelength and hence determine which harmonic of the oscillator is beating with the receiver.

An example will make this clear: Suppose we obtain chirps at 120, 150, and 180 metres, the differences between readings are both 30 metres and we see that the receiver is oscillating at 30 metres, beating with the 4th, 5th and 6th harmonics of the wavemeter respectively.

If, however, we try to calibrate on about 5 to 10 metres from a wavemeter whose fundamental range is, say, 100 to 200 metres, some considerable difficulty is experienced in determining which harmonic of the wavemeter is causing the chirp. The reason for this is as follows:—

An ordinary condenser dial cannot be read to within less than about half a degree, that is roughly to within one-third per cent. This, combined with the fact that the calibration curve will not actually be perfectly smooth—although it will be drawn so—causes the average wavemeter to have an accuracy not better than half of one per cent. Now suppose we get chirps at 100 and 105 metres by wavemeter. Our 100 metres may be anywhere between 100.5 and 99.5; similarly the 105 metres is somewhere between 105.5 and 104.5 roughly. Hence the difference between these may be anything between 4 and 6 metres. Are we, therefore, at the 25th harmonic of 100 metres or at the 17th, or which one in between these is the right one to choose? If we go higher up the scale of the wavemeter the latitude of successive differences will increase so that even by averaging we are still left to make the choice between four or five possible values.

After some thought the writer has evolved a method of deciding which harmonic is causing the chirp, and is writing this article trusting that the method may be of some help to other experimenters interested in the ultra short wavelengths. The method is best explained by an example:—

In an actual calibration (of the minimum wavelength for a particular coil) chirps were heard at settings of the calibrated oscillator corresponding to 150.7, 156.1, 161.4, 167, and 172.5 metres. The successive differences are: 5.4, 5.3, 5.6, 5.5 metres. Set out five columns and at the head of each place the readings 150.7, 156.1, etc. (see Table I.). In each column write the value of the different harmonics of the particular wavelength which may be correct and also one or two above and below these, *i.e.*, under 150.7 we have written the readings 6.03, 5.80, 5.58, 5.38, 5.20, 5.03; being respectively the 25th, 26th, 27th, 28th, 29th, 30th harmonics of 150.7 metres. Under 156.1 we have 6.02 . . . 5.04 being the 26th . . . 31st harmonic. And so on for the other readings.

TABLE I.

150.7	156.1	161.4	167	172.5
6.03	6.02	5.98	5.97	5.95
5.80	5.79	5.77	5.77	5.75
5.58	5.58	5.57	5.57	5.56
5.38	5.38	5.38	5.39	5.39
5.20	5.21	5.21	5.22	5.23
5.03	5.04	5.05	5.06	5.07

Differences are: 5.4, 5.3, 5.6, and 5.5.

TABLE II.

147.8	153	158.4	163.8	169
5.68	5.67	5.67	5.65	5.64
5.47	5.47	5.46	5.47	5.45
5.28	5.28	5.28	5.28	5.28
5.10	5.11	5.12	5.12	5.125
4.83	4.94	4.95	4.96	4.97

Differences are: 5.2, 5.4, 5.4 and 5.2.

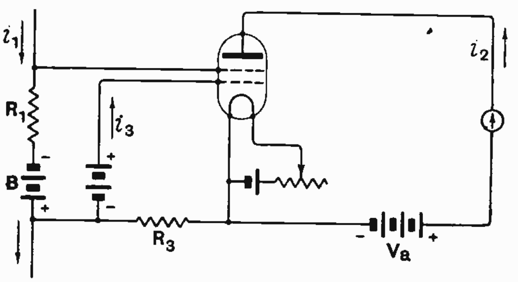
Now look along the first line; the readings are: 6.03, 6.02, 5.98, 5.97, 5.95: there is a steady *fall* from left to right. Along the bottom line the readings are 5.03, 5.04, 5.05, 5.06, 5.07—a steady *rise* from left to right. On looking at the whole table, it will be seen that in all the lines above the one 5.38, 5.38, . . . 5.39, there is a *fall* from left to right, whereas in all the lines below this one there is a steady *rise* from left to right. It is therefore clearly seen that the particular wavelength measured lies between 5.38 and 5.39. Our probable error, therefore, is of the order of 0.2 per cent. despite the fact that the successive differences differed by quite a considerable amount.

To make the method quite clear a further example is set out in Table II. As before, the readings of the wavemeter are given at the head of the columns; successive differences give the clue as to which harmonics to write down and these are entered in the columns. It will be seen that in this case the wavelength was 5.28 metres.

A Very Sensitive Valve Galvanometer.

By Prof. G. W. O. Howe, D.Sc. [R251

R. JAEGER and H. Scheffers, of the Siemens & Halske Co., have recently described* a very sensitive valve galvanometer employing a double grid valve with resistance back-coupling. The diagram of connections is shown in the figure. The



space charge current i_3 of the inner grid and the anode current i_2 are always together equal to the saturation current, so that $i_3+i_2=i_s=$constant. The current i_3 passes through the back-coupling resistance R_3 and tends thus to lower the potential of the outer grid. The current i_1 to be measured passes through the resistance R_1 and thus tends to raise the potential of the outer grid; hence its resultant potential $V_g=i_1R_1-i_3R_3+B$. The bias voltage B may be positive or negative. In the anode circuit, $i_2=(V_g+aV_a)/R_i$ where a and R_i are constants of the valve, assuming that one is working on the straight part of the characteristic.

From these three equations it can be shown that

$$\frac{dV_g}{di_1}=\frac{R_1}{\left(1-\frac{R_3}{R_i}\right)}$$

As R_3 approaches R_i in magnitude this expression approaches infinity, and a very small change in the current i_1 causes a very large change in V_g and therefore also in the anode current which is read on a sensitive galvanometer. The effect of the back-coupling is equivalent to an increase in the steepness of the characteristic of the valve; it can be explained very simply as follows: The current i_1 increases the potential of the outer grid; this causes an increase of the anode current, but since the inner grid is so positive that its current together with the anode current is equal to the constant emission current of the filament, the increase of anode current causes a decrease in the current i_3 and therefore a reduced voltage drop in the resistance R_3. This tends to raise the potential of the outer grid still further and the whole cycle is gone through again, the effects being cumulative.

One cannot push the sensitivity too far, however, owing to the difficulty of keeping the filament temperature constant, but with care the value of R_3 can be so adjusted that the effective steepness of the characteristic is ten times its original steepness.

* See *Elektrotechnik und Maschinenbau*, p. 1038, 27th December, 1926.

Abstracts and References.

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R000.—WIRELESS AND GENERAL.

R008.—United States—Radio Patents. (*Electrical Review*, 13th August, 1926, p. 264.)

"The rise of radio has resulted in the swamping of the United States Patent Office with applications." Although the number of examiners handling radio applications has been almost trebled, 1,850 petitions are pending, and the radio division is five months behind the applications.

R008.—Safeguards for the Radio Inventor.—E. Curtis. (*Proc. Inst. Radio Engineers*, Vol. 14, August, 1926, pp. 471—477.)

Precautions to be taken by the radio inventor who is not associated with an organisation which includes a patent department, with explanation why such precautions are necessary.

R070.—Collegiate Training for the Radio Engineering Field.—C. Jansky, Jr. (*Proc. Inst. Radio Engineers*, Vol. 14, August, 1926, pp. 431—445.)

A paper presented before the Chicago section, I.R.E., in March, and at the New York meeting in June, together with the discussion following it.

R080.—Short-wave Transmissions. (*Wireless World*, 18th August, 1926, pp. 221—222.)

A list of some 140 stations in all parts of the world working on wavelengths between 13 and 150 metres.

R100.—GENERAL PRINCIPLES AND THEORY.

R113.—Notes on Wireless Matters. (*Electrician*, 23rd July, 1926, p. 100.)

Two letters referring to Mr. Turner's article on wave propagation in the issue of 9th July, p. 42 (these abstracts, *E.W. & W.E.*, September, 1926, p. 567). The first is from the author himself correcting certain misprints in formula (*d*), and the second is from Mr. T. L. Eckersley, showing that formula (*b*) is incorrect, and that the field strength is not proportional to $1/\sqrt{H}$, but to $1/H$, the power radiated not being independent of H.

In the *Electrician* of 13th August, p. 176, Mr. Turner replies to this objection.

R113.—Wireless Transmission I. & II.—Charles E. Snell. (*Electrical Review*, 23rd July, p. 138 and 6th August, 1926, p. 207.)

The first article discusses the subject particularly from a theoretical aspect and suggests a way of bringing theory and practice into agreement.

The second article deals with the phenomena of the daylight effect and atmospherics showing that light is thrown upon these by the views put forward in the first article.

The following conclusions are reached :—

1. Wireless transmission is dependent partly on the electrical conductivity of the earth's surface and partly on the dielectric properties of the earth's atmosphere.

2. The electrical conductivity of the earth's surface is invariable and is the contributory cause of the constancy of efficiency shown in daylight transmission.

3. The variations in transmission efficiency at night are occasioned by variations in the air dielectric brought about by night radiation from the earth's surface.

4. The night radiation from the earth's surface is a function of the sun's mean altitude so far as this radiation influences the electrical efficiency of the air dielectric; other causes, however, occasion transient variations in the night radiation sufficient to obscure this relationship in isolated observations.

5. The transient variations in the earth's night radiation are present to a greater degree in cases of overland transmission and in the vicinity of land masses.

With regard to "atmospherics," disturbances at night are stated to be frequently due to earth currents circulating in the neighbourhood of the receiving aerial. It is suggested that these currents arise from the equalisation of potential differences between the materials of the earth's surface.

A letter referring to this article, by T. Barton, in the issue of 20th August, p. 301, suggests that the all-important factor in wireless transmission is its wavelength of propagation. Evidence is given to show that greater distances of transmission can be obtained during the day than during the night, using short wavelengths.

R113.1.—Wireless Signal Fading.—E. V. Appleton. (*Wireless World*, 11th August, 1926, pp. 181—182.)

A simple method of measurement and some of the results obtained.

R113.1.—On the Relation between Short Wavelengths and Possible Communication Hours together with the Communication Distance.—T. Nakayama, T. Ono, and C. Anazawa. (*Journ. Inst. Elect. Engineers of Japan*, July, 1926, pp. 695—711.)

Description of a year's investigation which leads to the following conclusions :—

1. The wavelength of about 24 metres is critical.

2. Waves of 25 metres or more are best utilised for night long distance communication.

3. Waves of 22 metres or less are good for daylight long distance communication.

4. The phenomenon of skipped distance exists especially for waves below 20 metres.

R113.2.—SPECIFIC STUDY OF CONDITIONS AFFECTING RANGE OF RADIO STATIONS.—C. Jansky, Jr. (*Bulletin No. 297, U.S. Bureau of Standards.*)

A paper describing the organisation of a group of observers by the bureau, the methods employed for making observations, and the forms used for recording 8,500 observations made over a period of a year (1922-23). The data obtained were analysed on automatic machines, and charts were given showing the variation of strength of atmospheric, variation of fading, relative magnitude of obstacles to reception, variation of interference from receiving sets, relative magnitude of obstacles to reception grouped in bi-monthly periods, and mean reliability of reception as a function of distance.

R113.4.—UPPER AIR PHENOMENA. (*Nature*, 14th August, 1926, p. 221.)

An account of Dr. Dobson's paper: "The Uppermost Regions of the Earth's Atmosphere," being the Halley lecture given on 5th May, 1926. The paper reviews the present state of our knowledge of the constitution of the upper atmosphere and of the chief natural phenomena occurring above the isothermal layer.

R113.4.—METEORS AND THE CONSTITUTION OF THE UPPER AIR.—Prof. Lindemann. (*Nature*, 7th August, 1926, pp. 195—198.)

The view is expressed that the persistence of the conducting layer at night is due to solar radiation forming some unstable substance, such as ozone, which gradually reacts or breaks up forming ions during the hours of darkness, and that the layer of maximum ionisation after sunset will move up as the ozone becomes used up during the night to regions of lower density where the rate of reaction is smaller. It is explained that it is above 50 km. that the concentration of ozone compared with that of water-vapour and carbonic acid becomes important and that the amount of ozone formed per $cm.^3$ reaches a maximum somewhere in the neighbourhood of 60 km.

This hypothesis will account for the height of the Heaviside layer varying from 50 km. at sunset to some 80 km. at sunrise which the facts observed in radio seem to require.

R113.4.—RELATION BETWEEN THE HEIGHT OF THE KENNELLY-HEAVISIDE LAYER AND HIGH FREQUENCY RADIO TRANSMISSION PHENOMENA. A. Hoyt Taylor.—*Proc. Inst. Radio Engineers*, Vol. 14, August, 1926, pp. 521—540.)

The theoretical basis of this paper was published in the *Physical Review* for January, 1926. That paper was in turn based upon certain experimental data which have been considerably extended since the date it was submitted for publication. The present paper describes further investigation of the skip distance effect, and the indication that it gives as to the height of the Heaviside layer, and the lower limit of wavelength which will be useful in long-distance communication. The results are not summarised. An interesting case is mentioned of a station that appears to show no skip at all.

R113.7.—ON THE ATTENUATION OF WIRELESS SIGNALS IN SHORT DISTANCE OVERLAND TRANSMISSION.—J. Ratcliffe and M. Barnett. (*Proc. Cam. Phil. Soc.*, July, 1926, pp. 228—303.)

The following summary is given:—

1. It is pointed out that the signal strength of a wireless wave at a distant point depends on:—

(*a*) the electrical constants of the ground,
(*b*) the curvature of the earth,
(*c*) the existence of an "atmospheric" ray coming downwards from the Heaviside layer.

2. We can eliminate the effect of (*b*) and (*c*), and so obtain direct evidence about the electrical constants of the ground, by making measurements near the transmitter.

3. Measurements on wavelengths of 300 metres and upwards give information about the resistivity of the ground, and on shorter wavelengths (15 metres) give the dielectric constant of the ground.

4. Attenuation measurements have been made over short distances for wavelengths of 1,600 metres and 360 metres.

5. The results are compared with those calculated from Sommerfeld's theory and show close correlation for distances beyond 10 wavelengths but show deviations from the theory for shorter distances.

They give as values for the resistivity of the ground

$$\rho = 1.8 \times 10^{13} \text{ E.M.U.}$$

for the Daventry signals, and

$$\rho = 0.6 \times 10^{13} \text{ E.M.U.}$$

for the London signals.

A note is added saying that since the paper was written further measurements have been made within 20 miles of the London transmitter, which show that calculations based on a single value of "ρ" will not give as close an agreement with the experimental results as can be obtained by assuming that ρ changes with the nature of the ground. For example, the results up to 20 miles agree with the value $\rho = 2 \times 10^{13}$ E.M.U., whereas the results for greater distances, as shown above, indicate the value $\rho = 0.6 \times 10^{13}$ E.M.U. It is interesting to note that such a change in ρ would be anticipated from the known geological nature of the ground, which consists of London clays up to about 20 miles from the transmitter and of chalk at greater distances.

R113.8.—RELATIONS ENTRE LES PERTURBATIONS ELECTROMAGNÉTIQUES ET LES TROUBLES SOLAIRES.—A. Nodon. (*L'Onde Electrique*, Vol. 5, July, 1926, pp. 359—364.)

The following summary is given:—

The propagation of electromagnetic waves appears to be closely linked with the state of ionisation and conduction of the upper layers of the atmosphere. The ionisation seems due to ultra penetrating radiation emitted by the sun and stars. This emission undergoes profound modifications during solar and electromagnetic disturbances, entailing corresponding effects in radio propagation.

R113.9. — POLARISATION CHANGES CAUSED BY GROUND ABSORPTION.—E. F. W. Alexanderson. (*General Electric Review*, August, 1926, pp. 553—554.)

In the reception of short waves, the signal often appears to come in with equal strength from all directions. Measurements with a loop indicate the presence of a horizontal and a vertical wave component with different velocities of propagation, resulting in differences of polarisation from point to point. The author discusses the phenomenon, using as an analogue sound waves proceeding from a loud-speaker horn, and suggests that the earth may absorb the horizontal polarised waves and reflect the vertical ones, thus giving rise to a twisting wave spiral.

R114. — PERTURBATIONS ATMOSPHÉRIQUES ET LONGUEURS D'ONDES.—H. de Bellescize. (*L'Onde Electrique*, Vol. 5, July, 1926, pp. 347—358.)

The following summary is given :—

Propagation formulæ, connecting the oscillations in transmitting and receiving antennæ, can only be of practical utility when the correspondence that exists between the electromotive forces received and the degree of security obtained is definitely known. Now atmospherics constitute the principal obstacle to be surmounted, and it is therefore upon them that the values to give these electromotive forces depend.

It is examined whether the hypothesis on which atmospherics vary arbitrarily is able to account for the results found by experiment.

A first verification based on the measurement of electromotive forces equivalent to the disturbances tends to prove that, on the average, these latter increase slightly with the wavelength, while a second method consisting of combining the hypothesis with Austin's propagation formula leads to the opposite result.

It seems then, on the one hand, that the hypothesis can be retained, as a first approximation, and on the other hand, that current propagation formulæ should undergo slight alteration so as to less favour decreasing waves.

It is insisted that where the hypothesis is concerned, as also the verifications attempted, refer only to a mean value around which the instantaneous phenomena vary without doubt within wide limits.

R114. — LES ATMOSPHÉRIQUES. — R. Bureau. (*L'Onde Electrique*, Vol. 5, July, 1926, pp. 301—346.)

" Conference de documentation faite à la Société des Amis de la T.S.F., le 19 mai, 1926."

The paper, whose main theme is that atmospherics are not caused by storms, but ascending currents of air, is divided into five sections :—

1. Methods of observation and measuring instruments.
2. Results.
3. Meteorological influences.
4. Theories.
5. Conclusion.

Observations on the freqnency of atmospherics are discussed, and on their intensity, directivity, wavelength and nature. The results are found to show three distinct types of variation :—

(*a*) With a maximum at night.
(*b*) With a maximum in the afternoon.
(*c*) With any distribution of the periods of violent atmospherics.

These three types point to three distinct causes for atmospherics and can serve as a basis for their classification.

The first type, which is the least important of the three, is thought to originate in layers of anti-cyclonic inversion ; its disappearance at sunrise corresponds to descending currents extending down to the ground ; the second type is attributed to the heating of the ground by the sun and the resulting ascending currents of air ; and the third to the effect of atmospheric discontinuities. All three refer back to the vertical temperature gradient.

The properties of atmospherics of the second type (grinders) are shown to follow from their origin (air ascending owing to solar heating of ground), for they

(*a*) Appear at a definite time (afternoon) ;
(*b*) Are much more intense in summer than in winter ;
(*c*) Are much more violent over the continents than oceans ;
(*d*) Are observed chiefly in low altitudes ;
(*e*) Diminish rapidly in intensity with altitude ;
(*f*) Are specially violent when the meteorological situation favours ascending currents due to solar heating of the ground (in France pseudo polar front).

The properties of the third type of atmospherics (clicks) are also linked with their origin (convection currents caused by the movement of masses of air), for they

(*a*) Appear at any hour of the day or night :
(*b*) Are not confined to the warm season, but are also observed in winter ;
(*c*) Are characteristic of medium latitudes ;
(*d*) Appear indifferently over sea or land, though they can be reinforced by mountain chains which have an effect on meteorological perturbations ;
(*e*) Vary in intensity with altitude, the direction of variation depending upon the meteorological situation ;
(*f*) Develop parallel with the meteorological perturbations (appear with cold fronts and disappear with warm).

The atmospherics coming through at any station almost always belong to the three categories, and if they are studied *en bloc* it is impossible to avoid observing a mixture of the properties of the three varieties.

As concerns other theories on the origin of atmospherics, cosmic ones are not considered justifiable, and the theory of local meteorological action is set over against that of a tropical origin for atmospherics.

An exhaustive bibliography of the subject is appended, also a communication from Mr. Watson Watt, made at the end of the lecture, where he briefly indicates the newer methods of the Radio Research Board, which lead to other conclusions than those arrived at by M. Bureau.

R114.—LIGHTNING. (*Nature*, 7th August, 1926, p. 190.)

A letter by Dr. Dorsey referring to Dr. Simpson's article (*Proc. Roy. Soc.*, May, 1926), intending to show that the positive tongue theory advanced by Dr. Simpson and the electronic dart theory proposed by himself are not conflicting, but mutually complementary (see these abstracts, *E.W. & W.E.*, July, 1926, p. 454.)

A reply from Dr. Simson follows in which he indicates fundamental difference between his point of view and that of Dr. Dorsey.

R120.—STRAIGHTENING OUT THE ANTENNA.—B. Melton. (*Q.S.T.*, Vol. 10, August, 1926, pp. 30-32.)

An article "intended to straighten out our ideas on radiating systems in general."

R125. — PRACTICAL DIRECTION - FINDING.—R. L. Smith-Rose and R. H. Barfield. (*Wireless World*, 11th August, 1926, pp. 193-197.)

Construction and calibration of an accurate direction-finder for amateur use.

R125.1.—THE CAUSE AND ELIMINATION OF NIGHT ERRORS IN RADIO DIRECTION-FINDING.—Dr. Smith-Rose and R. Barfield. (*Journ. Inst. Elect. Engineers*, Vol. 64, August, 1926, pp. 831-843.)

A paper read before the Wireless Section, 5th May, 1926, summarised as follows :—

The paper describes experiments which have been carried out with a view to obtaining more conclusive evidence as to the causes of the apparent variations in bearings observed under certain conditions on wireless direction-finders. In the course of the experiments the Adcock "four-aerial" direction-finder has been developed, and with its aid it has been shown that the actual deviation in azimuth of wireless waves is practically negligible. These experiments thus constitute a proof that the variable errors observed on closed-coil direction-finders at night are caused by down-coming waves arriving from the upper atmosphere and polarised with the electric force in a horizontal plane. The investigation also indicates the possibility of the Adcock system being developed into a practical direction-finder which is free from night errors, and those errors associated with observations on aircraft transmissions made at a ground direction-finding station.

The discussion following the reading of the paper is also given.

R125.6. — DIRECTIVE DIAGRAMS OF ANTENNA ARRAYS.—R. Foster. (*Bell System Technical Journal*, Vol. 2, pp. 292-307.)

Two systematic collections of directive amplitude diagrams are shown for arrays of two and of sixteen identical antennæ spaced at equal distances along a straight line with equal phase differences introduced between the currents in adjacent antennæ, assuming that each antenna radiates equally in all directions in the plane of the diagram. The diagrams may be used to obtain the directive diagram in any plane though an array made up of antennæ which do not radiate equally in all directions in this plane but which satisfy the other conditions. The total directive effect is given as the product of the individual effect multiplied by the group effect.

R130.—DEMONSTRATION OF SOME SIMPLE EXPERIMENTS WITH THERMIONIC VALVES.—Dr. Rayner. (*Proc. Phys. Soc. Lond.*, Vol. 38, November 4, 1926, pp. 335—336.)

R130.—OPERATION OF THERMIONIC VACUUM TUBE CIRCUITS.—F. B. Llewellyn. (*Bell System Technical Journal*, July, 1926, pp. 433—462.)

The following synopsis is given :—

Given the static characteristic of grid current-grid potential, and plate current-plate potential, for any three-element vacuum tube, the general exact equations for the output current when the tube is connected in circuits of any impedance whatsoever, and excited by any variable voltage, are here derived. The method of derivation is illustrated in the special case where resistances only are considered, and the adaptation of complex impedance to use in non-linear equations is shown. Approximations that are allowable in various practical applications are indicated, and the equations are applied in some detail to grid-leak detectors, and in brief to other types of detectors, modulators, amplifiers and oscillators.

R131. — VALVE CHARACTERISTIC SURFACES. — E. Harwood. (*Wireless World*, 11th August, 1926, pp. 185-187.)

Investigation of the best working conditions for a valve oscillator.

R.131.—USE OF PLATE CURRENT-PLATE VOLTAGE CHARACTERISTICS IN STUDYING THE ACTION OF VALVE CIRCUITS.—E. Green. (*E.W. & W.E.*, July, 1926, pp. 402—406 ; August, 1926, pp. 469—476.)

R138.—EQUATIONS FOR THERMIONIC EMISSION.—P. Freedman. (*Nature*, 7th August, 1926, p. 193.)

R144.—EFFECTIVE RESISTANCE OF INDUCTANCE COILS AT RADIO FREQUENCY—PART IV.—S. Butterworth. (*E.W. & W.E.*, August, 1926, pp. 483—492.)

R149.—SUR LA DÉTECTION PAR LES CONTACTS MÉTALLIQUES DÉTECTEUR SYMÉTRIQUE.—H. Pelabon. (*Comptes Rendus*, 28th June, 1926, pp. 1605—1607.)

R162.—AERIAL FILTER CIRCUITS. — P. Tyers. (*Wireless World*, 4th August, 1926, pp. 169—171.)

Experiments with a simple method of improving unselective receivers.

R200.—MEASUREMENTS AND STANDARDS.

R201.—EMPLOI DE L'ELECTROMÈTRE À QUADRANTS DANS LES MESURES DE PRECISION EN HAUTE FRÉQUENCE.—L. Cagniard. (*Comptes Rendus*, 21st June. 1926. pp. 1528—1530.)

R235.—THE PROPERTIES OF MUTUAL INDUCTANCE STANDARDS AT TELEPHONIC FREQUENCIES. —L. Hartshorn. (*Proc. Phys. Soc. Lond.*, 35, 4, pp. 302—320.)

The following abstract is given :—

It is well known that when a mutual inductance carries alternating current, the value of the effective mutual inductance varies with the frequency, and further that the secondary P.D. is not exactly in quadrature with the primary current. Thus certain frequency corrections are introduced into all alternating-current bridges in which a mutual inductance standard is used. An experimental investigation has been made of the actual magnitude of such corrections for mutual inductance standards of three types :—

1. A stranded wire fixed standard, with spaced winding to minimise capacity effects.

2. The Campbell variable mutual inductance standard.

3. The Tinsley variable mutual inductance standard made in accordance with Butterworth's recommendations. Values of the corrections are given for all these instruments under various conditions. It is shown that whereas the variation of mutual inductance with frequency is mainly due to capacity effects; dielectric losses in the insulation, or alternating current conductance, play an important part in the determination of the phase defect, the impurity being found to be proportional to a power of the frequency higher than the second, over the telephonic range of frequency.

R240.—EIN NEUES RÖHRENGERAT ZUR MESSUNG SEHR HOHER WIDERSTÄNDE MIT SEINER SONDERANWENDUNGEN. (A new valve high-resistance ohmmeter with particular applications.)—S. Strauss. (*Elektrotechnik und Maschinenban*, 44, 19, pp. 348—355.)

If the grid of a vacuum tube is charged negatively no current can flow in the anode circuit. If a high resistance is connected beween the grid and the cathode, a negative charge placed upon the grid will slowly leak across this high resistance. As soon as the grid voltage approaches a certain minimum value an anode current will begin to flow, increasing proportionally to the decrease of the grid voltage. Parallel to the high resistance is a fixed condenser, which will be charged by the anode current and later discharged across the resistance, the charging and discharging taking place at definite intervals. The number of discharges of the condenser in a given time interval is a direct measure of the unknown resistance. A complete portable equipment based upon this principle is described.

R251.2.—MEASURING SMALL ALTERNATING CURRENTS.—E. Banner. (*Electrician*, 20th August, 1926, pp. 202—203.)

Description of some modifications of the Duddell thermo-galvanometer for H.T. work.

R251.3.—TRANSFORMERS FOR THE MEASUREMENT OF LARGE CURRENTS AT RADIO FREQUENCIES. —I. Maloff. (*General Electric Review*, Vol. 29, August, 1926, pp. 555—558.)

An account of the theoretical and experimental considerations leading to the development of two types of radio-frequency current transformer. The first type is intended for a primary current range of 5 to 100 amps, at frequencies from 10 to 500kC and 2,000 volts at radio frequency between the windings. The core consists of a number of very thin ring-type enamelled laminations of high grade iron. The secondary is wound around this ring and placed in a box container, made from specially treated maple wood. The primary winding is placed in the groove in the outer surface of the box. The second type of instrument covers radio-frequency current transformers of maximum primary current rating from 40 to 400 amps at frequencies from 10 to 200kC and with 10,000 volts at radio frequency between the windings. The primary consists of a copper tube conductor passing through the centre of the ring-type core, while the secondary is wound around this core. The secondary is intended to operate at ground potential, while the primary may carry current at radio frequency with a potential as high as 10,000 volts effective value with respect to ground. All transformers are designed for 5 amps maximum secondary current. Illustrations of the two types described are shown.

R272.—A RADIO FIELD-STRENGTH MEASURING SYSTEM FOR FREQUENCIES UP TO FORTY MEGACYCLES.—H. Früs and E. Bruce. (*Proc. Inst. Radio Engineers*, Vol. 14, August, 1926, pp. 507—519.)

The apparatus is a double detection receiving set which is equipped with a calibrated intermediate frequency attenuator and a local signal comparison oscillator. The local signal is measured by means of the intermediate frequency detector which is calibrated as a tube voltmeter.

R300.—APPARATUS AND EQUIPMENT.

R337.—MERCURY ARC RECTIFIERS.—A. B. Goodall. (*Q.S.T.*, Vol. 10, August, 1926, pp. 8—11.)

An account of some reliable arrangements recently developed at Washington.

R340.—THE POWER SUPPLY OF WIRELESS SETS.— P. Tyers. (*Electrical Review*, 20th August, 1926, p. 299.)

Present methods for obtaining filament and high-tension supply from the electric lighting mains are stated to be complicated, not universally applicable to every type of receiver, and not fool proof.

A device is required which, when plugged into the mains, can be substituted immediately for the ordinary filament accumulator and high-tension battery, without necessitating any change in the wiring of a set or the use of special valves. "Anyone who succeeds in producing some arrangement at a competitive price should be assured of a very ready market."

R340.—SENSITIVE VALVE RELAY.—G. Blake. (*Wireless World*, 11th August, 1926, p. 188.)

R340.—COMPLETE SUPPRESSION OF A SINGLE FREQUENCY BY MEANS OF RESONANT CIRCUITS and REGENERATION. J. Stratton. (*Journal of the Optical Society of America*, Vol. 13, July, 1926, pp. 95—105.)

Discussion of the possibility of suppressing a given frequency by both tuned grid and tuned plate circuits. Curves are shown which indicate a greater sharpness of tuning for the tuned grid than for the tuned plate circuit. This may be accounted for by the fact that whereas the condenser of the tuned grid circuit is shunted only by the very high input resistance of the valve from grid to filament, the condenser of the tuned plate circuit is shunted by the internal plate resistance which is relatively low compared with the resistance of the condenser. From this point of view the tuned grid is preferable to the tuned plate circuit.

R343.—PROBLEMS IN BROADCAST RECEIVER DESIGN.—P. P. Eckersley. (*E.W. & W.E.*, August, 1926, pp. 499—507.)

A lecture delivered before the Radio Society on 26th May, together with the discussion that followed.

R343.7.—OPERATING RECEIVING FILAMENTS WITHOUT BATTERIES.—R. Kruse. (*Q.S.T.*, Vol. 10, August, 1926, p. 25.)

R344.9—LE QUARTZ OSCILLANT ET SES APPLICATIONS À LA T.S.F.—J. Quinet. (*Radio Revue*, Vol. 5, August, 1926, pp. 114—127.)

A reprint of a paper read before the Radio Club de France in May, 1926. The first part of the paper is devoted to the theory of piezo-electricity in general and to the case of quartz in particular. The second part of the paper describes an important application of the quartz oscillator (due to Prof. Langevin) to submarine signalling, and the location of obstacles under water, depth of the sea, etc. The principle is to send out a wave towards the obstacle and receive the echoed or reflected wave, when the distance can be calculated. The method described utilises the vibrations of a quartz oscillator of suitable dimensions as a means of creating, in the water, waves of compression as of sound waves but of ultra audible frequency. The oscillator also acts as a receiver of the reflected wave, so that the time of emission and return can be studied. Illustrations and diagrams of the apparatus are given.

The third part of the paper first describes the application of the quartz crystal to various measurements, *e.g.*, as a manometer, electrometer, oscillograph, etc. The use of the crystal for the generation of oscillations is then considered. The standard forms of quartz oscillator circuit are illustrated and discussed, and a complete transmitter shown, using quartz as master control, with radio-frequency, power amplification to a tuned aerial. The application of the crystal to correction of a wavemeter is also discussed, and the paper concludes with notes on the preparation of the quartz for use as an oscillator.

R344.9.—USES AND POSSIBILITIES OF PIEZO-ELECTRIC OSCILLATORS.—A. Hund. (*Proc. Inst. Radio Engineers*, Vol. 14, August, 1926, pp. 447-469.)

A survey of what is known about piezo-electric oscillators, the following conclusions being drawn:—

1. Experiments with quartz plates show that they can be used in a valve circuit for producing radio-frequency currents of fixed frequencies bearing a definite relation to the dimensions of the plate.
2. The piezo oscillator can be used together with an auxiliary generator for standardising a frequency meter.
3. A single piezo-electric plate can be employed as a standard for the entire range of frequencies used in radio communication.
4. By using special arrangements a small plate can be employed for producing audio-frequency currents.
5. Methods are given for grinding a plate accurately to a given frequency.
6. Formulæ are given in designing plates to a direct frequency to a fair degree of accuracy.
7. Other miscellaneous applications are described.

R384.1.—A SHORT WAVE WAVEMETER.—A. E. Tubbs. (*E.W. & W.E.*, August, 1926, pp. 479—482.)

R400.—SYSTEMS OF WORKING.

R423.—A 20-40-80 METRE CRYSTAL-CONTROLLED TRANSMITTER.—L. Root. (*Q.S.T.*, Vol. 10, August, 1926, pp. 33—35.)

R430.—BEHAVIOUR OF RADIO RECEIVING SYSTEMS TO SIGNALS AND TO INTERFERENCE (Abridged).—L. J. Peters. (*Journ. Amer. Inst. Elect. Engineers*, August, 1926, pp. 707—716.)

The following synopsis is given:—

This paper develops a point of view and method by means of which it is possible to arrive at many of the transient effects occurring in radio systems by a consideration of steady-state properties alone. The scheme is to replace the voltages in radio receiving systems due to interference and signals by a group of generators having the correct voltages and frequencies. These generators can be thought of as having been in the circuit for an indefinitely long time, so that only the steady-state response of the system need be considered.

The generators which replace the voltages induced in an antenna by interrupted continuous wave stations, by spark telegraph stations, by telephone stations and by static are worked out. The desirable properties of radio receiving systems for receiving various types of signals through interference are arrived at and an ideal system is described which may be used as a standard of reference for judging the merits of any actual frequency selecting system. It is shown that this ideal system reduces the interference from all sources to the smallest possible value which can be obtained in a system which makes use of frequency selection to reduce interference. The paper thus arrives at the degree to which interference can be mitigated by frequency-selection methods. In order to illustrate the method of treating actual systems, calculations are given for a simple series receiver. The interference caused by transmitting stations of various types and by static is discussed and the factors determining such interference are pointed out.

R435.—Cipher Printing Telegraph Systems for Secret Wire and Radio Telegraphic Communications.—G. S. Vernam. (*Bulletin Reprint B-198 Bell Telephone Laboratories*, June, 1926.)

The paper describes a printing-telegraph cipher system developed during the war for the use of the Signal Corps, U.S. Army. The system is so designed that the messages are in secret form from the time they leave the sender until they are deciphered automatically at the office of the addressee. The operation of the equipment is described, as well as the method of using it for sending messages by wire, mail or radio. The paper also discusses the practical impossibility of preventing the copying of messages, and the relative advantages of various codes and ciphers as regards speed, accuracy and the secrecy of their messages.

R500.—APPLICATIONS AND USES.

R500.—Electrical Communication.—H. Charlesworth. (*Journ. of the Amer. Inst. Electrical Engineers*, August, 1926, pp. 737—742.)

Report of Committee on Communication presented at the annual convention of the A.I.E.E., at White Sulphur Springs last June.

As concerns radio telegraphy, mention is made of a new service between the Dutch East Indies and San Francisco and also from New York to Holland for handling through traffic from Java.

The work of decreasing the use of spark transmitters with their corresponding interferences has progressed to such an extent that over 150 American merchant ships are now equipped with valve transmitters.

The use of the radio direction finder for navigation is rapidly increasing and has passed the experimental stage. The Great Lakes are leading in this respect, due to the demonstration of the particular value of this apparatus in the difficult navigation problems inherent in the Great Lakes.

With regard to radio telephony, the two-way conversation tests between England and the United States are of course referred to, of which we have had full accounts.

The research of radio propagation is stated to have confirmed the existence of a positive ionisation gradient in the upper atmosphere, postulated independently by Kennelly in America and Heaviside in England. Short wave experiments show that the "skipped" distance, in general, increases with increase of transmission frequency and is greater at night-time than by day. These phenomena are explained by the waves received at a distance being deflected downwards by an upper ionised region of relatively low index of refraction and low attenuation.

The observed indications of rotation in the plane of polarisation and directional errors find a qualitative explanation when due account is taken of the fact that the earth's magnetic field, acting upon the free electrons, will change the velocity of the wave and produce rotation. This effect is especially marked in the vicinity of 214 metres, which corresponds to the resonant frequency of an electron in the earth's magnetic field.

Investigations of fading and signal distortion show that they are closely related to the high degree of frequency selectivity exhibited by the radio medium.

An observed variation of signal strength during magnetic storms is significant, the effect being a reduction of the normal signal strength by night and an increase above normal by day.

That increasing use is being made of the short wave range is evidenced by the continued increase in the number of short wave licences issued to commercial concerns. Experimental work indicates the possibility of twenty-four-hour telegraph service with short waves over distances of several thousands of miles. The transmission varies largely with the time of day, however, one frequency transmitting much better for one period of the day and another frequency for another period, so that the use of several wave frequencies appears to be required to give uniform operation.

Reports are also given on radio broadcasting and the electrical transmission of pictures.

R510.—Wireless at Sea.—J. Slee. (*Electrician*, 30th July, 1926, pp. 124 and 132.)

An account of recent development in apparatus employed on board merchant ships.

R514.—A Unicontrol High-Frequency Radio Direction Finder.—F. Dunmore. (*Bulletin No. 525, U.S. Bureau of Standards.*)

The development of such a direction-finder enabling a ship to readily locate another ship, is described, and its installation on a coastguard patrol boat. The direction-finder coil consists of four turns of ignition cable wound on a 20-in. frame. A tuning unit and coupling transformer have been designed so that the coil may be used on the ship's receiving set without changing its tuning adjustments, which are locked in the two 100kC position. The controls necessary when taking a bearing are reduced to one—that of rotating the direction-finder coil to obtain the minimum signal.

R514.—WIRELESS POSITION-FINDING ON SHIPS.—L. B. Turner. (*Electrician*, 30th July, 1926, pp. 127 and 128.)

A discussion of the results of recent investigation by the Radio Research Board.

R514.—MARINE DIRECTION-FINDING—L. Bainbridge-Bell. (*Electrician*, 30th July, 1926, pp. 125—126.)

Description of the latest development of the Radio Communication Company's apparatus, which works on the Robinson principle, and the methods of operation.

R540.—SHORT-WAVE RADIO IN THE ANTARCTIC.—L. Jenssen. (*Q.S.T.*, Vol. 10, August, 1926, pp. 12—14.)

It is related how, with comparatively low power on short waves, the Ross Sea Whaling Expedition was able to maintain nightly contact with the rest of the world, whereas before, when the longer waves had been relied on, the Expedition was cut off most of the time.

R545.—LA PRATIQUE ET L'EXPÉRIENCE DE L'EMISSION.—M. Sacazes. (*Radio Revue*, Vol. 5, August, 1926, pp. 128—134.)

A note on the author's work during the past three or four years on small power transmitters. Descriptions are given of the results obtained with several different circuits, the systems shown being a Mesny symmetrical circuit, a Colpitt's circuit, a master oscillator with power amplifier, etc. Remarks on adjustment and operation are given.

R582.—RADIO PICTURE TRANSMISSION.—F. Schröter. (*Electrical World*, 17th July, 1926, p. 129.)

Abstract of article in *Zeitschrift des Vereines Deutscher Ingenieure*, 70, 22, pp. 725—732.

A new process of transmitting line drawings or photographs over wires or by radio is described. Judging from the six samples reproduced, the process is much superior to that employed in America. The perfect results obtained are ascribed to a highly efficient photo-electric cell and a receiving apparatus free from inertia. The former is a potassium cell in a toroid-shaped glass bulb which reacts on reflected light instead of light passing through a transparency. The receiving element is a Kerr cell, based upon the hitherto not utilised physical fact that polarised light passing through nitro-benzol between electrically charged condenser electrodes suffers double refraction, the degree of which is influenced by the electric charge. The photo-electric cell responds to frequencies as high as 10^5 cycles, while the Kerr receiver does not lag appreciably for 10^8 cycles. It is therefore possible to transmit a picture 4 in. × 4 in. in size within 5 seconds. It is further possible to transmit a motion picture with 10 frames per second, which makes television readily possible.

R586.—TELEVISION AN ACCOMPLISHED FACT.—A. Dinsdale. (*Radio News*, September, 1926, pp. 206, 207, 280 and 282.)

Description of the apparatus invented by J. L. Baird.

R600.—STATIONS: DESIGN, OPERATION AND MANAGEMENT.

R624.—SERVICING OF BROADCAST RECEIVERS.—L. Manley and W. Garity. (*Proc. Inst. Radio Engineers*, Vol. 14, August, 1926, pp. 541—566.)

A paper attempting to group service problems under general classifications, prescribing methods of diagnosing them followed by a prescription for correcting them.

R616.5.—"KDKA."—D. Little and R. Davis. (*Proc. Inst. Radio Engineers*, 14, 4, August, 1926, pp. 479—506.)

Description of the latest equipment in use at this station, both for regular broadcasting and for short-wave international broadcasting and relay work. An account is also given of the short-wave transmitter employed for interworks telegraph service.

R622.—WAVELENGTH REORGANISATION. (*Electrical Review*, 13th August, 1926, p. 264.)

The Office International de Radiophonie, Geneva, announces that after 18 months' work, an agreement has been ratified concerning the repartition of wavelengths in Europe. The problem was to fit 200 stations (erected and projected) in a waveband wherein there would be only room for 99 if each station were given a different wavelength. It has been decided to employ 83 exclusive and 16 common waves. The former are divided among the different countries of Europe according to their requirements, Great Britain having 9, and the latter will be shared by 117 low power stations serving limited areas.

R800.—NON-RADIO SUBJECTS.

534.—METHODS OF HIGH QUALITY RECORDING AND REPRODUCING OF MUSIC AND SPEECH BASED ON TELEPHONE RESEARCH.—J. Maxfield and H. Harrison. (*Bell System Technical Journal*, v, 3, July, 1926, pp. 493—525.)

A detailed analysis of the general requirements of recording and reproducing sound without appreciable distortion. It is pointed out, at length, how many of the hitherto unsolved problems of sound recording and reproduction have been readily solved by the application of a detailed knowledge of telephone transmission theory.

534.—THE POWER OF FUNDAMENTAL SPEECH SOUNDS.—C. Sacia and C. Beck. (*Bell System Technical Journal*, July, 1926, pp. 393—403.)

A continuation of work on speech power by means of oscillographic studies of vowels, semivowels and consonants. A previous paper considered the characteristics of a few individual sounds from the power standpoint, but the principal emphasis was placed upon speech as a whole. In this later analysis, sounds are considered individually on the basis of instantaneous and mean power. A practical application of the results is suggested.

535.3.—DIE PHOTOZELLE NACH ZWORYKIN. (*Zeitschrift des Vereines Deutscher Ingenieure*, 70, 22, p. 732.)

Description of a new photo-cell, discovered by the Russian physicist Zworykin, which is a combination of a valve and a light cell, and can be employed to start machines, etc., since it controls relatively strong currents.

535.3.—THE ALKALI METAL PHOTO-ELECTRIC CELL. —H. Ives. (*Bell System Technical Journal*, v, 2, pp. 320—335.)

537.—THE COSMIC HARNESS OF MOVING ELECTRICITY.—M. Pupin. (*Journ. Amer. Inst. Elect. Engineers.* August, 1926, pp. 758—761.)

Presidential address delivered at the annual convention of the A.I.E.E., White Sulphur Springs, last June.

537.—CONTEMPORARY ADVANCES IN PHYSICS—XI. IONISATION.—K. Darrow. (*Bell System Technical Journal*, v. 5, July, 1926, pp. 463—492.)

621.355.01.—A NEW THEORY OF THE LEAD ACCUMULATOR ?—Prof. Howe. (*E.W. & W.E.*, August, 1926, pp. 466—468.)

621.353.—DRY CELLS FOR WIRELESS PURPOSES.—R. L. Smith-Rose. (*Wireless World*, 28th July, 1926, pp. 117—119.)

Length of life that may be expected from H.T. and L.T. batteries.

Esperanto Section.

Abstracts of the Technical Articles in our last Issue.

Esperanto - Sekcio.

Resumoj de la Teknikaj Artikoloj en nia lasta Numero.

R000.—RADIO ĜENERALE.

R050.—RESUMOJ KAJ ALUDOJ.

Kompilita de la *Radio Research Board* (Radio-Esplorada Komitato), kaj publikigita laŭ aranĝo kun la Brita Registara Fako de Scienca kaj Industria Esplorado.

R100.—ĜENERALAJ PRINCIPOJ KAJ TEORIO.

R127.2.—OFTAJ ERAROJ EN KONDENSATORAJ KALKULADOJ.—E. H. W. Banner.

Oni montras, ke la kutimaj esprimoj por la kalkulado de la kapacito de kondensatoro laŭ ĝiaj korpaj dimensioj ne kunkonsideras la modifiĝon kaŭze de la "randaj" efektoj. Ci tiuj estas nur nekonsiderindaj kiam la proporcio de la "plata surfaco" rilate al "distanco aparta" estas tre granda. Por la korekto, kiam ĉi tio ne estas, esprimoj estas donitaj, kiuj traktas pri kondensatoraj de rondaj kaj rektangulaj platoj. Oni ankaŭ rimarkigas pri la efikoj de la vera dikeco de dieleltriko kaj de variado je la valoro de dielektrika konstanto.

R161 & R162.—LA AMPLIFADO KAJ SELEKTIVECO DE NEŬTRALIGITA AGORDITA CIRKVITO ANODA.—D-ro. N. W. McLachlan.

Larĝa revuo de la neŭtraligita agordita cirkvito anoda laŭ la duala vidpunkto pri la faktoroj kiuj regas ŝtupan amplifadon kaj selektivecon respektive. Post enkonduka revuo pri la neŭtraliga principo, la aŭtoro pasas al amplifo de la kompleta ŝtupo. Ekvivalentaj cirkvitoj estas diskutitaj matematike kaj rezultoj montritaj por efektivaj valvaj amplifiĝoj dum kapacito trans fiksa bobeno estas altigita por plilongigi la ondolongon, kaj dum kapacito estas altigita kaj indukteco malgrandigita por teni la agordecon je konstanta ondolongo. La rezultoj de valva rezisteco p kaj volta faktoro m estas ankaŭ diskutitaj, kaj oni montras, ke amplifo malgrandiĝas ĉe pligrandiĝo de p, se m restas konstanta, kaj grandiĝas ĉe pligrandiĝo de m, se p restas konstanta. Koncerne selektivecon, oni montras rezonancajn kurvojn por ilustri la diversajn statojn diskutitajn. Laŭ nuna okazo, oni konkludas, ke la rezultoj de l'faktoroj cititaj estas ĝuste kontraŭaj de iliaj rezultoj je l'okazo de amplifado.

R200.—MEZUROJ KAJ NORMOJ.

R218—SENDADOJ DE SENFADENAJ ONDOJ DE NORMAJ FREKVENCOJ EL LA NACIA FIZIKA LABOREJO (Brita).

Komunikaĵo de la Brita Registara Fako de Scienca kaj Industria Esplorado.

Pro la rekomendo de la Radio-Esplorada Komitato de la Departemento, plioftaj sendadoj de ondoj de normaj frekvencoj estas farotak el de la Nacia Fizika Laborejo, Teddington, Anglujo (Voksignalo 5HW).

La sendadoj estas laŭjene :—

(A) Mallongonda programo dum la unua mardo en ĉiu monato, de 1,500 horo ĝis 1,600 horo, Tempo de Greenwich, la frekvencoj sendotaj estanta 260, 300, 360, 500, 580, 700, 840, kaj 960 kilociklој.

(B) Longonda programo dum la tria jaŭdo en ĉiu monato, la frekvencoj sendotaj estantaj 30, 40, 50, 66, 86, 115, 160 kaj 200, kC.

Oni faras rimarkigojn pri la ricevado de normaj ondoj kaj ilia utileco dum normigado.

R251.—KONTINUKURENTAJ INSTRUMENTOJ EN SENFADENAJ APARATOJ.—J. F. Herd.

La aŭtoro unue konsideras la bezonon por preciza scio pri kontinukurentaj valoroj kaj alĝustigoj ĉe senfadena ricevilo, speciale se kvanta laboro estas necesigita. Li tiam montras kiel, per aranĝo de ĵakoj (de la ordinara telefona modelo), unu K.K. instrumento, kiel ekzemple, taŭga miliampermetro, estas uzebla por apliko al diversaj cirkvitoj. La aranĝoj montritaj enhavas mezuron de anoda kurento, de filamenta aŭ potenciometra tensio, filamenta kurento, k.t.p. Oni ankaŭ aldonas ĝeneralajn rimarkigojn pri l'aranĝoj.

R.251.—AMPERMETRA PANELO. E. C. Atkinson.

La artikolo priskribas panelon por utiligi ampermetron por diversaj celoj. Pere de ŝtopiloj (laŭ modelo de Wheatstone'a Ponto), plenskalaj gradaroj de 3.0, 0.6, kaj 0.024 amperoj estas haveblaj, dum la instrumento estas ankaŭ utiligebla por legi 3 kaj 12 voltojn. La ŝarĝa kurento por akumulatoro estas ankaŭ montrebla sur unu skalo, kaj filamenta kurento sur alia, sen ŝanĝo de konektaĵoj.

R300.—APARATO KAJ EKIPAĴO.

R384.—APARATO POR KONTINUKURENTA PROVADO. —T. S. Skeet.

La artikolo pritraktas la utiligon de movbobena instrumento (Weston'a Modelo 301, plena skalo montranta ĝis 5 m.a.) kiel voltmetron montrantan 1000 v., 100 v., 10 v., 5 v., 0.5 v., kaj 0.1 v., kaj kiel ampermetron montrantan 10A., 5A, 2.5A, 500mA, kaj 50mA. La instrumento estas muntita en skatolo kun bornoj kaj komutatoroj por la reguligo de la bezonitaj seriaj kaj ŝuntaj rezistancoj, kaj la kompleta instrumento estas ilustrita kaj priskribita.

R.385.—LA KLAVARANĜOJ DE VALVAJ SENDILOJ. —W. T. Ditcham.

Bonega priskribo estas donita pri moderna praktiko rilate al la enkonduko de klavaj interuptoroj en valvaj sendiloj. Tiaj sendiloj estas dividitaj en du klasojn, (A) Memekscitaj oscilatoroj, (B) Amplifikatoroj ekscititaj de mastra oscilatoro, kaj oni donas ilustraĵojn de diversaj klavaj motodoj por ĉiu. En la unua klaso, la metodoj montritaj enhavas aranĝojn por utiligo ĉe aparatoj ĝis 5 K.V., kaj por potencoj ĝis 20 K.V., je rapideco de 60 vortoj ĉiuminute, kaj de 100 v.ĉ.m. En la klaso de mastra oscilatoro, oni montras metodojn por klavi longtrafajn rapidegajn komercajn staciojn uzantajn rektifitan Alternkurenton por potencoprovizo, ekzemple, la Marconi'aj stacioj ĉe Ongar, Essex, Anglujo. Fine, oni diskutas klavajn metodojn por altpotencaj·stacioj provizitaj per Kontinukurenta Alta Tensio. Klaraj ilustraĵoj pri la diversaj metodoj estas presitaj tra l'artikolo.

R500.—APLIKOJ KAJ UZOJ.

R545.009.2.—AMATORA LONGDISTANCA FUNKCIADO. —H. N. Ryan. Perioda kontribuaĵo pri la temo de longdistanca funkciado.

R600.—STACIOJ : DESIGNA, FUNKCIADO, KAJ ADMINISTRADO.

R616.5.—RADIO-VIENO.—Prof. G. W. O. Howe.

Tre kompleta priskribo pri la nova altpotenca Brodkasta Stacio ĉe Vieno. Oni donas planojn de la antena kaj kontraŭpeza aranĝoj, dum diagramoj montras la konektaĵojn de la sendilo, amplifikatoroj, modulaj metroj, k.t.p. Fotografaj ilustraĵoj montras la staciajn konstruaĵohn, la sendilon, valvojn de la diversaj tipoj uzataj, reguligan panelon, amplifikatorojn, modulajn metrojn, k.t.p.

La stacio uzas la mastro-oscilatoran funkcimetodon, kun potenca amplifado per akve malvarmigitaj valvoj. Rektifita Alternkurento provizas la altan tension. La senilo estas ses mejloj malproksime de la mikrofonejo en Vieno, al kiu ĝi estas ligita per speciala kablo. La aparato ĉe la mikrofoneja konstruaĵo konsistas el, krom la meikrofono, triŝtupa amplifikatoro, plua unuŝtupa amplifikatoro, amplifikatora modula metro kontrolanta la parolan kurenton senditan tra la kablo. Estas ankaŭ sendila modula metro funkciigita de kurentoj senditaj tra la kablo el de la senda stacio, tiel ke la antena modulado estas observebla ĉe la mikrofonejo.

R800.—NE-RADIAJ TEMOJ.

510.—MATEMATIKO POR SENFADENAJ AMATOROJ. —F. M. Colebrook.

Daŭrigo de la serio el antaŭaj numeroj. La nuna numero traktas pri Indicoj, kun la Difino de Indico, Indica Leĝo, Negativaj Indicoj, Ripetitaj Produtoj de Potencoj, Produtoj de Potencoj kaj Kvocientoj, Radikoj, Produto de Radikoj, la Plena Ĝeneralizo de Indica Formularo, k.t.p.

Correspondence.

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.

Plate-Current, Plate-voltage Characteristics.

To the Editor, E.W.& W.E.

SIR,—Your contributor Mr. E. Green makes an error on pp. 370, 471 of the August issue of *E.W.& W.E.*, which is a very common one. The valve is a voltage operated device, and we spend our existence trying to get the biggest *voltage* amplication from valve to valve.

No power is present in the secondary of a transformer or tuned coupling unless there is grid current or charging current and in either of these cases the grid filament voltage is cut down by the IR voltage drop.

No power is taken from the primary and so the transformation is a pure voltage transformation and the greater the voltage across the primary the greater the overall amplification. The greater the primary impedance the greater the fraction of μ that is utilised.

Theoretically then, infinite impedance and an infinite step up would be ideal. In practice one is limited by intercapacities and space considerations, but still the main law holds good that the transformer should be of the utmost possible impedance and not of equal impedance with the valve as it would have to be for maximum power amplification.

The matter is totally different when the last valve driving the loud-speaker is under consideration. Here power is required to move the air and the best power output is obtained when the load impedance equals that of the valve.

Here again, practical details upset any attempt at maximum efficiency. The matching of impedances only holds good at one frequency, the impedance is changed at every alteration of the air-gap in the loud speaker, and the makers give us only the D.C. resistance in ohms!

In support of my views of the above, I would refer you to articles which have appeared in the *Wireless World*, "The Resistance-Coupled Amplifier," by Dr. H. Kröncke, 23rd September, 1925. "Everyman's four-valve," by W. James, 28th July and 4th August, 1926. They are using resistance amplification with a resistance of 1 megohm, grid-leak of 5 megohms, coupling condenser of .0003μF, and a plate current of *a few microamps*. They are in fact employing the principles of pure voltage amplification.

I do not know who started the error originally, but it is certainly time it was laid to rest..

I. A. J. DUFF, B.A., A.M.Inst.C.E.

To the Editor, E.W.& W.E.

SIR.—With reference to the remarks of your correspondent, Mr. I. A. J. Duff, we are both agreed that the valve is a voltage operated device, and the biggest voltage amplification from valve to valve is what is normally aimed at. I note that the two articles he mentions as supporting his views on tuned circuit and transformer amplifiers, both deal with resistance amplification.

In the case of a tuned circuit amplifier, as shown in my figure 6 (*b*) (*c*) and (*d*), used for amplification at one definite frequency, the power output of the valve is used to maintain the oscillating current in the tuned circuit, and obviously maximum power output will give the maximum voltage across the condenser.

The case of the transformer amplifier, as Mr. Duff says, is not so simple, and the theory I gave was reproduced from memory from an article by Mr. Catterson Smith published in the *Radio Review* of July, 1920. I find on referring to the article that he did not consider the case where grid current was eliminated.

The simple theory that the transformer load is made equal to the anode A.C. resistance of the valve must be abandoned, nevertheless Mr. Duff's statements require some correction. If they were true we could fix on a standard transformer which would be best for all types of valve. In fact, however, the step-up ratio of the modern type of transformer is arranged so that the transformer load has a definite ratio to the anode A.C. resistance of the valve in use. In proof of this I would refer Mr. Duff to an abstract of a paper by Mr. P. W. Willans, on "Low Frequency Intervalve Transformers," published in *E.W.& W.E.* for July, 1926. The transformers described were made with a fixed secondary winding, and as regards the primary winding, I quote the following from page 437—"Four different ratios were specified, *i.e.*, 2.7 : 1 for a 40,000 ohm valve, 4 : 1 for a 16,000—18,000 ohm valve, 6 : 1 for a 7,000 ohm valve, and 8 : 1 for a 4,000 or 5,000 ohm valve."

The remarks on the valve driving the loud-speaker do not call for any comment.

E. GREEN.

Valve Nomenclature.

To the Editor, E.W. & W.E.

SIR,—With reference to your paragraph on "Valve Nomenclature" (differential resistance) in your Editorial of the current issue, I suppose it is too late, now, to raise objections to the term "Anode A.C. resistance." But it appears to me that, though this term is better than "impedance," it is still misleading, and ambiguous.

If we consider the case (which frequently occurs) of a valve with anode differential resistance R_a, having an inductance L in its anode circuit—the static differential resistance of the whole circuit will $=R_a$, but the dynamic dif. res. will $=R_a+\omega L$.

The expressions "dynamic" and "static differential resistance" seem to me to be reasonable; but if we substitute "A.C. resistance" for "differential resistance," we have "static A.C. resistance," which is a contradiction in terms.

This objection seems to me to be real and not merely superficial. The quantity "differential resistance" is not dependent on A.C.

If "differential resistance" is too long or obscure, would not "slope resistance" be better than A.C. resistance?

Surrey. R. St. Q. Leng.

[Our correspondent is incorrect in assuming that the whole circuit would have a "dynamic differential resistance" of $R_a + \omega L$. This is the impedance of the circuit at the frequency $\omega/2\pi$; there is no such thing as a dynamic differential resistance, it is essenially static, being determined from the slope of the static characteristic curve. It is for this reason that we think that either "differential resistance" or "slope resistance" preferable to the adopted term "A.C. resistance." If a valve had any property resembling skin effect, the A.C. resistance would not be exactly the same thing as the differential resistance, but so far as we know the two things are identical.

It is not too late, however, to raise objections to the contents of the Glossary of Terms used in Electrical Engineering, recently issued by the British Engineering Standards Association. This first edition is regarded as tentative and we ourselves have already objected to many of the terms and definitions.—G. W. O. H.]

Power Losses in Insulating Materials.

To the Editor, E.W. & W.E.

Sir,—In the Editorial in the current number of the *E.W. & W.E.*, there is a reference to a paper of mine entitled "Parasitic Losses in Inductance Coils at Radio Frequencies." You mention the paper of Mr. E. T. Hoch on the subject.

I would like to draw your attention to the sequel of my paper, which appeared in the following number of *E.W. & W.E.* (June, 1925) in which I specially mentioned Mr. E. T. Hoch's paper (page 543) and I quoted the first part of the paragraph that was quoted in your Editorial.

I remember being astonished at the time that so obvious a criterion of the suitability of dielectrics as the product of power factor and dielectric constant was not more generally used and I consider that it would be advantageous if this should become standard practice.

Raymond M. Wilmotte.

London, S.W.10.

A New Theory of the Lead Accumulator.

To the Editor, E.W. & W.E.

Sir,—In your issue of August, on page 468, Dr. Howe describes a "cell which cannot sulphate," which seems likely to be useful for H.T. supply. This appears to be another case of lost knowledge rediscovered, for I remember seeing many years ago an antique "Rochefort" station at Newhaven, Sussex—with a spark like a brick in a bucket and a log. dec. like X's—where they had a battery not unlike that described.

The plates were in the form of saucers and were about a yard across, and were stacked up one inside another, slightly separated by porcelain pieces, with the under side of one in a pool of acid held by the next lower one. This battery was not of negligible capacity, however, as it was used to run a motor alternator.

It appears that the arrangement—which was, I think, of French origin—would fulfil the requirements of M. Féry's new theory as regards freedom from sulphation.

It would be perfectly easy to substitute acid soaked kieselguhr for the earlier free acid since this silicious skeletony stuff has long been used as an absorbent for sulphuric acid, nitro-glycerine and other tasty fluids.

I have much pleasure in sending this recollection for publication in the hope that the Patents Office will give a suitable reception to the inevitable millionaire corporation when it arrives from the land of "bounce" to conduct a 100 per cent. campaign against the pockets of our wireless enthusiasts.

Ashford, Kent. Wm. A. Richardson.

Fading and Mountains.

To the Editor, E.W. & W.E.

Sir,—I would like to explain to Mr. Maddison that I introduced the subject of D.C. conductivity because it is a property of real importance when considering a reflecting medium. Moreover it can be and has been measured. For this reason my argument was hardly "futile."

I am sorry to say this manner of so lightly dismissing others' statements pervades Mr. Maddison's subsequent remarks. He makes, in the most casual way, the following exceptionable statements:—

> "The only limiting factor of this rise in pressure is the rate at which the charge will leak——" (The factors limiting the extent of coalescence limit the potential rise.) "The air around the cloud will be very highly ionised——" (Why?) "The extent of this ionisation can rise far higher than in the Heaviside layer for this reason." (What reason? Not the following sentence, which is incorrect). "——the Heaviside layer is *only* ionised by electronic bombardment from the sun." (*Only*, indeed!).

One may be excused for hazarding the opinion that unsupported statements like these are responsible for Mr. Maddison's "first and foremost difficulty."

Nevertheless, I still agree with Mr. Maddison that cloud may have some effect which should be investigated. His implied conception of a cloud as (may we say) a multitude of minute condensers is new. We must ask the mathematicians.

A. Woodmansey.

Harrogate.

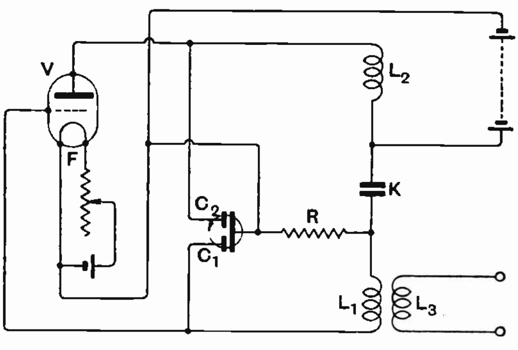
Some Recent Patents. [R008

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

A SHORT-WAVE OSCILLATOR.

(*Convention date* (*U.S.A.*), 17*th February*, 1925. *No.* 247,942).

C. F. Burgess Laboratories and W. H. Hoffman describe in the above British Patent the construction of a rather interesting short-wave oscillator, in which the grid and anode circuits are connected in bridge formation. The invention is of even more interest as it states that very high frequency oscillations, corresponding to a wavelength of a few metres, can be generated with a valve of the normal type, the inter-electrode capacity not being of any great importance. The accompanying illustration shows the general arrangement of the circuit, and it will be seen that there are two similar oscillatory circuits L_1 C_1 and L_2 C_2. The two capacities C_1 and C_2 may be variable condensers mounted on a common shaft so arranged that rotation of the shaft gives substantially equal variation of the capacity of the two condensers. The circuit L_1 C_1 is included in the grid-filament circuit of the valve *V*, and the circuit L_2 C_2 is included in the anode circuit of the valve *V*. The stopping condenser *K* of about 0.003μF is employed to isolate the positive potential of the high tension battery, which is connected between the filament *F* and one end of the coil L_2. A resistance *R*, having a value of about 5,000 ohms, is connected between the mid-point of the condensers C_1 and C_2, and one end of the coil L_1 and the far side of the stopping condenser. Thus it will be seen that the resistance *R*

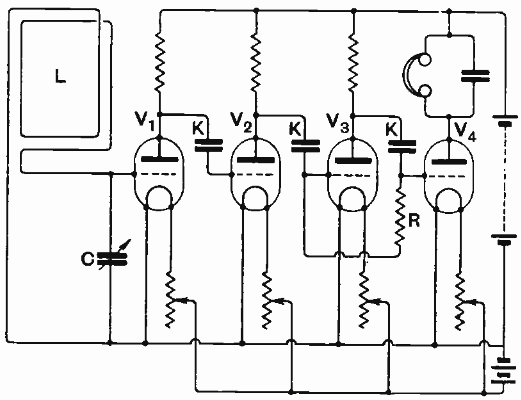


is connected across points of substantially equal potential. The patent specification is fairly detailed, and gives considerable information regarding the arrangement of the circuit and the values of the components. For example, it is stated that the inductances L_1 and L_2 may consist of half a turn of No. 10 S.W.G. copper wire, the radius of the turn being about two inches. An inductance L_3 is shown coupled to the inductance L_1, this inductance L_3 being used to transfer the output of the generator to an aerial or other load circuit.

A LOW-CURRENT RESISTANCE AMPLIFIER.

(*Application dates, 7th April, 9th July, 13th July, and 5th November*, 1925. *No.* 256,299.)

Several resistance amplifiers have recently been devised in which the anode circuits contain resistances of the order of 5 megohms, and the above British Patent, which is the subject of four provisional patent specifications, and is granted to A. H. Midgeley, discloses the arrangement of an amplifier which is the result of experimental work on the lines of the provisional specifications.

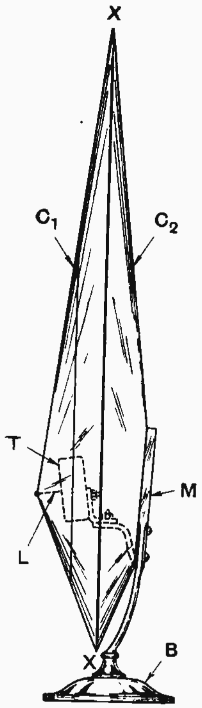


While the invention can be carried out by the use of ordinary valves, it is preferred to use a valve in which the anode is about 3/16 inch long, and 1/4 inch in diameter, the valve being provided with a cathode designed to take a current of half an ampere at 0.8 of a volt. The accompanying illustration shows one form of circuit, in which the input circuit of the first special valve contains an inductance *L* in the form of a frame tuned by a variable condenser *C*. The first three valves, V_1, V_2 and V_3 are of the special type referred to, and contain anode resistance *R* of the order of 5 megohms. The anodes are coupled to the succeeding grids by means of coupling condenser *K*, no grid-leaks being employed. In operation the filament emission is reduced to a point such that saturation occurs at zero grid volts. The potential of the high tension battery may be of the order of 50 volts. The last valve, V_4, which operates the telephones or loud-speaker, is of the ordinary type, and is provided with a grid-leak *R*, which is connected to the grid of the preceding valve. The specification states the manner in which the amplifier may function. It is believed that the first three valves all act as detector amplifiers. It is further suggested that there is a high-frequency component throughout the amplifier which has a ripple upon it of progressively diminishing amplitude in each stage, while there is also a low frequency component which increases correspondingly in amplitude. The specification is extremely lengthy and detailed, and gives considerable practical information and suggested methods of working.

AN ELLIPTICAL DIAPHRAGM LOUD-SPEAKER.

(*Convention date* (*U.S.A.*), *30th July*, 1924. *No.* 237,878.)

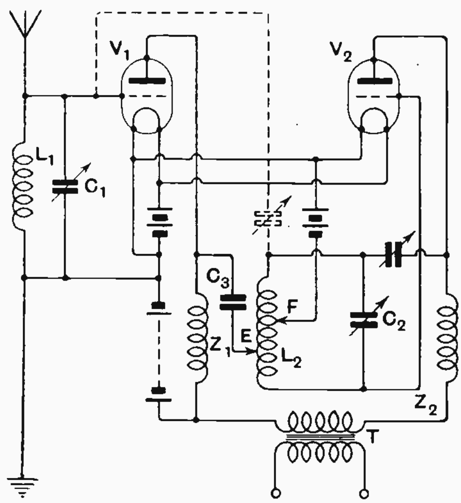
The Western Electric Company Limited and C. E. Lane describe in the above British Patent a rather interesting type of cone diaphragm loud-speaker. Readers are, no doubt, familiar with the patent specification of the Western Electric Company's "Kone" loud-speaker, which consists essentially of two cones joined at their bases, one cone being truncated and fixed to a support, a telephone driving mechanism being located within two cones and driving the apex of the cone by means of a link, a substantially free edge being obtained. It has been found that with a symmetrical arrangement of this description, although responding very uniformly to both the upper and lower frequencies of the musical band, a certain amount of resonance is apt to be set up unless the symmetrical diaphragm is of very considerable area. This difficulty is overcome by the use of a diaphragm of elliptical formation. Thus the general arrangement should be clear by reference to the accompanying illustration. Here two cones C_1 and C_2 are joined at X, X, the cones being of elliptical formation. The cone C_2 is truncated, and is fixed to a supporting member M provided with a base B. The telephone driving mechanism T, such as the well-known balanced armature, drives the apex of the cone C_1 by means of a link L. It is claimed that by an arrangement of this description any resonance effects due to symmetrical vibration are overcome, and thus a more linear characteristic and substantially undistorted reproduction can be obtained.



A RADIO-FREQUENCY AMPLIFIER.

(*Convention date* (*Belgium*), *18th October*, 1924. *No.* 241,530.)

A rather interesting form of two-valve receiver which should be of interest to experimenters is described in the above British Patent, which has been granted to J. Abelé and J. H. Berens. The accompanying illustration should make the invention clear. The first valve V_1 acts as a radio-frequency amplifier, and has connected between the grid and filament a tuned circuit L_1 C_1. The second valve V_2 is used as a rectifier and regenerative amplifier. The anode circuits of the two valves contain respectively radio-frequency chokes Z_1 and Z_2. Incoming potentials applied between the grid and filament of the first valve cause amplified potential to be produced across the impedance Z_1, from which they are transferred by a condenser C_3. Another tuned circuit L_2 C_2 is provided, and is arranged so as to act as an auto transformer, the far side of the condenser C_3 being connected to a point E, while the filament is connected to a point F, one end of the tuned circuit L_2 C_2 being connected directly to the grid of the valve V_2, and the other end taken through a variable condenser C_2 to the top of the choke Z_2. The amplified potentials occurring across Z_1 are then transferred to the primary of the auto-coupled transformer, these potentials being detected, and regeneratively amplified by the valve V_2. It will be noticed that the contact point F of the filament is variable,

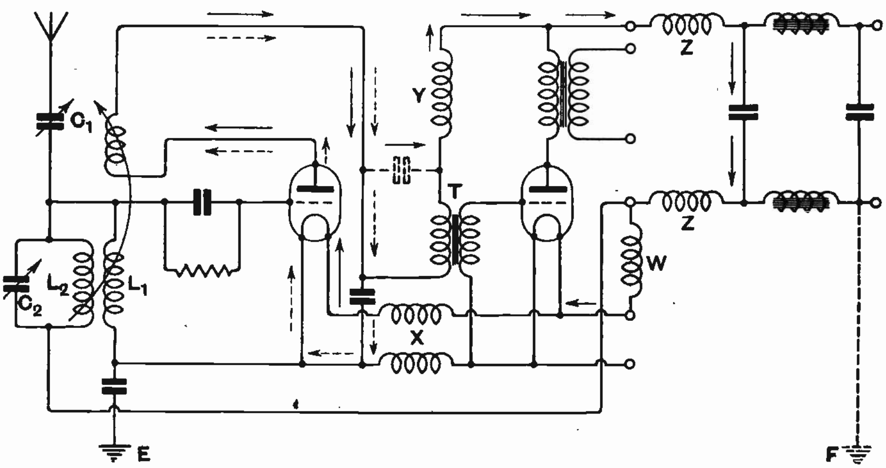


and may constitute a slider working over the inductance L_2. Reaction or self oscillation can be controlled by the reaction condenser and the position of the filament slider F. The specification states that the circuit possesses many advantages, and the degree of reaction is not varied by altering the position of the two tuning condensers. The rectified currents are transferred by means of a low frequency transformer T included in the anode circuit of the second valve.

MULTIPLE EARTH CONNECTIONS.

(*Application date*, *4th May*, 1925. *No.* 256,317.)

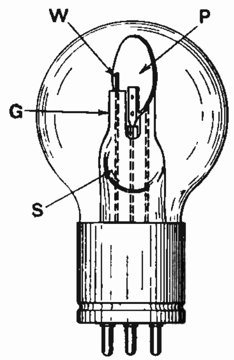
It is well known that the use of a multi-earth connection to a radio-frequency receiving system will bring about considerable loss of efficiency unless the earth system is balanced. (It is usually preferred to employ one earth connection.) When a broadcast receiver derives its anode current from electric light supply mains trouble of this nature may arise due to the fact that one side of the mains may be earthed. The above British Patent, granted to Fullers United Electric Works Limited and A. P. Welch, overcomes this difficulty by the introduction of radio-frequency chokes, which tend to keep any radio-frequency currents from the earth connection of the supply mains. The accompanying diagram illustrates a circuit in which a number of radio-frequency chokes are inserted in various parts of the circuit. An ordinary two-valve receiver is shown provided with an aerial circuit consisting of a variable condenser C_1, an inductance L_1 and a normal earth connection at E through a stopping condenser, the earth on the mains supply being shown at F. Two radio-frequency chokes Z, Z are shown in the main high-tension leads. Owing to appreciable self capacity across the primary of the first inter-valve transformer T, or the existence of a by-pass condenser across it another choke is shown inserted at Y. Chokes are again shown inserted at X between the filament leads to the two valves. Again another choke is shown at W, and is used in conjunction with a parallel wave-trap circuit L_2 C_2.



A GAS DISCHARGE RECTIFIER.

(*Convention date* (*U.S.A.*), *17th July*, 1924. *No.* 237,236.)

An exceedingly interesting form of full-wave gas discharge rectifier is described in the above British Patent by the British Thomson-Houston Company Limited and E. E. Charlton. The novelty of the invention lies partly in the shape and arrangement of the electrodes, and partly in the filling of the tube. The accompanying illustration shows a very simple form of the rectifying tube, in which the cathode consists of a plate P of nickel, molybdenum, or tantalum. The anodes consist of two wires W, only one of which is visible, of tungsten or nickel, tungsten being preferable owing to its suitability for sealing into the glass foot. The cathode P and the anodes W are mounted on a glass stem or foot S, and a glass tube G surrounds the lower portion of the anode wire so as to prevent any discharge taking place between the bottom of the anode wire and the edge of the plate. The leads from the two anodes and the cathode are brought out to fins on the base of the tube in the usual manner. The tube is filled with a gas which, at the operating temperature of the device, has a density sufficiently high to produce the necessary conductivity by ionisation. In one embodiment of the invention a mixture of helium and neon is employed, but it is stated that helium alone gives better results. The best pressure of the gas depends upon the geometrical features of the device and the voltage at which it is desired to work. It is stated that from 5 to



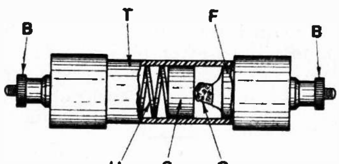
80 mms. of mercury are pressures which are found to be suitable, but helium alone at a pressure of 19 mms. appears to be preferable. The specification states that it is advisable to place in the tube a material which has chemical reaction towards gaseous impurities. Metallic magnesium and calcium are mentioned as being suitable. It is stated that the voltage drop is lowered by about 20 per cent. by observing this precaution, and it

may be lowered still further by admitting an alkaline metal such as caesium or rubidium before the magnesium getter is vapourised. The alkaline metal just mentioned is oxidised by admitting oxygen and warming the tube. The oxide then appears to combine with any hydrogen which may be liberated during operation of that tube. The specification, which is very extensive, gives details for the construction of high power tubes in which the cathode is made in the form of two cylinders mounted side by side enclosing the two anodes.

AN INTERESTING CRYSTAL PATENT.

(*Application date, 26th March*, 1925. *No.* 251,078.)

A rather interesting modification of the carborundum crystal detector associated with a valve receiver is described in the above British Patent by the Carborundum Company. If a crystal detector is used for a powerful valve amplifier it frequently happens that the magnitude of the potentials is such that the detector is not capable of rectifying them properly. It has been found, however, that by suitable treatment of the crystal it can be made to rectify efficiently voltages of an appreciable magnitude. A piece of carborundum or silicon carbide is freed on its surface from any impurities, and one end is coated or sprayed in some known manner with a fine metallic layer of copper or silver, the layer being further built up and soldered into some convenient holder.

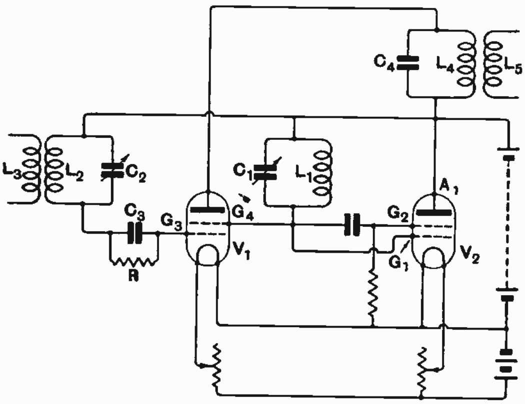


The rectifying end of the crystal is then used in conjunction with a steel plate with which it is held in contact by considerable pressure. A suitable arrangement of the detector is shown in the accompanying illustration, in which it will be seen that the carborundum *C* is attached as mentioned to a block of metal or solder *F*, while the other end of the crystal is in contact with a steel plate *S*, controlled by a helical spring *H*, the whole being contained within a tube *T* provided with terminals *B*.

A FOUR-ELECTRODE VALVE SUPERSONIC CIRCUIT.

(*Application date, 5th March*, 1925. *No.* 252,789.)

A rather interesting arrangement of two four-electrode valves as a frequency changer is described by H. Andrews and the Dubilier Condenser Company, Limited, in the above British Patent. The invention should be quite clear by reference to the accompanying illustration. The second valve V_2 is arranged as a generator of continuous oscillations to provide the local source and an inductance L_1 and capacity C_1 tuned to the desired local frequency



are connected between the anode A_1 and the inner grid G_1. The oscillations thus produced are transferred to the outer grid G_4 of the first valve V_1. The incoming oscillations are introduced to the inner grid circuit of the valve V_1 by means of the tuned circuit L_3 L_2 C_2, a grid condenser and leak C_3 R being used for rectification purposes. The oscillations introduced to the first valve from the second modulate the anode current of the first valve, this anode current further being varied by the applied grid potentials from the circuit L_2 C_2. Thus a beat frequency is obtained in the anode circuit of the first valve, potentials at the beat frequency being produced across the tuned circuit L_4C_4, from which they are passed on to an intermediate amplifier at L_5. The specification also described a somewhat similar arrangement in which only one valve is utilised, one grid being used for the generation of oscillations, and other for dealing with the input voltages.

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