

THE  
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No. 7

Editor :

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**CONTENTS**

- Double-grid Valves . . . . . THE EDITOR
- On a Kink in the Characteristic of a Soft Three-electrode Valve  
B. HODGSON, O.B.E., M.Sc., Ph.D., and L. S. PALMER, M.Sc.
- A New Dutch Marine Type Receiver
- Current Suppression by means of Parallel Resonance  
H. G. CORDES
- German Developments in C.W. Stations
- A Peculiar Electrostatic Phenomenon
- Long Distance Wireless Transmission
- Notes : Personal, Commercial, New Wireless Services, etc.
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Editor: Prof. G. W. O. HOWE, D.Sc., M.I.E.E.    Asst. Editor: PHILIP R. COURSEY, B.Sc., A.M.I.E.E.

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## Contents

	PAGE
DOUBLE-GRID VALVES. By THE EDITOR . . . . .	337
ON A KINK IN THE CHARACTERISTIC OF A SOFT THREE-ELECTRODE VALVE. By B. HODGSON, O.B.E., M.Sc., Ph.D., and L. S. PALMER, M.Sc. . . . .	340
A NEW DUTCH MARINE TYPE RECEIVER . . . . .	354
CURRENT SUPPRESSION BY MEANS OF PARALLEL RESONANCE. By H. G. CORDES . . . . .	353
GERMAN DEVELOPMENTS IN C.W. STATIONS . . . . .	370
A PECULIAR ELECTROSTATIC PHENOMENON . . . . .	373
LONG DISTANCE WIRELESS TRANSMISSION . . . . .	373
NOTES :—	
Personal . . . . .	373
Commercial . . . . .	374
New Wireless Services . . . . .	375
REVIEW OF RADIO LITERATURE :—	
Abstracts of Articles and Patents . . . . .	377
Book Review :	
“The Thermionic Vacuum Tube and its Applications.” By H. J. van der Bijl . . . . .	391
Books Received . . . . .	392
CORRESPONDENCE :—	
Mica Condensers for Radio Work . . . . .	392
A. C. Bartlett on “Triode Characteristics with High Grid Potential” . . . . .	392

# THE RADIO REVIEW

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150 . . . . .	1	9	0	2	6	6	3	3	3	4	0	9	4	12	3	5	7	3	1	3	6
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250 . . . . .	1	12	3	2	12	0	3	10	0	4	9	9	5	2	0	5	18	3	1	9	0

# THE RADIO REVIEW

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JULY, 1921

NO. 7

## Double-grid Valves.

By THE EDITOR

In an ordinary three-electrode valve with a single grid the plate current depends on both the plate voltage  $V_p$  and the grid voltage  $V_g$ . This relationship can be expressed by the equation

$$I_p = f(V_g + DV_p) = f\left(V_g + \frac{V_p}{\mu}\right)$$

in which the current is expressed as a function of an effective control voltage made up of the grid voltage and a fraction  $D = \frac{1}{\mu}$  of the plate voltage.

German writers usually employ the fraction  $D$  to express the relative importance of a given change of voltage on the grid and plate respectively; in this country and in the United States the whole number  $\mu = \frac{1}{D}$  is more often

used and is known as the amplification factor or voltage ratio. In either form it is a measure of the extent to which the grid screens the filament from the action of the plate or anode. This is clearly expressed in the German "Durchgriff," the through-grid or extent to which the anode voltage penetrates the openings in the grid and acts on the electrons emitted from the filament. A valve is thus said to have a "Durchgriff" of 5 per cent. or an amplification factor of 20. If the grid has large openings  $D$  will be large and  $\mu$  small; if the openings in the grid are small, it will more effectively screen the filament from the action of the plate voltage,  $D$  will be small and  $\mu$  large.

If the plate current be kept constant by decreasing  $V_p$  as  $V_g$  is increased,  $\mu$  is equal to the ratio  $-\frac{\partial V_p}{\partial V_g}$ . If  $V_g$  be kept constant a change of plate

voltage  $\partial V_p$  produces a change of plate current  $\partial I_p$  and the ratio  $R_i = \frac{\partial V_p}{\partial I_p}$

is called the internal resistance of the valve to an oscillatory current in the plate circuit. The slope  $S$  of the ordinary characteristic curve of the valve

is equal to the ratio  $\frac{\partial I_p}{\partial V_g}$ ,  $V_p$  being kept constant. These three charac-

cc

teristic constants of the valve are connected by the relation

$$\mu = S \cdot R_i.$$

If the valve be used as an amplifier with a non-inductive load of resistance  $R$  in the plate circuit, an increase in the plate current of  $\partial I_p$  will cause a drop of plate voltage equal to  $\partial I_p \cdot R$ , which is equivalent to a drop  $\mu$  times as small in the grid voltage. Hence the effective increase of grid voltage which must have caused the plate current to increase is less than the actual increase of grid voltage by this amount and  $\partial I_p$  is not equal to  $S \cdot \partial V_g$  but

$$\begin{aligned} \partial I_p &= S \left( \partial V_g - \frac{R}{\mu} \cdot \partial I_p \right) = \frac{\mu}{R_i} \partial V_g - \frac{R}{R_i} \partial I_p \\ &= \frac{\mu \cdot \partial V_g}{R_i + R} \end{aligned}$$

If an alternating voltage with an effective value of  $v_g$  be applied to the grid, the effective value of the alternating current produced in the plate circuit is given by the equation \*

$$i_p = \frac{\mu v_g}{R_i + R}$$

The power supplied to the load is  $i_p^2 R$  which reaches its maximum value when  $R = R_i$ , and is then

$$\begin{aligned} P_{\max.} &= \frac{\mu^2 v_g^2}{4R_i^2} \cdot R_i = \frac{\mu^2}{4R_i} \cdot v_g^2 \\ \frac{4P_{\max.}}{v_g^2} &= \frac{\mu^2}{R_i} = S^2 R_i = S\mu. \end{aligned}$$

This ratio of four times the maximum power output to the square of the input voltage has been taken by Barkhausen as a measure of the goodness of the tube; it might be called its figure of merit as an amplifier. Unfortunately it is not a mere numeral but has the dimensions of a conductivity; it differs therefore from an efficiency ratio in that it depends on the units adopted, but one cannot speak of the efficiency of an apparatus which gives a power output for zero power input, and there can be no input if the grid current is zero. The valve does not draw its supply of power from the grid but from the anode battery.

The figure of merit is proportional to the product of the steepness of the characteristic and the amplification factor. The former can be increased to some extent by decreasing the distance between the grid and filament, but a limit is soon reached in this direction; the amplification factor can be increased by making the openings in the grid very small. A high value of  $\mu$ , however, gives a high internal resistance and therefore, to obtain the maximum output, a high load resistance; moreover, a close grid and a negative grid potential (to prevent grid current) necessitate a high plate voltage to bring the working point into the middle of the straight part of the characteristic. The high resistance and high plate voltage are disadvantageous from a practical point of view.

\* The calculation of the amplification from the characteristics of the valve was described by Latour in his French Patent application of April 15th, 1916 (No. 512295).

With the object of obtaining a large amplification factor without the disadvantage of a high voltage plate battery, valves with two grids were introduced (Fig. 1). If the voltage on the grid nearer the filament be called  $V_{g1}$  and that on the other  $V_{g2}$ , then

$$I_p = f[V_{g1} + D_1(V_{g2} + D_2V_p)] = f[V_{g1} + D_1V_{g2} + D_1D_2V_p]$$

or 
$$I_p = f\left[V_{g1} + \frac{1}{\mu_1}V_{g2} + \frac{1}{\mu_1\mu_2}V_p\right].$$

So far as the filament and first grid are concerned the second grid and anode may be assumed to have an effective voltage  $V_{g2} + D_2V_p = V_{g2} + \frac{V_p}{\mu_2}$ .

This replaces the anode voltage of the ordinary valve. The filament, the first grid and this effective second grid may then be treated as an ordinary valve with an amplification factor  $\mu_1$ , giving an effective voltage of

$$V_{g1} + D_1(V_{g2} + D_2V_p) \text{ or } V_{g1} + \frac{V_{g2}}{\mu_1} + \frac{V_p}{\mu_1\mu_2}.$$

The first grid  $G_1$  is very open, the second  $G_2$  very fine. The large openings in  $G_1$  allow the anode voltage to be small; the small openings in  $G_2$  cause a high amplification factor, which is now equal to the product  $\mu_1\mu_2$ . The second grid being very positive and of fine mesh takes an appreciable current which is thus lost to the anode circuit.

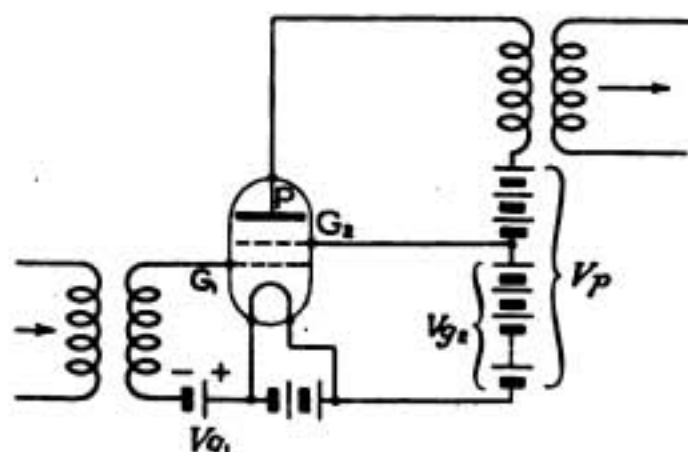


FIG. 1.

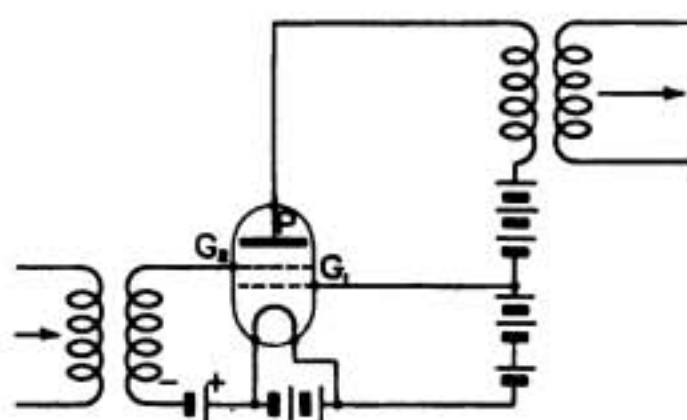


FIG. 2.

This must be minimised by making the anode sufficiently positive with respect to the grid. In an example given by Barkhausen  $\mu_1$  is  $3\frac{1}{2}$ , requiring a voltage  $V_{g2}$  of about 20 to bring the working point on the steep part of the characteristic for  $V_{g1} = -1$  volt.  $\mu_2$  can then be made about 30 and the anode voltage  $V_p$  about 30, that is 10 volts higher than  $V_{g2}$ . The resultant amplification ratio is then  $30 \times 3\frac{1}{2} = 100$ . To obtain this with a single-grid tube would require an anode voltage of about 600.

Fig. 2 shows another method of using valves with two grids. The slightly negative input circuit is here connected to the second grid, whilst the first grid is connected to the anode battery and thus raised to a potential equal to or nearly as high as that of the plate itself, which, however, is only about 10 volts. The emission current reaches nearly the saturation value, the

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electrons passing through the first grid and forming a space charge in the space between it and the anode. With respect to P and  $G_2$ , the first grid may be regarded as the source of the electrons. The space charge being so distributed, it is easily controlled by  $G_2$ , which results in a steep characteristic and an increased figure of merit.

In the method shown in Fig. 1,  $G_2$  may be called an anode-screening grid, since its function is to screen the control grid  $G_1$  and the filament from the effects of the fluctuations of the anode potential which normally limit the amplification. In the method shown in Fig. 2,  $G_1$  may be called the space-charge grid or filament-screening grid since its function is to produce a redistribution of the space charge on which  $G_2$  acts. It is claimed that for a given anode voltage the figure of merit can be increased tenfold by the use of these double-grid valves. Barkhausen claims that the advantages of both the above methods could be combined in a valve with three grids, but any advantage thus gained would be counter-balanced by the constructional disadvantages.

## On a Kink in the Characteristic of a Soft Three-electrode Valve.\*

By B. HODGSON, O.B.E., M.Sc., Ph.D., and L. S. PALMER, M.Sc.

**1. Introductory.**—It has been known for some time that a three-electrode valve containing a trace of gas is much more sensitive as a detector for wireless signals than a geometrically similar hard valve. In the case of a soft valve there is usually a very critical adjustment at which the sensitiveness is abnormally great whilst with the hard valve no such point can be found. Such a sensitive valve was obtained by W. C. White † who introduced into the bulb a small quantity of mercury vapour. He proved that the characteristic possessed a discontinuity or "kink" at the particular adjustment for which it was most sensitive as a detector. The mercury vapour was introduced into the valve by using a silver amalgamated anode. Referring to this phenomenon, Dr. Eccles ‡ states in his handbook, "To ensure the necessary gas pressure there is placed in the bulb before sealing off a small amount of vapourisable material, for example, an amalgam, or sulphur or phosphorus pentoxide." Later he states that the cause of this phenomenon is decidedly obscure but its existence very real. The present work was undertaken to investigate the causes of the "kink."

**2. Form of the Kink.**—Typical forms of kinks are given in Figs. 1, 2 and 3 which were obtained by varying the grid potential  $v$  and observing the anode current  $I$  and the grid current  $i$ . Fig. 1 is the characteristic of a mercury vapour valve (the N.P.L. No. 2 valve), which contains an amalga-

\* Received February 3rd, 1921.

† W. C. White, *General Electric Review*, p. 635, August, 1917.

‡ W. H. Eccles, "Handbook of Wireless Telegraphy and Telephony," pp. 295–296, 1918 edition.



mated silver anode. Fig. 3 shows a kink from the same valve on a larger scale, and Fig. 2 shows a kink from a helium filled valve—the R.2A receiving valve. The kink obtained by White in the paper previously referred to is very similar in form to these. An important point, which will be referred to later, is that the changes in the grid and anode currents are similar and occur simultaneously.

**3. Relation between Grid Potential, Anode Potential and Filament Temperature at the Point where a Kink occurs in the Characteristic.**—A series of experiments were made in which the grid potential  $v$ , the plate potential  $V$  and the voltage across the filament  $v_f$  were measured at the point where the kink occurred. As is customary all potentials were measured from the negative end of the filament. The plate current  $I$  and grid current  $i$  were also recorded. It was noticed that with a dull filament

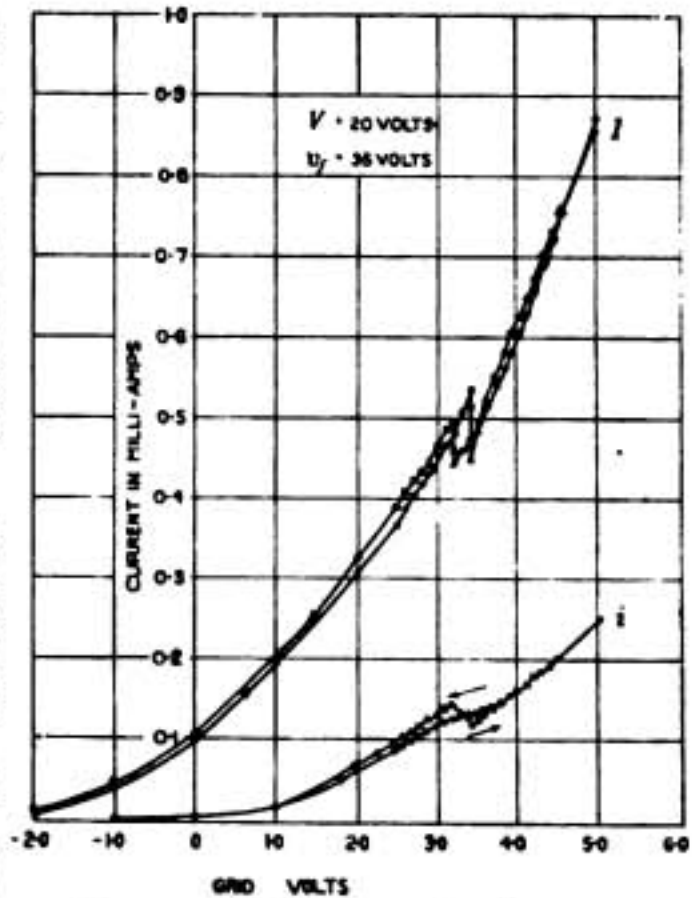


FIG. 1.—N.P.L. No. 2 (Hg) Valve.

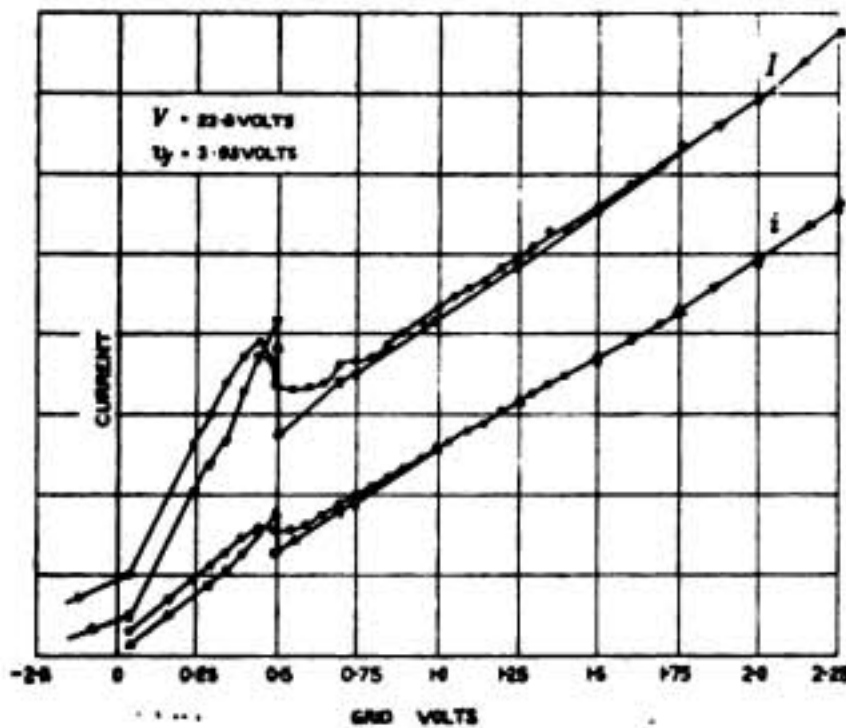


FIG. 2.—R.2A (He) Valve.

$I$  and  $i$  are displaced vertically and not to same scale.

adjustment of the grid voltage would produce a kink. Thus the boundary curve shown divides the region determined by any values of  $V$  and  $v_f$  into

with a dull filament [*i.e.*,  $v_f$  small] a relatively high value of plate potential was necessary to obtain a kink, and on the other hand, high values of  $v_f$  made it possible to obtain kinks with relatively low values of  $V$ . Fig. 4 shows the results of these experiments. The circles on the boundary curve shown indicate the lowest values of  $V$  for the corresponding filament voltage at which it was possible to get a kink. For example, with a filament voltage of 3.2 volts kinks can be obtained with any value of  $V$  greater than 14, but with  $V$  less than 14 no

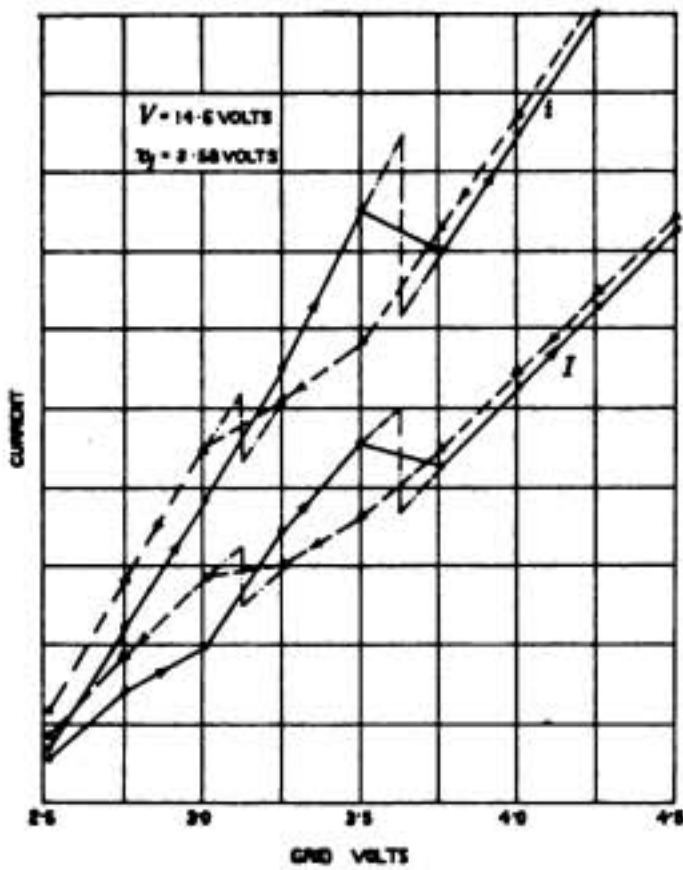


FIG. 3.—N.P.L. No. 2 (Hg) Valve.  
I and i are displaced vertically and are not to same scale.

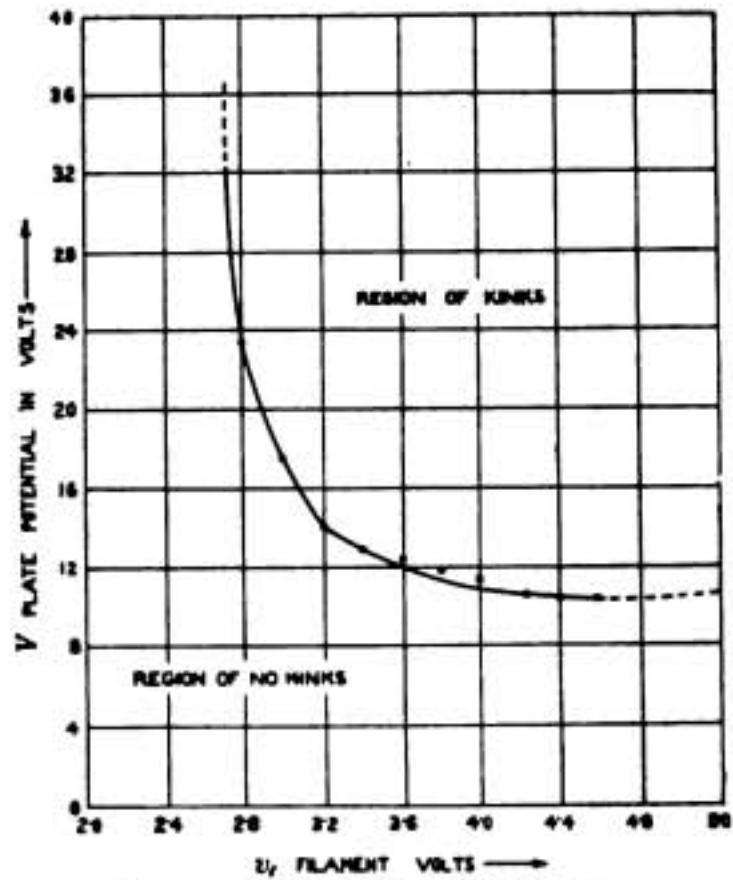


FIG. 4.—N.P.L. No. 2 (Hg) Valve.

two. At any point above the curve a suitable adjustment of  $v$  will produce a kink, the values of  $V$  and  $v_f$  being determined by the position of the point, but for any point below the boundary curve a kink can never be obtained.

Although a kink cannot be obtained with the conditions represented by a point below the boundary curve yet a deviation from the ordinary characteristic can be observed. Fig. 5 shows the characteristics obtained under conditions where  $V$  is just sufficient and also just insufficient to produce a kink, and the deviation from the normal characteristic is clearly noticeable. In Fig. 6 curves are shown where  $v_f$  is constant and  $V$  gradually increased until a kink is obtained.

The experiments performed suggested that some phenomenon essential to the production of a kink was occurring at the grid and an estimate of the energy of the electrons when they arrived in the neighbourhood of the grid was obtained. This energy depends upon the velocity of emission of the electrons from the tungsten filament and upon the potentials of both grid and anode. The velocity of emission is a function of the temperature of the filament which varies considerably from one end to the other. The majority of the electrons come from the mid-portion of the filament where it is hottest and where the velocity of emission is therefore greatest. In the following considerations the electrons are assumed to start from the mid-portion of the filament and thus to fall through a potential of  $(v - \frac{v_f}{2})$  in

passing from the filament to the grid wire, and through a potential of  $(V - \frac{v}{2})$  in passing from the filament to the anode.

The surface containing the grid wires is usually a cylinder or a plane and is not an equipotential surface. The wires themselves are maintained by batteries at a potential  $v$ , but the potential of the space between the grid wires varies from point to point. The amount of variation depends upon the geometry of the valve and the potential of the anode  $V$ . Although the potential of any point in the surface containing the grid wires cannot readily be calculated, an average potential for the surface can be obtained easily by experiment. This average potential is usually written in the form  $(v + \gamma V)$  where  $\gamma$  is a constant depending upon the geometrical distribution of the electrodes.

Then it has been shown that

$$I = A(v + \gamma V)^m$$

where  $A$  and  $m$  are constants.

By obtaining the same values of  $I$  with different combinations of  $v$  and  $V$ ,  $\gamma$  can be calculated.

The expression  $(v + \gamma V)$  yields an approximate value for the potential through which an electron falls in passing from the filament to the grid cylinder. Assuming that the electrons came from the mid-point of the

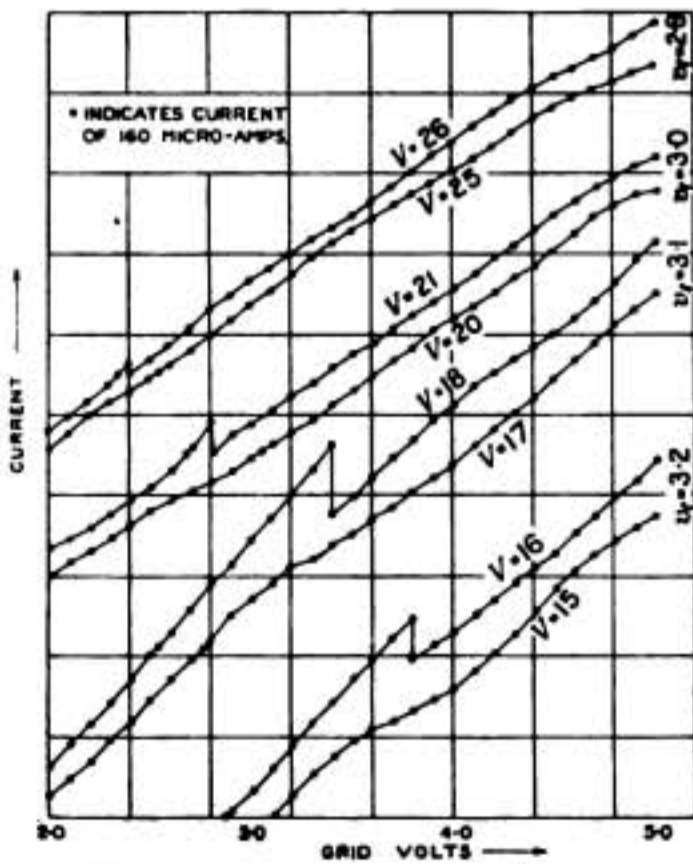


FIG. 5.—N.P.L. No. 2 (Hg) Valve. Curves displaced vertically. Side of one square represents 33 micro-amperes.

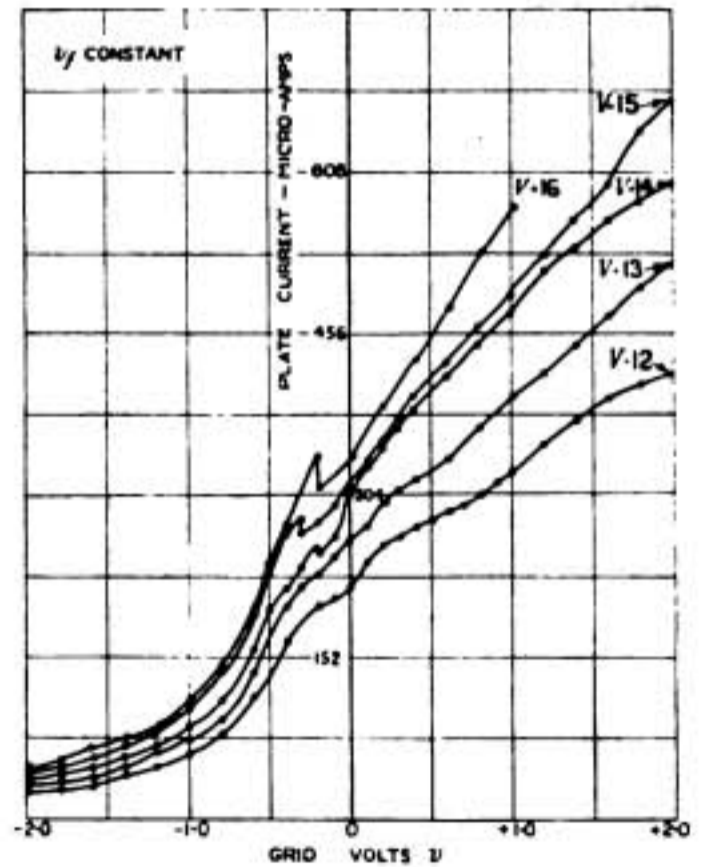


FIG. 6.

filament, this expression becomes :—

$$\left(v - \frac{v_f}{2}\right) + \gamma\left(V - \frac{v_f}{2}\right).$$

Further, if the electron is ejected from the filament with the energy it would acquire in falling freely through the voltage  $e$ , then an electron in passing to the grid cylinder from the mid-point of the filament, possesses energy equal to that acquired in falling through a voltage—

$$\left(v - \frac{v_f}{2}\right) + \gamma\left(V - \frac{v_f}{2}\right) + e.$$

Similarly the energy possessed by an electron on arriving at the plate and coming from the mid-point of the filament is that acquired in falling through a potential of

$$\left(V - \frac{v_f}{2} + e\right).$$

The quantity  $e$  was determined by a method similar to that adopted by Van der Bijl. The anode was maintained at a constant potential which was less than the ionising potential of the gas and the grid was reduced in potential till the anode current was nearly zero. Then

$$-v = \gamma V + e.$$

By obtaining the same current with two different values of  $v$  and  $V$ ,  $e$  and  $\gamma$  could be determined.

**4. Experimental Results.**—In addition to the helium-filled R.2A valve and the N.P.L. No. 2 mercury vapour valve, there were used an R valve filled with a pure argon and an audion. This latter is an air valve with a fairly good vacuum and the residual gas is chiefly nitrogen since any oxygen present would combine with the tungsten filament and be sputtered to the walls of the valve as oxide.

Kinks were obtained with all these valves for different values of  $V$ ,  $v$ , and  $v_f$ , and the functions :—

$$\left[V - \frac{v_f}{2} + e\right] \text{ and } \left[v - \frac{v_f}{2} + \gamma\left(V - \frac{v_f}{2}\right) + e\right] \text{ calculated.}$$

These quantities will be denoted by  $V_a$  and  $V_g$  respectively. They were plotted against  $v_f$ , and  $V_a$  yielded a region of kinks and one of no kinks with a boundary curve very similar to that of Fig. 4. In Fig. 7 curves for the four gases are shown.

It will be seen that the boundary curves tend to become horizontal and possess minimum values of  $V_a$  for large values of  $v_f$ . These minimum values of  $V_a$  are roughly the ionising potentials of the gases. The minimum values of  $V_a$  thus determined and of the ionising potentials of the gases in question are shown in Table I. The column (I.P)\* shows the ionizing potentials found by a method used by the authors with the actual valves employed in the present piece of work.

\* Hodgson and Palmer, RADIO REVIEW, 1, pp. 525—531, August, 1920.

TABLE I.

Gas.	$V_a$ .	I.P.	Ionising Potentials.
Mercury . . .	10.5	10.4	10.2 * 10.3 †
Helium . . .	22.0	21.9	25.7 ‡ 25.3 § 25.5
Argon . . .	16.6	16.6	15.1 and 18.1 ¶ 17 **
Nitrogen . . .	18.0	17.4	18.5 †† 17.18 ‡‡

\* *Physical Review*, 10, p. 495.

† *Physical Review*, 10, p. 101.

‡ *Proceedings of the Royal Society*, 95A, p. 408.

§ *Physikalische Zeitschrift*, 20, No. 21.

|| *RADIO REVIEW*, 2, pp. 113—125, March, 1921.

¶ *Proceedings of the Royal Society*, 97A, p. 1.

\*\* *Physical Review*, 13, p. 297.

†† *Physical Review*, 13, p. 1.

†† *Physical Review*, 14, p. 409.

The minimum value of  $V_a$  is very approximately the ionising potential of the gas, and it appears essential to the production of a kink that this value of  $V_a$  should be reached.

When the values of  $V_g$  (the energy an electron possesses on arriving at the grid), were plotted against  $v_f$ , straight lines were obtained. The values of  $V_g$  are reasonably constant over the whole range of filament voltage used.

In the case of helium and mercury vapour two kinks upon one characteristic were obtained. The values of  $V_g$  found are given in Table II.

TABLE II.

Gas.	$V_g$	Resonance Potentials.
Helium . . .	6.1 4.5	20.54 * 20.7 †
Mercury . . .	6.3 4.7	6.7 ‡ 4.9
Nitrogen . . .	7.3	7.3—8.3 §—9.0
Argon . . .	11.4	12.0 ¶ 11.5 ** 12.5 ††

\* *Proceedings of the Royal Society*, 95A, p. 408.

† *RADIO REVIEW*, 2, pp. 113—125, March, 1921.

‡ *Physical Review*, 10, p. 101.

§ *Physical Review*, 14, p. 409.

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\*\* *Proceedings of the Royal Society*, 97A, p. 1.

†† *RADIO REVIEW*, 2, pp. 113—125, March, 1921.

Except in the case of helium the values of  $V_g$  correspond to some known resonance potential of the gas in question, with helium resonance potentials as low as 4 or 6 volts have never been detected. The valves used for helium were factory made and further experiments are being undertaken to obtain

$V_a$  and  $V_g$  with pure helium. The fact that the ionising potential of the helium used was also less verifies the assumption that the helium was impure for Horton \* found a steady decrease in the value of the ionising potential as the amount of impurity was increased. Table III., which gives some data for argon, illustrates two additional facts with regard to the values of  $V_a$  and  $V_g$ . The values of  $V_g$  are seen to be approximately constant over a range of pressures from 0.03 mm to 0.8 mm of mercury and the minimum value of  $V_a$  for a pressure of 0.03 mm was 16.57 and for a pressure of 0.8, 16.6 volts. By using a valve of different electrode geometry no change was found in the value of  $V_g$  and although the minimum value of  $V_a$  was not reached it was certainly not greater than 16.6 volts. The values of  $V_a$  and  $V_g$  thus appear to be independent of the electrode geometry and also of the gas pressure.

TABLE III.

Valve.	Pressure. (mm of Hg.)	$V_a$ . (Volts.)	$V_g$ . (Volts.)	Anode Current $I$ . (Arbitrary units.)	$\gamma$ .	$v_f$ . (Volts.)
R. valve filled with argon.	0.03	16.57	11.4	10.7	0.37	7.2
	0.03	19.4	11.4	10.5	0.35	7.0
	0.45	16.6	11.1	10.6	0.37	7.0
	0.55	16.6	10.4	10.5	0.40	7.0
	0.80	16.6	10.3	10.4	0.40	7.0
Another argon- filled valve.	{ —	22.2	10.2	—	0.16	3.4
	{ —	21.9	12.4	—	0.16	3.2
		(16.57) Min. value	(11.0) Mean value			

Another experimental fact recorded in Table III. is that the value the anode current  $I$  assumes when a kink occurs, is practically constant for a particular valve, but probably this is dependent upon the fact that  $V_g$  is constant, because

$$V_g = v - \frac{v_f}{2} + \gamma \left( V - \frac{v_f}{2} \right) + e = v + \gamma V + \left[ e - (1 + \gamma) \frac{v_f}{2} \right]$$

and  $\left[ e - (1 + \gamma) \frac{v_f}{2} \right]$  is seen from the following table to be approximately constant.

\* Horton, *Physical Review*, 15, p. 498, and Palmer, *RADIO REVIEW*, 2, pp. 113—125, March, 1921.



$v_f$  for a given valve. It was noted in section 2 and in Figs. 2 and 3 that the current changes for both plate and grid currents were similar in form and that the changes occurred simultaneously. This fact is of importance when an explanation of the phenomena is sought as certain possible causes are thus eliminated.

Another experimental fact is the small difference in position of the kink when obtained first with increasing and secondly with decreasing grid potential. This "lag" is seen in Figs. 1, 2, 3, 12, and 13.

**5. Discussion.**—There is little doubt that ionisation is an essential part of the kink phenomena, because a kink has not been observed in a hard valve, and in a soft valve only under conditions where ionisation is possible. The evidence that a resonance potential occurs near the grid is not so strong. It depends upon the observed fact that the values of  $V_g$  in the gases argon, nitrogen and mercury are very near the respective resonance potentials of these gases.

If one assumes that the origin of the kink is in physical processes occurring in the valve itself, then the following analysis of the currents  $I$  and  $i$  shows that the source of the current carriers producing the changes in  $I$  and  $i$

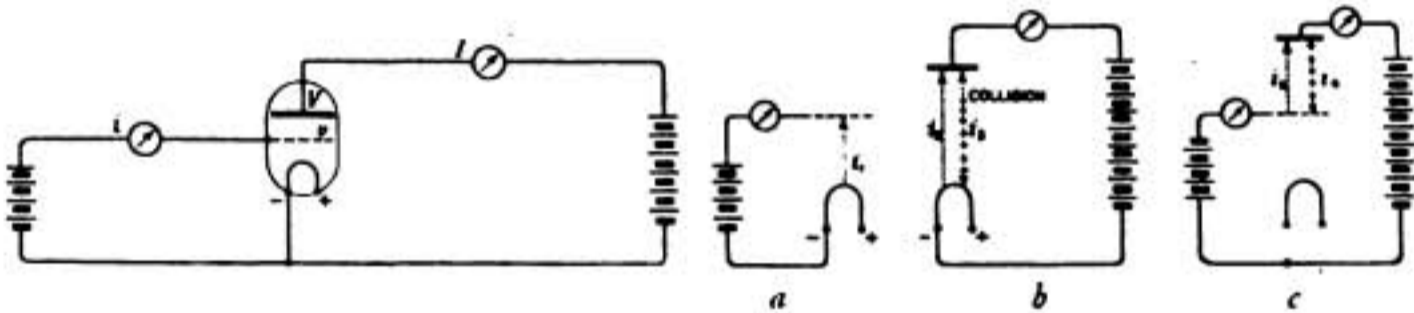


FIG. 9.

FIG. 10.

must be the filament. The circuit used in obtaining the characteristics can be shown diagrammatically as in Fig. 9.

In the valve there are three possible paths for the current carriers, viz. :—

- (1) From filament to plate and *vice versa*.
- (2) From filament to grid and *vice versa*.
- (3) From grid to plate and *vice versa*.

Thus we may consider the circuit of Fig. 9 to consist of three component circuits as shown in Fig. 10.

The electrons and positive ions carrying the currents in these circuits are due to various causes. The hot filament yields the bulk of the electrons. The positive ions are formed by collision between electrons and gas molecules, and as the grid potential  $v$  under the conditions that yield a kink, is much less than ionising potential and the plate potential  $V$  is above it, the positive ions are formed in the space between the grid and the plate. Photoelectrons can be emitted from the metal electrodes if ultra-violet light of suitable wavelength is generated in the tube. This occurs when an electron collides with a gas molecule after falling through "Resonance" potential. For example, an electron that has gained energy in falling through a potential of 4.9 volts and collides with a mercury vapour molecule, causes ultra-



violet light of a single wavelength to be emitted from the bombarded molecule. No ionisation occurs until the electron has fallen through 10.4 volts.

Now mercury vapour has three resonance potentials at 3.2, 4.9 and 6.7 volts respectively, and with the mercury vapour valve two kinks were often obtained, with values of  $V_0$  4.7 and 6.3 volts. When ultra-violet light falls upon metals, electrons are only emitted if the wavelength of the light is below a certain threshold value which depends upon the metal upon which the light is incident. In the case of a molybdenum grid the wavelength corresponding to 3.2 volts resonance potential is above this threshold value, and a kink with a 3.2 volt value for  $V_0$  would not be expected.

The bombardment of the filament by positive ions is a further cause of electron emission. Intense local heating is produced where the ion strikes the filament and increased emission results.

The bombardment of the grid and plate by both electrons and positive ions can produce additional carriers of current,\* but these will be few in number under the conditions of the experiments with which we are concerned.

The plate current  $I$  is the sum of the plate currents in circuits b and c of Fig. 10, viz. :—

$i_2$  an electron current from filament to plate (circuit b).

$i_3$  a positive ion current from plate to filament (circuit b).

$i_4$  a positive ion current from plate to grid (circuit c).

$i_5$  a photo-electron current from grid to plate (circuit c).

Thus  $I = i_2 + i_3 + i_4 + i_5$ .

The grid current  $i$  consists of the sum of the grid currents in circuits a and c, viz. :—

$i_1$  an electron current from filament to grid (circuit a).

$i_5$  a photo-electron current from grid to plate (circuit c).

$i_4$  a positive ion current from plate to grid (circuit c).

Thus  $i = i_1 - i_4 - i_5$ .

This analysis of the currents  $I$  and  $i$ , together with the fact that both  $I$  and  $i$  increase or decrease simultaneously, enables one to eliminate certain phenomena as causes of the kink. For example a photo-electric current from the grid alone cannot be the cause, for this would mean an increase in  $I$  when the effect sets in, and a decrease in  $i$  by the same amount  $i_5$ .

Similarly ionisation alone demands an increase in  $I$  accompanied by a decrease in  $i$  by the amount  $i_4$ . This is readily observed in a soft valve and an example of this is shown in Figs. 11 and 11A. The "backlash" test for the vacuum of a three-electrode valve also utilises this fact. If however any of these phenomena are accompanied by a bombardment of the filament by positive ions, the extra electron emission might mask the decrease in the value of  $i$  and produce a simultaneous increase in  $I$  and  $i$ .

A satisfactory explanation of the kink based upon the experimental evidence given above is, however, difficult to find. If photo-electrons from the grid wires produced additional ionisation, then a discontinuity in the characteristic would be expected. The photo-electrons falling from grid to

\* Horton, *Proceedings of the Royal Society*, 95A, p. 419.

anode do not always possess energy sufficient to ionise—as for example when  $V_a$  has its minimum value—in which case the potential fall between grid wires and anode is usually much less than ionising potential. Thus ionisation by photo-electrons is not possible and the simultaneous rise in both grid and plate current cannot be thus explained.

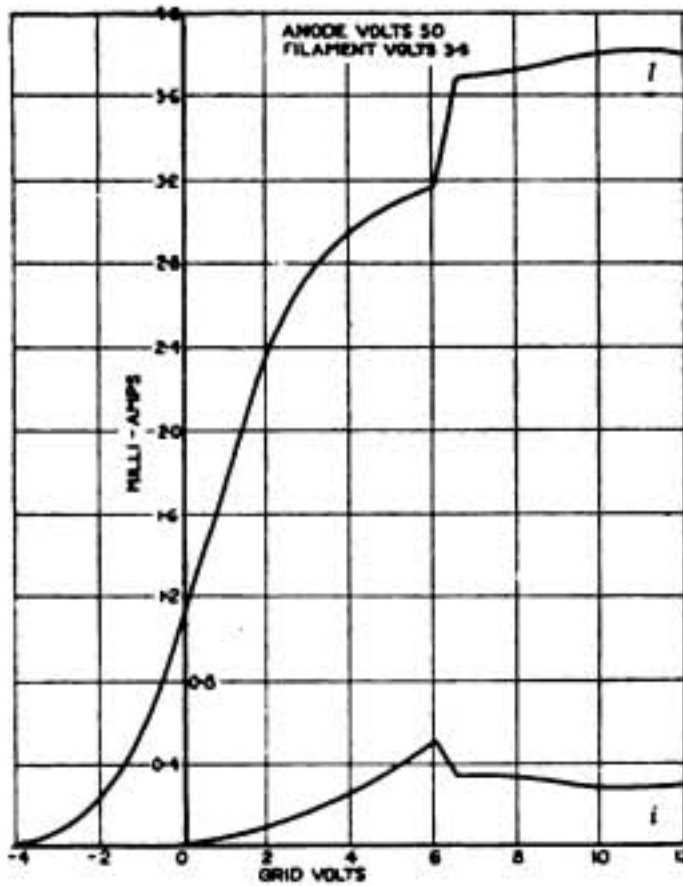


FIG. 11.

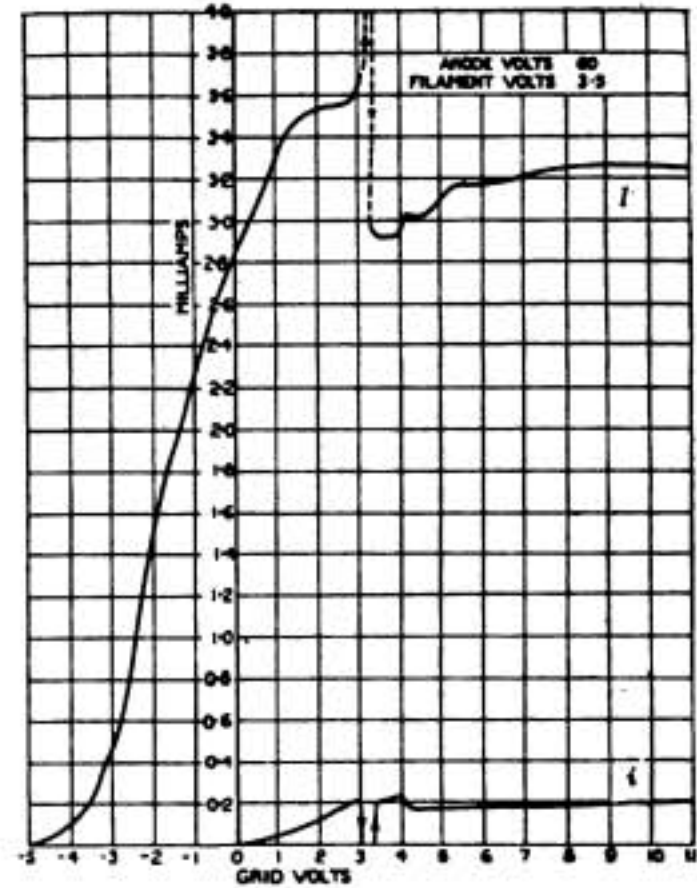


FIG. 11A.

Nor can the space charge effect due to photo-electrons emitted from the grid yield a satisfactory explanation. The region in which resonance collision occurs moves from near the anode towards the grid, as the grid potential is increased and radiation from this region falls in increasing amount upon the grid wires. Photo-electrons will be projected from the grid wires towards the anode, and they will be removed rapidly from the grid. When, however, the region on which resonance occurs appears between the grid and the filament, the photo-electrons are projected from the filament side of the grid wires into a field which tends to drive them back to the grid, and their presence here will tend to diminish the electron emission from the filament—by diminishing the field at the surface of the filament. It is improbable however that the photo-electrons are in sufficient number to produce the kink by such action as described.

Another possible explanation is afforded by the similarity of the changes in  $I$  and  $i$  with those observed when a valve generates an oscillatory current. Whiddington\* has shown that high frequency oscillation can be generated in circuits devoid of the usual inductance-capacity arrangements. In the case described by him, the oscillations are maintained by the periodic bombardment of the filament by positive ions produced by the collision of

\* RADIO REVIEW, 1, p. 53, November, 1919.

the electrons with gas molecules. When a valve commences to generate oscillations both  $I$  and  $i$  usually increase, and if the oscillations for some reason ceased then the current  $I$  would fall back to the corresponding point upon the characteristic. Further, if oscillations are started by changing the grid potential, the point where the sudden change in anode current occurred would depend upon whether the grid potential was increasing or decreasing. Thus the generation of oscillations would account for all the observed phenomena of the kink. Whiddington assumed that a cloud of electrons from the filament collided with gas molecules just outside the grid and ionised them. The resulting positive ions were driven as a group back to the filament and the local heating of the filament by this bombardment produced another cloud of electrons. In this way both the  $I$  and  $i$  currents would be periodically increased, and this periodic fluctuation of these currents could be detected in a beat reception circuit placed near, and the periodicity or wavelength of the oscillatory current measured. The periodicity can also be calculated by finding the times between two consecutive bombardments.

The energy equation

$$\frac{1}{2}mu^2 = \bar{V} \cdot e$$

(where  $m$  is the moving mass,  $u$  its final velocity,  $V$  the potential through which  $m$  falls, and  $e$  its charge), yields the final velocity  $u$ . The time between two bombardments is the time taken for the electrons to reach the molecules with which they collide, plus the time taken for the positive ions so produced to fall to the filament. As the former time is small compared to the latter, only the latter need be evaluated. Whiddington took the quantity  $\bar{V}$  as the potential between the filament and the grid, and the following quantities are those used by him to evaluate the frequency of the oscillations generated by the valve.

$$\bar{V} = 1 \text{ volt.}$$

$$e/m = 50 \text{ (E.M.U.) (for mercury atoms).}$$

$$\text{Hence } u = 10^5 \text{ cm/sec.}$$

The distance between filament and grid was 3 mm.

Thus the mean time between two collisions was  $6.0 \times 10^{-6}$  secs.

This yields a frequency of  $\frac{1}{6} \times 10^6$  or a wavelength of 1,800 metres and not as Whiddington works out, 450 metres. Since he found experimentally a wavelength of 640 metres, there is no agreement between experiment and theory. His theory can, however, be amended readily to give a reasonable agreement. Suppose that the electrons are emitted from the filament with zero velocity, then they must fall through a field of about 10.4 volts in order to acquire ionising velocity in mercury vapour, and they will acquire this energy just outside the grid because the plate voltage used was 50 volts or more. Thus the final velocity will be:—

$$\sqrt{10.4} \times 10^5 \text{ cm/sec} = 3.16 \times 10^5 \text{ cm/sec}$$

$$\text{and the mean velocity } 1.58 \times 10^5 \text{ cm/sec}$$

and the mean time between two bombardments will be  $1.9 \times 10^6$  secs and the corresponding wavelength 570 metres.

This, however, is only a lower limit of the value of the frequency because the electrons are emitted with some initial velocity. This reduces the value of the field through which they must fall to acquire ionising velocity and so increases the wavelength of the generated oscillatory current.

Thus in such a valve as Whiddington used, wavelengths of 570 metres upwards should be generated if this modified theory is correct. This is in fair agreement with the 640 metres found by Whiddington.

It was thought that oscillations of this sort might be generated when a kink occurred. In the experiments performed to yield a kink, ionisation occurred somewhere between the grid and the anode, and the distance the positive ions travel before reaching the filament is not known exactly but is between two limits  $D$  and  $d$ , where  $D$  is the distance between the filament and the anode, and  $d$  the distance between filament and grid. Using these two distances and the theory outlined above, two frequencies were calculated between which the frequency should be observed if oscillations occur during a kink. The following table gives the data concerning three of the valves in use and the expected frequencies.

TABLE V.

Gas.	$d$ .	$D$ .	$e/m$ .	$\bar{V}$ .	$u$ (final).	$\lambda_1$ .	$\lambda_2$ .
Mercury	0.14	0.44	48	10.4	$3.16 \times 10^5$	268 m	840 m
Nitrogen	0.22	0.49	340	17.5	$1.1 \times 10^6$	120 m	267 m
Argon	0.17	0.45	240	16.6	$8.9 \times 10^5$	114 m	300 m

Where  $\lambda_1$  and  $\lambda_2$  are the lower and upper limits of wavelength and  $\bar{V}$  the ionising potential in volts.

A search for such frequencies between wavelengths of 100 and 2,000 metres was made, but no oscillations could be detected. A more sensitive receiver is being made to make a further search.

The addition of inductances to either the grid or anode branches of the circuit used for obtaining the kink produced no change in its size or position. Inductances from a few hundred centimetres to a value of 43 million centimetres were used.

The effect of connecting either anode to filament or grid to filament by means of condensers also produced no effect. When non-inductive resistances (platinum films on glass) up to 80,000 ohms were inserted in either the grid or anode circuits, no change in the kink was obtained, provided that the anode battery was adjusted so that the potential difference between filament and anode was the same. Figs. 12 and 13 show the forms of the  $I$  kink with and without inductances, capacities and resistances.

The above experiments show that if the kink phenomena are produced by the generation of oscillations then such oscillations are practically independent of the nature of the grid and anode circuits.

In soft vacuum tubes sudden changes in current similar to that observed in the kink are common—especially when there is connected to the bulb through which the visible discharge usually passes, a tube leading to other volumes of gas. Under certain conditions the glow extends beyond the bulb into the connecting tube and an increase in current can be observed. A similar phenomenon might occur in the valve. The main discharge

usually occurs in a very limited volume of the bulb—that between the filament and anode—but it is quite possible that gas in the remaining portion of the bulb takes part in conducting the current under certain electrical potentials of grid and plate.

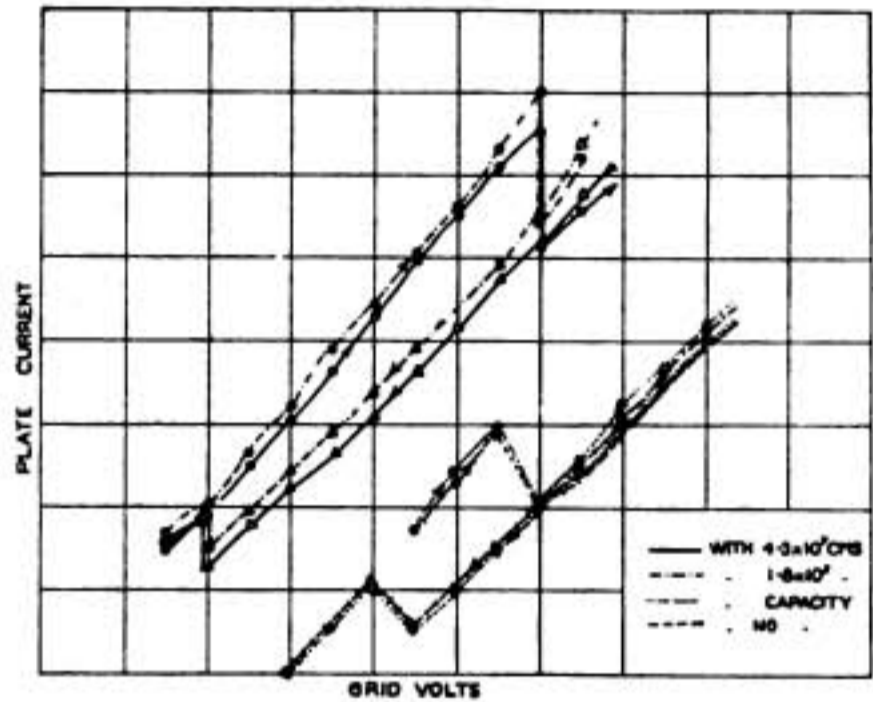


FIG. 12.

The experiments described have not solved the problem of the kink, but it is hoped that the additional knowledge concerning the kink phenomena may lead to an early solution.

The advantages of the remarkable rectifying power of the valve, when adjusted for a "kink," can now be more readily used, because the essential conditions can be very approximately calculated.

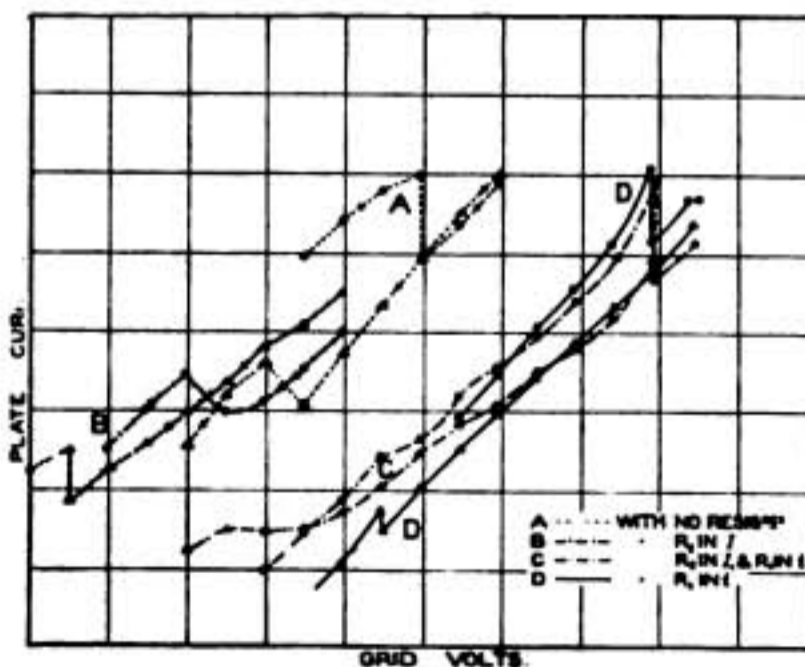


FIG. 13.

**6. Summary.**—(1) The kink in the characteristic of a soft three-electrode valve has been obtained in five types of valves and with four different gases.

(2) The necessary conditions for obtaining a kink are:—

- (a) The valve should be "soft."
- (b) The function  $V_a$  must be at least the ionising potential of the gas in the tube.

D D

- (c) The function  $V_g$  must be a resonance potential of the gas in the tube.
- (d) The resonance potential must exceed in value the minimum potential necessary for the emission of photo-electrons from the material of the grid.
- (3) The kink is independent of :—
- The gas pressure.
  - The valve geometry.
  - The nature of the external circuit.
- (4) Possible explanations have been discussed, but a satisfactory solution has not yet been found.

The above work was carried out in the Physics Department of the University of Bristol, and the expenses entailed were met by a grant from the University Colston Research Fund.

## A New Dutch Marine Type Receiver.

The standard receiving apparatus manufactured by the Nederlandsche Radio Industrie is arranged for the reception of all European and the principal trans-ocean radio stations, and is suitable for both telephonic and telegraphic reception on wavelengths between 400 and 20,000 metres. It consists of

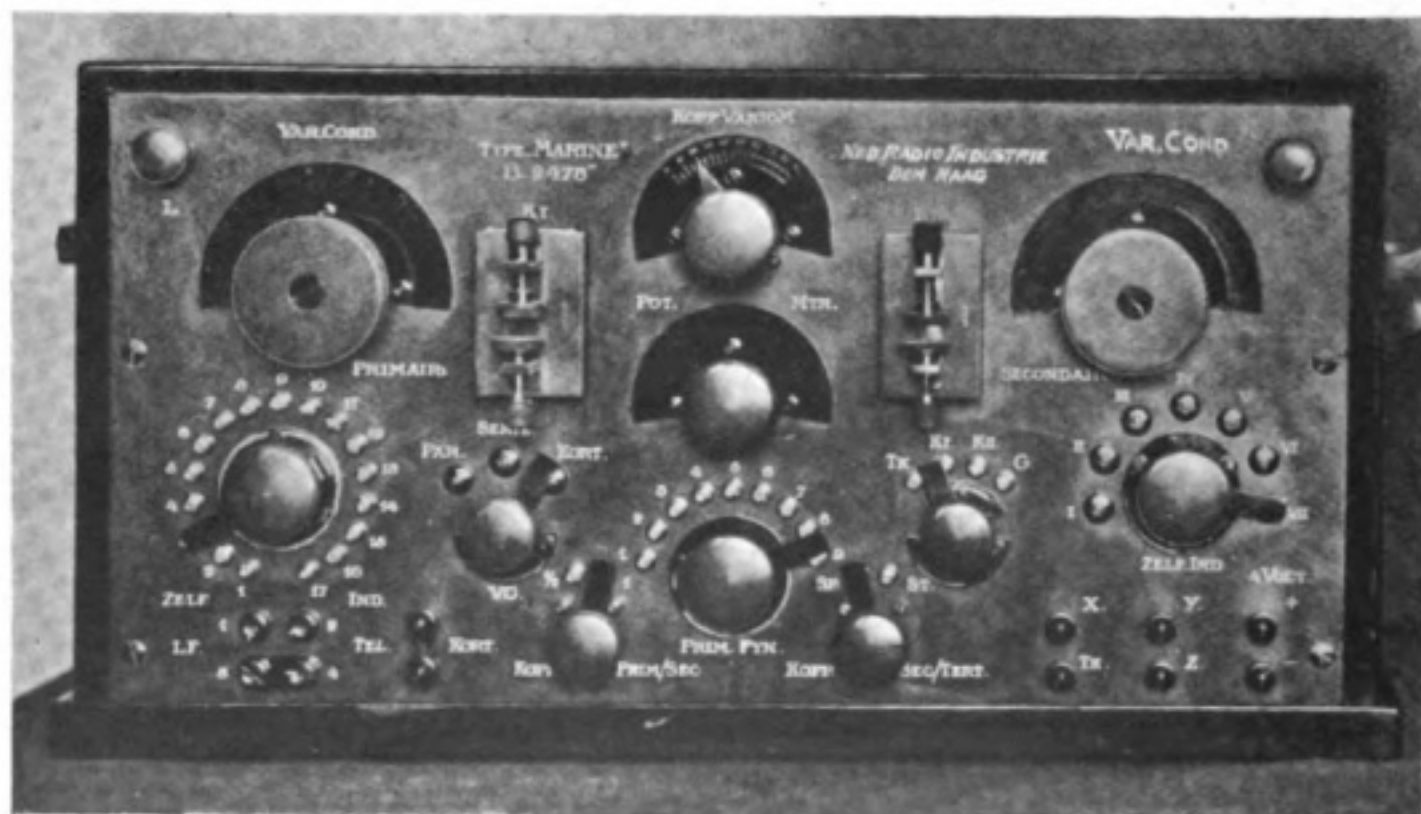


FIG. 1.

two parts : the Receiver type " Marine B," and the Amplifier type " H.F. 1," Figs. 1 and 2. Both units are mounted in polished mahogany cases with ebonite front panels, on which are fitted all the terminals, adjusting and tuning handles and switches.

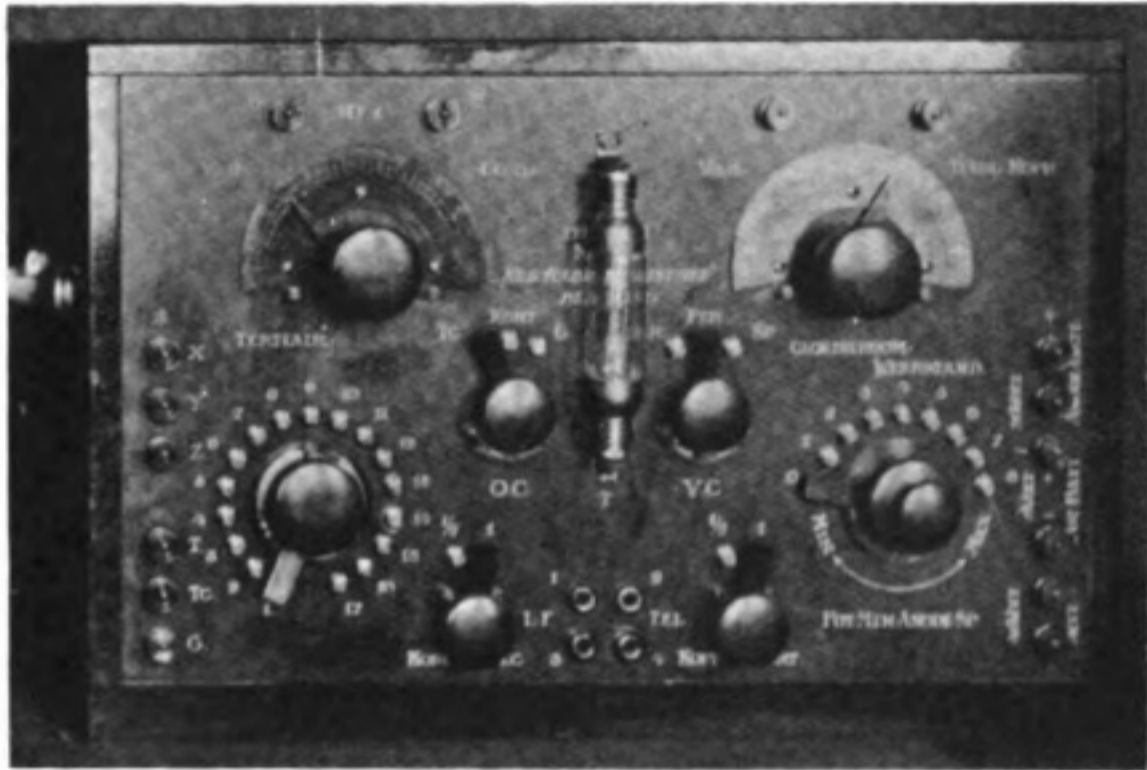


FIG. 2.

The arrangement of the receiver unit proper, type " Marine B," is shown in Fig. 3. It has inductive coupling between the aerial circuit and the secondary, the coupling coils being arranged like a variometer, with the inner coil connected in the aerial circuit. The advantages of this arrange-

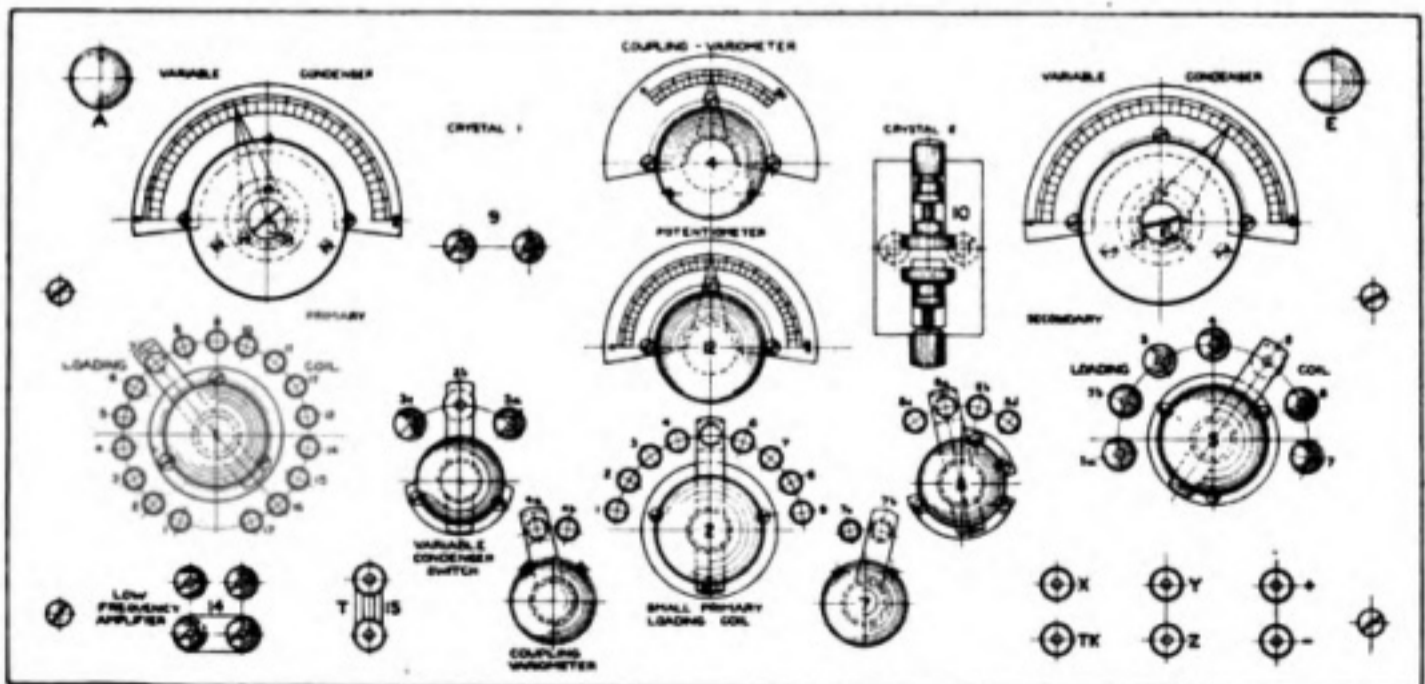


FIG. 3.

D D 2

ment are fineness of adjustment of the coupling and ability to reduce it completely to zero—an adjustment not easily possible with solenoid type coils. For short wave reception both coils of the coupling transformer are divided—the primary by a centre tapping, and the secondary into two parts which may be used singly or in series. With a normal aerial the coupling need not be greater than  $20^\circ$ — $30^\circ$ , except for wavelengths over 10,000 metres.

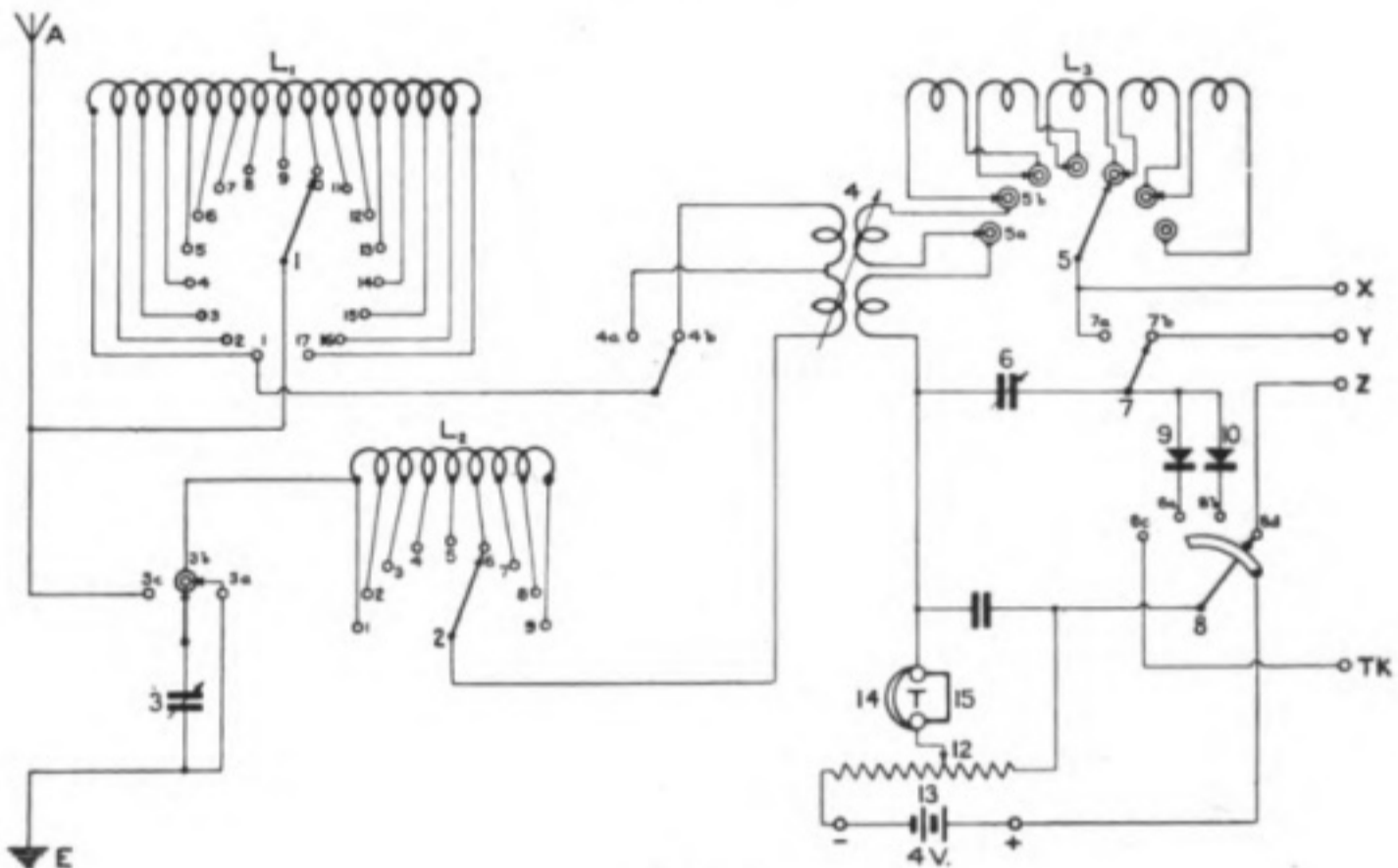


FIG. 4.

The rough tuning of the aerial circuit is accomplished by switch **1** (contacts 1—17) Figs. 3 and 4, and the fine tuning on switch **2** (contacts 1—9), the inductance of this second coil  $L_2$  covering the range of inductance between two contacts of **1** on the coil  $L_1$ . Finer adjustment is obtained by the variable condenser **3** which may be placed in series, or in parallel with the aerial circuit or cut out entirely by the switch **3a**, **3b**, **3c**.

For aerials having a capacity greater than  $0.005\mu\text{F}$ , it is suggested that the primary condenser **3** should be filled with paraffin oil.

The secondary circuit comprises the inductance  $L_3$  with its tapping switch **5**, in parallel with the variable condenser **6**. The self-capacity of the coils is kept down as much as practicable, and the minimum capacity of condenser **6** is also small (about  $0.00003\mu\text{F}$ ). The tapping switch **5** is fitted with dead-end contacts to cut off the parts of the winding which are not in use.

When this receiver unit is used alone, for crystal reception, switch **7** is put on contact **7a**, and switch **8** enables either of the crystal detectors **9** or **10** to be used, or a tikker to be connected to the terminals marked **TK** and **X**.

The two crystal detectors are mounted on the front of the panel by means



of plug and socket connections. Either one or two pairs of telephones may be plugged into the contacts provided.

When valve reception is required the amplifier unit, type H.F. 1 is joined up by connecting the terminals marked **XYZ** on the receiver unit to those

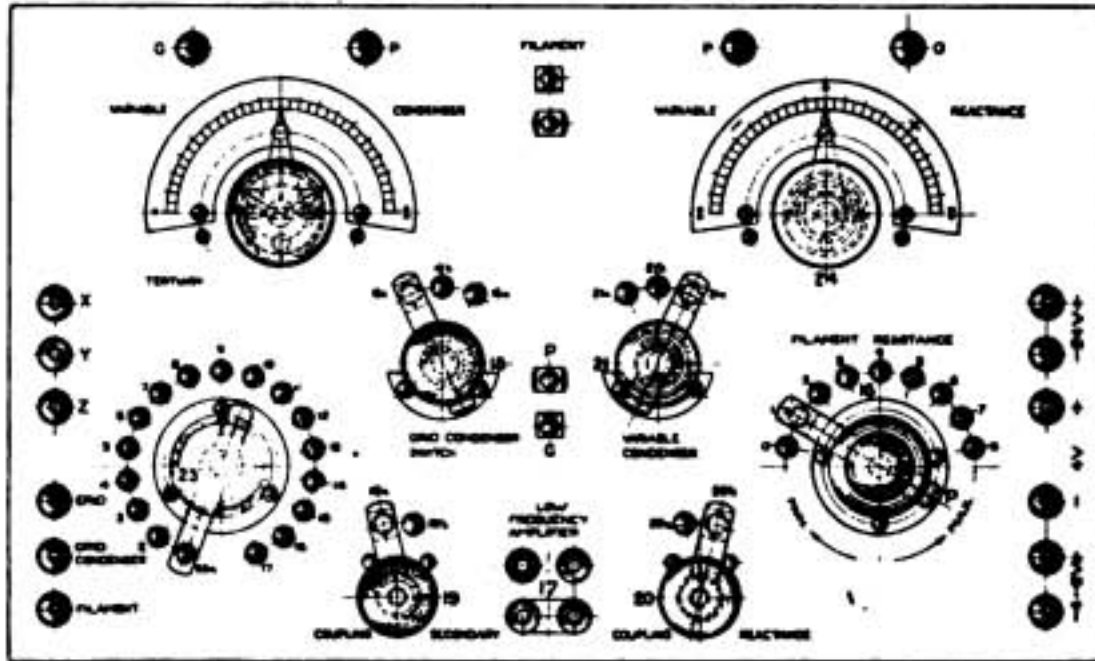


FIG. 5.

with the corresponding markings on the amplifier unit. The general arrangement of the front panel of this instrument is shown in Fig. 5, and the connection scheme in Fig. 6. To connect in this unit switch **8** is put on to contact **8d** which closes the connection between the tuned secondary circuit of the receiver unit and the tertiary circuit coupling coil of the amplifier unit.

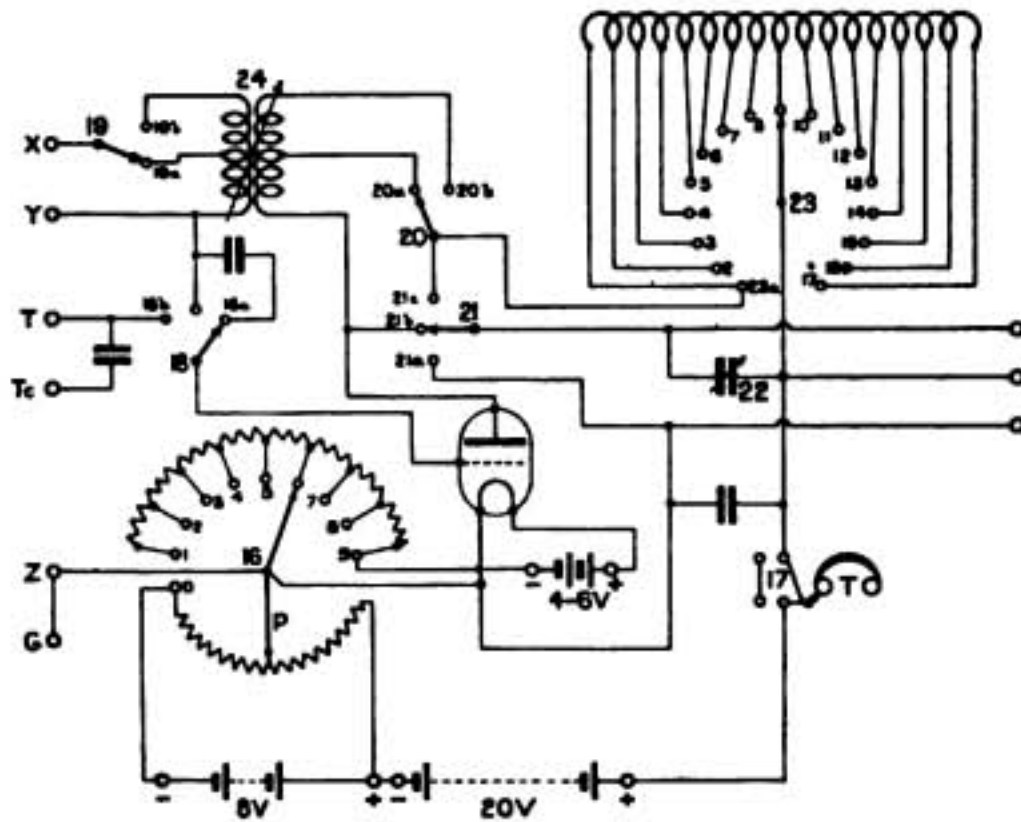


FIG. 6.

The valve filament may then be regulated by the rheostat **16** and the telephones changed over from the sockets on the receiver unit to those marked **17** on the amplifier unit. This unit enables C.W. signals to be received. The condenser can be placed in the grid circuit by putting switch **18** on to contact **18a** or a negative potential can be applied to the grid if it is put on to contact **18b**. The value of this negative potential can be adjusted by means of potentiometer **12** on the receiver unit if the short-circuiting link **15** is put in place. A fine adjustment of the potential applied to the anode of the valve is obtained by means of the potentiometer **P** connected across eight volts of the unit battery. Reaction between the anode and grid circuits of the valve is obtained by means of the coupling **24**, both windings of which are tapped at the centre point so that either half or the whole of the coils may be obtained by means of the switches **19** and **20**. A variable condenser **22** can also be shunted across the reactance inductance to provide finer tuning. It is claimed that a more selective adjustment may be obtained when jamming is severe and when using the valve for detection, by placing switch **7** on the receiver unit over to the left-hand contact **7a** instead of to the right-hand contact **7b** as is usual when using the additional amplifier unit H.F. 1. When this change is made the reactance **23 24** needs a finer adjustment.

## Current Suppression by Means of Parallel Resonance.\*

*By H. G. CORDES, Radio Research Engineer.*

The theory of suppressing radio frequency current by means of parallel resonance has been little dealt with in radio publications. It is the purpose of this paper to present the theory of this subject as applicable to radio signalling. Parallel resonance includes all coupled circuits in which the secondary is adjusted for resonance to the E.M.F. impressed upon the primary but the term is generally applied to coupled circuits in which no useful energy is withdrawn from the secondary circuit, the function of the secondary circuit being the suppression of current in the primary having an undesired frequency. The term "parallel resonance" will be used to indicate resonance in a secondary circuit the function of which is to suppress an undesired frequency in the primary circuit.

The fact that a radio parallel resonance circuit is practically always associated with a series resonance circuit distinguishes the former from parallel resonance in power circuits. The large impedance of a parallel resonance circuit to the flow of current in the primary circuit is due to the reaction of stored energy and not to the reaction of storing energy, in other words, energy must be stored in the parallel resonance circuit before it im-

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\* Received in final form January 3rd, 1921.

presses a counter E.M.F. upon the primary. This is similar to the counter E.M.F. of a motor with no load. The motor constitutes a large impedance to a steady impressed E.M.F. A change of impressed E.M.F. requires that kinetic energy be added to, or withdrawn from, the rotor which produces a flow of current. The energy stored varies with the size of the rotor; the energy stored in a parallel resonance circuit varies with the ratio of capacitance to inductance; and, the impedance decreases as the size or ratio increases.

The full benefits of parallel resonance are obtained when the current to be suppressed is a constant frequency sinoidal wave current having a constant or slowly varying amplitude. In addition to suppressing an undesired frequency parallel resonance can also be used to increase the selectivity of a received signal by suppressing the desired frequency in a circuit which is in parallel with a receiver.

In radio signalling where series resonance is desired at one frequency and parallel resonance at another frequency it is important to determine the condition which will simultaneously give minimum impedance to current of one frequency and maximum impedance to current of the other frequency. It is also desirable to introduce a parallel resonance circuit into a series resonance circuit without changing the resonant frequency of the series resonance circuit. The amplitudes of current and potential depend upon the impedance. The impedance depends upon the resistance and the reactance. The reactance depends upon the frequency. When the reactance is zero at a given frequency the resistance determines the amplitude of current and potential. In practice the reactance cannot be made zero, but it can be made small compared to the resistance of the circuit. The resistance of radio circuits is small compared to reactance at all frequencies except the resonant frequency at which frequency the reactance is small compared to the resistance. Adjustment depends upon reactance while efficiency depends upon resistance.

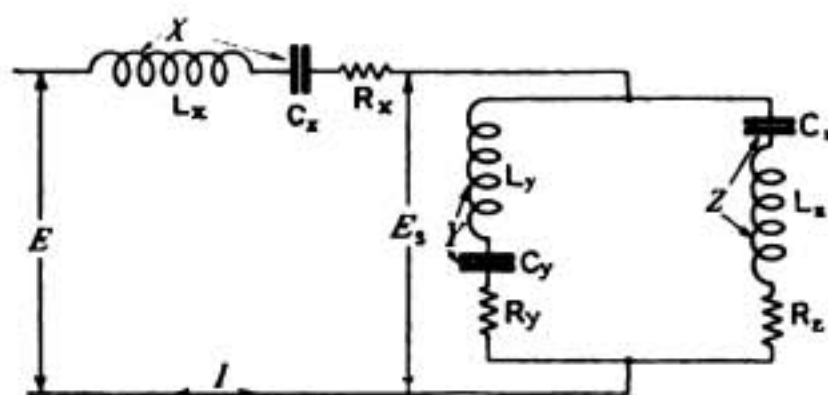


FIG. 1.

A parallel resonance circuit being a coupled circuit any type of coupling may be used to suppress current. The direct coupled circuit is best adapted to the suppression of current and will be the only one considered. All other types of coupling can be replaced with an equivalent direct coupling.

Fig. 1 shows a simple radio circuit. The inductance  $L_x$  and capacitance  $C_x$  having a resistance  $R_x$  constitute the series reactance of the series resonance circuit. The parallel reactances  $Y$  and  $Z$  constitute the parallel resonance

circuit. The reactance  $Y$  is due to the inductance  $L_y$ , and capacitance  $C_y$  having resistance  $R_y$  and reactance  $Z$  is due to the inductance  $L_z$  and capacitance  $C_z$  having resistance  $R_z$ .

Let  $I$  = the effective current flowing in the series resonance circuit due to an effective potential  $E$  impressed upon the circuit.

Let  $I_1$  = the effective current through  $L_y$  and  $C_y$ , and let  $I_2$  = the effective current through  $L_z$  and  $C_z$ . Then

$$I = I_1 + I_2 \text{ (vectorially)} \quad \dots \dots \dots (1)$$

The potential  $E_s$  in vector notation is

$$E_s = I_1(R_y - jY) = I_2(R_z - jZ) \quad \dots \dots \dots (2)$$

The potential  $E$  is

$$E = I(R_x - jX) + E_s \quad \dots \dots \dots (3)$$

Let  $S = R_p - jP$  = the impedance of the parallel reactances. The impedance  $S$  will be referred to as "suppressive" impedance and the components,  $R_p$  as suppressive resistance, and  $P$  as suppressive reactance. Then from (1) and (2)

$$S = \frac{E_s}{I} = \frac{(R_y - jY)(R_z - jZ)}{R_y - jY + R_z - jZ} \quad \dots \dots \dots (4)$$

From (4) the suppressive resistance  $R_p$  is

$$R_p = \frac{(Y + Z)(R_z Y + R_y Z) + (R_y + R_z)(R_y R_z - YZ)}{(R_y + R_z)^2 + (Y + Z)^2} \quad \dots \dots (5)$$

and the suppressive reactance  $P$  is

$$P = \frac{(Y + Z)(R_y R_z - YZ) - (R_y + R_z)(R_z Y + R_y Z)}{(R_y + R_z)^2 + (Y + Z)^2} \quad \dots \dots (6)$$

Let  $Q = R_u - jU$  = the total impedance of the parallel resonance circuit in series with the series resonance circuit, then

$$Q = \frac{E}{I} = R_x + R_p - j(X + P) \quad \dots \dots \dots (7)$$

From (7)  $R_u = R_x + R_p \quad \dots \dots \dots (8)$

and  $U = X + P \quad \dots \dots \dots (9)$

The scalar value of  $Q$  in the general equation (7) is

$$Q = \sqrt{\frac{[R_x(R_y + R_z) + R_y R_z - X(Y + Z) - ZY]^2 + [R_y(X + Z) + R_z(X + Y) + R_x(Z + Y)]^2}{(R_y + R_z)^2 + (Z + Y)^2}} \quad (10)$$

Equations (1) to (10) are general expressions from which special relations will be derived by letting certain reactances equal zero. The condition for series resonance is that  $X + P = 0$  and for parallel resonance is that  $Y + Z = 0$ . For brevity let "suppressor" indicate the positive and negative reactances in parallel which constitute the suppressive impedance. The parallel resonance circuit will be referred to as the suppressor circuit.

SERIES AND PARALLEL RESONANCE WITH ZERO PARALLEL REACTANCE.

It is desirable to obtain minimum impedance (series resonance) at one frequency and then secure maximum impedance (parallel resonance) at another frequency without annulling the adjustment for minimum impedance. This can be done by making both  $X$  and  $Y$  zero at the desired frequency and then making  $Y + Z = 0$  at the undesired frequency by varying  $Z$ .

Let  $Y = 0$  for the desired frequency, then from (5) the effective resistance of a zero-reactance suppressor is

$$R_p = \frac{R_y[Z^2 + R_z(R_y + R_z)]}{(R_y + R_z)^2 + Z^2} \dots \dots \dots (11)$$

and from (6)

$$P = - \frac{R_y^2 Z}{(R_y + R_z)^2 + Z^2} \dots \dots \dots (12)$$

Reactance  $Z$  is large compared to resistance  $R_y$  when the desired and undesired frequencies differ appreciably, therefore

$$\left. \begin{aligned} R_{p(\text{min.})} &= R_y \\ P_{(\text{min.})} &= 0 \\ S_{(\text{min.})} &= R_y \\ Q_{(\text{min.})} &= R_z + R_y \end{aligned} \right\} \dots \dots \dots (13)$$

Equations (13) are sufficiently accurate for practical purposes and show that series resonance or minimum reactance is practically independent of the value of  $Z$ . The value of  $Z$  may be either positive (inductance), negative (capacitance) or both (Fig. 1).

Let  $Y + Z = 0$  for the undesired frequency, then from (5) the suppressive resistance is

$$R_{p(\text{max.})} = \frac{R_y R_z + Z^2}{R_y + R_z} = \frac{R_y R_z + Y^2}{R_y + R_z} \dots \dots \dots (14)$$

and the suppressive reactance is

$$P_{(\text{max.})} = \frac{(R_y - R_z)Z}{R_y + R_z} = \frac{(R_y - R_z)Y}{R_y + R_z} \dots \dots \dots (15)$$

Since  $Z$  is large compared to the resistances, equation (14), for practical purposes, becomes

$$R_{p(\text{max.})} = \frac{Z^2}{R_y + R_z} = \frac{Y^2}{R_y + R_z} \dots \dots \dots (16)$$

Equation (15) shows that the suppressive reactance is zero when  $R_y = R_z$  and approaches  $Z$  as either  $R_y$  or  $R_z$  becomes negligible compared to  $R_z$  or  $R_y$ . It is a common fallacy to refer to the reactance  $P$  as being infinite; the fact is that  $P$  is small or equals zero while  $R_p$  approaches infinity as the sum  $R_y + R_z$  approaches zero. The value of  $R_p$  increases as the ratio of inductance to capacitance of the suppressor increases and also as the ratio of reactance to ohmic resistance increases.

ZERO PARALLEL REACTANCE.

The method of adjusting the parallel reactance  $Y$  to zero at the frequency at which the series reactance  $X$  is zero will now be considered. Let  $\omega$ ,  $L$  and  $C$  represent frequency in radians, inductance and capacitance respectively. Then referring to Fig. 1, the relation  $X = Y = 0$  when  $\omega = \omega_1$  gives

$$\omega_1 L_x - \frac{1}{\omega_1 C_x} = \omega_1 L_y - \frac{1}{\omega_1 C_y} = 0 \dots \dots \dots (17)$$

From (17)  $L_y C_y = L_x C_x \dots \dots \dots (18)$

which is the relation of inductances and capacitances of the series reactance  $X$  and a parallel reactance  $Y$  for zero value of  $U$  in equation (9).

There is a second frequency  $\omega_2$  at which  $U = 0$ . Resistances can be neglected in the determination of frequency. Neglecting resistances, (9) becomes

$$U = X + \frac{YZ}{Y + Z} \dots \dots \dots (19)$$

From (18) substituted in (19)

$$U = (\omega^2 L_x C_x - 1) \left[ \frac{1}{C_x} + \frac{\omega^2 L_x C_x - 1}{\omega^2 L_x C_x + \omega^2 L_x C_x C_y - (C_y + C_z)} \right] \dots (20)$$

From (20)  $U = 0$  when

$$\omega_1^2 = \frac{1}{L_x C_x} \dots \dots \dots (21)$$

and when

$$\omega_2^2 = \frac{C_x + C_y + C_z}{[L_x C_x + L_x (C_x + C_y)] C_z} \dots \dots \dots (22)$$

The frequency  $\omega_1$  is independent of the values of  $L_x$  and  $C_x$ . The second resonant frequency  $\omega_2$  can seldom be utilised in radio circuits.

Maximum impedance is determined by zero reactance in the suppressor circuit. Let  $\omega = \omega_\infty$  when  $Y + Z = 0$  in (19). Then

$$\omega_\infty^2 = \frac{C_y + C_z}{C_y C_z (L_y + L_z)} \dots \dots \dots (23)$$

The frequency  $\omega_\infty$  is independent of the values of  $L_x$  and  $C_x$ . There is only one frequency at which the impedance is a maximum. When  $\omega_\infty$  is known equation (23) can be solved for  $C_z$  or  $L_z$  to find the value required to suppress a given  $\omega_x$ .

AMPLITUDE OF CURRENTS AND POTENTIALS.

When resistances are negligible compared to reactances and  $P$  is negligible compared to  $X$  the minimum value of  $I$  from (7) and (16) is

$$I_{(min.)} = \frac{E}{\sqrt{\left(\frac{Y^2}{R_y + R_z}\right)^2 + X^2}} \dots \dots \dots (24)$$

The maximum value of  $I$  from (7) and (13) is

$$I_{(\max.)} = \frac{E}{R_x + R_y} \dots \dots \dots (25)$$

Assume that  $I_{(\min.)}$  is negligible compared with the current through  $Y$  and  $Z$  when the suppressive impedance is a maximum. Let  $I_p$  = current in the suppressor circuit. The energy supplied to the suppressor is equal to the energy dissipated in the suppressor circuit, that is,

$$[I_{(\min.)}]^2 \frac{Y^2}{R_y + R_z} = I_p^2 (R_y + R_z) \dots \dots \dots (26)$$

From (26)

$$\frac{I_{(\min.)}}{I_p} = \frac{R_y + R_z}{Y} \dots \dots \dots (27)$$

and the potential  $E_s$  impressed upon the suppressor is

$$E_s = I_p Y \dots \dots \dots (28)$$

$I_{(\min.)}$  is in quadrature with  $I_p$  and is therefore doubly negligible compared to  $I_p$ .

SERIES AND PARALLEL RESONANCE WITH ZERO SERIES REACTANCE.

There is a second arrangement by which a suppressor may be introduced into an oscillatory circuit without changing the resonant frequency of the oscillatory circuit.

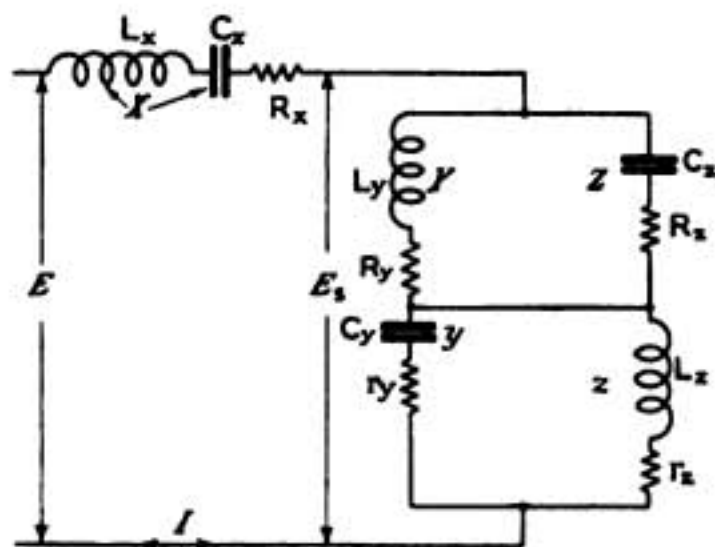


FIG. 2.

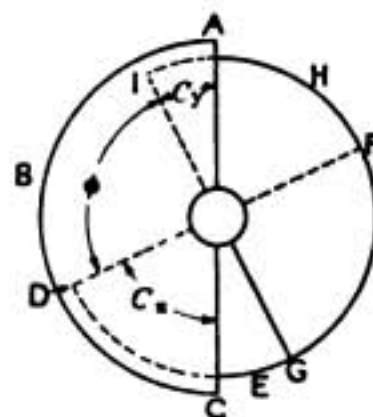


FIG. 3.

In Fig. 2 the suppressor comprises the suppressive reactances  $Y$  and  $Z$  and the compensating reactances  $y$  and  $z$  which have values to make the reactance of the suppressor zero at the series resonance frequency. The suppressive impedance is represented by

$$S = \frac{(R_y - jY)(R_z - jZ)}{R_y + R_z - j(Y + Z)} + \frac{(r_y - jy)(r_z - jz)}{r_y + r_z - j(y + z)}$$

$$= R_p - jP = R_p' + R_p'' - j(P' + P'') \dots \dots \dots (29)$$

The value of  $R_p'$  in terms of  $Y$ ,  $Z$ ,  $R_y$  and  $R_z$  is similar to  $R_p$  in equation (5). Similarly,  $R_p''$  in terms of  $y$ ,  $z$ ,  $r_y$  and  $r_z$  is similar to (5). The values of  $P'$  and  $P''$  are expressed by equations similar to equation (6).

The condition for minimum impedance of the suppressor, Fig. 2, is  $P' + P'' = 0$ , that is,

$$\frac{YZ}{Y + Z} + \frac{yz}{y + z} = 0 \quad \dots \dots \dots (30)$$

For given inductances and capacitances the frequency which will satisfy equation (30) is

$$\omega_1^2 = \frac{L_y + L_z}{(C_y + C_z)L_yL_z} \quad \dots \dots \dots (31)$$

The condition for maximum impedance is the same as in Fig. 1, that is,  $Y + Z = 0$  and the corresponding frequency is

$$\omega_\infty^2 = \frac{1}{L_y C_z} \quad \dots \dots \dots (32)$$

It is seen by referring to equations (31) and (32) that there is a second method for obtaining series resonance at one frequency and then secure parallel resonance at another frequency without nullifying the adjustment for series resonance. This consists in adjusting  $C_z$  to secure the proper value of  $\omega_\infty$  without changing the value of  $C_y + C_z$ .

Fig. 3 shows a practical method of adjusting  $C_y$  without varying  $C_y + C_z$ . Let ABC represent the fixed semi-circular plates of an air condenser. Let DEF be a set of rotatable semi-circular plates. Let GHI be a second set of rotatable semi-circular plates. Let DEF and GHI be rotatable with respect to each other and with respect to ABC. Fig. 3 therefore represents two air condensers of the usual type having shafts on a common axis. Let  $C_z$  represent the capacitance between ABC and DEF. Let  $C_y$  represent the capacitance between ABC and GHI. The capacitance  $C_y + C_z$  can be adjusted to any value by rotating DEF with respect to GHI, that is, by varying the angle  $\phi$ . For a given value of  $C_y + C_z$  the capacitance  $C_y$  can be varied while  $\phi$  remains constant.

This form of zero-reactance suppressor has greater suppressive impedance than a parallel zero reactance arrangement but it introduces more resistance into the circuit. It practically doubles the resistance to secure the advantages of simultaneous zero reactance and adjustability for maximum impedance.

#### NUMERICAL EXAMPLE.

A comparison of the arrangement of Figs. 1 and 2 can be best made by referring to Table 1, which is a tabulation of suppressive resistance, reactance and impedance for assumed values of frequency, inductance, capacitance and ohmic resistance. Let the series resonance frequency  $\omega_1 = 10^6$  and the parallel resonance frequency  $\omega_\infty = 9 \times 10^5$ . Assume in Fig. 1 that  $Y = 100 - 100 = 0$  ohms, when the series resonance frequency  $\omega_1 = 10^6$  which corresponds to  $L_y = 0.1$  millihenry and  $C_y = 0.01$  microfarad. Assume resistance  $R_y$  of  $L_y$  and  $C_y$  in series to be 1 ohm. Assume



$Y + Z = 0$  when  $\omega_\infty = 9 \times 10^5$  which corresponds to  $L_z = \frac{1.9}{81} \times 10^{-1}$  mH and  $C_z = \infty$ . Assume  $R_z = 0.2$  ohm. The wavelength  $\lambda$  is given in metres.

The suppressor circuit of Fig. 2 is the same as in Fig. 1 including the total ohmic resistance; therefore  $L_y = \frac{1.9}{81} \times 10^{-1}$  mH and  $C_z = 0.01 \mu\text{F}$ . Assume  $R_y = 1$  ohm and  $R_z = 0.2$  ohm. Assume  $L_z = 0.1$  mH then from (31)  $C_y = 0.0081 \mu\text{F}$  for minimum suppressive impedance when  $\omega_1 = 10^6$ . Assume  $r_z = 1$  ohm and  $r_y = 0.2$  ohm.

TABLE I.

$\omega \times 10^{-4}$	$\lambda$	FIG. 1.				FIG. 2.						
		$R_p$	$P$	$S$	$\frac{YZ}{Y+Z}$	$R_{p'}$	$P'$	$R_{p''}$	$P''$	$R_p$	$P$	$S$
102	1,848	0.74	-3.42	3.50	3.40	16.4	442	33.3	-646	50	-204	210
101	1,866	0.85	-1.87	2.05	1.84	19.5	480	26.1	-580	46	-100	110
100	1,885	1.00	-0.05	1.00	0	23.7	525	20.8	-525	44	0	44
99	1,904	1.20	2.14	2.45	-2.20	29.2	580	16.8	-480	46	101	111
98	1,923	1.48	4.82	5.04	-4.90	37.0	649	13.7	-441	51	209	215
97	1,943	1.88	8.19	8.40	-8.32	48.4	738	11.3	-407	60	330	336
96	1,963	2.5	12.6	12.9	-12.8	65.9	855	9.4	-378	75	476	482
95	1,984	3.5	18.7	19.0	-19.0	94.8	1,018	7.9	-353	103	665	673
94	2,005	5.4	27.6	28.1	-28.2	148	1,259	6.6	-330	154	928	941
93	2,027	9.5	42.0	43.1	-43.5	260	1,651	5.6	-310	266	1,341	1,367
92	2,049	20.7	68.8	71.8	-73.9	569	2,388	4.7	-292	574	2,095	2,173
91	2,071	70.4	129.7	147.6	-163.9	1,955	4,072	4.0	-276	1,958	3,796	4,272
90	2,094	371.5	-14.1	371.5	$\mp \infty$	10,288	74	3.4	-262	10,292	-188	10,292
89	2,118	71.9	-162.0	177.2	196.7	1,977	-4,015	2.8	-248	1,980	-4,264	4,701
88	2,142	22.3	-106.6	108.9	105.8	579	-2,333	2.4	-236	581	-2,569	2,634

Table I. is self-explanatory. Among other interesting facts it shows the low resistance introduced into the series resonance circuit in Fig. 1 and the high suppressive impedance introduced into the circuit of Fig. 2. The reactance of a suppressor determines the impedance except when the reactance is zero; the reactance is zero at practically both minimum and maximum impedance. The reactance has a positive and negative maximum value when  $\omega$  is slightly greater or less than  $\omega_\infty$ . Let  $R_z = R_y$  in (6) then the maximum value of  $P'$  as  $\omega$  is varied occurs when  $\pm (Y + Z) = 2R_y$ .

The suppressor of Fig. 1 should be used where minimum resistance is the most important factor. The suppressive impedance of Fig. 1 can be made to approach that of Fig. 2 by increasing the ratio of inductance to capacitance of the suppressor circuit; this increases the resistance for series resonance and the ratio is limited in practice by the distributive capacitance of the inductance coil or spiral. Research work is required to determine the best form and size of coil for minimum ratio of resistance to inductance for a given distributive capacitance; also the arrangement for maximum value of the ratio of maximum to minimum impedance in any particular case.

The suppressor of Fig. 2 should be used where maximum suppressive impedance is required. The addition of the compensating reactances,  $y$  and  $z$ , nearly doubled the resistance introduced at series resonance; this resistance can be reduced by making  $C_y = 0$  and  $L_z = 0.5$  mH but at the sacrifice

of adjustability. The series resonance resistance of the suppressor can be further reduced by omitting the compensating reactances when only one fixed wavelength is to be suppressed.

In Fig. 2 the suppressor introduces two additional frequencies at which series resonance takes place and one additional frequency at which parallel resonance occurs.

#### SUPPRESSION OF INTERFERING CURRENT IN AN AERIAL CIRCUIT.

Parallel resonance is especially useful in suppressing an undesired frequency current in an aerial circuit. A zero-reactance suppressor introduces a relatively small ohmic or effective resistance into the aerial circuit for received signal current but a high effective resistance to interfering current.

Fig. 4 shows an antenna circuit arrangement in which the signals from two stations are being received and two interfering signals are being suppressed. The zero-reactance suppressors  $S_1$  to  $S_6$  are either as shown in Fig. 1 or in Fig. 2.

Let the wavelengths  $\lambda_r'$  and  $\lambda_r''$  be received by receivers 1 and 2 respectively and let the interfering wavelengths be  $\lambda_i'$  and  $\lambda_i''$ . Then  $S_1, S_3$  and  $S_4$  are a minimum for  $\lambda_r'$  and  $S_2, S_5$  and  $S_6$  are a minimum for  $\lambda_r''$ .  $S_1$  is a maximum for  $\lambda_r''$  and  $S_2$  is a maximum for  $\lambda_r'$ .  $S_3$  and  $S_5$  are maximum for  $\lambda_i'$  and  $S_4$  and  $S_6$  are maximum for  $\lambda_i''$ . Opening a switch introduces a low resistance to one frequency current and a high resistance to another frequency current. Any number of zero-reactance suppressors may be placed in series or in parallel. Suppressive impedances  $S$  may be treated mathematically as non-inductive resistances having either small or large values. As the ratio

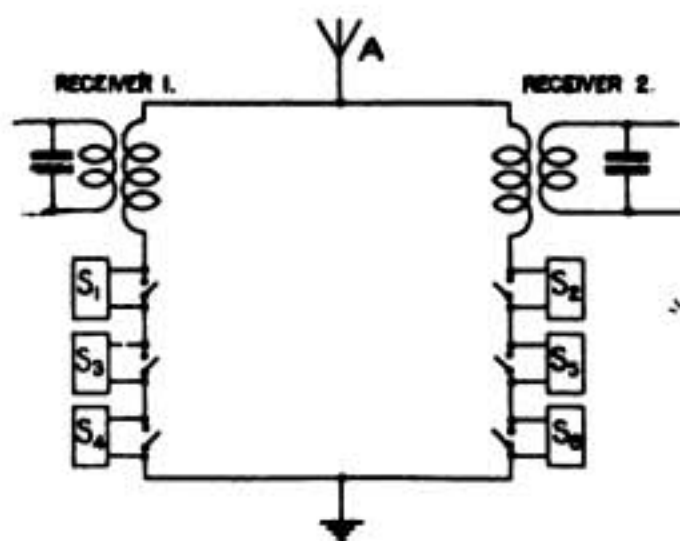


FIG. 4.

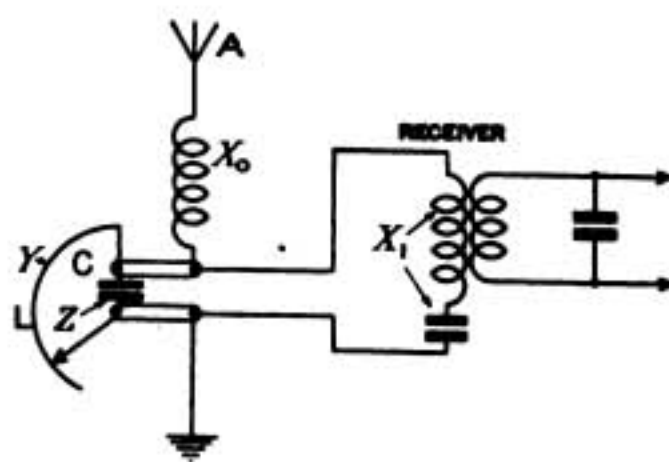


FIG. 5.

of  $L$  to  $C$  of a suppressor circuit decreases the energy consumed by the suppressor increases and the suppressive impedance decreases. Each suppressor introduces at least one additional resonant frequency into the series resonance circuit. Each suppressor can be graduated in wavelengths for minimum impedance and graduated in arbitrary units for interfering wavelengths. The interfering wavelengths corresponding to the arbitrary

units for each received wavelength can be tabulated for reference. For duplex sending transmitters are substituted for the receivers.

SELECTIVITY.

The selectivity secured and the energy absorbed from waves by an aerial circuit is greatly increased by series resonance. Selectivity can also be attained by parallel resonance. Fig. 5 shows an arrangement by which the selectivity of a series resonance circuit is increased by means of a parallel resonance circuit.

In Fig. 5 the parallel resonance circuit consists of a small inductive reactance  $Y$  and a small capacitive reactance  $Z$ . The inductance  $L$  is very small and the capacitance  $C$  is very large.

The parallel resonance circuit is connected in parallel with the reactance  $X_1$  to which the receiver is coupled. At the wavelength  $\lambda_r$  which is being received  $X_0 = X_1 = Y + Z = 0$  where  $X_0$  is the reactance of the antenna circuit. For  $\lambda_r$  the impedance of  $X_0$  and  $X_1$  is a minimum and the impedance of the shunted suppressor is a maximum. Nearly all the signal current flows through  $X_1$  and little through  $Y$  and  $Z$ . For an interfering wavelength  $\lambda_i$  the impedance of  $X_0$  and  $X_1$  is large while the impedance of the shunted suppressor is much less than for  $\lambda_r$ . The parallel reactances  $Y$  and  $Z$  constitute a by-pass or diverter for the current of all wavelengths differing from  $\lambda_r$ . The efficiency of the shunted suppressor as a divertive reactance increases as the product of positive reactance  $Y$  and negative reactance  $Z$  decreases, that is, as the ratio of  $L$  to  $C$  decreases.

The divertive reactance  $S_d$  of the diverter, for all wavelengths differing from  $\lambda_r$  sufficiently to make the effective resistance negligible compared to the reactance, is

$$S_d = \frac{YZ}{Y + Z} = \frac{K\lambda_i}{\lambda_r^2 - \lambda_i^2} \cdot L \quad \dots \dots \dots (33)$$

where  $K$  is a constant. The impedance  $S_d$  for  $\lambda_r$  is expressed by equation (16) and for any interfering wavelength  $\lambda_i$  the divertive reactance is given by (33). As the ratio of  $L$  to  $C$  decreases the selectivity is increased but the received signal intensity becomes less because the suppressive resistance of the diverter is reduced and a larger part of the signal current passes through the diverter. The selectivity due to series resonance is increased by *increasing* the ratio of  $L$  to  $C$  but intensity of the signal is decreased due to the increase of resistance in the antenna circuit. The ratio of  $S_d$  for  $\lambda_i$  to  $S_d$  for  $\lambda_r$  varies directly as the damping factor of the diverter circuit, that is, as the resistance of  $L$  and  $C$  in series divided by  $2L$ . The leads to the diverter should not be allowed to inductively affect  $L$ .

By tuning  $X_1$  and the diverter to  $\lambda_r$  and detuning  $X_0$  from  $\lambda_r$  the signal-stray ratio can be greatly increased but at a great sacrifice of received signal intensity.

Fig. 6 shows a combination of suppressors and diverters. The suppressive resistance of  $S_1$  is a maximum for the wavelength  $\lambda_r$  selected for reception and is a minimum for the transmitted wavelength  $\lambda_t$ . The suppressors  $S_2, S_3$

and  $S_4$  are similar and have a maximum  $R_p$  for  $\lambda_t$  and a minimum  $R_p$  for  $\lambda_r$ . The diverters  $D_1$  to  $D_3$  are tuned to  $\lambda_r$ . The arrangement of  $S_2$ ,  $S_3$  and  $S_4$  is equivalent to one suppressor having an increased ratio of  $L$  to  $C$  and  $D_1$ ,  $D_2$  and  $D_3$  is equivalent to a diverter having a decreased ratio of  $L$  to  $C$ . Two

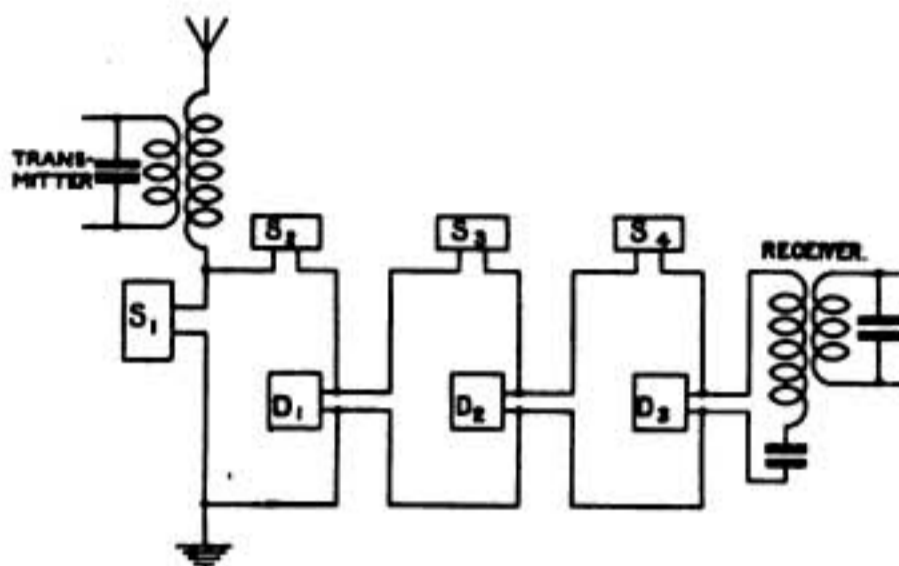


FIG. 6.

suppressors connected in series and tuned to the same interfering wave are equivalent to one suppressor with a larger ratio of  $L$  to  $C$ .

#### QUALITY OF WAVES.

Suppressive impedance and selectivity are determined by sharpness of resonance which depends upon the resistance and ratio of inductance to capacitance of the resonant circuit of the receiver and upon the quality of wave emitted by the transmitter. When further increase in sharpness of resonance is limited by poor quality of waves improvement in the receiver is useless. The three principal factors which determine the quality are: (1) The rate of change of amplitude, (2) the constancy of wavelength, and (3) the distortion of wave-form from a sine wave.

Suppressive impedance decreases as the rate of change of amplitude of the interfering wave increases; it decreases as the ratio of energy dissipated to the energy stored in, or withdrawn from, the suppressor circuit decreases. In other words, the counter E.M.F. of the suppressor is too low while the amplitude is increasing rapidly and too large while the amplitude is decreasing rapidly.

The beginning and ending of a dot or dash of telegraphic signals permits generally a large rate of change of amplitude. This difficulty can be largely overcome by changing the frequency of beats to produce signals, gradually increasing and decreasing the amplitude of current, or both. The rate of change of amplitude due to speech in telephony is too small to appreciably reduce sharpness of resonance at short wavelengths.

Maximum impedance depends upon a definite frequency and any variation reduces the impedance. Reference to Table I. will show the decrease as the frequency varies.

Distortion of the wave-form from a sine wave reduces the maximum suppress-

sive impedance because the instantaneous counter E.M.F. of the suppressor must be of the same form as the impressed E.M.F.; the former is practically a pure sine wave. In order for a transmitted wave to be a pure sine wave the instantaneous rate at which energy is transferred to an antenna circuit during a complete cycle must equal the instantaneous rate at which energy is dissipated in the antenna circuit by radiation and losses; this cannot be realised in practice. The constant amplitude waves of high frequency alternators, Poulsen arcs and thermionic current oscillators approach a sine wave.

A standard method should be adopted for comparing the quality of waves. The present standard of damping factor or logarithmic decrement of a damped wave is a measure of one form of rate of change of amplitude. As interference from other stations becomes more common and the use of constant amplitude waves becomes more general the need for a more general and exacting standard becomes more urgent. Fig. 7 is suggested as an arrangement which will meet the requirements.

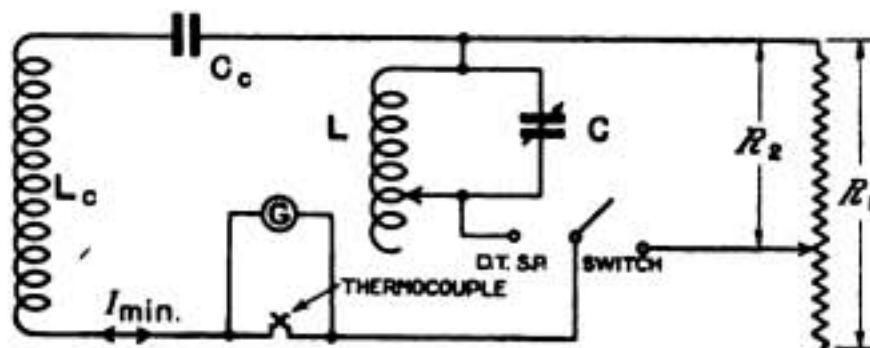


FIG. 7.

Fig. 7 is an arrangement of a wave tester comprising an inductance  $L_c$  which is very loosely coupled to the transmitter of the wave to be tested, a suppressor LC, a thermocouple and galvanometer G to measure the suppressed current  $I_{(min.)}$ . The non-inductive resistance  $R_1$  is equal to the suppressive resistance of LC for a sine wave and  $R_2$  is equal to the suppressive impedance of LC for the wave to be tested. The values of  $R_1$  and  $R_2$  are determined by throwing the double throw switch without changing the deflection of the galvanometer. The large condenser  $C_c$  stops D.C. flowing through  $L_c$  from the thermocouple. The ratio of  $R_2$  to  $R_1$  is a measure of the quality of the wave. The value of  $R_1$  can be either measured with a sine wave current or calculated from the constants of the suppressor by equation (16). The only part in this arrangement which would require standardisation is the suppressor circuit.

Suppressive impedance as a standard has decided advantages when compared with a minimum impedance standard or a standard of maximum current  $I_p$  in the suppressor circuit. Minimum impedance depends upon the measurement of a small resistance and impedance which approaches zero instead of infinity as a pure sine wave is approached. The maximum value of  $I_p$  varies directly with the square root of the suppressive resistance  $R_p$ ; both  $I_p$  and  $R_p$  depend upon the small resistance  $R_v + R_z$  of the suppressor

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circuit. It is difficult to measure  $I_p$  without adding an effective resistance to  $R_y + R_z$  due to the withdrawal of energy from the suppressor circuit. Furthermore, both the suppressor and method of measuring  $I_p$  would have to be standardised.

#### REFERENCES.

Among the few references available the following are briefly noted. The most complete is the *U.S. Bureau of Standards Circular No. 74* which deals principally with variation of reactance with frequency and not with impedance. The apparently simple fact that  $U = 0$  when  $X = Y = 0$  was overlooked although the special case (pp. 50 and 62) is noted that  $U = 0$  when  $C_x = C_y$  and  $L_x = L_y$  and that the zero value of  $U$  is then independent of the value of  $Z$ .

In the *Proceedings of the Institute of Radio Engineers* for December, 1919, F. A. Kolster proposes a suppressive impedance to suppress an undesirable harmonic in a Poulsen arc transmitter. The proposed suppressor comprises three tungsten lamps and the suppressor circuit is termed a "sucking out" circuit because it is believed that suppressive impedance is due to absorption of energy by the lamps. Reference to equation (16) discloses the error.

The impedance of a parallel resonance circuit to an electrical impact in the series resonance circuit is correctly stated by J. H. Morecroft, in the *Proceedings of the Institute of Radio Engineers* for February, 1920, to be very small. This is due to the large rate of change of amplitude and no resonance effects.

The use of a divertive reactance was described by J. S. Stone in U.S. Patent No. 884108, filed in 1906, but the subject has apparently been ignored by radio publications since that date.

BREMERTON, WASH., U.S.A.

November, 1920.

## German Developments in C.W. Stations.\*

One of the minor results of the war has been that the German telegraphic lines are either in a bad state of repair or completely out of service. In consequence of this and of the growing commercial demands the Telegraph Department have erected a considerable number of medium power radio stations designed to replace in part the imperfections of the wire telegraph system. At the present time these stations are handling considerable traffic. Several of them operate on continuous waves using valve oscillation generators working on wavelengths between 900 and 2,500 metres. The most important stations are set out in the table below which also gives their wavelength and the system of operation.

Of these the most interesting are the recently developed 1 kW C.W. stations which are operated with valve oscillation generators. These

\* Abstracted from *La T.S.F. Moderne*—see Abstract No. 2094 in this issue for reference.

stations are divided into three main parts—the transmitting unit, the receiving unit, and the power unit.

Locality.	Call Sign.	Wavelength.	Type of Transmission.
Munich . . . . .	C W	1,200	Quenched spark.
Darmstadt . . . . .	D A	1,725	C.W. valves.
Berlin Wolff . . . . .	D K	2,100	do.
Berlin . . . . .	D M	1,900	do.
Dortmund . . . . .	D R	1,400	do.
Friedrikshafen . . . . .	F D	?	do.
Frankfort-on-the-Maine . . . . .	F M	1,975	do.
Frankfort-on-the-Oder . . . . .	F 4	1,200	Quenched spark.
Stettin . . . . .	G M	1,200	do.
Hamburg . . . . .	H G	2,100	C.W. valves.
Hanover . . . . .	H W	2,300	do.
Constance . . . . .	K N	1,450	do.
Königsberg . . . . .	K O	2,500	do.
Leipzig . . . . .	L Z	1,100	do.
Magdeburg . . . . .	M A	1,200	Quenched spark.
Neuenmunster . . . . .	O K	1,200	do.
Staaken . . . . .	S K	?	C.W. valves.
Hanover . . . . .	S F	1,200	Quenched spark.
Stettin . . . . .	S N	1,800	C.W. valves.
Stuttgart . . . . .	S G	1,200	Quenched spark.
Frankfort-on-the-Maine . . . . .	W H	1,200	do.
Munster Rühr . . . . .	W I	1,200	do.
? . . . . .	W U	1,200	do.
Nuremberg . . . . .	X I	1,200	do.
Cassel . . . . .	X U	1,200	do.

The transmitter is made up into four boxes containing respectively the valves and their filament circuits, the grid and plate coils, the aerial tuning inductance and variometer, and the aerial shortening condensers.

For this transmitter two 500 watt three-electrode valves are employed. These valves are carefully constructed without any internal soldering or welding, the plate being rivetted to its support. The filament is V-shaped and is maintained in tension by a spring. The grid is wound around four metallic supports arranged at the corners of a square of one inch side while the plate is in the form of a cylinder of about  $1\frac{1}{2}$  inches diameter. The external dimensions of the valve which is roughly cylindrical in shape are approximately 10 inches high by 3 inches diameter. The filament requires five amperes at 15 volts to heat it.

Transmission may be effected in either of two ways, using a rectified alternating current or plain alternating current for the plate circuit supply,

the latter giving a tonic train emission. In the actual installation a special switch is provided for quickly changing from one to the other arrangement.

The general scheme of connections of the transmitting unit is given in Fig. 1 from which it may be noted that the two valves are used in parallel, and that the filament circuit of each is fed from an independent transformer.

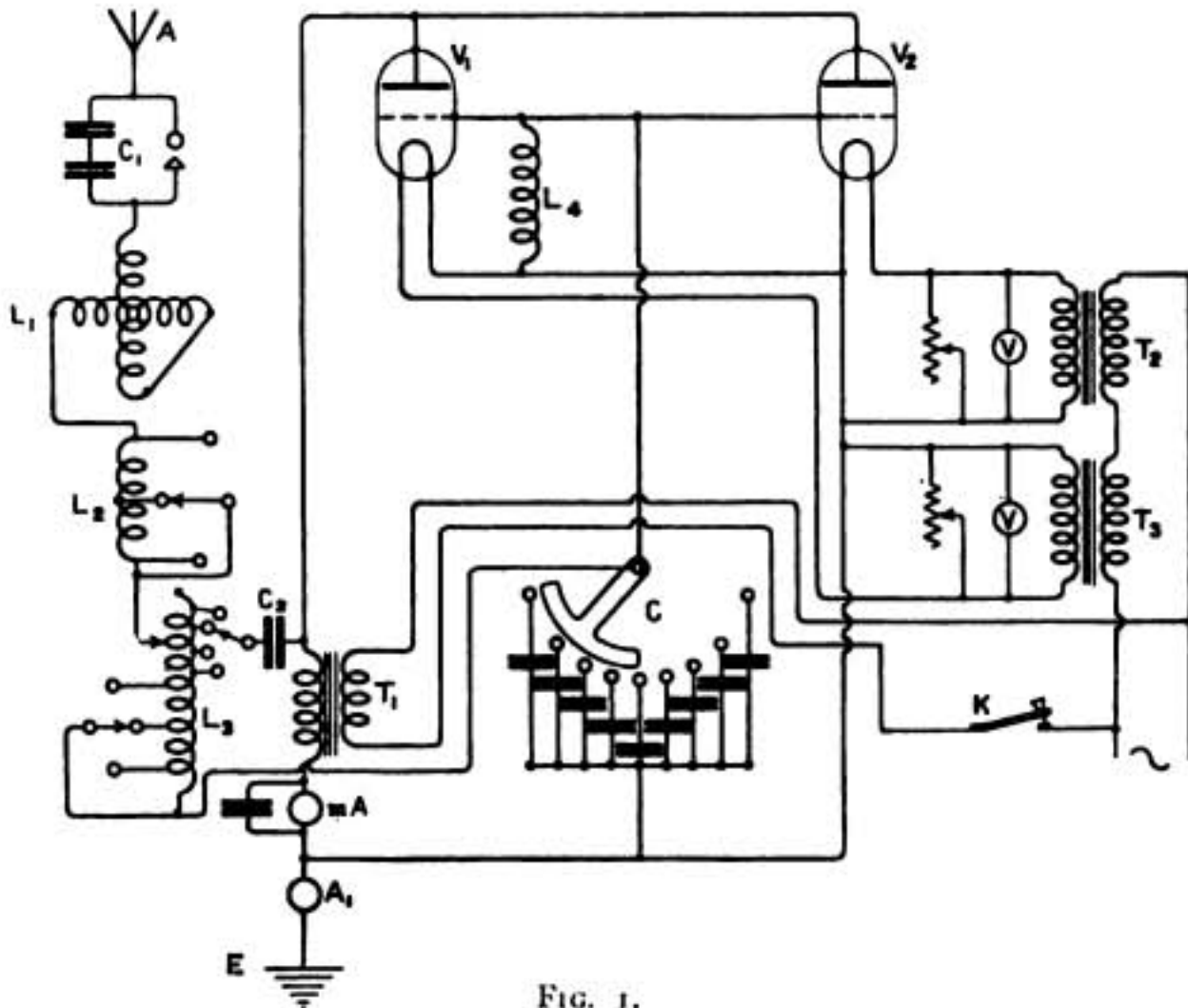


FIG. 1.

In this diagram only the A.C. plate circuit supply for tonic train emission is indicated but when rectified A.C. is employed the transformer  $T$  is replaced by the condenser in which the rectified pulses are stored up.

The supply for the plate circuits and for the filament is drawn from the same alternator as indicated in the diagram. The temperature of the filaments can be regulated by means of the rheostats shown. For smoothing out the irregularities in the rectified current eight condensers of two microfarads each are joined in series, the supply for the three-electrode valves being taken from their terminals. For reducing the wavelength of transmission condensers  $C$  are arranged so that a variable number may be inserted in the earth connection. The normal aerial current is about 5 amperes.

For reception a two-valve low frequency amplifier is employed using the same aerial as is also employed for transmission.

In each station two power units are fitted one for normal operation and the other a spare. The power unit consists of a 110 volt motor driving a 500 cycle 220 volt alternator from which the valve supply is drawn in the manner indicated above.



### A Peculiar Electrostatic Phenomenon.

A lecture describing a peculiar electrostatic phenomenon was given at an ordinary meeting of the Institution of Electrical Engineers by Messrs. A. Johnsen and K. Rahbek on May 26th. The lecturers described apparatus developed by them from experiments commenced in 1917 on the properties of semi-conducting materials. By placing a slab of such a material between the plates of a condenser—one plate being in the form of a disc 2" diameter suspended from the arm of a balance—it was shown that when a potential of 400 volts was applied to the plates, it required a weight of over a kilogram to pull the disc away from the material. The current flowing through the apparatus was extremely minute.

The effect appears to be due to the formation of a layer of ions on the surface of the semi-conducting material, so that the small distance separating this layer from the metal disc resting on it accounts for the large attracting force. If the semi-conductor is made up in the form of a disc or cylinder on the surface of which one metal electrode rests, the attractive force called into play when a potential is applied gives rise to an increased friction between the metal and the material if the latter is maintained in rotation by a suitable motor.

Applications of this apparatus to "no-volt" relays, to telegraphic recorders and to loud-speaking telephones were described. A demonstration was given of a violin used as a loud speaker by attaching to it an agate cylinder round which was wrapped a metal band attached to the body of the violin, the reproduction of both music and speech being very clear and loud. Many materials have the property of showing these effects, and in particular lithographic stone, slate, and agate may be mentioned.

### Long Distance Wireless Transmission.

A discussion on this subject took place at a meeting of the Wireless Section of the Institution of Electrical Engineers on May 25th. The discussion was opened by Mr. C. F. Elwell who reviewed the theoretical and experimental work on the subject and maintained that there was no reliable data for the determination of the power required for distances and wavelengths beyond those covered by the experiments of Austin. He thought that amateurs could assist in collecting data. Admiral Sir Henry Jackson regarded the measurements as too difficult for amateurs, but emphasised the necessity for such measurements being made. Messrs. Round, Eckersley and Lunnon described the work being done by the Marconi Company at Chelmsford using a carefully calibrated aerial 16 metres high and determining by a substitution method the E.M.F. induced in it by some of the large American transmitting stations. Although varying considerably the average E.M.F. was 1.8 times that given by the Austin-Cohen formula. The measured E.M.F. agreed fairly well with the field strength of 0.37 microvolts per cm which we assumed as the basis for the tables of necessary transmitting power (see *RADIO REVIEW*, 1, p. 598, September, 1920).

Captain Lee described somewhat similar measurements made by the Radio Communication Company using a 4-foot frame with 120 turns; preliminary tests have given a field strength of 0.2 microvolts per cm for the signals from Annapolis. Several speakers mentioned that the signals from these American stations are weaker during the night than during the day, although for stations in other directions the reverse is true.

G. W. O. H.

## Notes.

### Personal.

**Mr. F. Golding**, Director of Radio Services in the Commonwealth of Australia Postal Department, has been appointed by the Commonwealth Postmaster-General as a commissioner to visit the United States, Canada, Britain and the Continent.—*Sydney Morning Herald*. [2580]

An announcement has recently been made that the following French radio engineers have been nominated Chevaliers of the Legion of Honour for their inventions :—

- J. Bethenod** (high-frequency alternators).
- E. Bloch** (applications of vacuum tubes to radiotelegraphy).
- L. Bloch** (applications of vacuum tubes to radiotelegraphy).

**A. Dufour** (cathode ray oscillograph).

**M. Latour** (high-frequency alternator; theoretical studies of vacuum tubes and their application to radiotelegraphic communication). [2808]

The Albert Medal of the Royal Society of Arts for 1921 has been awarded by the Council, with the approval of the President, H.R.H. the Duke of Connaught and Strathearn, K.G., to **Professor John Ambrose Fleming**, M.A., D.Sc., F.R.S., in recognition of his many valuable contributions to electrical science and its applications, and specially of his original invention of the thermionic valve, now so largely employed in wireless telegraphy and for other purposes.

The Medal was instituted in 1862 as a memorial of H.R.H. the Prince Consort and is awarded annually for "distinguished merit in promoting Arts, Manufactures and Commerce." [2999]

*The Times* announces the death of **Dr. Edward B. Rosa**, Chief Physicist at the Bureau of Standards, Washington, U.S.A., on May 17th. One of America's leading scientists he was known to scientific men in England from his attendance at meetings of the British Association, and by his numerous publications on electrical investigations. [2784]

**Mr. George S. Davis**, who is in charge of the Radio Service of the United Fruit Company, has been elected a director of the Radio Corporation of America. Mr. Davis is also President of the Wireless Specialty Apparatus Company of Boston, Mass. [2753]

**Dr. F. B. Jewett**, Chief Engineer of the Western Electric Company, U.S.A., has been elected a Vice-President and Director of that Company, but he will continue his present duties in charge of the Technical Department. During the war he was a Lieut.-Colonel in the U.S. Signal Corps and was decorated with the D.S.M. [2754]

**Commander R. L. Nicholson** has been appointed Director of Wireless Telegraphy in India in succession to Colonel A. Simpson. [2789]

**H. Brodow** has been appointed Secretary of State to the Ministry of Posts, for the whole of the telegraph, telephone and wireless services of Germany. [2863]

### Commercial.

It is reported that the concession recently given to Marconi's Wireless Telegraph Company for operating the Peruvian wireless and land line telegraph service for twenty-five years has been made the subject of representations by the United States Government. [2742]

The balance sheet of the Radio Corporation of America at December 31st shows the following:—Assets, cash and receivables, \$881,507; merchandise inventories, \$689,516; investments in Government and industrial bonds, \$3,375,210; stocks of associated companies, \$550,385; plant and equipment, \$8,901,675; deferred charges, \$606,669; patents and goodwill, contracts and franchises, \$10,107,982. Current liabilities are \$1,883,227. [2850]

**WIRELESS EQUIPMENTS ON SWEDISH VESSELS.**—It is stated that the operation of the British Merchant Shipping Wireless Telegraphy Act which renders compulsory the installation of radio apparatus on all vessels over 1,600 tons is meeting with opposition in Swedish merchant shipping circles and that a petition has been forwarded to the Swedish Ministry of Marine to secure exemption from the operation of the Act until the end of the current year owing to difficulties in obtaining the necessary apparatus. [2853]

**NEW WIRELESS PLANT FOR COLTANO.**—A decree dated December 20th, 1920, refers to an agreement between the Italian Minister of Posts and Telegraphs and the Italian Minister of Marine for the reorganisation of the wireless installation at Coltano naval radio station. The station is to be handed over to the Minister of Posts and Telegraphs after reorganisation. [2846]

**IMPERIAL WIRELESS SCHEME.**—An announcement has been made that preliminary action has been taken for the selection of a site in Western Australia for the erection of a wireless station in connection with the Imperial Chain. [2848]

Lieut.-Colonel E. Gold, Assistant Director of the Meteorological Office, reports that it has been decided to establish a wireless station in Greenland for daily weather reports. Another development expected in the near future is the establishment of daily weather communications between Britain and Canada. [2730]

**New Wireless Services, etc.**

**A NEW WIRELESS SERVICE.**—It is announced from Washington that a commercial wireless service has been established between the United States and the Dutch East Indies. [2651]

**WIRELESS MESSAGES TO SHIPS—SIMPLIFIED PROCEDURE.**—Post offices in London and the provinces will now accept wireless messages addressed to persons on ships at sea (which are within range of the coastal wireless stations of the United Kingdom) without requiring the sender to specify the station through which the message should be transmitted. This new arrangement removes what undoubtedly has been a serious obstacle to the free use of wireless telegraphy between this country and ocean travellers. [2781]

**SIGNALLING RANGE OF THE EASTHAMPTON RADIO STATION.**—We have received from the Cutting and Washington Radio Corporation, New York, an interesting chart showing some of

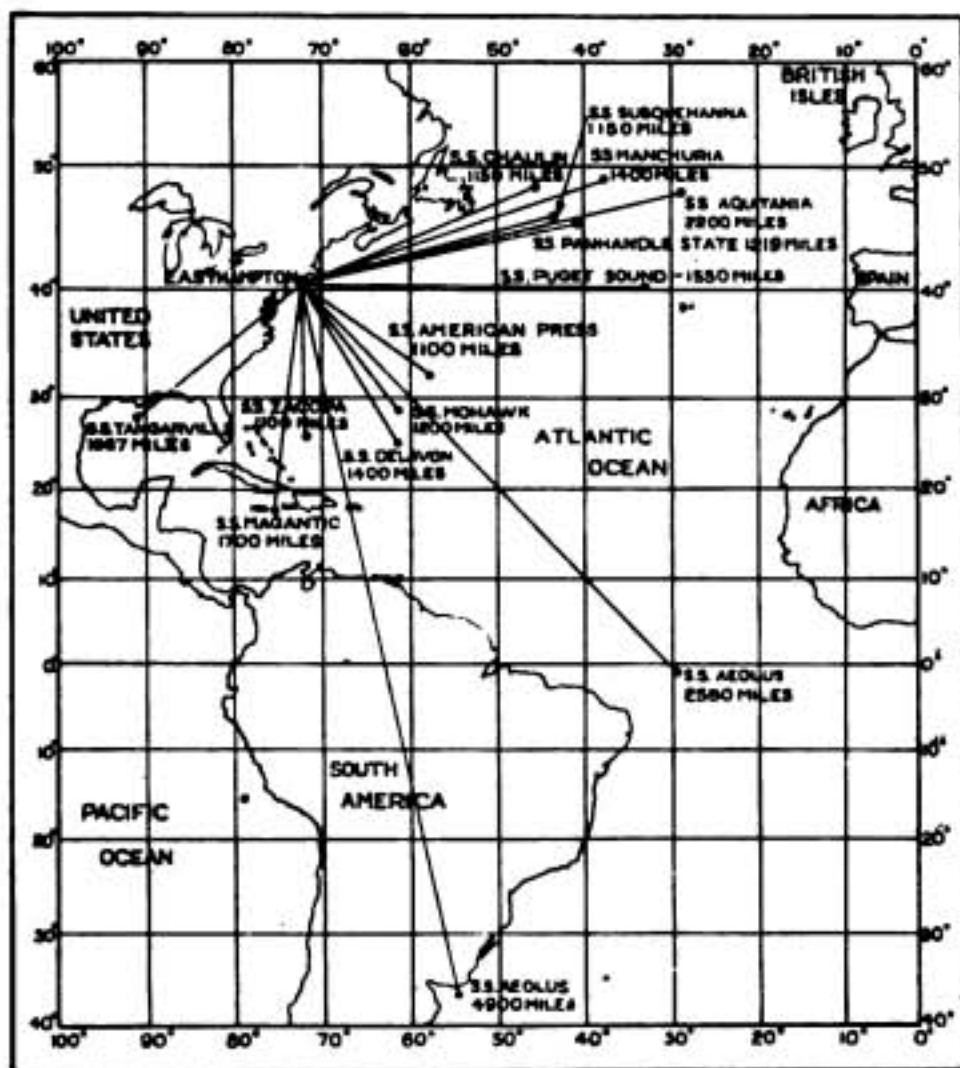


Chart of Long Range Communication by the Easthampton Station.

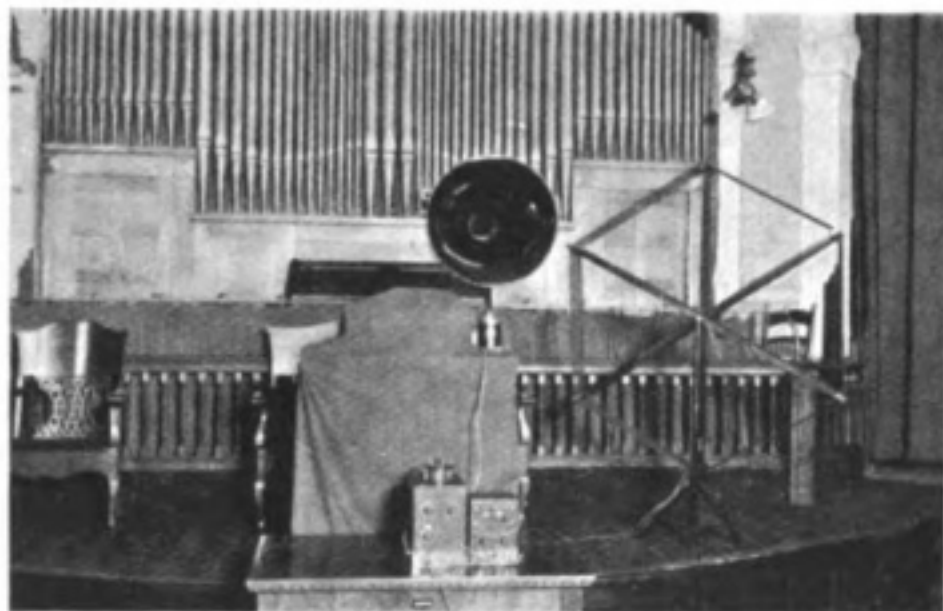
the long range communications that have been effected by their new coast radio station at Easthampton, L.I. A brief description of this station was published in our issue of February, 1921, and the chart reproduced herewith shows that signals from the station have been heard over a range of 4,900 miles. [2644]

**WIRELESS FOG SIGNALS.**—The Secretary of Commerce, U.S.A., announces that three wireless fog signals are to be immediately installed at the entrance to New York Harbour. Each of these three stations will be equipped with an automatic set which will send out signals continuously during fog or thick weather. These signals may be picked up on shipboard by means of a radio compass so that, by taking observations on the different stations, the captain of a vessel may determine his exact position. The method has been developed as the result of co-operative experiments by the Bureau of Standards and the Lighthouse Service. The sending apparatus is easily installed and can be operated by the regular light keepers without any skilled personnel. [2729]

**WIRELESS TELEPHONY EXPERIMENTS IN FRANCE.**—Some experiments with wireless telephonic apparatus have recently been made between Sainte-Assise (near Melun) and Beauvais. Transmission and reception were effected by means of valve sets manufactured by the Société Française Radioélectrique using a transmitting energy of not more than 5 watts. The distance between the two stations is 120 km. [2847]

**RECEPTION OF RADIO SIGNALS IN ARGENTINE.**—As a preliminary measure in connection with the proposed establishment of direct wireless communication between Germany and Argentine, engineers of the Telefunken Company have been making experiments in the reception of signals from Nauen at various points in Argentine. Further experiments are to be made with improved receiving apparatus during the present year. Whereas in June the atmospheric disturbances were equal in strength to the signals, they became steadily worse until in November they were seven or eight times as strong as the signals as measured in ohms in parallel with the telephone receiver. During November reception was possible on only ten days. The experiments were made with a frame coil of 30 metres side carried from a 50 metre mast. [2887]

For the first time, so far as is known, wireless telephony has been used to transmit services from one church to another in order that a congregation without a regular pastor could have the benefits of Sunday evening worship. The churches involved in this test were the Calvary



A Sermon by Wireless in U.S.A.

Episcopal and the Herron Avenue Presbyterian, both of Pittsburg, Pennsylvania, U.S.A., and for several months past the Sunday evening services of the former church have been broadcasted by radio from a test station in East Pittsburg. The arrangements were made by the Westinghouse Electric and Manufacturing Co. For reception a loop antenna, amplifier and condenser was placed on the rostrum in front of the pulpit. The loud speaking horn rested directly on the pulpit. The music, singing and sermon were clearly received in the second church. [3003]

It is stated in the *Elektrotechnische Zeitschrift* for March 10th, 1921, that successful experiments have been made in the application of the Siemens high-speed printing telegraph to wireless telegraphy between Berlin and Leipzig. For five days the whole traffic was carried in this way during the hours of the experiment. [2888]

The station at Deutsch-Altenburg was opened in August, 1920. Built by the Telefunken Co. on similar lines to the station at Pola, *i.e.*, with high-frequency alternator and frequency transformers, with an aerial power of 50 kW, it has three alternative wavelengths, viz., 7,500, 5,000, and 3,750 metres. The station was ordered in 1915 by the Austro-Hungarian Government and intended for a range of 2,000 to 3,000 km. [2889]

The Lizard wireless direction-finding station is to be reopened after the aerial system has been reconstructed. [2743]

**RADIO TRAFFIC ON THE AMERICAN SEABOARD.**—In order to avoid unnecessary calls and interference an agreement has been made between the companies operating the stations set out below to observe certain rules in the handling of traffic and unnecessary repetition of signals. The shifting of the wavelength from 600 metres to 300 or 450 metres is also recommended for handling the traffic after the initial calling has been effected. Alternative wavelengths suggested for handling all traffic are 1,800 and 3,000 metres when these are licensed:—

<b>WSA</b>	Easthampton, Long Island, N.Y.	
<b>WCY</b>	Cape May, New Jersey.	
<b>WCG</b>	Brooklyn, New York.	
<b>WLC</b>	New London, Connecticut.	
<b>WSC</b>	Sisconset, Massachusetts.	
<b>WCI</b>	Newport, Rhode Island.	
<b>WNN</b>	Belfast, Maine (now under construction).	
<b>WSE</b>	Babylon, Long Island, N.Y.	
<b>WBC</b>	East Moriches, Long Island, N.Y.	
<b>WNY</b>	New York, N.Y.	
<b>WST</b>	Rockland, Maine.	
<b>WBF</b>	Boston, Massachusetts.	[2843]

The radio direction-finding station **FEC** at Brest-Capucins has been replaced by the station Brest-Moulin du Seigneur, which has the call letters **FEI**. The wavelengths used are 450, 600 and 800 metres and the range of the station is about 105 nautical miles. [2848]

## Review of Radio Literature.

### 1. Abstracts of Articles and Patents.

#### (H.) Radio Receiving Apparatus.

##### (3) SPECIAL ELECTRON-TUBE DETECTORS AND RECEIVERS.

1988. **Société Française pour l'Exploitation des Procédés Thomson-Houston.** Valve Detector. (*French Patent* 506987, April 14th, 1919. Published September 2nd, 1920.)

The received oscillations are conveyed to an auxiliary controlling grid, whereby the value of the negative resistance of the vacuum tube is varied. The external circuit of the cathode and the plate contain an inductance and a capacity in parallel and so adjusted that the circuit is resonant to the received frequency. For further particulars see *British Patent* 117283.

1989. **H. Fassbender** and **E. Habann.** Audion Receiver. (*German Patent* 312587, August 30th, 1918. Patent granted December 12th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, p. 383, November, 1920—Abstract.)

A valve circuit in which the condenser in the grid circuit is placed in parallel with a resistance of sufficiently high self-inductance.

1990. **E. H. Armstrong.** Recent Progress in Reception with the Audion. (*La T.S.F. Moderne*, 1, pp. 133—144, August; pp. 169—175, September; pp. 215—221, October; pp. 250—287, November; pp. 291—298, December, 1920.)

A translation of an article which was first published in the *Proceedings of the Institute of Radio Engineers* in September, 1915.

##### (4) HETERODYNE AND C.W. RECEIVERS.

1991. **M. Adam.** The Reception of Undamped Waves—The Tikker and the Heterodyne Method. (*Radioélectricité*, 1, pp. 305—309, November; pp. 355—361, December, 1920.)

Includes details for constructing a heterodyne set.

1992. **M. Latour.** The Heterodyne Method of Wireless Reception: Its Advantages and its Future. (*Bulletin de la Société Française des Électriciens*, 10, pp. 363—374, November, 1920. *Radioélectricité*, 1, pp. 335—340, December, 1920.)

Paper read before the Société Française des Électriciens. See RADIO REVIEW, 2, pp. 15—21, January, 1921, where the full paper was printed.

1993. **T. G. Thornblad (Svenska Radioaktiebolaget).** Continuous Wave Receivers. (*British Patent* 143857, May 21st, 1920. Convention date May 23rd, 1919. Patent not yet accepted.)

Relates to a C.W. receiver in which the capacity of a condenser is varied at an audible frequency. The condenser may be included either in the high-frequency circuits or may be charged by the rectified current impulses from an ordinary pattern of detector.

1994. **M. Latour.** A New Generator for the Heterodyne. (*Wireless Age*, 8, p. 21, December, 1920. *Science Abstracts*, 24B, pp. 157—158, Abstract No. 311, March 31st, 1921—Abstract.)

An evacuated bulb is used containing a small quantity of mercury which serves both as an anode and as vapour emitting metal. An incandescent filament is used as a cathode. It has been experimentally verified that the characteristics of the discharge in the mercury vapour in this arrangement are those of the arc, that is the apparatus behaves as a negative resistance and sets up sustained oscillations in a shunt inductance-capacity circuit.

1995. **E. Roger.** The Tikker for the Reception of Undamped Waves. (*La T.S.F. Moderne*, 1, pp. 195—197, September, 1920.)

An illustrated description of the instrument manufactured by Ateliers Ducretet, E. Roger successeur, Paris.

#### (5) RELAYS, RECORDERS AND AUTOMATIC CALLING APPARATUS.

1996. **M. Latour.** Relay. (*French Patent* 503936, December 5th, 1917. Published June 21st, 1920.)

The apparatus employs two or more thermionic relays and further particulars may be obtained from the corresponding *British Patent* No. 140506. See Abstract No. 897, October, 1920.

1997. Automatic Printing of Wireless Messages. (*Discovery*, 2, pp. 49—50, February, 1921.)

A brief summary of the automatic printing apparatus developed for wireless reception by Messrs. Creed & Co., Ltd., of Croydon. (See also RADIO REVIEW, 2, pp. 37—38, January, 1921.)

1998. **R. D. Doner.** The Hall Jet Relay for Recording Radio Signals. (*Science and Invention*, 8, pp. 1099 and 1130, February, 1921.)

A description is given of this recording apparatus in which a jet of air is influenced by the sound waves from a telephone connected to the receiving apparatus. The resulting change in the form of the jet affects the cooling of a spiral of hot wire on which the jet impinges. The recorder is operated by the resulting changes in the resistance of the wire. A sample of received slip is given.

#### (I.) Amplifiers.

1999. **J. K. Catterson-Smith.** The Design of Inter-valve Transmitters. (*Electrician*, 85, pp. 388—390, October 1st; pp. 414—416, October 8th, 1920. *Science Abstracts*, 23B, pp. 547—548, Abstract No. 1039, November 30th, 1920—Abstract. *Technical Review*, 8, p. 262, March 15th, 1921—Abstract.)

The procedure in designing iron core transformers for use with valve magnifiers differs very much from that employed for ordinary transformers. The article is concerned solely with the design of aperiodic amplifiers for low frequencies. A preliminary survey is given of the principle of operation of the valve as an amplifier followed by a consideration of an ideal inter-valve transformer having no magnetising current or loss. The effect of the magnetising

current is then considered and expressions derived for the step-up in each stage of the amplifier for any value of the transformer reactance. Formulæ are given for the calculation of the inductance of winding and for calculating the leading core dimensions together with examples of their use. The final sections treat of the modifications introduced when an auto transformer is used for coupling the valves; and the similar problems of telephone transformers.

2000. **C. M. Minnis.** The Design and Construction of Audio Frequency Transformers. (*Wireless Age*, 8, pp. 26—27, February, 1921.)

Constructional details are given for building intervalve transformers for multi-stage low-frequency amplifiers.

2001. **R. Barthelemy.** The Calculation of the Intervalve Transformers for Low-frequency Amplifiers. (*La T.S.F. Moderne*, 1, pp. 97—103, July, and pp. 144—148, August, 1920.)

A mathematical consideration of the mode of operation of intervalve transformers for low-frequency amplifiers, with the derivation of design formulæ and curves.

2002. **L. Jacquot.** The Practical Construction of a Low-frequency Transformer Coupled Amplifier. (*La T.S.F. Moderne*, 1, pp. 103—109, July, 1920.)

Gives detailed dimensions for the construction of the necessary intervalve transformers.

2003. **M. Adam.** The Construction of a Resistance Amplifier. (*Radioélectricité*, 1, pp. 415—418, January, 1921.)

2004. **J. H. C. Harrold.** Thermionic Valves and their Application to Wireless Telegraphy. (*Radiograph*, 3, pp. 6—7, January; pp. 25—26, February; pp. 41—42, March, 1921.)

Short articles dealing with various types of high and low-frequency amplifiers.

2005. **Société Française pour l'Exploitation des Procédés Thomson-Houston.** Relay. (*French Patent* 507099, December 5th, 1919. Published September 4th, 1920.)

The specification describes an arrangement for amplifying potential variations comprising a particular arrangement of two and three-electrode valve tubes.

For further particulars, see *British Patent* 5373/1915.

2006. **Société Française pour l'Exploitation des Procédés Thomson-Houston.** Amplifier. (*French Patent* 507094, December 5th, 1919. Published September 4th, 1920. *British Patent* 129313, October 10th, 1917.)

A series of valve relays are employed for amplifying small currents and for minimising interference due to strays. Resistance-capacity couplings are used between the valves. The heterodyne oscillator for C.W. reception is shown coupled to the circuit of the receiving telephones, and it is suggested that when the valves are arranged to limit the intensity of incoming signals or X's, the successive intervalve coupling condensers should be of progressively increasing capacity. To further reduce atmospheric interference the aerial may be rendered aperiodic by inserting in series with it a resistance  $= 2\sqrt{LC}$  where  $L$  and  $C$  = capacity and inductance of aerial respectively. The grid circuit of the first valve may be connected across the resistance and the plate circuit of the third valve tuned to the incoming signal frequency.

2007. **M. Pirani.** The Measurement of the Efficiency of Amplifiers. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, pp. 2—30, July, 1920.)

The author discusses the basis upon which it is possible to determine the efficiency of an amplifier. The results obtained in any case depend upon the amplifier itself and upon its adaptation to the input and output apparatus. The author leaves this adaptation to a subsequent occasion and deals only with the amplifier itself. Both low and high-frequency amplifiers are dealt with. In one method an oscillating triode is used as a source, the current passing through two resistances in series; the amplifier is supplied from the P.D. across one of these resistances or a known fraction of it, and the telephone receiver can be put alternately on to the amplifier and across the other resistance. The resistances can be varied until a sound balance is obtained. In another method artificial cable is inserted in one of the two paths and the effect of the amplifier expressed in terms of the attenuation thus introduced. The use of the Franke machine is also mentioned. The measurement of the resistance and

inductance of low-frequency amplifiers by means of a bridge is also discussed and some results given. For stable note amplifiers with various numbers of triodes the author gives the following values for the power amplification:—1 triode 10—15; 2 triodes 150—200; 3, 1,000—1,500; 4, 4,000—6,000; 5, 20,000—25,000. Much greater values can be obtained by sacrificing stability. For high-frequency amplifiers, the oscillating triode was caused in any way to vary with audible frequency and its current was passed through two condensers in series; the P.D. across one was supplied to the telephone receiver through an audion and that across the other through the amplifier; the condensers were adjusted until a balance was obtained. A number of difficulties which arise in carrying out such measurements are discussed.

2008. **C. W. Heaps.** Amplification of Electric Currents in the Bunsen Flame. (*Physical Review*, 16, pp. 238—246, September, 1920. *Annales des Postes, Télégraphes et Téléphones*, 9, pp. 547—552, December, 1920—Abstract. *Revue Générale des Sciences*, December, 1920—Abstract. *Engineering*, 110, p. 554, October 22nd, 1920—Abstract.)  
The full paper corresponding to Abstract No. 520, July, 1920.

2009. **L. W. van Slyck.** An Electrolytic Amplifier. (*Wireless Age*, 8, pp. 22—23, January, 1921.)

The arrangement consists of an electrolytic cell having one electrode constructed of fine Wollaston wire which is vibrated in contact with the electrolyte by means of an appropriate electromagnet connected to the receiving circuits.

2010. **Société Française pour l'Exploitation des Procédés Thomson-Houston.** Relay. (*French Patent* 506591, November 26th, 1919. Published August 25th, 1920.) Also **A. W. Hull.** (*British Patent* 147149, July 7th, 1920—Convention date, November 8th, 1915. Patent not yet accepted but open to inspection.)

Electrical impulses which are to be amplified are applied to an ordinary resistance and a "negative resistance" in parallel, much greater current variations being thereby produced in each of the resistances. A three-electrode type of valve is employed with a higher positive potential upon the grid than upon the anode. The ordinary or positive resistance is connected between the anode and the intermediate point on the H.T. battery, and the output circuit or current utilising device is connected in series or parallel with the positive resistance. The positive resistance may be formed by the secondary of the input transformer.

### (J.) Subsidiary Radio Apparatus (Power Rectifiers; Protective Apparatus; Telephones; Materials, etc.).

2011. **V. J. F. Bouchardon and M. A. Lesage.** Rectifier. (*French Patent* 505592, October 30th, 1919. Published August 2nd, 1920.)

The rectifier described is for high pressures of the order of 30,000 to 100,000 volts and the incandescent filament and the anode are mounted a considerable distance apart in the tube, so that reverse currents are avoided.

There is a corresponding British Application No. 153295, of October 12th, 1920 (Convention date October 30th, 1919), the patent on which has not yet been granted.

2012. **Société Anonyme des Etablissements H. Pilon.** Rectifier. (*French Patent* 506978, April 9th, 1919. Published September 2nd, 1920.)

In rectifying high-tension alternating currents the valve is connected at the mid-point of a transformer secondary which is at zero potential. The filament is heated by a small coil arranged as a secondary to the main transformer primary,

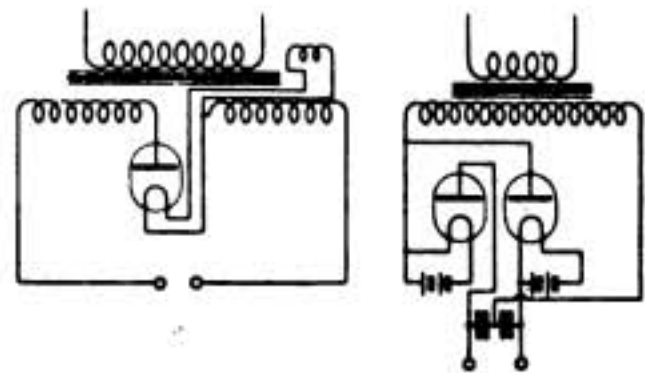


FIG. 1.

FIG. 2.

For rectifying both half-waves the connections may be arranged as in Fig. 2.

There is a corresponding British Application No. 143929, of May 29th, 1920 (Convention date April 9th, 1919), the patent on which has not yet been granted.



2013. **V. E. Goodwin.** Alternating Current Lightning Arresters. (*General Electric Review*, 23, pp. 429—432, May, 1920.)

Deals with the use of a condenser in series with resistance for protecting electrical machinery from high-frequency surges.

2014. **H. J. Hinks.** The Construction of a Loud Speaker. (*Radiograph*, 3, pp. 38—40, March, 1921.)

Constructional details are given for an instrument utilising an ordinary pattern of Brown's telephone receiver.

2015. **C. W. Hewlett.** A New Tone Generator. (*Physical Review*, 17, pp. 257—258, February, 1921.)

The instrument described can be used as a telephone transmitter, receiver, or loud speaker, or as a standard source of sound. It consists of a thin aluminium diaphragm mounted between two flat pancake coils through which a steady current is passed from a battery to produce the steady polarising field. The coils are connected in series as regards the impressed alternating E.M.F.'s, and in series for the steady battery current.

2016. A New Style of Amplifying Telephone of Simple Construction. (*Scientific American*, 124, p. 13, January 1st, 1921.)

In the apparatus described two powerful horseshoe magnets are employed having an armature mechanically connected to a large mica diaphragm through a magnifying lever. It is claimed that speech can be heard 200 feet from the instrument in the open air, when operated directly by a microphone transmitter without amplifying apparatus.

2017. **W. Schaller.** The Properties of Mica. (*Technical Review*, 9, p. 76, May 3rd, 1921, abstracted from *Cement, Mill and Quarry*, December 5th, 1920.)

2018. **J. G. Frayne.** A High-frequency Resistance Standard. (*Physical Review*, 17, pp. 415—416, March, 1921.)

For high resistances with negligible inductance and capacity "sputtered" quartz fibres are used. Quartz fibres about 10 cm long and about 0.01 mm diameter coated with platinum and immersed in oil were found to meet the requirements. Their skin effect is negligible. Measurements are quoted showing the constancy of the resistances.

2019. **Gesellschaft für drahtlose Telegraphie.** Improvements in Electric Machines. (*German Patent* 298473, October 31st, 1915. Patent granted January 20th, 1920. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 15, p. 498, June, 1920—Abstract.)

A method of maintaining constant revolution frequency in high-frequency machines by the use of alternating current synchronous motors fed from a source the frequency of which is dependent wholly on the values of a capacity and inductance.

2020. **M. Latour.** Valve Amplifier. (*French Patent* 507308, March 5th, 1919. Published September 10th, 1920. *British Patent* 155254, July 12th, 1920. Convention date March 5th, 1919. Patent not yet accepted.)

The specification describes a method of feeding the filament circuit of a three-electrode amplifier from a power distribution network. The filament is connected to the high voltage mains through a resistance and an inductance. The filament is also shunted by a resistance.

2021. **G. Johannes.** The Kenotron Rectifier. (*Revue Générale de l'Électricité*, 7, pp. 733—746, May 29th, 1920. *Technical Review*, 7, p. 220, November 16th, 1920—Abstract. *Telegraphen- und Fernsprech-Technik*, 9, p. 115, September, 1920—Abstract.)

Continuation of an article published in June, 1919. The limiting factors of current capacity, etc., are discussed, as well as the factors which determine the dimensions of the tube. Various diagrams are reproduced showing the use of one or both half waves also oscillograms to explain the action of the condensers.

2022. **Brown, Boveri & Co.** Rectifier. (*French Patent* 506672, November 27th, 1919. Published August 27th, 1920. *British Patent* 154545, November 26th, 1920. Convention date, November 27th, 1919. Patent not yet accepted.)

According to this patent metallic vapour rectifiers are fed with polyphase currents by employing a combined star and polygon connection of the secondary windings of a three-phase transformer.

2023. **M. Adam.** Alternating Current Rectifiers. (*Radioélectricité*, 1, pp. 553—558, April, 1921; pp. 599—602, May, 1921.)

2024. **W. Hahnemann** and **H. Hecht**. Theory of Telephone Receiver. (*Annalen der Physik*, 62, pp. 57—84, September 16th, 1920.)

The method is based on replacing the mechanical load by an equivalent electrical load. The effects of losses and magnetic leakage are discussed. The calculated efficiency is checked by means of experiment, and good agreement is found.

2025. **E. F. Huth**. Wireless Receiver. (*German Patent* 316033, August 29th, 1917. Patent granted November 18th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, p. 384, November, 1920—Abstract.)

A receiver in which the telephone receiver coil is divided into two portions, T and T' (see Fig. 3) each half being in series with a detector, the windings and detectors being arranged so as to produce additive effects in the telephones.

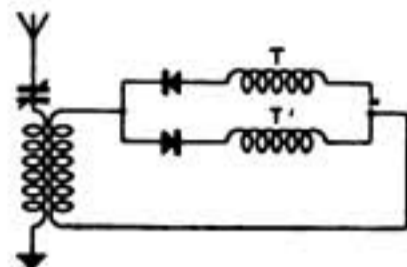


FIG. 3.

2026. **A. H. Lynch**. Ship Line finds Use for Telemegaphone. (*Science and Invention*, 9, p. 48, May, 1921.)

2027. **T. E. Shrader**. Conductivity of Insulating Materials near the Breakdown Voltage. (*Physical Review*, 17, pp. 502—507, April, 1921.)

Test results are given on representative specimens of three classes of insulating materials: (1) those which obey Ohm's law throughout up to the breakdown point; (2) those which obey Ohm's law up to near breakdown followed by an increasing rate of current flow; and (3) those in which the current increases for the whole range of voltage with an accelerating rate up to the breakdown point.

2028. **S. R. Winters**. Tests of Insulating Materials for Radio Use at the Bureau of Standards. (*Radio News*, 2, p. 682, April, 1921.)

A description is given with illustrations of the testing apparatus for insulating materials used at the Bureau of Standards.

2029. **Compagnie Française pour l'Exploitation des Procédés Thomson-Houston**. Continuous Wave Transmitter. (*French Patent* 507995, December 30th, 1919. Published September 28th, 1920.) Also **General Electric Co.** (British Thomson-Houston Co.). (*British Patent* 149409, May 9th, 1919. Patent accepted July 9th, 1920.)

The specification describes a system of continuous wave wireless transmission in which an alternator is employed whose speed is maintained at a predetermined value, whereby the energy is radiated at a constant frequency. The action of keying controls the speed of the driving motor so as to maintain a constant speed of the set, while a resonance circuit is also employed for effecting a further control.

### (K.) Aerials (including Earthing Systems, etc.).

#### (1) AND (2) COMPARISONS OF AERIAL SYSTEMS; ELEVATED AERIALS.

2030. **H. Hoffmann**. The Use of Coils instead of Antennæ as Wireless Receivers. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, pp. 31—66, July, 1920.)

A comparison of the advantages of the two methods, followed by a general discussion on the design of coil or frame aerials. Calculations and measurements are given of the inductance and natural frequency of various coils with different types of wire, different pitches, etc. An account is given of five different ways of arranging the receiving apparatus with respect to the coil, some suitable for short and others for long waves. A section is devoted to a study of the errors in direction finding by means of a rotating coil. The concluding section deals with special applications, particularly to submarines. The work was done in the Torpedo Department at Kiel.

2031. **J. E. Stroebel**. The Antenna. (*Q.S.T.*, 4, pp. 5—9, May, 1921.)

A comparison of different antennæ particularly with regard to the arrangements of the leading-in wires. Curves of comparative capacities are given.

2032. **General Electric Co. (U.S.A.)** (British Thomson-Houston Co.). Multiple Aerials. (*British Patent* 142610, March 21st, 1919. Patent accepted July 13th, 1920.)

In connection with multiple aerials—i.e., aerials having several tuned connections to earth disposed along their length—special arrangements are described for grouping the connections to the earth network wires so as to further reduce the resistance of the aerial.

2033. **W. H. Eccles.** The Capacitance of Flat Top Antennæ. (*Electrician*, 86, p. 72, January 14th, 1921. *Science Abstracts*, 23B, p. 99, Abstract No. 194, February 28th, 1921—Abstract. *Radioélectricité*, 1, pp. 587—588, May, 1921—Abstract. *Revue Générale de l'Électricité*, 9, p. 184 D, June 4th, 1921—Abstract.)

The author refers to a formula recently published by L. W. Austin,\* and then gives a simpler one that he has used for some years in designing flat top aeriæ—viz. :

$$C = cl\sqrt{n-1} \quad \text{E.S. units.}$$

$l$  = length of flat top ;  $c$  = capacity per unit length of a single wire of the same gauge and placed at the same height ;  $n$  = number of wires.  $c$  may be written  $c = 1/2\log_e(2h/r)$ , where  $h$  = height and  $r$  = radius of the wire.

Examples are given in the paper showing good agreement between calculated and observed values.

2034. **E. Bellini.** Aerial Construction. (*French Patent* 504092, January 28th, 1918. Published June 24th, 1920.)

A receiving aerial for wireless telegraphy or wireless telephony to give the maximum clearness of reception is constituted by two aeriæ arranged with a right angle between them, the one having the ordinary functions and the other having the greatest possible absorbing power for atmospheric disturbances.

2035. **E. Bennett.** Abstractive and Selective Properties of Radio Antennæ Circuits. (*Journal of the American Institute of Electrical Engineers*, 39, pp. 995—1004, November, 1920 ; pp. 1052—1062, December, 1920. *Science Abstracts*, 23B, p. 100, Abstract No. 195, February 28th, 1921—Abstract. *Technical Review*, 9, p. 48, April 19th, 1921—Abstract.)

An analytical study of the power abstractive and selective properties of simple antenna circuits, with the object of determining the circuit proportions and frequencies which will make the circuit most highly responsive to the desired signal and least responsive to interference. The main sections dealt with in the article are as follows :—Basis of comparison of receiving circuits ; relative response of simple series antenna circuits to detuned C.W. signals ; the selective coefficient of a receiving circuit ; relations between selective coefficient and the antenna dimensions and operating frequency ; relation between selective coefficient and time constant ; the calculation of antenna height and area and resonant frequency which will give the highest selective coefficient for a given time constant ; feasibility of obtaining tuning inductances with time constants of 0.04 seconds or longer ; the maximum power which an antenna can abstract from sustained waves and deliver to a detector ; the directive efficiency of a radio system and abstractive factor of an antenna circuit ; the combination of frequency with antenna height and area which will lead to a high selective coefficient against strays ; effect of the antenna dimensions upon the energy delivered to the detector by an impulse E.M.F. ; effect upon the power received of unavoidable departures from the best conditions ; conclusions relating to the plain series antenna for receiving purposes.

Curves of transmission efficiencies for various wavelengths and ranges are also included.

2036. **Société Française pour l'Exploitation des Procédés Thomson-Houston.** Aerial Construction. (*French Patent* 506989, April 14th, 1919. Published September 2nd, 1920.)

The aerial system comprises a primary aerial supplied by a high frequency source and a plurality of secondary aeriæ supplied from the primary aerial.

For further particulars see *British Patent* 130064. See RADIO REVIEW Abstract No. 198, February, 1920.

2037. **General Electric Co. (U.S.A.)** (British Thomson-Houston Co.). Wireless Aeriæ. (*British Patent* 144075, May 26th, 1919. Patent accepted June 10th, 1920.)

Relates to an arrangement of multiple aeriæ, in which the intermediate grounding connectors along the aerial are connected to capacity counterpoises, instead of to earth.

### (3) LOOP OR COIL AERIALS.

2038. **M. Adam.** The Construction of Frame Aeriæ for Receiving. (*Radioélectricité*, 1, pp. 48—51, June, 1920.)

\* See RADIO REVIEW Abstract No. 466, July, 1920.

2039. **F. Duroquer.** Radio Direction Finding; the Construction and Utilisation of a Frame Aerial. (*La Nature*, 49(1), Supplement pp. 3—4, January 1st, and pp. 11—12, January 8th, 1921.)  
A general outline of direction-finding methods with constructional details for a simple frame aerial, etc.
2040. **E. R. Clarke.** Loop Aerials. (*British Patent* 143580, October 12th, 1917. Patent accepted February 4th, 1920. Published June 24th, 1920.)  
For loop aerials for directional radio work the conductor forming the loop may be given a large effective diameter (of the order of 5 feet) by forming it of a number of wires spaced so as to form a cylinder of that diameter. Special arrangements of loops supported by a single mast are also detailed.
2041. The Superlative in Loop Antennæ. (*Scientific American*, 124, p. 29, January 8th, 1921.)  
A large loop aerial, measuring 130 feet across, and used in Germany for inter-city wireless communication, is briefly described and illustrated.
2042. **Société Française pour l'Exploitation des Procédés Thomson-Houston.** Receiving Apparatus. (*French Patent* 506980, April 10th, 1919. Published September 2nd, 1920.)  
The receiving conductor is formed as a coil lying in the vertical plane containing the receiving station and the desired transmitting station. A second coil is placed at right angles to the first-mentioned coil to screen it from undesired waves emitted from an adjacent station.  
For further particulars see *British Patent* 129722.\*
2043. **E. J. Berg.** A New Coil Antenna. (*Wireless Age*, 8, p. 22, November, 1920.)  
A description of the same arrangement as referred to in Abstract No. 43, November, 1919.
2044. **E. F. W. Alexanderson.** A Selective Receiving System. (*Wireless Age*, 8, p. 20, November, 1920.)  
The arrangement described is the same as that referred to in Abstract No. 60, November, 1919.
2045. **W. E. Brakes.** A Coil Aerial buried in the Ground. (*Wireless Age*, 8, pp. 17—18, March, 1921.)  
Refers to the use of a loop aerial buried in the earth and connected to screened receiving instruments for diminishing atmospheric interference.
2046. **J. Hollingworth.** Loop Aerials. (*British Patent* 149532, September 5th, 1919. Patent accepted August 19th, 1920.)  
An aerial which responds to signals from all directions is formed of three or more loops, arranged in more than one plane, consecutive loops being connected in series and wound in opposite directions like the two halves of a figure eight. With a number of such loops the intensity of the received signals is independent of their direction.
- (4) TO (12) VARIOUS FORMS OF AERIALS; EARTHING SYSTEMS; MASTS, ETC.
2047. **E. T. Jones.** Jones' System of Underground Reception. (*Experimental Science*, 1, pp. 51—52, August, 1920.)  
Contains constructional details for the apparatus for use in conjunction with the aerial system described in RADIO REVIEW Abstract No. 378, May, 1920.
2048. **R. H. G. Matthews.** The Underground Antenna adapted to Amateur Waves. (*Q.S.T.*, 3, pp. 14—16, June, 1920; pp. 18—19, July, 1920.)
2049. **J. J. Honan.** Aeroplane Aerials. (*Wireless World*, 8, pp. 653—656, December 11th, 1920. *Radioélectricité*, 1, p. 113D, April, 1921—Abstract.)  
See RADIO REVIEW Abstract No. 90, January, 1920, where the same material has already been dealt with.
2050. **J. H. Rogers.** Aerial Construction. (*French Patent* 506521, November 24th, 1919. Published August 24th, 1920. *L'Électricien*, 52, p. 65, February 1st, 1921.)  
The specification describes an aerial for use on submarines. The aerial extends longi-

\* See RADIO REVIEW Abstract No. 60, November, 1919.

tudinally above the submarine, and is insulated therefrom, except at its ends. For further particulars, see *British Patent* 137511.\*

2051. A New Design of Aerial Insulator. (*RADIO REVIEW*, 2, pp. 197—199, April, 1921, and p. 155, March, 1921.)

Describes new insulators designed by C. F. Elwell and Messrs. Bullers, Ltd.

2052. E. Isherwood. Electric Earth Plates. (*British Patent* 144376, March 8th, 1919. Patent accepted July 8th, 1920.)

Describes a form of earth connection.

2053. Wooden Masts for Radio. (*Scientific American*, 124, p. 303, April 16th, 1921.)

A short note *re* the advantages of wooden masts, and the stability of those of the Elwell type.

2054. M. Abraham. A Law regarding Antenna Models. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, pp. 67—70, July, 1920.)

An investigation of the application of the principle of similitude to antenna models. The conclusion reached is as follows: If the model is  $\alpha$  times as small in every direction, the model earth must have a conductivity  $\alpha$  times as great, for the same dielectric constant. The earth resistances will then be equal, and since being similar the aerial and model have the same radiation resistance, they will have the same decrement.

## (L.) Radio Wave Transmission.

### (1) GENERAL THEORY.

2055. J. Brun. Wireless Telegraphy and the Electrical State of the Atmosphere. (*Radioc-électricité*, 1, pp. 241—247, October, 1920. *Génie Civil*, 78, p. 162, February 12th, 1921. *Revue Générale de l'Électricité*, 9, p. 116D, April 9th, 1921—Abstract; p. 158D, May 14th, 1921—Abstract.)

A summary of present knowledge and current theories dealing with wave propagation and with the effect of meteorological factors, and the electrical condition (ionisation, etc.) of the upper atmosphere. The hypotheses of the Heaviside layer are dealt with, as well as Eccles' theory on the effects of ionisation.

2056. O. Schrieven. Electromagnetic Waves on Dielectric Wires. (*Annalen der Physik*, 63, pp. 645—673, December 1st, 1920.)

A theoretical discussion of the transmission of waves along wires of dielectric material, followed by a description of an apparatus for the production of such waves by means of a triode and their quantitative investigation by means of a crystal detector. The experiments confirmed the theoretical results.

2057. R. C. Trench. Range of Wireless Stations. (*Journal of the Institution of Electrical Engineers*, 59, pp. 157—180, January, 1921.)

The contents of this paper have already been abstracted—*RADIO REVIEW*, 2, pp. 58—59, February, and p. 169, April, 1921. A full report of the discussion by Professor G. W. O. Howe; Major H. P. T. Lefroy; Professor E. W. Marchant; Professor C. L. Fortescue; Mr. L. B. Turner; Major A. C. Fuller; Dr. E. H. Rayner; Dr. W. H. Eccles; and Mr. J. E. Taylor, is included, together with Captain Trench's reply.

2058. H. M. Macdonald. The Transmission of Electric Waves around the Earth's Surface. (*Proceedings of the Royal Society*, 98A, pp. 216—222, December 3rd, 1920; and pp. 409—411, March 3rd, 1921.)

Two mathematical papers dealing with Professor G. N. Watson's discussion of the theory of wave propagation. The second paper deals especially with the conditions for the "steady state" in the case of wave propagation between the surfaces of two concentric conducting spheres.

2059. J. R. Carson. Wave Propagation over Parallel Wires: The Proximity Effect. (*Philosophical Magazine*, 41, pp. 607—633, April, 1921.)

A mathematical investigation of the problems of wave propagation over parallel wires in connection with developments of carrier-wave telephony, starting with Maxwell's equations

\* See *RADIO REVIEW* Abstract No. 835, September, 1920.

and making the simplifying assumption that the exponential propagation factor is a small quantity. The problem is thus reduced to a two-dimensional one.

2060. The Use of the Austin-Cohen Formula for the Solution of some Important Problems in Radio-telegraphic Transmission. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, pp. 114—125, August, 1920. *Radioélectricité*, 1, p. 89D, February, 1921—Abstract.)

A Translation from the French (see **Léon Bouthillon**, *Revue Générale de l'Électricité*, 3, pp. 419—425, 1918). Describes a graphical construction for giving the range, best wavelength, etc., in any given case, in accordance with the Austin-Cohen formula.

2061. **G. W. O. Howe**. The Upper Atmosphere and Radiotelegraphy. (*Radio Review*, 1, pp. 381—383, May, 1920.)

2062. **S. Chapman** and **E. A. Milne**. The Composition, Ionisation and Viscosity of the Atmosphere at Great Heights. (*Quarterly Journal of the Royal Meteorological Society*, 46, p. 357, 1920. *Nature*, 105, p. 690, July 29th, 1920—Abstract.)

In this paper read on June 16th, 1920, the authors deal very fully with the present state of knowledge of the upper atmosphere. They conclude that Wegener's geo-coronium does not exist, that the upper atmosphere is free from hydrogen, and that nitrogen is a prominent constituent up to nearly 200 km; above 150 km helium is the principal constituent. The atmosphere changes very greatly at about 100 km and this is the height at which aurora are usually observed. This height and the sharply defined lower surface of auroral displays are consistent with ionisation due to  $\alpha$  particles emitted from the sun.

Ionisation may exist at lower levels due to  $\beta$  and  $\gamma$  radiation from the sun; these may penetrate to heights of 50 and 25 km respectively. In all cases the lower surface of the ionised layer would be sharply defined, a point of interest in radiotelegraphy. The question of the persistence of the ionisation and the difference between day and night conditions is not investigated.

#### (2) TRANSMISSION TESTS; RANGES; FADING, ETC.

2063. The Reception of the Lyons Station in Buenos Aires. (*Radioélectricité*, 1, p. 58, June, 1920.)

Reference is made to the successful reception in Buenos Aires of signals from the Lyons station, which uses not more than 150 kW in the aerial. A frame aerial of only a few decimetres side was used in conjunction with specially selective apparatus.

2064. **L. W. Austin**. The Wave-front Angle in Radiotelegraphy. (*Journal of the Washington Academy of Sciences*, 11, pp. 101—106, March 4th, 1921. *Science Abstracts*, 24B, p. 269, Abstract No. 539, May 31st, 1921—Abstract.)

Experiments are described with a view to actual measurement of the inclination of the wave-front of an incoming signal wave to the vertical at the receiving station. The use of a frame aerial rotatable in two directions at right angles is considered unsatisfactory for this purpose, and a pair of oppositely directed straight wires were mounted upon a wooden frame supported on a mast so that the two wires, which served as aeriels, could be rotated together in both the vertical and the horizontal planes. The positions of extinction of the signal were determined, and the line of the wavefront was taken as perpendicular to the wires when in this position. Measurements indicated that for wavelengths over 10,000 metres, the deviation of the wavefront from the vertical under ordinary conditions did not much exceed three degrees. It was also found possible to determine the wavefront inclination of atmospherics, and in some cases to determine a slightly different inclination from that of the incoming signals. In general, however, the atmospherics also had a sensibly vertical wavefront.

2065. The Radio Station at Sandham (Finland). (*Electrician*, 86, p. 390, April 1st, 1921.)

A short note with regard to range tests from this station. It is stated to have been in communication with Poldhu, a distance of 2,300 km.

2066. **J. Kruse**. The Bureau of Standards—A.R.R.L. Tests of Short Wave Radio Signal Fading. (*Q.S.T.*, 4, pp. 6—12, November, 1920, and pp. 13—19, December, 1920. *Telegraph and Telephone Age*, 39, p. 113, March 1st, 1921—Abstract. *Electrical Review*, 88, p. 654, May 20th, 1921—Abstract.)

In conjunction with the Bureau of Standards and the American Radio Relay League test signals were transmitted three nights each week through June and July, 1920, by six amateur

transmitting stations operating on 250 metres wavelength. Observations of the intensity of the signals were made by fifty recording stations. Frequent checks between curves on adjacent and distant stations were found. No definite connection between weather and transmission was found and occasionally travelling curves appeared successively at various recording stations. Three types of fading were observed, a rapid and very abrupt type occurring mainly in New England, a less rapid and less abrupt type found in all districts covered by the tests and a very slow type of large area which affected all sending stations to the same degree. There was no marked difference in the fading experienced with different types of sending sets, but with spark transmission, a signal that had faded out could often be recovered by re-tuning. This phenomenon was not found with C.W. The tests furnished evidence in support of the belief that such variations are due to varying reflection and refraction of the waves.

2067. Elwell-Poulsen Arcs on Board Ship. (*Electrical Review*, 88, p. 586, May 6th, 1921.)

Reference is made to some long distance communications effected with the Elwell-Poulsen arc installation on board the s.s. *Caronia*. Ranges of 2,800 to 3,500 miles are mentioned and it is stated that the arc was fitted with a special method of keying so that no spacing wave is radiated. The arc was particularly valuable in enabling messages to be got through when atmospheric and other jamming was bad.

2068. Long Distance Work. (*World Wide Wireless*, 2, p. 5, March, 1921.)

Refers to a communication between Eureka radio station and the s.s. *West Camargo* over a range of 1,200 miles in daylight, using a 2 kW 600 metre quenched spark set.

2069. The A.R.R.L. QSS Tests. (*Q.S.T.*, 3, pp. 5—6, June, 1920; pp. 5—8, July, 1920; 4, pp. 5—6, August, 1920.)

Preliminary notes *re* the short wave "fading" tests organised by the Bureau of Standards and the American Radio Relay League.

2070. S. Kruze. Station Performance during the Bureau of Standards—A.R.R.L. QSS Tests of June and July, 1920. (*Q.S.T.*, 4, pp. 11—14, September, 1920.)

Tabular results are given of the performance of the recording stations which took part in the Bureau of Standards fading tests.

2071. The Fading Tests. (*Q.S.T.*, 4, pp. 12—14, January, 1921.)

A preliminary report is given in the form of curves of a further series of fading tests carried out for the Bureau of Standards in October, 1920.

2072. Performance of January Q.S.S. Recorders. (*Q.S.T.*, 4, pp. 14—15, May, 1921.)

Some further data with regard to the third Bureau of Standards fading tests.

### (M.) Atmospherics (General Articles, Anti-atmospheric Devices, etc.).

2073. Electrical Disturbances due to a Meteor. (*Electrical Review*, 88, p. 554, April 29th, 1921.)

Reference is made to a report from the s.s. *Saxonia* with regard to a large meteor which was seen 15 miles off Halifax. Unusual atmospheric disturbances were reported by wireless operators for a period of twenty-four hours prior to the event, and they ceased after the fall of the meteor.

2074. L. W. Austin. Determination of the Direction of Atmospheric Disturbances or Static in Radiotelegraphy. (*Journal of the Franklin Institute*, 171, pp. 617—629, May, 1921.)

In order to study atmospheric disturbances during the months when they are too weak at Washington to be of value for investigation a number of observations were taken on a receiving apparatus set up in various other places. The results obtained at San Juan, Loiza, Cayey, Astora, Bremerton, San Francisco and San Diego are set out in tabular form. It is concluded that: In general static comes from the land rather than from the sea, and that when it appears to come from the sea there is generally land in the given direction at no great distance; that static which increases in a marked degree with the wavelength comes from a great distance while that which varies little with wavelength comes from centres not far away; that Washington afternoon summer static is much more sharply directional than that in the forenoon. In many cases the source of sharply directional static was apparently located in high mountain

peaks. Two types of static were recognised, one giving a pure shock effect which is heard over a wide range of wavelengths and one which is not heard simultaneously at different wavelengths. The latter has been termed the "spectrum" type since it appears to consist of a large number of independent waves of different lengths. There is some reason to believe that the spectrum type forms a large part of the directive static. The importance of further directional observations is emphasised.

2075. **L. J. B. Verdier.** Eliminating Atmospheric Disturbances. (*French Patent* 498168, January 7th, 1918. Published December 31st, 1919.)

The specification describes a method of eliminating atmospheric disturbances in wireless telegraphy and telephony reception. The method consists in employing an antenna of great capacity and a plurality of successive selecting circuits which eliminate progressively the parasitic currents, so that only the required current is produced in the last circuit. The antenna is arranged to form a circular or polygonal winding.

2076. **International Radio Telegraph Company.** Reducing Interference. (*French Patent* 502782, July 11th, 1919. Published May 26th, 1920.)

For reducing interference from atmospherics two receiving aerials (one or both of which are of the directional type) are employed connected differentially to the receiving instrument, and one of them being so arranged as to give a minimum response to signals from the required direction. Both aerials are affected equally by atmospherics which are consequently balanced out in the receiving instrument. Both radio and audio frequency differential balancing arrangements are shown in different modifications. See also *British Patent* 146997 of July 6th, 1920 (Convention date November 27th, 1916) in the name of **J. L. Hogan.**

2077. **H. J. J. M. de R. de Bellesize.** Reducing Interference. (*French Patent* 504783, October 10th, 1919. Published July 16th, 1920.)

In a wireless telegraphy receiver comprising the usual elements and for receiving musical signals, there are provided two resonators of low and distinct frequency, both operated by the same current rectified by the receiving detector. One of the resonators is tuned to the musical frequency of the signal and the other is out of tune therewith. The resonators act oppositely on a recording apparatus without the interposition of a detector.

2078. **L. Cohen and J. O. Mauborgne.** A New Method for the Reception of Radio Signals, eliminating Static and Interference. (*Journal of the Franklin Institute*, 191, pp. 423—424, March, 1921.)

A short abstract of a lecture dealing with the use of "resonance-wave-coils" for radio reception and the elimination of interference.

2079. **Le Matériel Téléphonique.** Reducing Interference. (*French Patent* 505127, November 17th, 1918. Published July 23rd, 1920.)

By combining a plurality of sections having resistance, capacity and no inductance, or resistance, inductance and no capacity, currents of a frequency below a certain value and also currents of a frequency above a certain value, may be eliminated. For further particulars see *British Patent* 135635.\*

2080. **H. J. J. M. de R. de Bellesize.** Eliminating Atmospheric Disturbances. (*French Patent* 506142, January 22nd, 1919. Published August 14th, 1920.)

For reducing atmospheric and similar interference the receiving apparatus has two aerials having no mutual reaction. The receiving aerial is tuned to the desired waves and the balancing aerial is slightly mistuned, both aerials having equal damping, inductance, and effective height.

In an example quoted, two closed coil aerials are employed, arranged symmetrically about a central plane but with one coil displaced laterally from the other. Resistances are placed in the leads from the aerials to the coupling coils (which are arranged inside a screened box) so as to equalise the damping of the two circuits. High and low-frequency amplifiers may be employed between the aerials and the differential indicating instrument to which both receivers are connected.

There is a corresponding British application No. 152679 of July 12th, 1920 (Convention date January 22nd, 1919), the patent on which has not yet been granted.

\* RADIO REVIEW Abstract No. 523, July, 1920.



2081. **R. A. Weagant.** Static Preventer buried in the Earth. (*Wireless Age*, 8, p. 18, December, 1920.)

A modification of the double loop static eliminator previously described by Weagant,\* in which the receiving station apparatus and the loops are fitted up below ground while a horizontal screening network is stretched over the surface of the earth above the apparatus.

2082. **L. Levy.** Eliminating Atmospheric Disturbances. (*French Patent* 506297, October 1st, 1918. Published August 18th, 1920.)

The specification describes receiving circuits for undamped high-frequency waves with means for eliminating parasitic disturbances.

See also British Specification No. 133306. (RADIO REVIEW Abstract No. 190, February, 1920.)

2083. **H. J. Round.** Wireless Receiving Apparatus. (*British Patent* 149434, May 13th, 1919. Patent accepted August 13th, 1920.)

Relates to electrostatic screening arrangements for the secondary circuit of the receiver and for the valves and other apparatus.

### (N.) Interference and Interference Prevention.

2084. **E. F. W. Alexanderson.** Transoceanic Radio Communication. (*General Electric Review*, 23, pp. 794—803, October, 1920. *L'Elettrotecnica*, 7, pp. 458—460, September 5th, 1920—Abstract. *Technical Review*, 7, pp. 322—323, December 7th, 1920—Abstract. *Science Abstracts*, 24B, p. 157, Abstract No. 310, March 31st, 1921—Abstract. *Bulletin de la Société Française des Électriciens*, 10, p. 400, November, 1920—Abstract. *Génie Civil*, 78, p. 491, June 4th, 1921—Abstract.)

The article covers the same general ground as the paper with the same title already abstracted—RADIO REVIEW Abstract No. 1209, December, 1920. The barrage receivers are also described and illustrated.†

2085. **H. J. Round.** Wireless Receiving Apparatus. (*British Patent* 149435, May 13th, 1919. Patent accepted August 13th, 1920.)

For the elimination or reduction of undesired signals it is proposed to use two receiving aerials coupled to the receiving telephones through a phase-changing arrangement. The heterodyne energy for reception is provided by a third auxiliary transmitting aerial. Signals from the direction of this aerial can be balanced out by adjusting the phase of the current from the two receiving aerials.

2086. **Western Electric Company.** Wireless Telephone Apparatus. (*British Patent* 143309, February 18th, 1919. Patent accepted May 18th, 1920.)

In a wireless telephone transmitter distortion arises from the fact that the aerial is tuned to the unmodulated, or carrier, frequency  $N$  and is out of tune to the additional frequencies  $N + n$  and  $N - n$  introduced by the modulation. To overcome this defect, resonant circuits or transformers may be introduced into the low-frequency or modulation circuits to accentuate the intensity of the higher modulating frequencies. For this purpose these circuits may be tuned to frequencies near or above the highest speech frequencies.

Alternatively the compensation for the distortion may be introduced, by similar means, into the low-frequency circuits of the receiver. Secrecy methods of communication become possible if this method is extended to a greater degree.

### (O.) Duplex and Multiplex Radio.

2087. **E. F. W. Alexanderson.** Duplex System for Wireless Telegraphy. (*Wireless Age*, 8, pp. 17—18, November, 1920. *Science Abstracts*, 23B, pp. 581—582, Abstract No. 1113, December 30th, 1920—Abstract.)

Description of the same arrangement as that referred to in Abstract No. 64, November, 1919.

\* RADIO REVIEW Abstract No. 18, October, 1919.

† See also RADIO REVIEW Abstract No. 75, December, 1919.

2088. **Gesellschaft für drahtlose Telegraphie.** Wireless Sending and Receiving Circuit. (*German Patent* 307646, April 10th, 1918. Patent granted January 22nd, 1920. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, p. 147, August, 1920—Abstract.)

A valve circuit (see Fig. 4) with separate aerials for sending (S) and receiving (R). During transmission the coupling coils to telephone and receiving aerial are short-circuited.

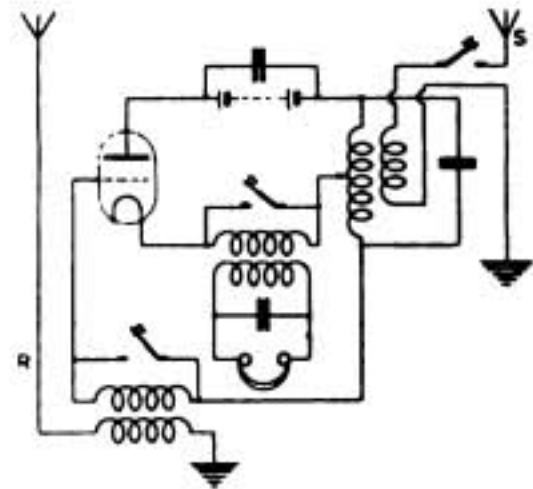


FIG. 4.

### (P.) High - frequency Circuits and Measurements.

#### (1) GENERAL ARTICLES.

2089. **A. Press.** Antenna Form-factor. (*Electrician*, 85, pp. 492—493, October 29th, 1920. *Science Abstracts*, 23B, p. 546, Abstract No. 1035, November 30th, 1920—Abstract. *Revue Générale de l'Électricité*, 9, p. 43D, February 5th, 1921—Abstract. *Technical Review*, 8, p. 190, February 22nd, 1921—Abstract. *Radioélectricité*, 1, p. 81D, January, 1921—Abstract.)

A mathematical discussion of the field at a distant point due to the current distribution in the aerial conductors. The formulæ obtained are not suitable for abstracting but it is shown that there are two form-factors, one magnetic and the other electrostatic, and that together they amply express the relative merits of two dissimilar antenna systems.

2090. **J. St. V. Pletts.** Some Slide Rule Improvements. (*Proceedings of the Physical Society of London*, 33, pp. 57—61, February 15th, 1921. *Technical Review*, 9, p. 112, May 17th, 1921—Abstract.)

The chief features of this new pattern of slide rule have already been described—*RADIO REVIEW*, 2, pp. 152—153, March, 1921.

2091. **A. Press.** Extension of Heaviside Principle to Operator Functions. (*Electrician*, 86, pp. 349—350, March 25th, 1921.)

Deals with the application of ordinary algebraic methods to mathematical operators.

2092. **H. L. Curtis.** An Integration Method of deriving the Alternating Current Resistance and Inductance of Conductors. (*Bureau of Standards Scientific Paper*, No. 374, April 7th, 1920. *Bulletin of the Bureau of Standards*, pp. 93—124. *Journal of the Franklin Institute*, 198, p. 655, May, 1920—Abstract. *Nature*, 106, p. 641, January 13th, 1921—Abstract. *Bulletin de la Société Belge des Électriciens*, 35, pp. 24—25, January—February, 1921—Abstract. *Science Abstracts*, 24A, p. 138, Abstract No. 306, February 28th, 1921—Abstract. *Physical Review*, 15, pp. 528—531, June, 1920—Abstract.)

The conductor is assumed to be divided into infinitesimal filaments by surfaces which coincide with the lines of current flow and the solution of the problem is then obtained by a process of induction. The formulæ developed correspond exactly with the asymptotic formulæ of Russell. Some experimental results are also quoted.

2093. **A. Russell.** The Capacity Coefficients of Spherical Conductors. (*Proceedings of the Royal Society*, 97, pp. 160—172, April 15th, 1920. *Science Abstracts*, 23A, pp. 287—288, Abstract No. 739, May 31st, 1920—Abstract.)

A mathematical investigation of the electrostatic capacity of spheres, and including approximate formulæ for the capacity between a sphere and a large conductor.

### (A.) Radio Stations and Installations.

2094. German Developments in C.W. Stations. (*La T.S.F. Moderne*, 1, pp. 176—180, September, 1920.)

See pp. 370—372, in this issue for abstract.

## 2. Book Review.

**THE THERMIONIC VACUUM TUBE AND ITS APPLICATIONS.** By H. J. van der Bijl. (New York: McGraw-Hill Book Co., Inc. London: McGraw-Hill Publishing Co., Ltd. 1921. Pp. 391. 9" × 6"; with 232 figures. Price 30s. net.)

The research work of van der Bijl is known to every student of the thermionic valve. As a research physicist of the Western Electric Company of New York he had unique opportunities for carrying out investigations on the thermionic valve, more especially with regard to its application to telephony. The results of these researches and those of his colleagues are embodied in the book under review. In the preface the author states that he has tried to make the treatment sufficiently elementary "to meet the demands that will necessarily be made on a book of this kind." In our opinion the author has succeeded up to a certain point, but we must confess that we sometimes found difficulty in following the author's reasoning; this was not due so much to the treatment not being sufficiently elementary, as to a lack of sequence in the arguments. We sometimes felt, as we read a sentence over again and wondered just how it followed from the preceding one, that the author, although obviously a master of his subject, could not have had much experience as a teacher. It should be pointed out, however, that the book consists of nearly 400 pages closely packed with facts and arguments with little descriptive matter and an attempt to read it rapidly and in large doses is apt to reduce one's mental alertness.

The book is divided into an introduction and ten chapters. In the introduction the author traces out the history of the subject of thermionic emission and its applications, and then proceeds to explain the plan of the book. The first chapter deals with the properties of electrons, their mass and field when stationary and moving and the relation between space charge and potential distribution. The following two chapters deal with the different methods of producing electrons, with special reference to their emission from heated solids. A clear explanation is given of the modern views on contact E.M.F. and electron affinity. The fourth chapter on the physics of the thermionic valve goes fairly fully into the subject so far as the hard valve is concerned, the effect of gas being treated in the following chapter. Chapter VI. deals with the subject of rectification by means of the two-electrode valve, and also with smoothing devices or filters to give a steady current output. Chapter VII. on the amplifier occupies 120 pages; the subject is treated both mathematically and experimentally. The mathematic treatment is for the most part based on the characteristic equation

$$I_p = a \left( \frac{E_p}{\mu} + E_g + \epsilon \right)^2$$
 which is used throughout the book. Various methods are described

for the direct experimental determination of the amplification ratio and other constants of the valve.

Chapter VIII. deals with the vacuum tube as an oscillation generator. All the usual methods are considered and questions of phase, wave form and efficiency are discussed. In Chapter IX. we reach the subject of detection which most people regard as the first application of the thermionic valve, as it undoubtedly was historically. Van der Bijl treats modulation and detection together in this chapter. The concluding chapter contains a collection of miscellaneous applications of thermionic tubes including Round's well-known slide-back method of measuring voltages, the ionisation manometer and a brief reference to valves with two grids.

A few misprints are almost unavoidable in a book containing so many symbols with subscripts, but there are two rather unfortunate ones on p. 165, where in equation (15) one of the terms is upside down, and in equation (17)  $E_p$  should be  $E_g$ . On the whole, however, the book is remarkably free from such blemishes. The book is very well illustrated with diagrams and curves as well as photographs of valves and other apparatus. It would be better if more information were given on the curves so that one might be able to differentiate between them without having to search through the text; sometimes, we must confess, we searched in vain.

Apart from these few criticisms, however, we have no hesitation in commending the book to any one interested in the thermionic valve.

G. W. O. H.

### Books Received.

DIE NEUERE ENTWICKLUNG DER FUNKENTELEGRAPHIE EIN SIEGESZUG DER VAKUUM-RÖHRE. By Dr. H. Wigge. (Cöthen-Anhalt: *Verlag der Ingenieur-Zeitung*. Second Edition, 1921. Pp. v + 71, 9½" × 6½", with 59 illustrations. Price not stated.)

MANUAL OF ELECTRICAL UNDERTAKINGS AND DIRECTORY OF OFFICIALS, 1920—1921. Compiled under the direction of E. Garcke, M.I.E.E. (London: *Electrical Press, Ltd.* Vol. XXIV., 1921. Pp. ccxxviii + 1627, 8½" × 5½". Price 30s. net.)

## Correspondence.

### MICA CONDENSERS FOR RADIO WORK.

In the March issue of the *RADIO REVIEW* we published a communication from the Wireless Specialty Apparatus Company with reference to recent litigation against them by the Dubilier Condenser Co. We have received a communication from the latter company pointing out that the statements made are misleading, that the W.S.A. Company have paid \$25,000 and the U.S.A. Government \$15,000 for licences under the Dubilier Patents, that the W.S.A. Co. have signed, agreed and conceded the priority of all the condenser patents issued to Mr. Dubilier at the time of signing the contract, that up to date the W.S.A. Co. have not obtained one patent on mica condensers and that Mr. Dubilier's latest patent applications are not included in the licence to the W.S.A. Co. The Dubilier Co. support these statements with copies of the contracts, the decision of the U.S. Courts, together with recent letters exchanged between the companies.

As we do not think it desirable to devote further space to this matter, we feel that we are doing justice to both parties in reproducing the above statements before closing the correspondence.—ED.

### TRIODE CHARACTERISTICS WITH HIGH GRID POTENTIAL.

#### TO THE EDITOR OF THE "RADIO REVIEW."

SIR,—In correspondence to the *RADIO REVIEW*, April, 1921, reference is made in a letter by Dr. B. van der Pol and in an Editorial note to secondary emission effects in three-electrode valves.

Secondary emission from the grid may occur in practice when using valves as oscillation generators. As one example of this, a 200-watt valve directly coupled to an oscillatory circuit was being used as a generator at a frequency of about 500,000 and in an attempt to obtain high efficiency the grid tapping was about three times the anode tapping. Oscillations were obtained satisfactorily, the valve running quite cold, but it was found that a slight increase of the high-tension voltage, which was about 2,000 V, would cause the anode to heat with extreme rapidity.

This phenomenon can be repeated and there is found to be a region of instability where slight changes in any part of the circuit will bring on this sudden heating of the anode.

The valve will be found to remain hard so that the effect is not due to the evolution of gas. A centre zero D.C. milliammeter placed in series with the grid leak indicates that the current changes in direction each time the effect occurs. The explanation appears to be that with the particular adjustment at which this phenomenon occurs the grid and anode voltages at that part of the cycle where the grid is positive, are favourable to a large secondary emission of electrons from the grid. This emission of electrons causes the mean grid current to reverse in direction, to charge the grid condenser to the opposite polarity, thus changing the mean voltage of the grid from negative to positive and enormously increasing the anode current.

A. C. BARTLETT.

Research Laboratories of the General Electric Co., Ltd.,  
London, W.  
May 20th, 1921.