PATENT SPECIFICATION

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PROVISIONAL SPECIFICATION

An Improved Method of and Apparatus for Testing Thermionic Valves

We, SYDNEY RUTHERFORD WILKINS, a British Subject, and THE AUTOMATIC COIL WINDER AND ELECTRICAL EQUIPMENT COMPANY LIMITED, a British Company, both of the Company's address at Winder House, Douglas Street, Westminster, London, S.W.1, do hereby declare the nature of this invention to be as follows:—

This invention relates to an improved method of and apparatus for testing thermionic valves.

In our prior Patent No. 480,752 we have described and claimed a method of testing and indicating the mutual conductance of a radio valve which consists in applying the requisite volts to the filament or heater, applying an alternating current to the anode and measuring the change in anode current by a suitable meter after impressing equal and opposite potentials on the grid, said method being characterised in that the voltages applied are related to the meter scale on the basis that, when the meter scale is based on milliamp readings, the R.M.S. value of the alternating voltage applied to the anode is equal substantially to 1.4 times the rated D.C. voltage for the test whilst the equal and opposite grid potentials differ by an amount equal substantially to twice the difference of the normally accepted D.C. grid voltages so that the meter reading indicates a proportion of the actual published mutual conductance figures.

Now such a method is very simple and enables simple and inexpensive apparatus to be provided for efficiently testing the mutual conductance of a valve. It will be appreciated, however, that it is an empirical method and gives only an indication of the mutual conductance of the valve at zero grid volts and the rated anode volts and, whilst at the date of our said prior Patent such a test was generally recognised as the standard test for the "goodness" of a valve, it has since been appreciated that in many cases such a test does not give a sufficiently accurate indication of the value under working conditions. Also, it is often required to know other things about a valve, for example its anode current at a given grid voltage, and so on. Such readings were not correctly given in the old method. It is, therefore, the chief object of the present invention to provide a method of and apparatus for testing thermionic valves which, whilst retaining all the advantages pointed out in our said prior Patent of applying A.C. voltages, as distinct from D.C. voltages, to the electrodes of the valves, will give readings from which any desired parameter of the valve under test may be produced.

One method of testing a thermionic valve according to the present invention consists in applying a sinusoidal alternating current voltage having an R.M.S. value equal to 1.1 times the normal applied D.C. voltage of the test conditions and applying to the grid an out-of-phase A.C. voltage whose peak value is equal to $\frac{1}{.63}$ of the normal applied D.C. negative grid volts for the conditions in question.

Under these conditions the anode current will be substantially one-half of that which would be passed under D.C. conditions of operation. This relationship, it can be proved, holds good throughout the whole of the valves characteristic performance down to cut-off and including the positive control grid region, and all that is required, therefore,

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is to calibrate the meter so that the scale reads twice the actual current passing.

It will be found, however, that with such an arrangement there is a risk of damaging the valve emission with large values of applied bias voltage. This is due to the fact that, whilst the anode is inoperative on the negative half cycle of the applied A.C. voltage, the grid is positive with respect to the cathode and the grid-cathode system operates as a diode and passes current which can be very great with large values of applied grid volts.

Due to the fluctuating anode voltage, the correct test conditions would not be established by the application of a steady D.C. negative bias to the grid, as will be readily appreciated.

It is preferred, therefore, in carrying out the present invention to apply to the grid during the test not the full cycle of out-of-phase A.C. voltage, as above mentioned, but to cut out the positive half wave of the applied grid voltage. This may quite simply be done by half-wave rectification. The rectified current should not be smoothed. Under these conditions, the voltage applied to the grid will have the desired sine-wave form over the effective position and its peak value should now be $\frac{1}{.636}$ of the equivalent D.C. bias.

The apparatus according to the present invention comprises one or more transformers adopted to provide the required A.C. voltages, a half-wave rectifier to remove the unwanted positive half-wave of the A.C. voltage applied to the signal grid, a meter to read the anode (or other voltage carrying electrode) current and switches to vary the voltages applied to the anode (or screen) and the grid. Preferably the switch for controlling the voltage applied to the grid is adapted to change the bias applied by steps equivalent to 1 volt D.C.

With the aid of such apparatus any of the characteristic curves of the valve under test can be blotted and mutual conductance figures for any operating conditions can be obtained from the change of anode current.

When testing valves with a plurality of anode systems, each system is tested separately, corresponding A.C. voltages being, however, applied to the other anode system. In other words, any anode system not under test is not left open.

The apparatus also preferably includes means for testing the efficiency of rectifier valves. The circuit is such that it enables the efficiency of the rectifier valve to be read under conditions of reservoir condenser load in terms of the total rectified current that can be taken from the anode. For this purpose an A.C. voltage high enough to overcome the internal resistance of the valve and the curvature of the characteristic is applied to the valve with a reservoir condenser of, say, 8 mfd. across the load. The shunt across the meter and the resistance in series therewith are set to predetermined positions according to the particular valve to be tested, and the D.C. current passed by the load is read against a coloured scale so that if efficient rectification at the rated load current takes place the meter registers in the middle of the " good " portion of the coloured scale. Each anode in the case of a full-wave rectifier is tested separately.

Dated this 24th day of January, 1946.

LESLIE N. COX,
Patent Agent,
329, High Holborn, London, W.C.1,
Agent for the Applicants.

COMPLETE SPECIFICATION

An Improved Method of and Apparatus for Testing Thermionic Valves

We, SYDNEY RUTHERFORD WILKINS, a British Subject, and THE AUTOMATIC COIL WINDER AND ELECTRICAL EQUIPMENT COMPANY LIMITED, a British Company, both of the Company's address at Winder House, Douglas Street, Westminster, London, S.W.1, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to an improved method of and apparatus for testing thermionic valves.

In our prior Patent No. 480,752 we have described and claimed a method of testing and indicating the mutual conductance of a radio valve which consists in applying the requisite volts to the filament or heater, applying an alternating current to the anode and measuring the change in anode current by a suitable meter after impressing equal and opposite potentials on the grid, said method being characterised in that the voltages applied are related to the meter scale on the basis that, when the meter scale is based on milliamp readings, the R.M.S. value of the alternating voltage applied to the anode is equal substantially to 1.4 times the rated D.C. voltage for the test whilst the equal and opposite grid potentials differ by an amount equal substantially to twice the difference of the normally accepted D.C. grid voltages so that the meter reading indicates a proportion of the actual published mutual conductance figures.

Now such a method is very simple and enables simple and inexpensive apparatus to be provided for efficiently testing the mutual conductance of a valve. It will be appreciated, however, that it is an empirical method and gives only an indication of the mutual conductance of the valve at zero grid volts and the rated anode volts and, whilst at the date of our said prior Patent such a test was generally recognised as the standard test for the "goodness" of a valve, it has since been appreciated that in many cases such a test does not give a sufficiently accurate indication of the value under working conditions. Also, it is often required to know other things about a valve, for example its anode current at a given grid voltage, and so on. Such readings were not correctly given in the old method. It is, therefore, the chief object of the present invention to provide a method of and apparatus for testing thermionic valves which, whilst retaining all the advantages pointed out in our said prior Patent of applying A.C. voltages, as distinct from D.C. voltages, to the electrodes of the valves, will give readings from which any desired parameter of the valve under test may be produced.

Following the principle of our abovementioned prior Patent, it is reasonable to assume that, with sinusoidal alternating voltage on the anode and a counterphase sinusoidal grid voltage of suitable magnitude, the required state of affairs would be produced, thus enabling Ia/Vg curves to be drawn.

There is, however, a serious drawback to this arrangement, particularly occurring during the half cycle in which the anode is being operated on by the negative half cycle of the applied anode volts. At this time, the anode is not drawing current, but the grid has applied thereto a positive half cycle of grid volts which may be of considerable magnitude. The grid thus being positive with respect to the cathode will draw considerable current, which can, due to the comparatively low impedance in the grid circuit, reach injurious proportions. Further, it tends to alter the effective phase of the negative grid half cycle with the result that anode voltage/grid current curves and other relevant characteristics are erroneously extended towards cut-off.

At first sight an immediate solution of this difficulty would appear to be the use of negative D.C. voltage on the grid, still with sinusoidal voltage on the anode. Since the current drawn by the grid when negative is for all practical purposes nil, this would be a fairly simple matter to include in the instrument, without complication, as regulation troubles would not be introduced, and the grid voltage could be pre-calibrated for all valves in the same way as could a sinusoidal A.C. voltage.

Reference to Figures 1 and 2 of the accompanying drawings will show, however, that this arrangement cannot give a true interpretation of the valve characteristics. Consider the general form of a Triode Valve characteristic which can be considered to follow the form:—

$$Ia = \frac{K(Va + \mu Vg)}{Ra}$$

where K is a constant dependant upon the physical proportions of the valve. Let Figure 1 represent a set of Ia/Va characteristics of such a valve which, for the sake of simplicity, have been idealised by making them parallel straight lines, neglecting the curvature at cut-off.

Let us assume that the valve is biased at minus 3 negative grid volts, and subjected to a sinusoidal alternating anode voltage having a peak value of 140 volts (RMS 100 volts), then Figure 2 will represent the excursion of anode current over the first half cycle of anode voltage. It will be seen that, due to the steady negative bias, anode current will not start to flow during the initial stages of the anode and voltage cycle until the instantaneous value of anode voltage exceeds that for which the $Vg = -3$ characteristic cuts-off (i.e. the amplification factor × the value of the negative bias). The actual anode current over the half cycle in question is thus represented by the shaded portion of the curve ABCDE. Relating this to the applied anode and grid voltages, and with the following notation, we have:—

Let $\overset{a}{e}$ be the peak value of the sinusoidal anode voltage

Eg be the value of the negative D.C.

volts on the signal grid

Ia be the mean value of the anode current over a positive half cycle of anode volts

μ be the amplification factor of the valve

Ra be the anode A.C. resistance of the value

Now, referring to Figure 2, let ABCDE represent a positive half sinusoid of applied anode voltage extending from $\omega t = 0$ to $\omega t = \pi$ radians.

Due to the D.C. fixed negative bias it is obvious that anode current will not flow during the cycle until the instantaneous anode voltage exceeds μeg. Let $\omega t = \theta$ be the point at which anode current starts to flow. Then the anode current will be a function of the curve BCD which is the portion of the cycle during which the anode voltage exceeds μeg.

The average anode current during the half cycle is then given by:—

$$2 \times \frac{1}{Ra} \times \left[\frac{\omega}{\pi/2} \int_{t=\frac{\theta}{\omega}}^{t=\frac{\pi}{2\omega}} \hat{\varepsilon} \sin \omega t \, dt - (\text{area GBHJ}) \right]$$

$$= \frac{2}{Ra} \times \left\{ \frac{2\omega}{\pi} \cdot \frac{\hat{\varepsilon}}{\omega} \left[-\cos \omega t \right]_{\frac{\theta}{\omega}}^{\frac{\pi}{2\omega}} - (\text{area GBHJ}) \right\}$$

$$= \frac{2}{Ra} \left\{ \frac{2\hat{\varepsilon}}{\pi} (\cos \theta) - (BG \times JH) \right\}$$

$$= \frac{2}{Ra} \left\{ \frac{2\hat{\varepsilon}}{\pi} \sqrt{1 - \sin^2\theta} + \mu Eg \times \left(\frac{\pi}{2} - \theta \right) \right\}$$

$$= \frac{4}{\pi Ra} \times \sqrt{1 - \sin^2\theta} \times \hat{\varepsilon} + \left(\frac{\pi}{2} - \theta \right) \mu Eg \times \frac{2}{Ra}$$

$$= K_1 \hat{\varepsilon} \sqrt{1 - \left(\frac{\mu \varepsilon g}{\hat{\varepsilon}} \right)^2} + K_2 \mu \varepsilon g \left(\cos^{-1} \frac{\mu Eg}{\hat{\varepsilon}} \right)$$

It will be seen that the expression for anode current so obtained is diminished in a non-linear manner from the general form:—

$$Ia = \frac{f(Va + Vg)}{Ra}$$

by the introduction of further terms dependant on the ratio of applied anode and grid voltages, and the general relationship can only hold at zero grid bias. It is thus obvious that with a steady D.C. applied to the grid, and with alternating voltage on the anode, due to the fixed cut-off that occurs at the ends of the sinusoidal anode current cycle it is impossible for the valve anode current to follow the general Ia/Vg characteristic.

To overcome this deficiency, and again presuming a linear valve characteristic, it is obvious that for anode current to flow throughout the anode voltage cycle the grid voltage and anode voltage must pass through zero and maximum at similar times. In other words, with a sinusoidal applied anode voltage the grid voltage must also be sinusoidal and since it is to represent a negative grid voltage it must be in exact anti-phase to the anode voltage. To overcome the previously mentioned drawback of the effect of the positive half cycle on the grid, when the anode is taking no current, some means must be obtained to procure a grid voltage which is sinusoidal during the negative half cycle and zero during the positive half cycle. This obviously gives rise to the provision of a half-wave rectified signal to which no smoothing has been applied to destroy the sinusoidal nature of the signal during its operative half cycle. This is the system which is adopted in accordance with the present invention, namely, the provision of alternative voltage to the anode, screen and/or other high voltage electrodes together with the application of a half-wave unsmoothed rectified signal in counter-phase to the anode voltage and of a suitable magnitude to replace the D.C. voltage conditions desired.

The magnitude of the A.C. anode voltage and the half-wave rectified grid voltages required to simulate D.C. conditions are obtained as follows and referring to Figures 3 and 4 of the accompanying drawings in which Figure 3 represents a set of idealised Ia/Va curves for the valve under consideration and Figure 4 represents a half sinusoid of anode voltage for the valve. Adopting the same notation as in the previous case with the exception that εg now represents the negative peak value of the grid volts, it will be seen that since the grid voltage varies sinusoidally in phase with the anode voltage, both starting from zero, the instantaneous anode current at $\omega t = \alpha$ can be taken as f.GH = f.(FH − FG)

$$= f \hat{\varepsilon} \sin \alpha - \mu \hat{\varepsilon}_g \sin \alpha$$

Then average anode current over the half cycle

$$Ia = K \frac{1}{Ra} \cdot \frac{\omega}{\pi} \left\{ \int_{\omega t=0}^{\omega t=\pi} \hat{\varepsilon} \sin \omega t + \int_{\omega t=0}^{\omega t=\pi} \hat{\varepsilon}_g \sin \omega t \right\}$$

$$= K \frac{\omega}{\pi Ra} \left\{ \hat{\varepsilon} \times \frac{1}{\omega} \left[-\cos \omega t \right]_{\omega t=0}^{\omega t=\pi} + \mu \hat{\varepsilon}_g \times \frac{1}{\omega} \left[-\cos \omega t \right] \right\}$$

$$= \frac{K}{\pi Ra} \left\{ 2\hat{\varepsilon} + 2\mu \hat{\varepsilon}_g \right\}$$

$$= \frac{2K}{\pi} \left(\frac{\hat{\varepsilon} + \mu \hat{\varepsilon}_g}{Ra} \right)$$

where K is a constant depending on the physical constants of the valve.

Deriving this in terms of the actual

applied voltages we have:—

$$I_a = \frac{K}{R_a}\left(\frac{2}{\pi}\hat{\varepsilon} + \frac{2}{\pi}\mu\hat{\varepsilon}_g\right)$$

Let ε_{RMS} be the RMS value of the applied A.C. (at would be the normal measurement of applied A.C. volts) and let represent the average value of the half wave rectified applied grid volts (as read on an ordinary moving coil D.C. voltmeter) then:—

$$I_a = \frac{K}{R_a}\left(\frac{2\,\varepsilon_{RMS}}{\cdot 707 \times \pi} + \frac{2\mu\,\varepsilon_{DC}}{\cdot 318\,\pi}\right)$$

$$= \frac{K}{R_a}\left(\frac{\varepsilon_{RMS}}{1 \cdot 1} + 2\mu\,\varepsilon_{DC}\right)$$

Thus, remembering that current only flows in the anode circuit on alternate (positive) half cycles of anode voltage, we have:—

$$I_a = \frac{K}{2R_a}\left(\frac{\varepsilon_{RMS}}{1 \cdot 1} + 2\mu\,\varepsilon_{DC}\right)$$

This can be written:—

$$I_a = \frac{K}{2} \cdot \frac{(\varepsilon_{RMS} \times \frac{1}{1 \cdot 1} + \mu\,\varepsilon_{DC} \times 2)}{R_a}$$

This is obviously of the form of the general characteristic:—

$$I_a = \frac{K(V_a + \mu V_g)}{R_a}$$

It is thus clear that with an RMS value of applied anode (and/or screen) voltage equal to 1.1 × Va (D.C.) and a mean value of half-wave rectified bias voltage equal to .5 × Vg (D.C.) where Va (D.C.) and Va (D.C.) are the required D.C. testing voltages, then the valve will give a mean value of D.C. anode current (as read on an ordinary D.C. moving coil meter) equal to precisely one half the anode current that the valve would take under D.C. conditions. Therefore, by scaling the meter in milliamps by a multiplying factor of twice its actual reading, and by applying the equivalent anode (or screen) voltages and grid voltage, as described above, the meter will be direct reading in anode current for the valve and this relationship will hold over the whole of the characteristic in question. Further, by changing the grid voltage in the above relationship at any point on the characteristic, the change in anode current for a given change in grid voltage will bear the same relationship to the mutual conductance of the valve and the change in anode current as measured on the meter will thus be a direct measure of the valves mutual conductance at any point on its characteristic.

The above relationship has, for the sake of simplicity, been calculated for a triode valve, but similar relationships exist in the case of a multi-electrode valve. For instance, a screen grid valve or pentode in which positive D.C. volts are normally applied to the screen as well as the anode has the general expression:—

$$I_a = f(V_a + \mu(a/s)V_s + \mu(a/g)V_g$$

and would obviously have a sinusoidal voltage applied to its anode whose RMS value is equal to 1.1 × the rated anode voltage, a sinusoidal voltage in phase with the anode voltage applied to the screen and of an RMS value equal to 1.1 × the rated positive D.C. screen voltage and a counter-phase half-wave rectified sinusoidal voltage applied to the grid, the mean value of which is .5 × the negative D.C. bias voltage. Under these conditions the equivalent mean measured D.C. anode or screen current would be half the D.C. anode or screen current obtained if the valve were working under full D.C. conditions. Anode and screen mutual characteristics can thus be plotted.

Similarly, for other multi-electrode valves employing electrodes normally subject to positive voltages on the current carrying electrodes (anodes, screens and so forth) and negative voltage on the normally non-current carrying electrodes (signal grids, suppressor grids and so forth) the stated relationships for applied in phase sinusoidal voltages to the anodes and screens and applied counter-phase half-wave rectified voltages to the grids and suppressor grids holds throughout, the mean D.C. anode current always being one half the D.C. current obtained under full D.C. conditions.

It must be understood that whilst the above general relationships have been worked out for an ideal characteristic without curvature, they give substantially correct results even when the characteristic curvature is taken into account. Minor modifications of the multiplying factors for anode and grid voltages can be introduced to correct small errors due to the curvature without departing from the scope of the present invention.

The apparatus for testing valves according to the present invention comprises one or more transformers adapted to provide the required A.C. voltages, a half-wave rectifier to remove the unwanted positive half-wave of the A.C. voltage applied to the signal or other grid or grids, a meter to read the anode (or other current carrying electrode) current and switches to vary the voltages applied to the anode or the like and the grid or grids. The meter is preferably scaled to indicate twice the actual current passing.

The valve tester according to the present invention also preferably includes means for testing the efficiency of rectifier valves. The testing of rectifying valves in an apparatus such as that described above presents a problem for two reasons, firstly, no test is really informative unless carried out under normal conditions of rectification, i.e. reservoir condenser and load, and, secondly, unless the rectifying valve is working under conditions of maximum loading, which is unusual, what is required is not necessarily whether the rectifier can supply its maximum rated current, but whether the valve will supply continuously the current that is required from it in the apparatus in question.

Since a rectifying valve has no single parameter (such as mutual conductance in the case of other valves) which will express its condition and the taking of a full set of load curves would be excessively tedious and not very informative to the comparatively inexperienced, the method adopted according to the present invention is as follows:—

Referring to Figure 5 of the accompanying drawings, the valve has applied thereto a sufficiently high A.C. voltage to render negligible its own internal resistance and to work it above the bend in its characteristic. It is connected in the circuit shown in Figure 5 where C is a reservoir condenser of sufficiently high capacity and L is a load resistance, M being a meter to measure the rectified current.

Assuming that the valve will be working with about 30% of the peak value of the applied voltage as a ripple voltage we can assume that normal conditions after the rectifying valve a D.C. voltage equivalent to about 70% of the applied peak voltage. The load L can therefore be tapped so that with this assumption and allowing for the voltage drop in the valve, D.C. currents of suitable magnitude for the different load conditions will flow in L and be indicated on the meter M. If now M is shunted so that for a given nominal current in L a zone on the meter M indicates, say, plus 15% to minus 30% of this value, then, the position of the needle of the meter M will show by its relation to this zone, which is conveniently coloured, the relative efficiency of the valve at the load current under consideration. Thus, by suitably tapping L, as shown in Figure 6 of the accompanying drawings, for load currents of, say, 5ma., 15ma., 30ma., 60ma. and 120ma. and arranging a shunt M^1 across M which is altered by means of the switch S in conformity with the tappings on the load resistance L so that the meter reads on the coloured zone 115% of the load current for full scale, and a zone marked "Pass" or "Good" on the meter corresponding to the region between plus 15% and minus 30% of the load value, then, by switching from one load to the other, the efficiency of the valve under reservoir condenser and full load rectification conditions can be gauged for the load that it has to supply.

It is to be understood that whilst minus 30% can be allowed for a "pass" figure under normal ratio conditions, under more exacting conditions the meter can be scaled accordingly. Further, the applied voltage and load current conditions can be changed for more specific applications.

Similarly, by applying a lower RMS voltage and introducing a load and meter tapping for, say, 1ma., signal diodes can be tested.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. Apparatus for testing thermionic valves comprising means for applying to an anode or like electrode of the valve a sinusoidal alternating current voltage having an RMS value equal to 1.1 (or approximately 1.1) times the D.C. voltage which would normally be applied in carrying out the test in question, means for applying a sinusoidal alternating current voltage whose means value is equal to one half (or approximately one half) of the normal applied D.C. negative grid volts for the test in question, in counter-phase to the voltage applied to the anode, means for suppressing the positive half cycle of said second-mentioned alternating current voltage and for applying such rectified sinusoidal alternating current voltage to the grid of the valve, and a meter for measuring the current flowing in the circuit to which the first-mentioned alternating current voltage is applied.

2. Apparatus for testing thermionic valves according to Claim 1, in which the meter scale is calibrated to read twice the actual current flowing.

3. Apparatus for testing thermionic valves according to Claim 1 or Claim 2, provided with switch means to vary the value of the half wave rectified alternat-

ing current voltage applied to the grid of the valve.

4. Apparatus for testing thermionic valves according to any of the preceding Claims 1 to 3 adapted also for testing the efficiency of rectifying valves, the means for this purpose comprising a reservoir condenser and a load resistance, means being provided for connecting the reservoir condenser in a lead from the source of unrectified A.C. to the anode of the rectifying valve and for connecting the meter and the load resistance in series with one another and in shunt across the reservoir condenser.

5. Apparatus for testing thermionic valves according to Claim 4, in which the load resistance is provided with a series of tappings and a tapped resistance is shunted across the meter, switch means being provided to select the desired tappings on the load resistance and the meter shunt.

6. The improved apparatus for testing thermionic valves, substantially as hereinbefore described with reference to the accompanying drawings.

Dated this 10th day of March, 1947.

LESLIE N. COX,
Patent Agent,
329, High Holborn, London, W.C.1,
Agent for the Applicants.

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Fig.1.

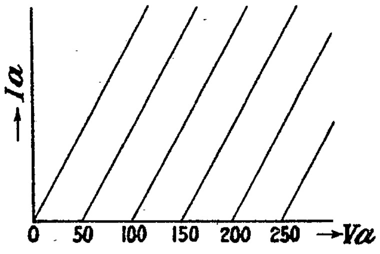

Fig.3.

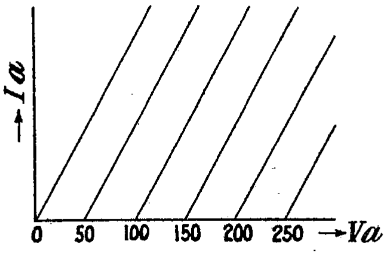

Fig.2.

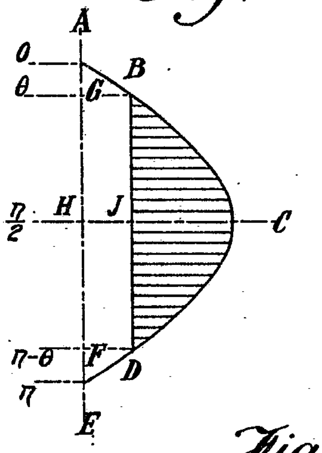

Fig.4.

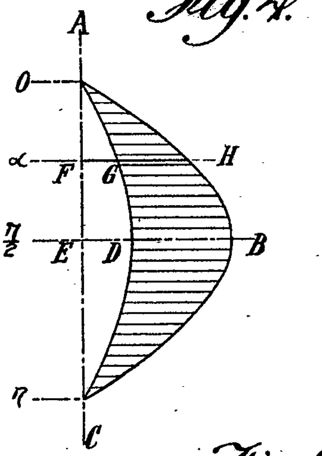

Fig.5.

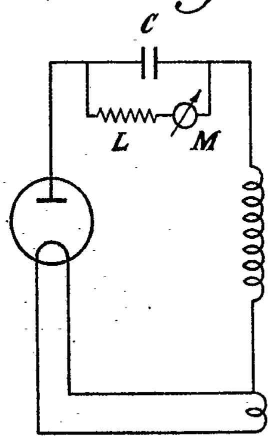

Fig.6.