PATENT SPECIFICATION

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PROVISIONAL SPECIFICATION

An Improved Method and Apparatus for Testing Radio Valves

We, Sydney Rutherford Wilkins, a British Subject, and The Automatic Coil Winder & Electrical Equipment Company Limited, a British Company, both of 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 the testing of radio valves, and has for its chief object to provide a novel method of testing valves and to provide a simple apparatus or test panel for carrying out the tests.

By common consent the static mutual conductance value has been chosen as the standard of merit of a valve. The mutual conductance value is usually stated on the valve maker's data sheets and a valve which gives a satisfactory mutual conductance figure, i.e., a figure approaching that given by the manufacturer, can be relied upon to operate satisfactorily and *vice versa*.

Mutual conductance is interpreted as the change in anode current, when the grid voltage is changed by one volt, under the correct conditions of anode voltage, screen voltage and the like applicable to the valve. The one volt change in grid voltage is obtained by swinging the grid voltage ∓ ½ volt about zero—i.e., from − ½ volt to + ½ volt.

Thus, if with the correct anode voltage (and, if necessary, screen voltage) the anode current obtained is " A " milliamps with − ½ volt on the grid, and rises to " B " milliamps when the grid voltage is changed to + ½ volt, then the change in current B—A represents the mutual conductance of the valve and can be compared with the maker's figure. If the current with − ½ volt on the grid be balanced out of the meter circuit, the meter will then show accurately the change in current when the grid voltage is changed and the scale can therefore be calibrated directly in mutual conductance.

Now, a manufacturer's mutual conductance test figures are taken at standard figures, such as 100 volts on the anode and zero grid volts for triodes. In order, therefore, to obtain such mutual conductance figures correctly, it is necessary for the applied anode and screen voltages to be exactly those required for the valve under test, and what is more important it is necessary that these voltages do not change with load during the taking of a reading. As the D.C. voltages for anode and screen etc. are obtained from A.C. mains through a suitable transformer and rectifier, the bad regulation that is inherent in the rectifier prevents the applied voltages being constant in all conditions unless a voltage control and voltmeter are supplied by which the voltage can be constantly checked. To satisfy these conditions, the valve testing apparatus is necessarily complicated as well as cumbersome and costly, as it requires a number of meters and various regulating devices.

It has now been found that, if instead of D.C. suitable A.C. potentials are applied to the anode (and, if necessary, to the screen) of valves, a D.C. current is obtained from the anode of the valve which is capable of being controlled by a D.C. voltage on the grid of the valve, and that, if the anode (and, if necessary, screen) A. C. voltages are given suitable values, and the D.C. grid voltage also suitably adjusted, the change in anode current for the given change in grid voltage, is equivalent to the mutual conductance of the valve.

Thus, the present invention provides a method of determining the mutual conductance of a radio valve which consists in applying to the anode of the valve an A.C. voltage equal to 1.4×the rated D.C. voltage and measuring the anode current after changing the grid volts from − 1 volt D.C. to + 1 volt D.C., whilst applying the requisite A.C. volts to the filament or filament heater.

For multi-electrode valves suitable voltage must be applied to the screens or screen grids. Thus, according to a further feature of the invention, for all screen pentodes, screen grid valves and the like, an A.C. voltage is applied to the screens which equals the rated D.C. voltage, whilst for the screening grids of L.F. pentodes there is applied an A.C. voltage equal to 1.4 × the rated D.C. voltage.

The invention has the advantage over prior proposals in that A.C. current may be regulated with certainty and without the necessity of constant checking, and can be maintained substantially constant during the test. The invention, therefore, still further consists in apparatus for obtaining a direct reading of mutual conductance on a meter comprising means for feeding selected A.C. voltage to the valve anode, optional means for feeding selected A.C. voltage to the valve screens, means for feeding selected A.C. voltage to the valve filament or filament heater, a meter in the anode circuit, regulatable means for feeding half wave rectified current through a resistance in a reverse direction through said meter and means for feeding regulated direct current to the valve grid. The voltage leads are preferably suitably connected to a number of valve holders arranged on a panel thus enabling any type of valve to be plugged into an appropriate holder.

In order that the invention may be clearly understood, a practical embodiment is hereinafter more fully described by way of example. A number of tappings on a transformer secondary are connected to the contacts of a switch, the moving member of which is connected via a measuring instrument to the anode socket of a valve holder. A further series of tappings are similarly connected to a switch which is connected to the screen socket of the valve holder. One end of the secondary is connected with the filament and the cathode socket. A further secondary or a secondary on another transformer is tapped and the tappings connected to a switch which is in turn connected with the filament positive, whilst the free end of this winding is connected to the common filament cathode socket or to the connection thereto. A further transformer secondary through a rectifier and a variable resistance feeds reverse unsmoothed half wave unidirectional current to the meter. A variable resistance is arranged in shunt with the measuring instrument. Yet another transformer secondary in circuit with a rectifier is connected with a fixed potentiometer having a central point connected to cathode and so connected with a two way switch as to supply either +1 volt or −1 volt to a lead connected with the grid socket of the valve holder. Whilst a single valve holder has been mentioned, the term is intended to include a number of valve holders arranged on a panel although a single holder and suitable adaptors may, of course, be used.

In operation, the valve to be tested is plugged into the valve holder and the requisite voltages applied therto, i.e., in the ratio to the recommended D.C. voltage previously mentioned, by manipulation of the several switches. These switches are preferably so marked that when the pointers are set to the makers recommended figures for D.C. voltage, the requisite A.C. voltages are applied. With the grid switch supplying −1 volt, the anode current reading on the meter is noted with the latter shunted to 100 *m*A full scale by operation of the variable resistance in shunt with the meter. The standing anode current is now suppressed by supplying the meter with suitable reverse current under control of the other variable resistance. The meter is now shunted to 10 *m*A and the grid switch is next turned to +1 volt. The meter now shows only the increase in anode current on a 10 *m*A scale since the original current has been backed out. Thus the mutual conductance is read directly from the meter scale. Alternatively, the variable shunt resistance may be so adjusted that the meter gives full scale deflection for the correct mutual conductance of the valve under test. The percentage "goodness" of the valve under test will be shown upon the meter scale which can be marked with suitable colours denoting "good," "bad," "indifferent" or the like.

Rectifying valves, of course, have no mutual conductance, but these can be tested by applying a suitable A.C. potential to the anode, and noting whether the rectified D.C. current on the meter is up to standard. Similarly with diode detector valves. Where more than one electrode system is contained in one envelope, these are tested separately by switching the meter from anode to anode by a suitable two way switch.

Dated the 30th day of July, 1936.
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COMPLETE SPECIFICATION

An Improved Method and Apparatus for Testing Radio Valves

We, Sydney Rutherford Wilkins, a British Subject, and The Automatic Coil Winder & Electrical Equipment Company Limited, a British Company, both of 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 the testing of radio valves.

By common consent the static mutual conductance value has been chosen as the standard of merit or " goodness " of a valve. The mutual conductance value is usually stated on the valve maker's data sheets and a valve which gives a satisfactory mutual conductance figure, i.e., a figure approaching that given by the manufacturer, can be relied upon to operate satisfactorily and conversely.

Mutual conductance of a valve is interpreted as the change in anode current which occurs when the grid voltage is changed by one volt, under the correct conditions of anode voltage, screen voltage, and the like, applicable to the valve. The one volt change in grid voltage is usually obtained by changing the grid voltage $\pm \frac{1}{2}$ volt about zero—i.e., from—$\frac{1}{2}$ volt to $+ \frac{1}{2}$ volt—by connecting the terminals of a battery alternately to the grid. Thus, if with the correct D.C. anode voltage (and, if necessary, screen voltage) the anode current obtained is " A " milliamps (shown on a suitable ammeter) with $-\frac{1}{2}$ volt on the grid, and rises to " B " milliamps when the grid voltages is changed to $+ \frac{1}{2}$ volt, then the change in current B—A milliamps represents the mutual conductance of the valve and can be compared with the maker's figure. If the D.C. voltages for anode and screen are to be obtained from A.C. mains through a suitable transformer and rectifier, the bad regulation that is inherent in the rectifier will prevent the applied voltages being constant in all conditions unless a voltage control and voltmeter are supplied by which the voltage can be constantly checked. To satisfy these conditions, the valve testing apparatus would necessarily be complicated as well as cumbersome and costly, as it would require a number of meters and various regulating devices. Alternating current has, however, been used for testing the total emission of valves, the plate and grid being connected together, but this is apt to be harmful to the valve and does not give a reliable indication of valve " goodness." It has also been suggested to apply alternating current voltages on the grid for obtaining mutual conductance figures, by connecting the filament circuit to the grid and providing means whereby the voltage applied to the grid may be put in phase and then in phase opposition with the anode voltage, the mutual conductance figures being obtained from a meter in the anode circuit. However, since no special values were selected for the alternating voltages applied to the various valve electrodes, the D.C. change in anode current had no special relation to the mutual conductance of the valve when expressed in its correct units. The test figure so obtained for any given valve will not be the same as the manufacturer's mutual conductance figure for a valve of equivalent " goodness " and accordingly it is not easy to ascertain what relation to mutual conductance the test figure is supposed to indicate. Moreover, variation of the current in the filament circuit involves variation of the potentials applied to the grid accompanied by further disturbance of the indicated mutual conductance figures.

If some attempt is made to co-relate the method of testing with the valve manufacturer's D.C. test figures, then the reasonable assumption is to apply A.C. voltages to the anode, grid, etc., the R.M.S. values of which are numerically equal to the manufacturer's D.C. test voltages.

For instance, if a triode mutual conductance was obtained with 100 v. D.C. on the anode and a grid change of $\pm \frac{1}{2}$ volt D.C. (following the maker's figures) then it would seem reasonable to apply 100 volts R.M.S. A.C. to the anode of the valve and change the grid potential from $\frac{1}{2}$ volt A.C. R.M.S. out of phase to $\frac{1}{2}$ volt A.C. R.M.S. in phase. Were this done it would be found that the mA/V figure obtained would be less than half the correct figure for the valve in question.

The main object of the present invention is to utilise alternating current for the anode circuit whilst enabling meter readings to be obtained which indicate proportions of the actual published mutual conductance figures.

We have ascertained that if the R.M.S. of the anode alternating voltage is made 1.4 times the rated D.C. voltage and the grid voltage is changed from $-\frac{1}{2}$ to $+\frac{1}{2}$ volt D.C. or from $\frac{1}{2}$ volt R.M.S. out of phase to $\frac{1}{2}$ volt R.M.S. in phase then the mutual conductance obtained is half the correct value. If the grid change is doubled, thus making the change from 1 volt R.M.S. out of phase with the anode volts to 1 volt R.M.S. in phase, the mutual conductance figure obtained is substantially correct.

The present invention therefore comprises 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 to the anode an alternating voltage and measuring the change in anode current by a suitable meter after impressing equal and opposite potentials on the grid, 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 following voltages are applied, viz., (1) alternating voltage on the anode, the R.M.S. value of which is equal substantially to 1.4 times the rated D.C. voltage, and (2) grid potentials differing 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.

Thus, if the meter figures represent milliamps the R.M.S value of the alternating voltage applied to the anode under test will be 1.4 times the rated D.C. voltage, and the difference between the potentials applied to the grid will be twice the normally accepted grid voltage, e.g. these potentials may be -1 and $+1$ giving a difference of 2 since the normally accepted grid voltage is $-\frac{1}{2}$ and $+\frac{1}{2}$ giving a difference of 1.

Instead of (or in addition to) the meter indicating results by figures it may show the results otherwise. For example, a coloured scale marked good—indifferent—replace—may be used and the meter circuit will be shunted so that for each valve tested the full scale (or nearly so) will represent the published mutual conductance milliamp figure of the valve. The meter needle will then indicate a rough proportion of this figure. For example, if the published mutual conductance of a valve to be tested is 4, the meter shunt will be adjusted so that the full scale meter reading is 4 milliamps. The needle movement on test will then show whether the actual mutual conductance is full scale (i.e. 4) or roughly what proportion of full scale and the colours and words are applied according to the proportions considered allowable for good, indifferent, and replace.

According to a further feature of the invention, for all H.F. screen pentodes, screen grid valves and similar H.F. valves an alternating voltage is applied to the screens, the R.M.S. value of which equals the rated D.C. voltage, whilst for the screening grids of L.F. pentodes there is applied an alternating voltage equal to 1.4 times the rated D.C. voltage.

The invention further consists in apparatus for obtaining a reading of the mutual conductance of a thermionic valve on a meter in the anode circuit having means for feeding selected alternating voltage to the valve anode, means for feeding selected voltage to the valve filament or filament heater, and A.C. winding or D.C. voltage supply for applying equal and opposite potentials on the grid said winding or voltage supply being separate from the filament or heater circuit, and means for varying the voltage applied to the filament or heater without appreciably affecting the voltage applied to the grid.

These and other important features of the invention will be hereinafter described and defined in the appended claiming clauses.

An embodiment of the present invention will be described by way of example with reference to the accompanying drawings wherein:—

Figure 1 shows the circuit diagram of a measuring instrument made in accordance with the invention,

Figure 2 illustrates the construction of a former for a resistance winding marked V2 in Figure 1,

Figure 3 illustrates the construction of the former for the resistance winding marked V1 in Figure 1,

Figure 4 is a graph of the resistance characteristic which would need to be given to a simple series resistance if it were used in place of either of the resistances V1, V2.

Figure 5 shows in diagrammatic form the operation of the circuit arrangement of the part designated MA/V in Figure 1, whilst

Figure 6 illustrates the shape of the former on which the variable resistance element in MA/V is wound.

The electrodes of the valve to be tested are connected to appropriate terminals N*x*, D2, D1, A2, L, G*d*, LT −, LT +, DX, on the instrument. N*x* is for screen current supply; D2, D1, A2, and L, for anodes according to the type of valve; G*d* for the grid; LT − and LT + for the filament and DX for the cathode of an indirectly heated valve. These terminals are preferably suitably connected to a number of valve holders arranged on a panel thus enabling any type of valve to be plugged into an appropriate holder.

The sockets for taking the valves to be tested may be disposed on a panel separate from the measuring instrument and the panel embodies sockets for a number of different types of valves. The valve panel is connected to the measuring instrument by means of a suitable plug and socket of known type which consequently need not be described here. The provision of a separate panel has the advantage that it allows the instrument to be adapted readily for any new type of valves that may be developed.

N*x* is connected to a rotary switch S*c* for selecting the voltage required for the screen. D2, D1, A2, and L, are connected to an anode selector switch AS for selecting the appropriate electrode to be tested. G*d* is connected to a source of current through a switch whereby the phase can be varied at will; and LT −, LT +, are connected to an alternating current supply variable by means of a switch H. DX is normally connected to LT −. The anode current is selected by the switch A*n*. The required results are shown by the milliammeter ME.

The instrument has a pair of input terminals 50, for plugging in to any suitable A.C. supply circuit. The instrument can be disconnected by disconnecting these terminals from the supply circuit or by means of a switch S*w*. The terminals 50 are connected within the instrument to the primary windings M*p*, L*p*, of two transformers M, L. A.C. voltages obtained from these transformers are applied to all valve electrodes although it is within the scope of the invention to apply D.C. to the grid, and normally changing this from −1 volt D.C. to +1 volt D.C. If desired, such D.C. current may be obtained from an A.C. tapping connected to a rectifier and potentiometer, the latter having a central point connected to a cathode and so connected with a two-way switch as to supply either +1 or −1 volt D.C. to a lead connected with the grid terminal.

The various A.C. voltages for supplying the filament (or heaters), anode, and, if necessary, screen of the valve to be tested are obtained as hereinbefore stated through three rotary switches marked H (heater), A*n* (anode) and S*c* (screen) respectively. The voltages which can be obtained from each one of these switches are marked on the panel of the instrument and are so arranged that suitable electrode voltages can be obtained for testing practically any standard valve.

Although the voltages marked on the panel for the anode switch are 80, 100, and so forth, the instrument parts are so arranged that the actual measured A.C. voltages applied to the anode of the valve are 1.4 times the figures marked. When the switch is set according to the D.C. operating potentials as recommended by the makers, the correct A.C. potential for purposes of test will be automatically applied.

The primary winding L*p* is tapped at various turns as indicated at L*x* in such a manner that it may be connected to A.C. supply mains of various voltages from 200 to 250 volts by adjustment at L*y*. Connected in parallel with the primary winding M*p* is a neon lamp N in series with a 0.25 megohm resistance and an "on and off" switch N*a* which is normally closed. Two pin sockets S, S are disposed near the switch N*a* in a manner such that when the two plugs to be mentioned later, are inserted into the sockets S, S the switch N*a* is opened. As will be explained later, the purpose of the neon lamp is to serve as an indicator lamp to show when the instrument is switched on and also to serve as a continuity and an insulation tester.

Two leads terminating in plugs at one end and clips at the other are provided; and when a resistance is connected across the clips on the leads, the plugs being inserted in the sockets S, the circuit is once more continuous and the lamp lights, the strength of the glow depending on the amount of resistance in circuit. This forms a useful test for filament continuity or inter-electrode shorts. It is merely necessary to insert the plug leads and connect the clips across the pins of the valve base under test when complete lighting of the lamp will show continuity in the case of a filament test, or partial lighting will show insulation breakdown in the case of an inter-electrode test.

The transformer L has four secondary windings L*s*1, L*s*2, L*s*3, L*s*4, of which winding L*s*1 is suitably tapped to give the various voltages indicated at H which are customarily used for the filament or heaters of valves to be tested.

Secondary L*s*2 is wound to give 140 volts across its complete winding and is tapped at 30 volts. One end of this winding is connected to a contact 100 of the anode multi-contact switch A*n* whilst the 30 volt tapping is connected to a second contact, marked REC 30 on the same switch through a resistance of, say 75 ohms. The other end of winding L*s*2 is connected to one end of the secondary winding M*s* of transformer M and to a centre tap of the third secondary L*s*3 of the transformer L. This winding L*s*3 has one end marked +, and the other −. The + end is connected to a pair of change-over contacts A, A^1 of a two-way multi-contact switch TWM, whilst the – end is connected to the break contacts of the same switch. The terminal G*d* which is to be connected to the grid of the valve under test, is connected to the movable contact A*x* of this set of contacts in a manner such that when the switch is thrown in one direction, marked MC, the + end of L*s*3 is connected to G*d*, when the switch is in the central position the – end is connected to G*d* and the + end disconnected, and when the switch is thrown to the position marked INS the end will be connected to G*d* over the make contact associated with contact A and the – end will be disconnected. Consequently, by means of this winding and set of contacts, the phase of the voltage impressed on the grid may be reversed at will. One volt A.C. is applied to the grid of the valve initially out of phase with the other electrode voltages. This will give rise to unidirectional anode current which is measured on the D.C. milliammeter ME. This current is then backed off to zero by means of a set zero control V described later. When the grid phase is reversed its potential is changed from 1 volt out of phase with the anode voltage to 1 volt in phase with the anode voltage. This gives rise to a change in D.C. anode current similar to that obtained when D.C. grid potential is used, and works in a perfectly satisfactory manner.

The value chosen gives an all round accuracy of mutual conductance reading which completely fulfils the requirement of the instrument.

The fourth winding L*s*4 is connected across a resistance V1 of a variable resistance V, the purpose of which will be described later. One end of this secondary winding is also connected through the central contact B*x* of the set of contacts B the two-way switch TWM, resistance *ma*/*v* of a potentiometer MA/V, a resistance V*x* of suitable value (say 40 ohms), the DC milliammeter ME, to the central contact D*x* of the contact set D operable by the two-way switch. These last named elements are all in series. The central contact B*x* of the set B normally closes a circuit to the movable contact of the rotary switch A*n*. The said movable contact can be connected by the front contact B*y* of the set B and through a condenser of, say, 0.05 MF, to a contact 75 of the screen multi-contact rotary switch S*c* and to a tapping 75 of the winding M*s*. The contacts of the switch S*c* are supplied with current from the winding M*s* for connection to the valve screen. The voltages selected on this switch are such that the R.M.S. A.C. potential supplied to the screen is numerically equal to the normal required D.C. voltages therefor, except that for an L.F. pentode screen the A.C. voltage applied will be 1.4 times normal D.C. voltage. The central contact D*x* of set D is in one position normally connected through its contact D*s* to one end of the resistance *ma*/*v* whilst through its front or make contacts D*y* it can be connected through a resistance D*o* of, say 0.1 megohms to the end 0 of the secondary winding L*s*1 and to the terminal LT –.

When the initial potential for example—1 volt D.C. or 1 volt A.C. in phase opposition is applied to the grid and the anode current is given on the meter, it is desirable to balance out or "back off" this current so that the meter pointer is brought back to zero and the reading given when the second potential, for example + 1 volt D.C. or 1 volt A.C. in phase is applied to the grid will then be the difference in anode currents. In order to provide this "backing off" between $\frac{1}{4}$ *m*/A and 80 *m*/A with a constant 20 volt supply, a single variable resistance, if used, would have to be variable from 250 ohms to 80000 ohms, and from the curve (Figure 4) it will be seen that $\frac{3}{4}$ of the angular rotation of a contact arm for varying it would then be taken up with a variation of only 1000 ohms, allowing only $\frac{1}{4}$ of the angular rotation for the remaining 79000 ohms.

To obtain a constant "backing off current/angular rotation" ratio a device has been provided in which although the characteristic is not quite linear, is near enough for ease of handling and allows the use of components which are comparatively easy and cheap to manufacture. The desired steep change in slope is obtained by using a variable series resistance element, the resistance of which per degree of angular rotation increases rapidly, coupled to a variable voltage source element such as a potentiometer the voltage/angular rotation characteristic of which decreases as the variable resistance increases. The two elements are coupled in a manner to be explained later and are called the "set zero" control.

In the embodiment shown in the drawings current is taken from the winding L*s*4. The variable resistance V comprises a potentiometer element V1 and adjacent thereto a second resistance winding V2 both traversed by a sliding element V3 pivoted at V*s*. The potentiometer winding is shaped so that the increase in resistance is not linear as the slider is moved but so that the rate of change of volts becomes greater as the backing off current is increased. V2 is also shaped so that the change of resistance per degree of angular rotation becomes less as the backing off current is increased. Suitable constructions of the formers on which V2 and V1 are wound are shown in Figures 2 and 3 respectively.

As shown in Figure 2, V2 comprises a strip or former of insulating material having as shown three sections Z, Y, X, each of constant slope which is not too steep. In the example shown the sections are two, one and a half, and two, inches long respectively. Each section is wound with a different gauge of resistance wire, for example 33 gauge enamelled Eureka, 40 gauge enamelled Eureka and 44 single silk nickel-chrome wire respectively, so that the resistance of the largest and final turn of the first section Z approximately equals the resistance of the smallest and first turn of the next section Y, and similarly for the final and first turns of Y and X respectively.

Even with the arrangement shown in Figure 2, the desired wide variation of backing off current could not be achieved on a single series resistance strip of proportions suitable to a commercial instrument.

A former of the shape shown in Figure 3 is therefore employed for the potentiometer V1. This is so connected that the voltage provided by the variable resistance V^1 decreases as the resistance provided by V^2 is increased. Moreover, this potentiometer is shaped so that the increase in voltage per degree of angular rotation is not constant. It will be seen that the overall change in slope of the current/rotation characteristics of the combined arrangement is very steep. Moreover, as at minimum backing off current the voltage is decreased to a very small proportion of the total voltage, the maximum series resistance necessary can be considerably reduced, and with the arrangement shown a maximum resistance for a backing off current of less than 1/10 *m*A is only about 2000 ohms. The insulating strip of the element V^1 as shown in Figure 3 increases regularly and has a length equal to the overall length of V2. This strip may be wound with 37 gauge enamelled nickel-chrome resistance wire but an unwound portion *a*—*a* is left at one end to serve as an "off" position for the co-operating slider V3 (Figure 1).

The two strips V1 and V2 may be bent in the form of almost complete rings and the slider V3 is arranged to wipe over that side of each strip which is not sloped.

With the foregoing arrangement the ratio between the resistance of the first and smallest turn of Z to the last and largest turn X can be made quite large and the change in the current resistance slope is also correspondingly steep. One end of V2 is connected to the slider of the potentiometer MA/V through a limiting resistance F*x* of, say, 50 ohms and a rectifier R.

The combined effect of this arrangement is to provide a backing off control which gives a much more nearly linear increase of current per degree of angular rotation of the set zero control, than would be the case if a plain series resistance control were utilised. The backing off current is left unsmoothed so that the ripple on the backing off current will counteract any slight vibration of the meter needle due to the pulsating nature of the D.C. anode current obtained from a valve under test.

The potentiometer MA/V which is in effect a universal shunt across the meter ME has a setting marked 100 and when the slider Mx is set to this point the meter has a full scale deflection equivalent to 100 milliamps. The slider is also connected to multi-contact rotary switch or anode selector AS.

The meter ME which is of the moving coil D.C. milliammeter type, has its face or scale marked to indicate the mutual conductance in milliamps per volt of the valve under test. A further scale is provided which is divided into three parts, differently coloured and marked "good," "indifferent" and "Bad" or "Replace." There is also a scale marked C.Ins.-Megohms for indicating the cathode to heater insulation of an indirectly heated valve.

The arrangement of the meter is as shown in Figure 5 where the total universal shunt is shown as the series of resistance E—K. The portion EF is a small low value fixed resistance accurately calibrated, terminating in a gold-silver alloy contact F. FG is a further accurately calibrated resistance terminating in a gold-silver alloy contact G. GH is a variable resistance strip and HK is a resistance whose value can be adjusted after the whole is assembled. The contacts F, G, are carried on the end of the variable resistance strip GH, and are so arranged that the slider of the universal shunt can travel from H to G and then on to contact G and finally on to contact F. The resistance values are so arranged that when the slider is at H, the effective range of the meter is about 1 *m*A full scale. As the slider is moved towards G the effective full scale deflection of the meter is increased slowly until when it is on the contact G it reads accurately 10 *m*A full scale. The resistance HK can be adjusted to counteract small errors in GH which would otherwise upset the accurate calibrations of the points F and G. It is essential that these positions are accurate because they represent the scale on which rectifier emissions—measured as described later—are read, and the scale on which direct mutual conductance is read respectively. The variable resistance GH is calibrated at useful intervals from 10 to 1. These calibrations are used with the coloured meter scale for comparison tests. For instance, if a valve has a mutual conductance of 4 *m*A/V, after the initial backing off, the mutual conductance scale is set to position 4 which shunts the meter so that it reads about 15% greater than 4 *m*A full scale. If now the grid potential is changed as above described the position of the meter pointer on the coloured scale will indicate the valve as good, bad or indifferent, according to the percentage its mutual conductance differs from 4. Similarly for other values of mutual conductance.

Owing to the steep change of slope of the curve governing the relation between angular rotation and current deflection, for the variable universal shunt GH, it will be appreciated that a linearly wound former having a constant cross-section strip would not be easy to handle. Assuming that the minimum setting was 1 *m*A, the setting for 2 *m*A would represent about 50% of the total rotation of the control and the settings for 5—10 *m*A would be crowded into the last 20% of rotation.

Accordingly, a similar device to that which was used in the backing off control, has been adopted. The resistance strip is wound on a former shaped as shown in Figure 6 and the resistance wires chosen are such that the full scale deflection/angular rotation characteristics, although not being linear is uniform enough for ease of handling. By the example shown in Figure 6 the strip is divided into two sections O.P of which O is three inches whilst P is two inches long. The parts O and P may be wound respectively with 28 and 36 gauge enamelled Eureka wire. The maximum width of this strip may be half an inch. It will, of course, be understood that these dimensions as those given for V1 and V2 are by way of example only.

The method of operation is as follows:—

First test the valve for electrode shorts. As previously described, for this purpose two leads are supplied, one terminating in a crocodile clip and the other in a short prod. These leads are plugged firmly into the sockets S (Figure 1). If now the crocodile clip be clipped on to the anode pin of the valve and the prod touched on the other pins in turn, the neon light (N) will light if leakage is present between the anode and any other electrode. With valves such as pentodes, in which high voltage is applied to the screen, this process should be repeated with the clip lead clipped on to the screen pin. The strength of the neon glow will indicate the amount of leakage present. This test is important and should be applied before the valve is inserted in the tester as a short between anode or screen and another electrode might cause excessive current to be taken from the tester. The above test can also be utilised for testing filament continuity as previously described and when the testing leads are not inserted in the sockets (S) the neon lamp merely serves as an indicator to show when the instrument is switched on.

Next, consult a data chart to ascertain the correct electrode voltages to be applied to the valve, and the valve holder into which it must be inserted. Then with the instrument switched off, these voltages should be selected on the appropriate switches H, A*n* and S*c* respectively, before the valve is connected with the appropriate terminals.

The MA/V control should be set to 100 and, in the case of triodes, screen grid valves and pentodes, the anode selector AS should be set at "normal."

Now with the valve connected, and the instrument switched on, the meter needle will rise, indicating the initial anode current of the valve. This current should be backed off to zero by means of the control marked V and the MA/V control then turned to the position marked G (Fig. 5). The control V can now be finally adjusted so that the meter reads zero accurately. If now the key of the two-way switch is pressed in the direction marked M.C., the meter needle will rise and indicate on the scale (calibrated 0—10) the mutual conductance of the valve in milliamps per volt. This can be compared with the figure given by the manufacturers for a good valve.

An alternative method of testing the comparative goodness of a valve is as follows:—When the initial current of a valve has been backed off to zero, consult the chart and note the mutual conductance figure given. The MA/V control should now be set to this figure and the meter needle set accurately to zero. The full scale (or nearly so) of the meter now represents the same number of milliamps as the mutual conductance number of the valve set on the MA/V control. If now the key aforesaid is pressed in the direction "M.C." the position of the needle on the coloured scale will show the valve as good—indifferent—or replace. If the needle moves over the full scale it will show that the actual mutual conductance value is equal to the published mutual conductance value.

With the valves which have more than one electrode assembly inside the same glass envelope it is necessary to test each electrode assembly separately. This applied to such valves as Class B valves, QPP valves, triode pentodes, double diode triodes and pentodes, and full wave rectifiers. For this purpose the appropriate anode is selected by the anode selector AS.

With the anode selector switch AS set at "normal" the instrument is correctly set for testing all valves with a single electrode assembly such as triodes, pentodes, S.G. valves, also one half of valves with two assemblies such as the triode portion of triode pentodes, one triode in a Class B valve. With the switch set at A2, the valve tester is ready for testing the other half of dual valves such as the pentodesection of triode pentodes, the remaining triode in Class B valves.

The positions D1, and D2, are for the testing of both anodes of full wave rectifying valves, the two diodes in double diode valves and also the diodes in double diode triodes and the like.

For the purpose of measuring the cathode to heater insulation of an indirectly heated valve, the key is pressed in the direction marked INS. By this operation (A) the grid potential is changed to one volt in phase, (B) the anode is disconnected from the normal source of potential via the switch "A*n*," and connected through a condenser of .05 mfd to the 75 volt tapping on the transformer M, (C) the connection between cathode and heater is broken and (D) the MA/V shunt and backing off control V is disconnected from the meter circuit and the unshunted meter (having a full scale deflection of .66 *m*A), is connected through the resistance D*o* between Anode and heater of the valve. The connection of the meter to the anode of the valve takes place through a part of the resistance of the MA/V shunt, which resistance, for the purpose of this test is negligible.

The action of this arrangement is then as follows:—

When the cathode is hot due to the valve having been on test, and the key is pressed in the direction "INS," an AC voltage is applied through the .05 condenser between anode and cathode of the valve. (The "in phase" voltage is applied to the grid to lower its effective impedance as a rectifier). This causes rectification to take place and a rectified voltage to appear between cathode and anode of the valve. If now any high resistance C/H appears between heater and cathode of the valve this causes the circuit through the meter to be completed via the resistance D*o*, the meter, and the resistance C/H. This will cause a current reading to appear on the meter due to the aforementioned rectified voltage. The magnitude of this current will, of course, be inversely proportional to the resistance C/H and the meter can accordingly be calibrated in megohm. The condenser (.05 mfd) is inserted to prevent the D.C. current from flowing back into the transformer, thus upsetting the meter readings. It will be seen that this arrangement will also show up any bad insulation between windings on the transformers, and the latter, therefore, have to be carefully impregnated.

It will be noticed that on the anode voltage switch A*n* are two positions marked "D_{12}" and "REC." These are for emission tests on diodes and mains rectifiers. To test diodes or double diodes, the anode volts switch A*n* is turned to the position marked "D_{12}," which applies 12 volt A.C. through a resistance of 500 ohms to the diode under test. The resultant reading on the meter shows the rectified D.C. current passed under the given conditions and from this reading the state of the diode can be estimated. As long as the rectified current is greater than ½ *m*A, the diode is taken as being in good condition. The actual current value obtained, of course, varies considerable with the characteristics of the valve. A similar test is applied to rectifying valves. For this purpose the switch A*n* is turned to position marked "REC." This arrangement applies a voltage of 30 volts through a resistance of 75 ohms to the rectifier anode. The rectified D.C. current passed under these conditions is measured on the meter (100 *m*A scale) and can be compared with the figure given for a good valve of the type under test.

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. 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 to the anode an alternating voltage and measuring the change in anode current by a suitable meter after impressing equal and opposite potentials on the grid, 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 following voltages are applied, viz., (1) alternating voltage on the anode, the R.M.S. value of which is equal substantially to 1.4 times the rated D.C. voltage, and (2) grid potentials differing 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.

2. A method as in Claim 1 wherein for the same meter conditions the current for the filament or heater is varied to the requisite amount without thereby varying the potentials applied to the grid.

3. A method of determining the mutual conductance of a radio valve according to Claim 1 or 2, wherein for the same meter conditions D.C. current is used for impressing potentials of + 1 and − 1 volts on the grid.

4. A method of determining the mutual conductance of a radio valve according to Claim 1 or 2, wherein for the same meter conditions the potentials respectively applied to the grid comprise 1 volt A.C. in phase with the alternating anode voltage and 1 volt A.C. 180° out of phase with the anode voltage.

5. A method as in any of Claims 1 to 4 wherein for the same meter conditions an alternating voltage, the R.M.S. value of which is numerically equal to the rated D.C. voltage, is applied to the screens of a H.F. screen pentode, or other H.F. screen grid valve.

6. A method as in any of Claims 1 to 4 wherein for the same meter conditions an alternating voltage, the R.M.S. value of which is 1.4 times the rated D.C. voltage, is applied to the screen of an L.F. pentode.

7. Apparatus for obtaining a reading of mutual conductance of radio valves on a meter in the anode circuit having means for feeding selected alternating voltage to the valve anode, means for feeding voltage to the valve filament or heater, an A.C. winding or D.C. voltage supply for applying equal and opposite potentials on the grid, said winding or voltage supply being separate from the filament or heater circuit, and means for varying the voltage applied to the filament or heater without appreciably affecting the voltage applied to the grid.

8. Apparatus as in Claim 7 having regulatable means for feeding unsmoothed half wave rectified current through a resistance in a reverse direction through said meter.

9. Apparatus as claimed in Claim 7 or 8 wherein means are provided for feeding selected alternating voltage to the valve screen.

10. Apparatus as claimed in any of the preceding Claims 7 to 9 wherein means for adjusting the anode current has markings associated therewith indicating rated D.C. anode voltages but the apparatus is arranged to provide alternating voltages, the R.M.S. values of which are 1.4 times these indicated voltages.

11. Apparatus as claimed in any of Claims 7 to 10 having adjustable means for supplying alternating current to the screens of H.F. screen pentodes, screen grid valves, the R.M.S. values of which are equal to the rated D.C. voltages and are indicated on appropriate markings associated with said means.

12. Apparatus as claimed in any of Claims 7 to 11 having means for supplying to an L.F. pentode screen an alternating voltage, the R.M.S. value of is 1.4 times the rated D.C. voltage.

13. Apparatus as claimed in any of Claims 7 or 9 to 12 wherein a device is provided for " backing off " the initial anode current.

14. Apparatus as claimed in Claim 13 wherein the " backing off " device comprises a potentiometer element arranged so that the rate of change of volts increases with increase of " backing off " current, associated with an adjustable resistance arranged so that the change of resistance for degree of adjustment becomes less as the backing off current is increased.

15. Apparatus as claimed in any of Claims 7 to 14 wherein separate secondary transformer windings supply current to the grid and anode.

16. Apparatus as in any of Claims 7 to 15 having means for varying the voltage applied to any other electrode of the valve without varying the potential to the signal grid.

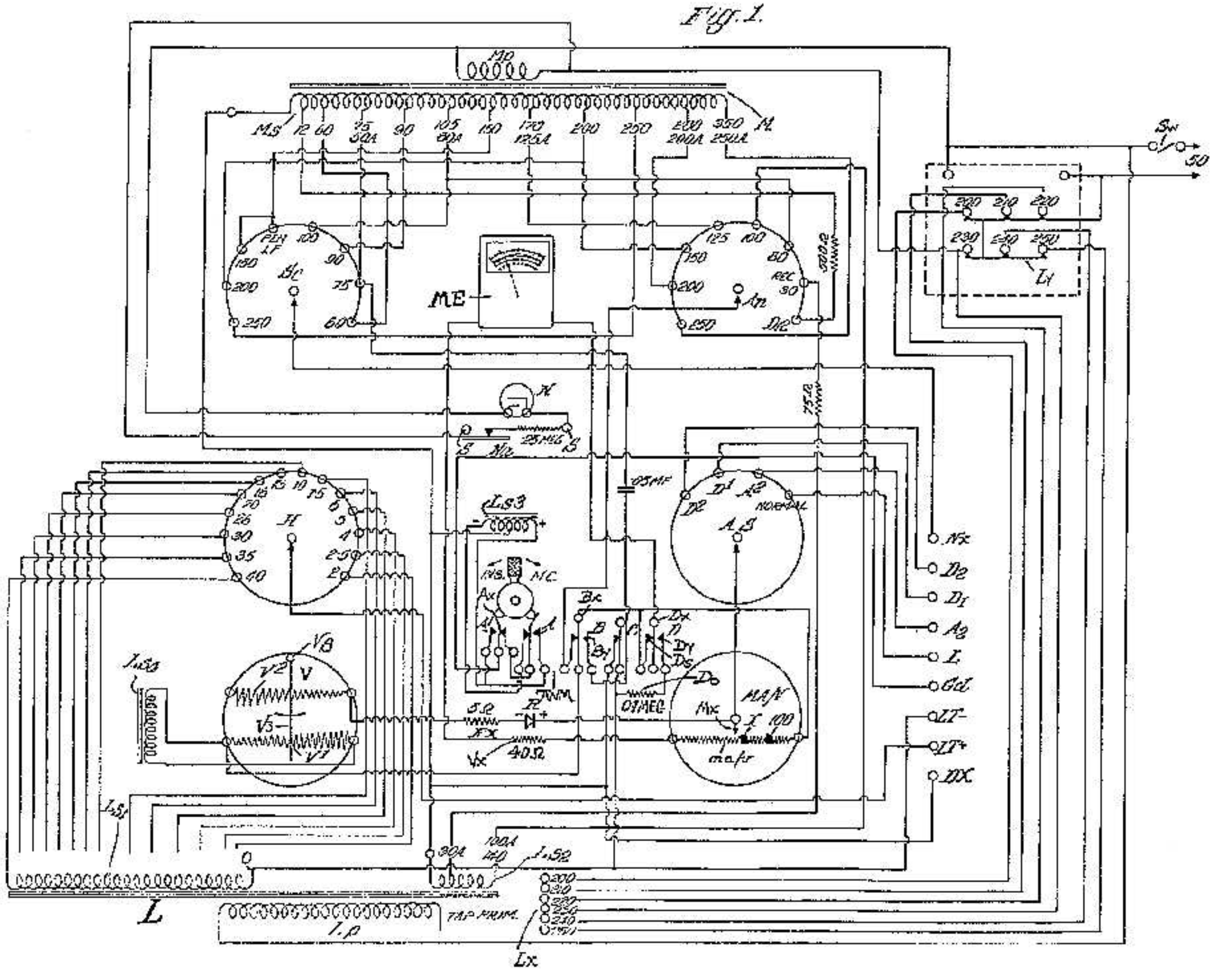
17. Apparatus for testing radio valves substantially as described and illustrated.

Dated the 27th day of May, 1937.
GEE & CO.,
Patent Agents,
Staple House, 51 and 52, Chancery Lane,
London, W.C.2,
Agents for the Applicants.

Leamington Spa: Printed for His Majesty's Stationery Office, by the Courier Press.—1938.

[This Drawing is a reproduction of the Original on a reduced scale]

Fig. 1.



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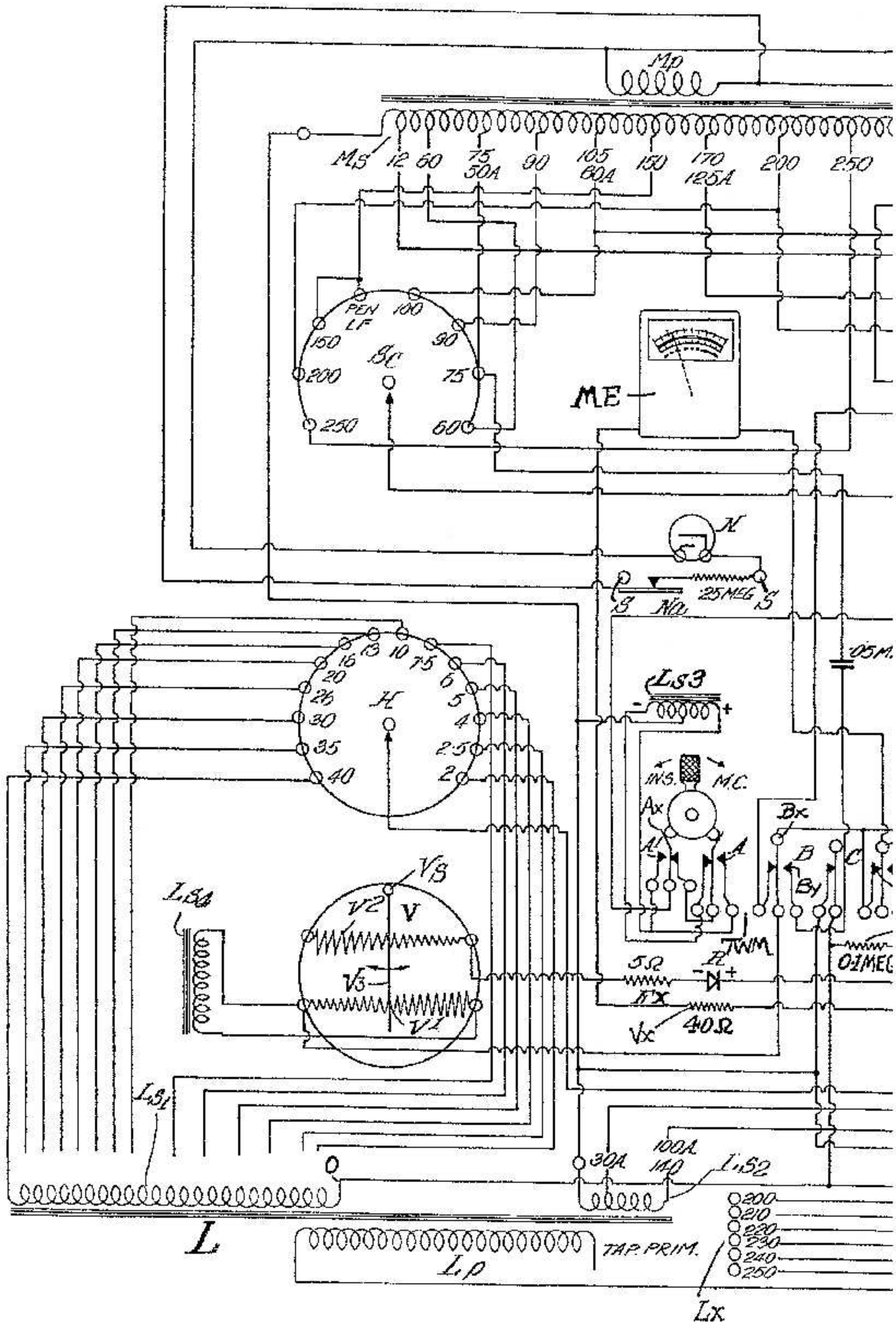

2 SHEETS
SHEET 1

Fig. 1.

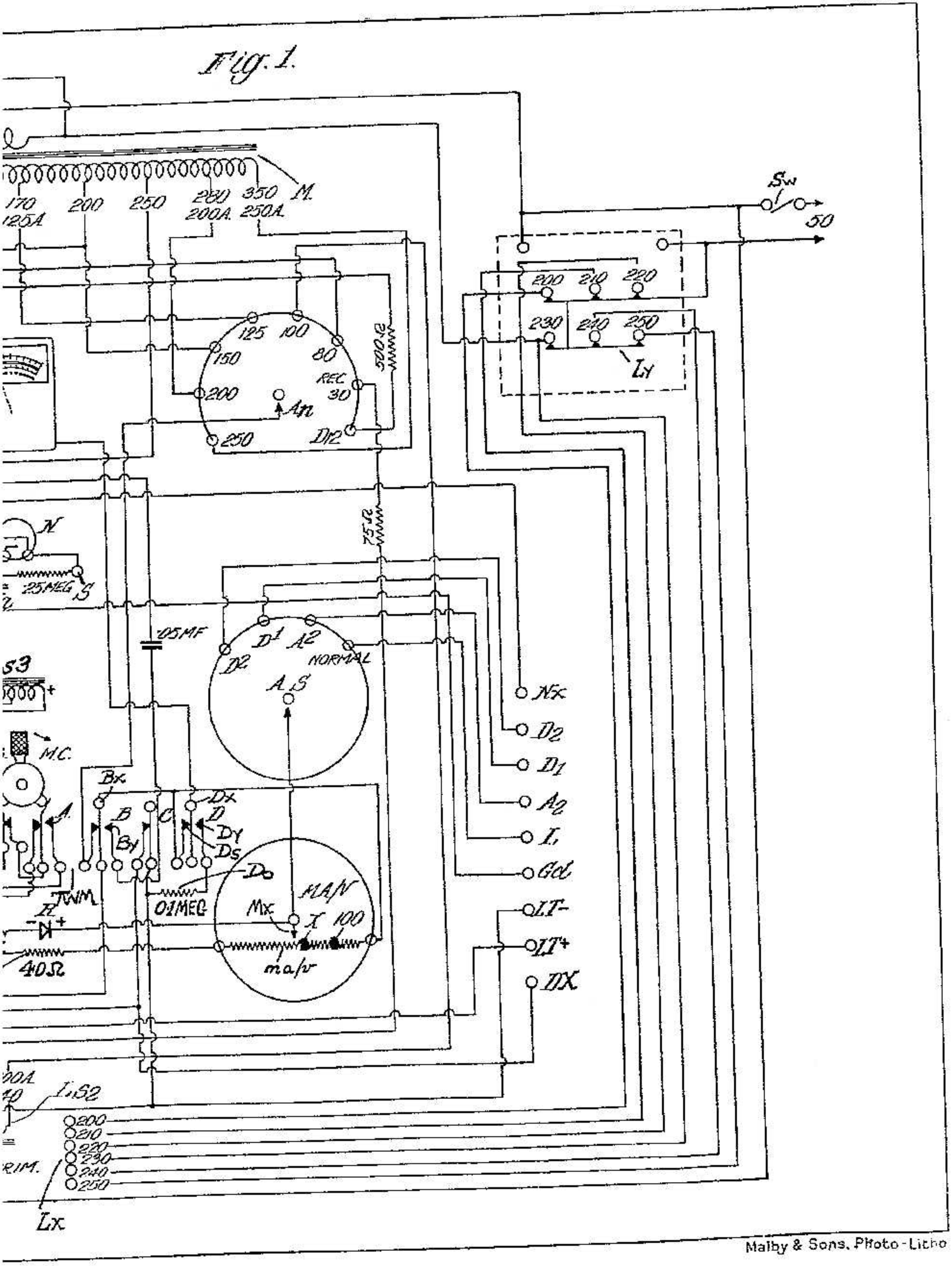

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Fig. 2.

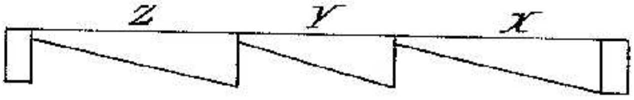


Fig. 3.

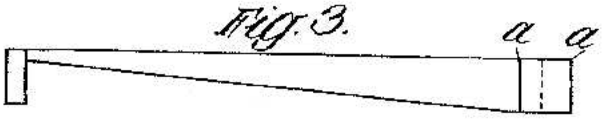


Fig. 5.

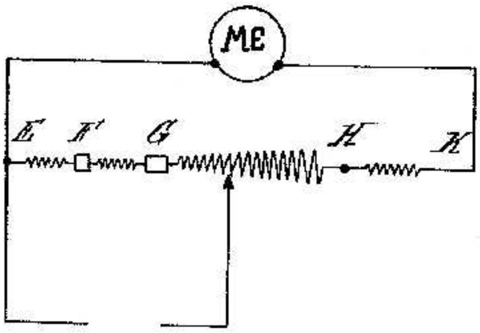


Fig. 6.

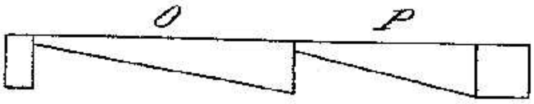
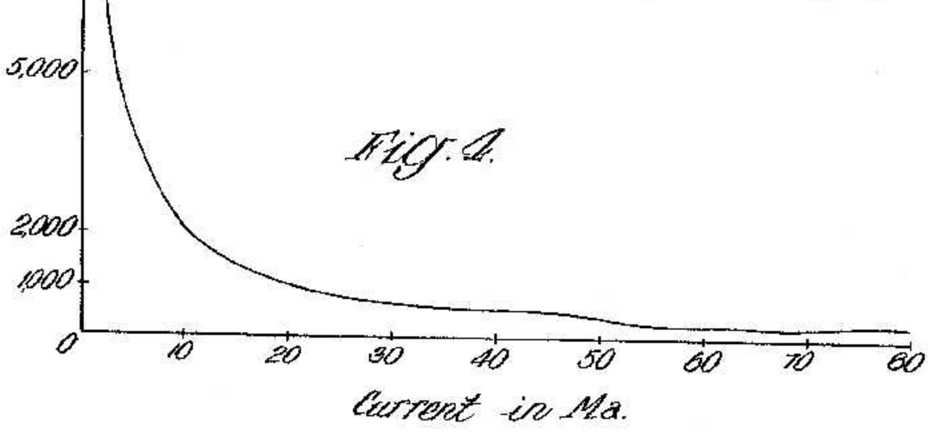


Fig. 4.



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PATENT SPECIFICATION

THE PATENT OFFICE LONDON

606,707

Application Date: Feb. 18, 1946. No. 5006/46.

Complete Specification Left: March. 18, 1947.

Complete Specification Accepted: Aug. 18, 1948.

Index at acceptance:—**Class 37,** A(12: 15).

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, 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:—

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

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

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

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

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

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

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 eg 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)

$$=f\hat{E}\sin\alpha-\mu\hat{E}g\sin\alpha$$

Then average anode current over the half cycle

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

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

$$=\frac{K}{\pi Ra}\left\{2\hat{E}+2\mu\hat{E}g\right\}$$

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

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:—

$$I_a = \frac{K}{R_a}\left(\frac{2\,\varepsilon_{RMS}}{\cdot707\times\pi} + \frac{2\mu\,\varepsilon_{DC}}{\cdot318\,\pi}\right)$$

$$= \frac{K}{R_a}\left(\frac{\varepsilon_{RMS}}{1\cdot1} + 2\mu\,\varepsilon_{DC}\right)$$

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

$$I_a = \frac{K}{2R_a}\left(\frac{\varepsilon_{RMS}}{1\cdot1} + 2\mu\,\varepsilon_{DC}\right)$$

This can be written:—

$$I_a = \frac{K}{2}\cdot\frac{(\varepsilon_{RMS}\times\frac{1}{1\cdot1} + \mu\,\varepsilon_{DC}\times 2)}{R_a}$$

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.
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[This Drawing is a reproduction of the Original on a reduced scale.]

Fig.1.

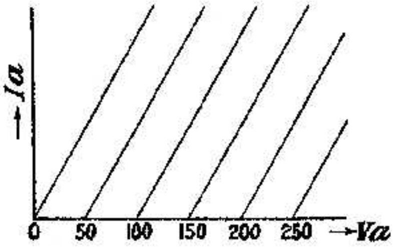


Fig.3.

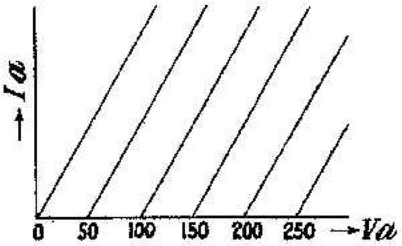


Fig.2.

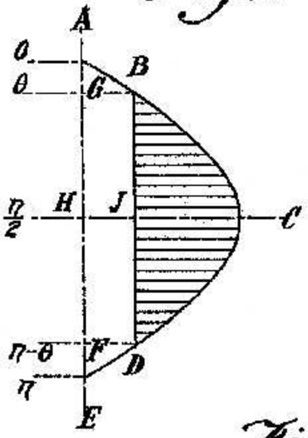


Fig.4.

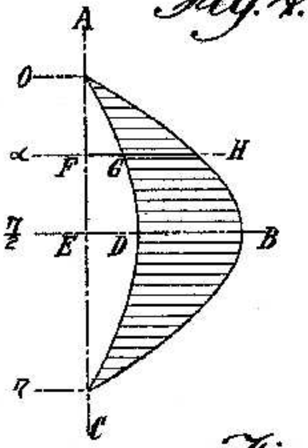


Fig.5.

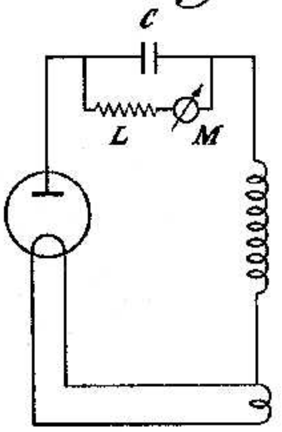
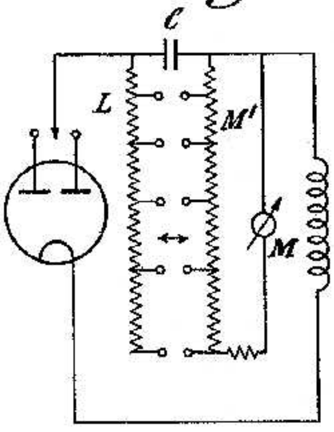


Fig.6.



H.M.S.O. (Ty.P.)