June 22, 1948. E. F. MacNICHOL, JR 2,443,794

ELECTRICAL APPARATUS

Filed Feb. 19, 1945

FIG. 1

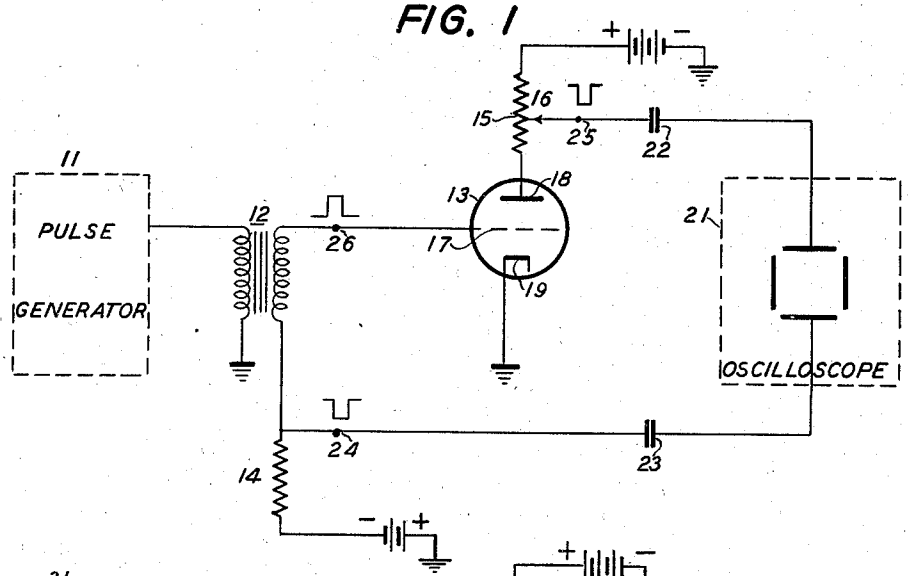


FIG. 2

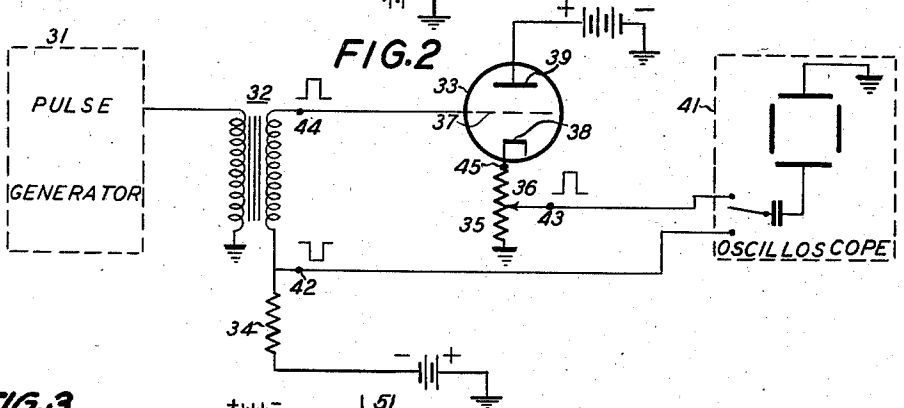
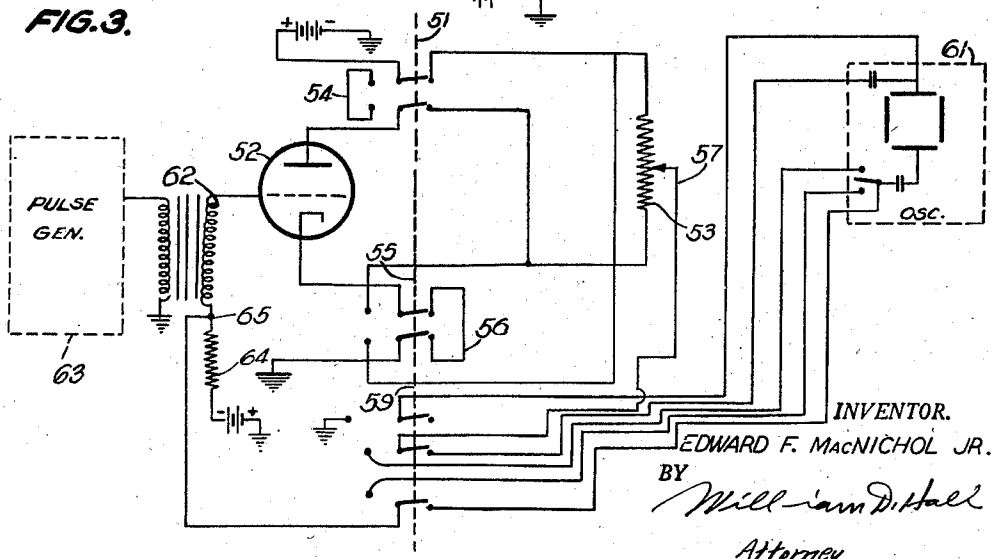


FIG. 3.



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UNITED STATES PATENT OFFICE

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ELECTRICAL APPARATUS

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8 Claims. (Cl. 315—370)

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This invention relates to electrical apparatus, and particularly to means for determining certain characteristics of electron tubes.

Expanding uses of electron tubes above and beyond the types of operation known in the prior art have made necessary other types of tests of these electron tubes than those known and used heretofore, and other means for making these tests, so that the operational and dependability characteristics of the electron tubes may be determined under these new conditions of use. Uses now made of electron tubes, such as in pulse generators, pulse amplifiers and other associated work require the provision of tube performance data or characteristics which would not be available ordinarily. The required characteristics in the type of work contemplated by the present invention include the ratio of the currents in the various electrodes.

In accordance with the present invention there is provided apparatus for determining the characteristics of an electron tube under conditions of pulsed operation. The electron tube under test must have at least a first, second and third electrode. The apparatus comprises a source of power connected to the electrodes of the electron tube and a pulse source. A coupling means is used for feeding the pulses from the pulse source to the first electrode of the electron tube. The apparatus also includes an indicating means which is connected to the circuit of the first electrode and one of the other remaining electrodes of the electron tube. The circuit of the first electrode includes a resistor and the circuit of said one of the other electrodes includes a potentiometer. The potentiometer is adapted to indicate the ratio of the current in the potentiometer to the current in the resistor when a pulse is fed to the first electrode and the indicating means shows the resistances in the effective part of the potentiometer and in the resistor are properly proportioned.

Hence, an object of this invention is to provide means for expeditiously determining the required tube characteristics.

Other objects of the invention will be apparent from the following description and the appended claims, taken in connection with the accompanying drawings, in which:

Fig. 1 shows a schematic diagram of one embodiment of electrical apparatus which may be used for determining characteristics of electron tubes;

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Fig. 2 shows a schematic wiring diagram of another embodiment of electrical apparatus which may be used for determining characteristics of electron tubes; and,

Fig. 3 is a fragmentary schematic diagram of a circuit which is adapted for combining the features of the apparatus illustrated in Figs. 1 and 2.

Referring now more particularly to Fig. 1 of the drawings, there is shown in this embodiment of the invention a circuit for determining the ratio of the plate current to the grid current of an electron tube. The circuit, as shown, includes a pulse source 11 preferably a pulse generator and a coupling means 12 preferably a pulse transformer. The coupling means 12 is adapted to couple the pulse source 11 to a grid 17 of an electron tube 13 so that the pulse to the grid 17 will be a positive going pulse. The tube 13 is the tube being tested and may be any electron tube with at least three electrodes. However, in the illustrations in Figs. 1, 2, and 3 the tube is a triode. A grid load resistor 14 is connected as shown between the transformer 12 and a source of negative bias sufficient to maintain the tube 13 at the desired operating point, normally at cutoff. A potentiometer consisting of a plate load resistor 15 and a variable tap 16, is connected between an anode 18 of the tube 13 and a source of positive voltage which is normally between +300 and +1000 volts. The resistor 15 is equal in magnitude to the resistor 14. The potentiometer 15—16 may be calibrated in a manner hereinafter described so that from the calibration the characteristics of tube 13 may be read directly. A cathode 19 of the tube 13 is connected to ground as shown. An indicating device 21 such as a cathode ray oscilloscope, peak reading voltmeter or other peak reading device is included in this circuit to show the relative amplitudes of voltages developed across the grid resistor 14 and across the effective portion of the potentiometer 15—16. One side of the indicating device is connected to the potentiometer 15—16 through a coupling capacitor 22 and the other side is connected through a coupling capacitor 23 to a point between the secondary of transformer 12 and the resistor 14. The rest of the connections of the indicating

means are not shown but are connected in any suitable manner well known in the prior art.

A pulse is applied to the tube 13 from the pulse generator 11 through the pulse transformer 12. The current i_g which flows in the grid circuit will produce a variational voltage at 24 of the form shown at 24 in Fig. 1 and is equal to:

(1) $$V_{24}=i_g R_{14}$$

where
V_{24} is voltage at 24 relative to bias
i_g is grid current
R_{14} is resistance of resistor 14

When the grid is driven positively above cutoff, plate current i_p will flow causing a variational voltage to appear at 25 of the form shown at 25 in Fig. 1 and is equal to:

(2) $$V_{25}=i_p r$$

where
V_{25} is voltage at 25 relative to plate battery
i_p is plate current
r is the resistance of resistor 15 from tap 16 to (+). Also referred to as the effective resistance of potentiometer 15—16.

It is assumed that grid bias is sufficient to eliminate both grid and plate current except during the pulses; if this is not the case only the changes in current and voltage should be used. This might be otherwise expressed in terms of pulse voltages since only the variations can pass the blocking condensers to the oscilloscope. The tap 16 is adjusted so that the peak voltage value V_{25} is equal to peak voltage value V_{24}. This equality is indicated by no deflection on the oscilloscope 21 when connected as shown in Fig. 1. We then have that:

(3) $$V_{24}=V_{25}$$

From the above three equations we get:

(4) $$\frac{i_p}{i_g}=\frac{R_{14}}{r}=\frac{\text{plate current}}{\text{grid current}}$$

However, since resistor 14 is equal in magnitude to resistor 15 then:

(5) $$\frac{i_p}{i_g}=\frac{R_{15}}{r}$$

The tapped resistor 15 may now be calibrated to read the ratio of R_{15}/r and the reading when the two aforementioned voltages are equal will be the desired characteristic under the biasing conditions being used. From Equation 4 it may be seen that if resistor 15 is calibrated to read the resistance of resistor 14 divided by $r(R_{14}/r)$ then resistor 15 need not equal resistor 14 in magnitude.

(6) $$\text{reading}=\text{ratio}\ \frac{i_p}{i_g}$$

Referring now to Fig. 2 of the drawings, there is shown a circuit for determining the ratio of the cathode current to the grid current of an electron tube. The circuit as shown, includes a pulse source 31 preferably a pulse generator 31 and a coupling means 32 preferably a pulse transformer connected to transfer pulses from the pulse generator 31 to a grid 37 of an electron tube 33. The pulse at the grid 37 normally is a positive going pulse. A grid load resistor 34 is connected as shown between the coupling means 32 and a source of negative bias. The negative bias applied to the grid 37 through the resistor 34 has a value which is suitable to maintain the tube 33 normally at cutoff. The connection of the resistor

34 permits the current flowing in the circuit of the grid 37 to develop a voltage across this resistor 34. A potentiometer consisting of a cathode load resistor 35 and a variable tap 36 is connected between a cathode 38 of the tube 33 and ground. The resistor 35 is equal in magnitude to the resistor 34. An anode 39 of the tube 33 normally is connected directly to a source of positive voltage as shown. The same conditions of biasing will normally be used in the circuit in Fig. 2 as are used in the circuit in Fig. 1. An indicating device 41 such as an oscilloscope, peak reading voltmeter or other peak indicating device is included in the circuit in Fig. 2 to show the relative amplitudes of voltages developed across the grid resistor 34 and across the effective portion of the potentiometer 35—36. The indicating device is connected to the potentiometer 35—36 and to a point between the resistor 34 and the secondary of the transformer 32 as shown in Fig. 2. The rest of the connections of the indicating means 41 are not shown but are made in a suitable manner well known in the prior art. As will be noticed, the connections of the indicator 21 in Fig. 1 are different from the connections of the indicator 41 in Fig. 2. The reason for this is because of the opposite polarities of the two voltages being compared in Fig. 2.

A pulse is applied to the tube 33 from pulse generator 31 through the pulse transformer 32. The current i_g which flows in the grid circuit will produce a variational voltage at 42 of the form shown at 42 in Fig. 2 and is equal to:

(7) $$V_{42}=i_g R_{34}$$

where

V_{42} is voltage at 42 relative to bias
i_g is grid current
R_{34} is resistance of resistor 34

When the grid 37 is driven positively above cutoff, cathode current i_k will flow causing a variational voltage to appear at 43 of the form shown at 43 in Fig. 2 and equal to:

(8) $$V_{43}=i_k r$$

where

V_{43} is voltage at 43 relative to ground
i_k is cathode current
r is resistance from tap 36 to ground. Also referred to as the effective resistance of potentiometer 35—36.

The tap 36 is adjusted so that the peak voltage value V_{43} is equal to the peak voltage value V_{42}. This equality is indicated on the oscilloscope 41 of Fig. 2. We then have:

(9) $$V_{42}=V_{43}$$

and solving the above three equations we obtain:

(10) $$\frac{i_k}{i_g}=\frac{R_{34}}{r}=\frac{\text{cathode current}}{\text{grid current}}$$

However, since resistor 34 is equal in magnitude to resistor 35 then:

(11) $$\frac{i_k}{i_g}=\frac{R_{35}}{r}$$

The tapped resistor 35 may now be calibrated to read the ratio R_{35}/r and the reading when the two aforementioned voltages are equal will be the desired characteristic under the biasing conditions used. From Equation 10 it may be seen that if resistor 35 is calibrated to read the resistance

of the resistor 34 divided by $r(R_{34}/r)$ then resistor 35 need not equal resistor 34 in magnitude.

(12) $$\text{reading} = \text{ratio}\ \frac{i_k}{i_g}$$

Fig. 3, as hereinbefore stated, illustrates one means of combining the features of the circuits illustrated in Fig. 1 and Fig. 2. By means of a switch 51, there may be inserted in the plate circuit of a tube 52 either a resistor 53 or a shunt 54. By means of a switch 55, mechanically connected to switch 51, there may be inserted in the cathode circuit of tube 52 either a shunt 56 or a resistor 53. By means of switch 59 also mechanically connected to switch 51 the appropriate connections are made to oscillograph 61 as in Figures 1 and 2. It will be observed that placing the resistor 53 in the plate circuit places the shunt in the cathode circuit and vice versa. The grid of tube 52 is connected through grid resistor 64 and coupling transformer 62 fed by pulse generator 63, with a terminal 65 corresponding to terminals 34 and 42 in Figs. 1 and 2. The tap 57 on resistor 53 is connected to an indicating device. If the indicating device is an oscilloscope, then the tap 57 is connected to the oscilloscope through switch 59 as in Figs. 1 and 2. With the tube 52 connected in the manner just described it is possible to measure with one system both the ratio of cathode current to the grid current and the ratio of anode current to the grid current.

While there has been described what is at present considered the preferred embodiments of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

I claim:

1. An apparatus for determining the characteristics of an electron tube under conditions of pulsed operation, said tube including at least a cathode, a grid, and an anode, said apparatus comprising a power supply having at least a positive terminal, a negative terminal, and an intermediate terminal; a pulse source; a pulse transformer for coupling said pulse source to said grid; a grid load resistor connected in series with said negative terminal, said pulse transformer and said grid; a second load resistor, equal in magnitude to said grid load resistor and having a variable tap, said second load resistor being calibrated to give the ratio of the resistance of said second load resistor to the resistance of said second load resistor from said tap to one end of said resistor; means for switching said load resistor selectively between said anode and said positive terminal with said end of said load resistor connected to said positive terminal and between the cathode and said intermediate terminal with said end of said load resistor connected to said intermediate terminal; means operative with said switching means to close the electrode circuit into which said second load resistor is not connected; and means for comparing the voltage developed across said grid load resistor by the current flowing through said grid load resistor, with the voltage developed across the portion of said second load resistor from said tap to said end by the current flowing through said second load resistor, said tap being adjustable to cause said two voltages to be possible of equalization in magnitude so that the ratio of current through said second load resistor to the current through said grid load resistor may be read from the calibration of said load resistor.

2. An apparatus for determining the characteristics of an electron tube under conditions of pulsed operation said tube including at least a first, second, and third electrode, said apparatus comprising a power supply having at least a positive terminal, a negative terminal, and an intermediate terminal; a pulse source; a pulse transformer for coupling said pulse source to said second electrode; a first load resistor connected in series with said negative terminal, said pulse transformer and said second electrode; a second load resistor having a variable tap, said second load resistor being calibrated to give the ratio of the resistance of said first load resistor to the resistance of said second load resistor from said tap to one end thereof; means for switching said second load resistor selectively, between said third electrode and said positive terminal, with said end of said second load resistor connected to said positive terminal, and between said first electrode and said intermediate terminal, with said end connected to said intermediate terminal; shunt means operative with said switching means to close the electrode circuit into which said second load resistor is not connected; and means for comparing the voltage developed across said first load resistor by the current flowing through said first load resistor, with the voltage developed across the portion of said second load resistor from said tap to said end by the current flowing through said resistor, said tap being adjustable to make possible equalization of the two said voltages so that the ratio of the current flowing in said second load resistor to the current flowing in said first load resistor may be read from the calibration of said second load resistor.

3. An apparatus for determining the characteristics of an electron tube under conditions of pulsed operation, said tube including at least a cathode, a grid, and an anode, said apparatus comprising a power supply having at least a positive terminal, a negative terminal, and an intermediate terminal; a pulse source; means for coupling said pulse source to said grid; a grid load resistor connected in series with said negative terminal, said coupling means, and said grid; a plate load resistor connected between said anode and said positive terminal, equal in magnitude to said grid load resistor, and having a variable tap, said plate load resistor being calibrated to give the ratio of the resistance of said plate load resistor to the resistance of said plate load resistor from said tap to said positive terminal; and means associated with said grid load resistor and said tap for comparing the voltage developed across said grid load resistor by current flowing through said grid load resistor, with the voltage developed across that portion of said plate load resistor from said tap to said positive terminal by current flowing through said plate load resistor, said tap being adjustable to make possible equalization of the two said voltages so that the ratio of the current flowing in said plate load resistor to the current flowing in said grid load resistor may be read from the calibration of said plate load resistor.

4. An apparatus for determining the characteristics of an electron tube under conditions of pulsed operation, said tube including at least cathode, grid, and plate elements, said apparatus

comprising a power supply having at least a positive terminal, a negative terminal, and an intermediate terminal; a pulse source; means for coupling said pulse source to said grid; a grid load resistor connected in series with said negative terminal, said coupling means and said grid; a cathode load resistor, equal in magnitude to said grid load resistor and connected between said cathode and said intermediate terminal and having a variable tap, said cathode load resistor being calibrated to give the ratio of the resistance of said cathode load resistor to the resistance of said cathode load resistor from said tap to said intermediate terminal; and means associated with said grid load resistor and said tap for comparing the voltage developed across said grid load resistor by current flowing through said grid load resistor, with the voltage developed across that portion of said cathode load resistor from said tap to said intermediate terminal by current flowing through said cathode load resistor, said tap being adjustable to make possible equalization of the two said voltages so that the ratio of the current flowing in said cathode load resistor to the current flowing in said grid load resistor may be read from the calibration of said cathode load resistor.

5. Apparatus for determining the characteristics of an electron tube under conditions of pulsed operation, said electron tube including at least a first, second and third electrode, said apparatus comprising a source of power connected to the electrodes of the electron tube; a pulse source; means for coupling said pulse source to said first electrode of the electron tube; indicating means; means for connecting said first electrode to said indicating means, said connecting means including a first resistor; potentiometer means connected to said indicating means; and switching means associated with said potentiometer means for connecting said potentiometer in series circuit with one of said remaining electrodes and closing a circuit to the remaining of said electrodes, said potentiometer being adapted to indicate the ratio of the current in said potentiometer to the current in said resistor when a pulse is fed to said first electrode and said indicating means showing that the resistances in the effective part of said potentiometer and in said resistor are properly proportioned.

6. Apparatus for determining the characteristics of an electron tube under conditions of pulsed operation, said electron tube including at least a first, second, and third electrode, said apparatus comprising a source of power connected to the electrodes of the electron tube; a pulse source; means for coupling said pulse source to said first electrode of the electron tube; indicating means; means for connecting said first electrode to said indicating means, said connecting means including a resistor; and means for connecting said second electrode to said indicating means, said second connecting means including a potentiometer, said potentiometer being adapted to indicate the ratio of the current in said potentiometer to the current in said resistor when a pulse is fed to said first electrode and said indicating means shows that the resistances in the effective part of said poentiometer and in said resistor are properly proportioned.

7. Apparatus for determining the characteristics of an electron tube under conditions of pulsed operation, said electron tube including at least a first, second, and third electrode, said apparatus comprising a source of power connected to the electrodes of the electron tube; a pulse source; a pulse transformer for coupling said pulse source to said first electrode of the electron tube; indicating means; means for connecting said first electrode to said indicating means, said connecting means including a first resistor; and means for connecting one of the other of said electrodes to said indicating means, said second connecting means including a potentiometer, said potentiometer being adapted to indicate the ratio of the current in said potentiometer to the current in said resistor when a pulse is fed to said first electrode and said indicating means shows that the resistances in the effective part of said potentiometer and in said resistor are properly proportioned.

8. Apparatus for determining the characteristics of an electron tube under conditions of pulsed operation, said electron tube including at least a first, second, and third electrode, said apparatus comprising a source of power connected to the electrodes of the electron tube; a pulse source; means for coupling said pulse source to said first electrode of the electron tube; indicating means; means for connecting said first electrode to said indicating means, said connecting means including a resistor; and means for connecting one of the other of said electrodes to said indicating means, said second connecting means including a potentiometer, said potentiometer being adapted to indicate the ratio of the current in said potentiometer to the current in said resistor when a pulse is fed to said first electrode and said indicating means shows that the resistances in the effective part of said potentiometer and in said resistor are properly proportioned.

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