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FILAMENT-PLATE VOLTAGE SYSTEM

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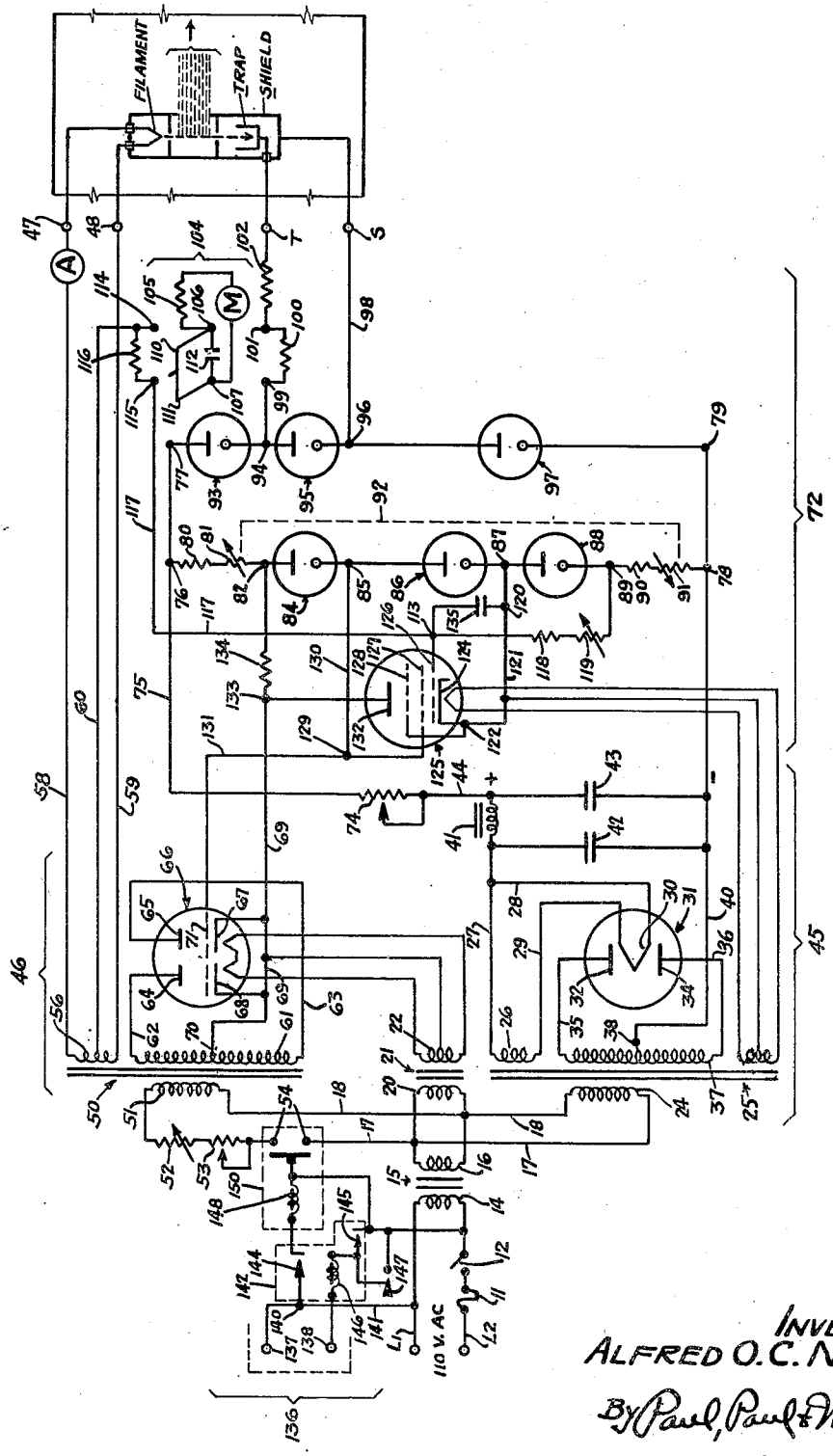

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FILAMENT-PLATE VOLTAGE SYSTEM

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In mass spectrometers and certain other instruments it is important in the satisfactory operation to provide a source of constant electron emission and in many instances also to provide a constant acceleration and trap potentials for the emitted electrons. The power supply systems heretofore available for such purposes have not been completely satisfactory in that the desired constancy of emission and potential has not been achieved, nor have power supplies heretofore available provided adequate safeguards against breaking of vacuum in the enclosing vessel and have not afforded the needed and desirable facilities for adjustment over wide ranges of emissivity.

It is an object of the present invention to provide an improved power supply of regulated character capable of providing regulated plate and filament voltages for achieving constancy of emission of electrons in mass spectrometer tubes and kindred instruments.

It is also an object of the invention to provide an improved power supply of the aforesaid character wherein adequate safeguards are provided against malfunctioning in the event loss of vacuum should occur in the instrument to which it is connected.

It is also an object of the invention to provide an improved power supply for mass spectrometer tubes affording easily regulated variations in filament and plate supply, while yet maintaining fixed proportionality between certain voltages supplied, as for example the voltage supply for the trap and shield of the mass spectrometer tube.

Other and further objects of the invention are those inherent in the apparatus herein illustrated, described and claimed.

The apparatus is illustrated in the drawing which shows a wiring diagram of an exemplary power supply system of the present invention.

Throughout the drawings corresponding numerals refer to the same parts.

Referring to the drawings, Figure 1, the power supply system includes the supply lines L_1 and L_2 which are supplied with alternating current at standard voltages and frequencies, such as 110-volt alternating current supply. Line L_2 includes the fuse 11 and a manually operated control switch 12 for turning the system on and off. Line L_2 continues to one terminal of the primary 14 of transformer 15. Line L_1 is connected to the opposite terminal of the winding 14. The secondary 16 of the transformer 15 supplies the power supply bus bars 17 and 18. To the bus bars 17

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and 18 there is connected the primary winding 20 of a transformer 21, the secondary 22 of which supplies the filaments of the indirectly heated cathodes of all tubes in the system for which filament supply voltage is not otherwise shown in the drawings. The bus bars 17 and 18 are also connected to the primary winding of a power pack shown over bracket 45, which includes supply transformer 25.

The transformer 25 includes a filament secondary 26 which is connected through lines 27, 28 and 29 to the cathode 30 of a full-wave rectifier tube generally designated 31. The rectifier tube anodes 32 and 34 are connected by lines 35 and 36, respectively, to the terminals of the secondary winding 37 of transformer 25. The mid tap 38 of the transformer winding 37 is connected to line 40 which constitutes the negative supply line of the power pack, including transformer 25 and rectifier 31. The output of the rectifier which appears on lines 27 and 40, respectively, is filtered through a filter network including an inductance 41 and two condensers 42 and 43, and the positive direct current supply voltage which is thus supplied to line 44 (positive), and line 40 (negative) is comparatively free from any ripple or alternating current component.

Under the bracket 46 is a transformer and thermionic tube network, the function of which is to supply a controlled filament voltage to the filament terminals 47 and 48 which are connected directly to the filament of the mass spectrometer or similar apparatus with which the supply system is intended to cooperate. A fragmentary schematic view of a portion of the ion source of an isotope mass spectrometer is shown at the right in Figure 1. In this view the filament which is connected to terminals 47 and 48 is insulated from and is housed in one compartment of a shield box which is connected to terminal S. The trap is connected to terminal T. The apparatus 46 includes a transformer generally designated 50 having a primary winding 51, one terminal of which is connected to the bus bar 18 and the other terminal connected through variable resistors 52 and 53 and through the contacts 54 of a control relay 150 to the opposite bus bar 17. The control relay 150 is of the type which closes its contacts 54 when the operating coil 148 of the relay is energized and is a safety device. Its function will be explained in greater detail hereinafter. During the operation of the power system the contacts of relay 54 are closed and the supply voltage across bus bars 17 and 18 is thus

applied to the series network including transformer winding 51 and resistors 52 and 53.

The transformer 50 includes a low voltage filament voltage secondary 56, the terminals of which are connected through the lines 58 and 59 through the filament supply terminals 47 and 48, respectively. The central tap of the secondary 56 is connected to line 60.

The transformer 50 also includes a comparatively higher voltage secondary winding 61, the terminals of which are connected through lines 62 and 63 to the anodes 64 and 65 of the grid-controlled thermionic tube generally designated 66. Tube 66 includes indirectly heated cathodes 67 and 68 which are connected to line 69 that is in turn connected to the center tap 70 of the secondary winding 61. Tube 66 includes also the control grids 71 for each cathode-anode system, the grids being connected together so as to be at the same voltage.

The tube 66 serves to load the transformer secondary 61 to a varying degree, depending upon the voltage which is applied to the grids 71. The voltage so applied to the grid 71 is the regulating voltage of the system and the manner in which this regulating voltage is supplied will be later described in detail. As the voltage on grid 71 varies, the loading on the tube 66 is likewise varied, and hence draws more or less current from the secondary winding 61 and accordingly variably loads the transformer primary 51. Inasmuch as the transformer winding 51 is supplied from bus bars 17 and 18 through a resistor network including resistors 52 and 53 in series, the varying load current flowing through the primary 51 in accordance with the varying load on the secondary 61 causes a variation in voltage across the terminals of the primary winding 51. These variations are manifested also upon the voltage supplied by the filament windings 56 and therefore as the secondary 61 is loaded in varying amount, the voltage on winding 56 will likewise vary, and the mass spectrometer or the like filament which is supplied by terminals 47 and 48 will be heated varying amounts, depending in final analysis upon the voltage supplied to grid 71.

In a mass spectrometer instrument it is desired to regulate the emission from the filament. Thus, a filament connected to the terminals 48 and 48 and thereby heated will emit electrons and it is desired to control the amount and to regulate the constancy of emission from such a filament. The heating of the filament, per se, is unimportant except as it has a bearing upon the emission of electrons therefrom. In order to provide for regulation of the amount of emission from the filaments supplied by terminals 47 and 48 and also to provide for constancy of such electron emission, there is provided a regulating network shown over the bracket 72. The network is supplied by lines 44 (positive) and 40 (negative). Line 44, it being noted, extends through a regulating resistor 74 and thence line 75 to junctions 76 and 77. Line 40 extends likewise to junctions 78 and 79.

Between junctions 76 and 78 there is a series circuit including a fixed resistor 80, variable resistor 81, junction 82, voltage regulator glow-tube 84, junction 85, voltage-regulator glow-tube 86, junction 87, voltage regulator glow-tube 88, junction 89, fixed resistor 90 and variable resistor 91. The controls of resistors 81 and 91 are connected together, as indicated by the common control line 92, and in such a manner that as the control 92 is moved to decrease resistor 81, the resistor 91 is simultaneously increased by a corresponding amount and vice versa. It may be noted, however, that even though variable resistor 81 should be reduced to zero, there is still a fixed resistance 80 between junctions 76 and 82 and that likewise even though variable resistance 91 is regulated to the zero position, there is still a fixed resistance 90 between junctions 78 and 89.

Across junctions 77 and 79 there is a series circuit parallel to that connected across junctions 76 and 78. The latter circuit includes a voltage regulator glow-tube 93, junction 94, voltage regulator glow-tube 95, junction 96, voltage regulator glow-tube 97 and thence to junction 79. The three tubes 93, 95 and 97 thus divide the voltage across junctions 77 and 79 constantly and in a manner determined by the voltage drop across the individual tubes, and junctions 94 and 96 which accordingly remain at fixed potentials in respect to junctions 77 and 79, serve to supply the trap and shield voltages of the mass spectrometer tube, the filament of which is supplied by terminals 47 and 48. Thus, line 96 connects junction 96 to the shield voltage terminal S. Junction 94 is connected to switch terminal 99 and through a resistance 100 to the cooperating switch terminal 101 and thence through a fixed resistance 102 to the trap voltage supply terminal T which is connected to the electron trap of the mass spectrometer tube, the filament of which is supplied by terminals 47 and 48.

Opposite the bracket 104 there is shown a metering system including the microammeter M which is connected through resistance 105 to the blade terminals 106 and 107 of a double pole double throw switch. Blade 110 is connected to the terminal 106 and blade 111 to the terminal 107, and a condenser 112 is connected across the two terminals 106 and 107 so as to by-pass any momentary surges which might be harmful to the meter M. The switch blades 110 and 111 are adapted to be closed on the terminals 99 and 101, respectively, and in this position the meter M reads the current flowing in the trap circuit of the mass spectrometer tube connected to terminal T. The switch blades 110 and 111 are also adapted to be moved into contact with terminals 114 and 115 which are shunted by a resistor 116. Line 60, which is connected to the center of the filament supply winding 56, is connected to switch contact 114 and switch contact 115 is connected to line 117. This circuit (which will be later explained in greater detail) supplies the emission current constituted by the electrons emitted by the mass spectrometer or other instrument filament connected to terminals 47 and 48. Hence, when the switch blades 110 and 111 are closed upon contacts 114 and 115, respectively, the microammeter M reads the emission current.

Line 117, which supplies the emission current, is connected to junction 113 on the lead of control grid 126 (tube 125) and thence through fixed resistor 118 and variable resistor 119 to junction 89. From junction 87 a line extends through junction 120 and thence through line 121 to junction 122 and to the cathode 124 of tube 125. Tube 125 includes a control grid 126 and screen grids 127 and 128, the latter being connected to junction 122 and is hence maintained at cathode potential. Grid 127 is connected to junction 129 which is connected through line 130 to junction 85 and from junction 129 line 131 extends to the grid 71 of the loading tube 66. The anode 132 of the tube 125 is connected to junction 133 and

thence through fixed resistor 134 to junction 82. Junction 133 is also connected through line 69 to the cathodes 67 and 68 of the loading tube 66. The control grid 126 of the tube 125 is connected to junction 113 and thence through a condenser 135 to junction 120 (hence to junction 87).

Opposite the bracket 136 is a vacuum break safety control circuit including terimnals 137 and 138 which are connected to a switch that is closed when vacuum is maintained in the system but which opens when the vacuum is broken, i. e. when the pressure increases in the mass spectrometer tube or other apparatus supplied by the filament terminals 47 and 48, trap terminals T and shield voltage supply terminal S. Terminal 137 is connected through junction 140 and line 141 to supply line L_1. The apparatus within the dotted line 142 is a double contact relay having pairs of contacts 144 and 145 which are open when the coil 146 of the relay is deenergized. Contacts 145 are shunted by push-button contact 147 and contact 144 is in series circuit with the coil 148 of the relay 150 having contacts 54 which are maintained closed when coil 148 is energized. When the mass spectrometer or other tube which is supplied by the instant system is put in operation the vacuum is initially pumped in the tube and through a suitable vacuum operated switch the circuit is closed across 137 and 138 when a sufficient vacuum is maintained. Push button 147 is then closed and this establishes the circuit from line L_1, through lines 141 and through the then closed circuit across terminals 137 and 138 to coil 146, thence through push button 147 to line L_2. Coil 146 being thus energized actuates its contacts 144 and 145. The latter serves to maintain a circuit through the winding 146 and is a self-holding circuit. The closure of contacts 144 energizes the coil 148 of relay 150, and this serves to close contacts 54 of relay 150 and thereby establishes the circuit from bus bar 17 through contacts 54, resistances 52 and 53 to winding 51 of the transformer 50 which supplies the filament voltage to terminals 47 and 48.

All of the tubes 84, 86, 88, 93, 95 and 97 are of the voltage regulator or glow type which maintain a constant voltage across their respective terminals, regardless of the amount of current flowing through them, within wide limits. The tubes 93, 95 and 97 divide the voltage which is supplied across positive line 75 and negative line 40. For purposes of analysis the voltage supplied at junction 96 through line 98 to the shield voltage tap S may be considered as the voltage of reference in the instrument. Voltage divider tube 97 is, for example, of the 150-volt type and hence junction 79 and line 40 are at minus 150 volts (150 volts below the voltage of shield tap S). Tubes 93 and 95 are each of the 75-volt type and hence the trap voltage supplied at terminal T is plus 75 (75 volts above the shield voltage at shield tap S), and the voltage at terminal 77 is plus 150 volts or 150 volts above that at the shield voltage tap S.

The voltage divider circuit through resistor 80, 81, tubes 84, 86 and 88 and resistor 90 and 91 establishes the voltage of the filament connected to terminals 47 and 48 in respect to the shield voltage tap S. Thus, the mid-point of winding 56 supplying the filament supply terminals 47 and 48 is connected through line 60, resistor 116, and line 117 and resistors 118 and 119 to junction 89 immediately below voltage divider tube 88. The voltage at junction 89 is determined by the voltage dividing circuit which includes resistors 80, 81 and 90, 91. Hence, the filament potential is maintained at the voltage of junction 89. Since resistors 81 and 91 are connected together in a put-and-take arrangement by the common control 92 so that as resistor 81 is decreased, resistor 91 is increased and vice versa, it follows that by operating the gang control 92, the voltage at junction 89 may be regulated from a minimum or most negative voltage which occurs when resistance 91 is reduced to zero and resistance 81 is at a maximum, thence through a range of more positive potentials to a maximum potential which occurs when resistance 91 is at a maximum and resistance 81 is at a minimum. In this manner the voltage of filament connected to terminals 47 and 48 is regulated with reference to the voltage of terminal S, which is connected to the shield of the mass spectrometer tube and is the voltage of reference. It may be noted that the value of the currents flowing normally through the circuit from junction 76 to junction 78 is much greater than the emission current from the filament connected to terminals 47 and 48 and hence in the emission control analysis hereinafter given the voltage drop occasioned by the emission current flowing through resistor 90 and 91 is neglected.

The electron stream constituting the emission flow from the filament connected to terminals 47 and 48 begins at the filament 30 of tube 31 and passes from the filament to one or the other of the plates 32 and 34, thence through the winding 37 to mid-tap 38 and by way of line 40 to terminal 78, thence through resistors 91 and 90 to terminal 89 and through resistors 119 and 118, grid junction 113, line 117, resistor 116 to line 60, thence through the winding 56 and through lines 58 or 59 to the filament. The electron flow returns from the electron trap of the mass spectrometer which constitutes one of the plates of that tube and is connected to the terminal T. The flow returns then through the resistors 102 and 100, junction 94, tube 93, junction 77 and then by way of line 75 through resistor 74 and line 44, inductance 41 and line 28 to the filament 30 of tube 31.

If it is assumed that the emission of electrons from the filament connected to terminals 47 and 48 decreases, the resistance drop through resistors 118 and 119 will accordingly likewise decrease and junction 113 tends to become more negative, thus decreasing the conducticity of tube 125. There is a parallel circuit around tubes 84 and 86 from junction 87 through line 121, to cathode 124 of tube 125 and thence to the anode 132, junction 133 and resistor 134 to junction 82. The potential of junction 133 in this parallel circuit is determined by the relative impedance of resistor 134 and tube 125. Hence, when the tube becomes less conductive the effective internal resistance of the tube 125 is in effect increased and the potential of junction 133 more nearly approaches the potential of 82, or stated another way the potential of junction 133 becomes more positive. The grids 71 of tube 66 are maintained at a constant potential by virtue of the connection through lines 131 and 130 to junction 85 on the voltage divider circuit between junctions 76 and 78. It may be noted parenthetically that the potential at junction 85 is fixed by the operation of tubes 86 and 88 so as to be constant in respect to the potential at 89. Hence, variation of control 92 does not effect the control of emmissivity of the filament connected to terminals 47 and 48. The cathodes 67 and 68

of tube 66 are, however, subject to the varying potential at junction 133 being connected thereto through line 69. Therefore, as junction 133 becomes more positive, as previously described, this makes the cathode 67 and 68 of tube 66 relatively positive which in effect makes the grid 71 relatively more negative in respect to the cathode, and tube 66 becomes less conductive. When this occurs a lesser current flows in the cathode-anode circuit of tube 66 and a lesser loading of the transformer secondary winding 61 occurs with consequent decreased loading on the primary winding 51. The decreased load on the primary winding 51 has the effect of decreasing the resistance drop through resistors 52 and 53. Hence, the portion of the potential across bus bars 17 and 18 which is effectively applied to the winding 51 is likewise increased, and consequently there is an increased voltage induced in secondary 56 which supplies the filament of the mass spectrometer tube. As the applied voltage to the filament is thus increased, its temperature is raised and the emission is increased until balanced conditions are re-established.

An increase in emission of the filament supplied by terminals 47 and 48 has a reverse effect as compared to that just explained and the voltage supplied to terminals is reduced until balance is again re-established.

The initial control voltage which accomplishes the aforesaid regulating function is the resistance drop across resistors 118 and 119 which determines the voltage of grid 126 with reference to the voltage of the cathode 124. As the emission current to be regulated flowing through resistances 118 and 119 increases, the voltage of grid junction 113 more nearly approaches the cathode reference voltage at line 121 and junction 87. Tube 88 maintains a constant difference in potential between junctions 87 and 89.

Fixed resistors 80 and 90 are included in the bridge circuit between junctions 76 and 78 to prevent run-away operation of the regulator. These resistors insure that the voltage of the filament connected to terminals 47 and 48 will always be at least a minimum amount below the shield voltage S and trap voltage T, regardless of the extreme operation of the put-and-take gang of resistors 81 and 91. This insures against a condition in which the regulating action of the system (portions 46 and 72) would tend to supply an ever-increasing voltage to the filament supply terminals 47 and 48 where the emission decreased or was absent altogether due to lack of proper potential gradient to the trap (connected to terminal T) and shield (connected to terminal S).

Regulation of emissivity of the filament supplied by terminals 47 and 48 can be manually regulated by varying resistance 119 since a change in the resistance of its circuit is equivalent to a change in emission current therethrough in producing the regulatory IR drop therethrough. Resistors 52 and 53 permit adjustment to insure that the amplifier tube 66 operates on a favorable part of its characteristic curve, and in this manner permit the sensitivity of the instrument to be varied. Variable resistance 74 provides a ready means of controlling the current through tubes 93, 95 and 97 to safe limits since these tubes are connected directly across lines 75 and 40.

As many apparently widely different embodiments of this invention may be made without departing from the spirit and scope thereof, it is to be understood that I do not limit myself to the specific embodiments herein except as defined by the appended claims.

What I claim is:

1. In a power supply system for mass spectrometers and the like thermionic tubes having a heated filament and a plate for accelerating and collecting the electrons emitted therefrom, variable voltage means connected to said filament, variable plate voltage supply means connected to said plate and filament, means responsive to the electron emission of the filament connected to the voltage supply means for increasing and decreasing the voltage of said variable voltage means connected to said filament in response to variations in emission from said filament, said plate voltage supply means including a pair of supply lines between which a relatively constant voltage is maintained and a series of resistances across said supply lines one of which resistances connected adjacent one end of the series and the last of which resistances at the other end are variable and connected together so that as one is increased the other is correspondingly decreased, said filament and plate being connected to an intermediate point on said series and to one of the supply lines respectively.

2. The apparatus of claim 1 further characterized in that it includes a second series comprised of voltage regulator elements between said supply lines, said filament and plate being connected to intermediate points, respectively, of said series of resistances and said second series comprised of voltage regulator elements.

3. In a power supply system for mass spectrometer and the like thermionic tubes having a heated filament and a plate for accelerating and collecting the electrons emitted therefrom, variable voltage means connected to said filament, plate voltage supply means connected to said plate and filament, means responsive to the electron emission of the filament connected to the voltage supply means for increasing the voltage of said variable voltage means when the electron emission decreases and for decreasing the voltage when the emission increases, said plate voltage supply means including a pair of supply lines between which a relatively constant voltage is maintained, and a series resistance network connected across said supply lines forming a voltage divider circuit which establishes the voltage of said filament in respect to said plate of the thermionic tubes including a first variable resistor, a plurality of voltage regulator tubes and a second variable resistor in the order named, said means responsive to the electron emission of the filament including a branch circuit having a resistance connected to an intermediate voltage point on said series resistance network and to said variable voltage supply means.

4. The apparatus of claim 3 further characterized in that said branch circuit resistance is variable.

5. The apparatus of claim 3 further characterized in that the first and second variable resistors are connected together for simultaneous manual operation to decrease one as the other is increased.

6. The apparatus of claim 3 further characterized in that the series resistance network includes a first fixed resistance connected to said first variable resistor and a second fixer resistance connected to said second variable resistor.

7. The apparatus of claim 3 further characterized in that said plate is connected between

serially connected voltage regulator tubes that are in series across said supply lines.

8. The apparatus of claim 7 further characterized in that the serially connected voltage regulator tubes are those in series with the first and second variable resistors.

9. The apparatus of claim 7 further characterized in that said serially connected voltage regulator tubes are in a separate series circuit connected across said supply lines.

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