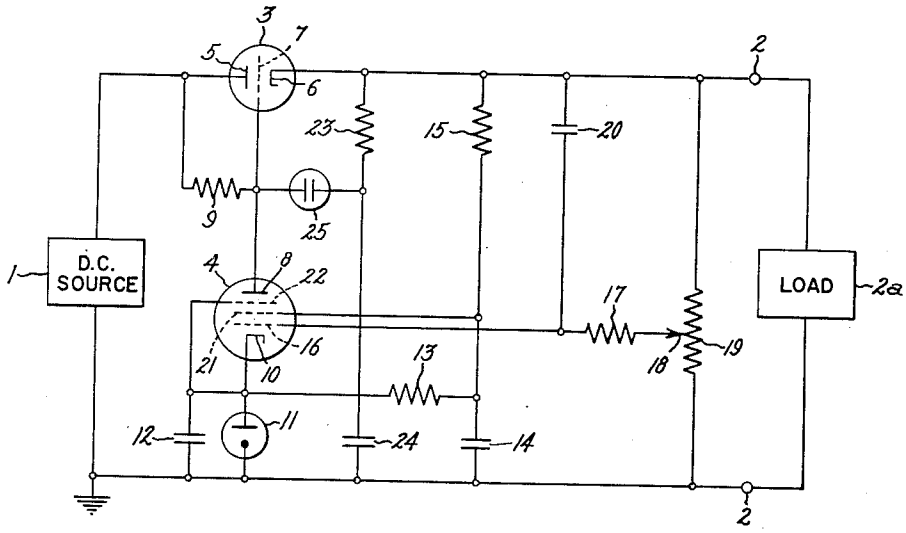
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VOLTAGE REGULATED POWER SUPPLY

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VOLTAGE REGULATED POWER SUPPLY

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This invention relates to regulated power supplies and has an object thereof to provide a voltage regulated power supply of uniform regulation having warm-up period protection.

A known voltage regulator comprises a variable resistance electric discharge device connected in series between a source of direct current potential and a load, and a control amplifier electric discharge device sensitive to changes in output voltage for altering the resistance of the variable resistance device to maintain the output voltage constant. In such a regulator, the anode voltage of the control amplifier discharge device is usually obtained from the output voltage of the supply. When such a connection is made, the available anode voltage is always less than that available from the direct current supply, and when low output voltages are developed, the reduction in anode voltage may considerably reduce the gain of the control amplifier device, thereby reducing the accuracy of regulation and making it dependent on the magnitude of the output voltage.

Warm-up protection is a second problem arising in regulated power supplies. In most applications, the electric discharge devices employed as variable resistances have relatively high current heaters having relatively short warm-up periods while the electric discharge devices employed as the control amplifiers have low current heaters having somewhat longer warm-up periods. As a result of this difference in warm-up time, there is a short period during which the variable resistance device is fully conductive but not under the control of the control discharge devices which are not yet conductive. Lack of control during this period usually results in a soaring potential at the output of the voltage regulator. This effect shortens the lives of components in the load designed for lower operating voltages.

Accordingly, it is an object of the present invention to provide an improved voltage regulator circuit in which the accuracy of control is independent of output voltage and in which the output voltage is maintained at a reduced value during the warm-up period.

Another object of this invention is to provide a voltage regulator of the type having a variable resistance electric discharge device and an amplifier control electric discharge device in which the gain of the amplifier discharge device is independent of the condition of conductivity of the variable resistance device and in which the variable resistance device is prevented from reaching full conductivity until the amplifier discharge device is fully warmed up.

In accordance with the present invention there is provided a source of unidirectional voltage, a load, a variable resistance electric discharge device connected in circuit with said source and said load, and a control electric discharge device responsive to variations in voltage across said load for controlling the conductivity of said variable resistance device. There is further provided a time delay circuit including a pair of resistances, a capacitance, and a gaseous discharge device, said elements being arranged

and proportioned to cause ionization of said gaseous discharge device from the time the combination is energized up to the time said control discharge device is rendered conductive and dionized thereafter, thereby to reduce the conductivity of said variable resistance device during the time said control discharge device is ineffective in controlling the conductivity of said variable resistance device and to operate said control discharge device with optimum effectiveness thereafter.

The novel features which are believed to be characteristic of this invention are set forth with particularity in the appended claims. The invention, however, both as to its organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying schematic drawing.

Referring now to the drawing, there is shown a regulated power supply comprising a direct current source 1, output terminals 2 for connection to a load 2*a*, a variable resistance discharge device 3, for convenience termed a variable resistance hereafter, a control voltage amplifier discharge device 4, for convenience termed a control amplifier hereafter, and a time delay circuit. The variable resistance 3, having an anode 5, a cathode 6, and a control grid 7 is connected in series between the source 1 of direct current voltage and the output terminals 2, the anode 5 being connected to the positive terminals of the direct current source, the cathode 6 being connected to one of the output terminals and the control grid 7 being connected to the output of the control voltage amplifier 4.

The control voltage amplifier 4 is shown as a pentode having an anode, a cathode and three grids. The anode 8 of the control voltage amplifier is directly connected to the grid 7 of the variable resistance device and the anode 8 is further connected through a load resistor 9 to the positive terminal of the direct current source 1. The cathode 10 of the control amplifier 4 is connected to a source of stabilized direct current potential comprising a voltage regulator discharge device 11, a first storage capacitor 12, a resistor 13, a second storage capacitor 14, and a second resistor 15. The negative terminal of the voltage regulator discharge device 11 is connected to the negative terminal of the power supply output which is preferably grounded and the positive terminal of the discharge device 11 is connected to the cathode 10 of the control amplifier, to the positive terminal of a storage capacitor 12, which shunts the discharge device 11, and to one terminal of the first resistor 13. The other terminal of the resistor 13 is connected to one electrode of the second storage capacitor 14, and to a second resistor 15, the other terminal of which is connected to the positive terminal of the power supply output. The other terminal of capacitor 14 is connected to ground. The control grid 16 is connected to a resistor 17, the other terminal of which is connected to a tap 18 on a bleeder resistor 19, connected across the power supply output terminals 2. A filter capacitor 20 is connected between the control grid 16 and the positive output terminal. The screen grid 21 is connected to the junction between resistor 13 and resistor 15. The suppressor grid 22 is connected to the cathode 10.

The time delay circuit includes a resistor 23, a capacitor 24, a gaseous discharge device 25 and resistor 9. The resistor 23 is connected in series with the capacitor 24 across the output terminals 2 of the power supply. The gaseous discharge device 25 is connected between the grid 7, and the junction of the resistor 23 and the capacitor 24. Resistor 9 is connected between anode 5 and grid 7.

Considering now the operation of the embodiment of the invention shown in the drawing, the direct current source 1 supplies a voltage to the load 2 through the variable resistance 3. The magnitude of the voltage supplied to the load is dependent on the condition of con-

ductivity of the variable resistance 3, the control grid of which receives a control voltage from the control amplifier 4. The control amplifier 4 develops a voltage proportional to the output voltage but in inverse phase thereto, which on application to the variable resistance 3, tends to maintain the output voltage constant.

Examination of the drawing will indicate the manner of obtaining this control voltage. The control grid 16 of the control amplifier is connected through a filter, comprising resistor 17 and capacitor 20 to a tap 18 on the bleeder resistance 19, thereby obtaining a voltage which is directly proportional to the output voltage appearing across the load. The voltage applied to the cathode 10 of the control amplifier is a stabilized reference voltage. It is obtained from a voltage regulator discharge device 11 which is supplied with energizing potentials through voltage dropping resistors 15 and 13, the voltages supplied thereto being filtered by storage capacitors 12 and 14, connected respectively at the voltage regulator discharge device and at the junction of the two resistors. The screen grid 21 also receives a positive potential from this circuit, being connected to the junction of the resistors 13 and 15. It may now be seen that the voltage between the control grid and the cathode is equal to the difference between a desired fraction of the output voltage and a reference voltage, and that any variation of the output voltage with respect to the reference voltage will produce a corresponding change across the output load resistor 9 of the control amplifier 4. This output voltage will be in inverse phase to the output voltage variations so that application of this voltage to the control element 7 of the variable resistance 3 will tend to maintain the output voltage substantially constant. The adjustment of the tap 18 upon the bleeder resistor 19 makes it possible to apply a differing fraction of the output voltage to the control amplifier discharge device 4, thereby permitting the production of different output voltages.

Connection of the load resistor 9 of the control amplifier to the positive terminal of the direct current source permits a uniformly high sensitivity voltage control. In addition to the increased potential available at this terminal over that available at a connection to the output of the power supply, the available potential is not subject to reduction whenever the power supply is operated to produce a low output voltage. The connection shown, consequently permits the use of a large plate load resistance for the control amplifier device 4, permitting higher gain operation, without the gain of the amplifier being adversely affected when low output voltages are desired. In addition, during the warm-up period, this connection tends to apply a high positive potential across the gaseous discharge device 25 used to initiate operation of the time delay circuit, the operation of which will now be described.

Prior to energization of the power supply, the capacitor 24 is in a discharged condition, the resistor 23 and the bleeder resistor 19 providing a discharge path for it. After energization of the power supply, upon the first appearance of a potential exceeding the ionization potential of the gaseous discharge device 25, the discharge device 25 fires, thereby presenting a conductive path between the capacitor 24, normally at zero potential, and the control grid of variable resistance 3. In this manner bias potential is supplied to the control grid 7 of the variable resistance 3. The magnitude of this bias potential is limited to the sum of the operating potential of the gaseous discharge tube 25 and the potential of the capacitor 24. When the variable resistance 3 begins to conduct and its cathode voltage begins to rise, the bias thus applied by the capacitor 24 through the gaseous discharge device 25 is effective to reduce the conductivity of the variable resistance to a value sufficient to prevent an excessive output voltage at terminals 2. The maximum value which the output voltage reaches is dependent on the current flowing through tube 3 and may be controlled by choice of a suitable bleeder resistance. The bias being supplied from the capacitor 24 continues until the control amplifier 4 is fully warmed up and capable of applying the usual control potentials to the variable resistance tube. After the control amplifier 4 has taken control, the current supplied to the amplifier through resistor 9 and the increasing voltage appearing across the capacitor 24 due to charging, reduces the potential across the gaseous discharge device 25. When the deionization potential of discharge device 25 is reached, the time delay circuit is no longer effective to control the variable resistance and it has no further effect upon the gain of the control amplifier 4, since it is isolated by the substantially infinite impedance of the deionized gaseous discharge device 25.

The duration of the protection period may be controlled by a suitable choice of the values for resistor 23 and capacitor 24. When time delay on the order of 4 or 5 seconds is desired, the resistance may be on the order of 100,000 ohms and the capacitor may be of approximately 40 microfarads. The conduction of the gaseous discharge device 25 does not appreciably effect the charging rate since the currents involved are substantially less than the normal charging current flowing through the charging resistor 23. The gaseous discharge device 25 should be chosen so as to have an ionization voltage and deionization voltage of substantial separation, both preferably being greater than the usual range of control potentials applied to the variable resistance tube so as not to restrict the operation of the variable resistance 3. An ionization voltage of the order of 180 volts and a deionization voltage of approximately 150 volts is suitable when a conventional variable resistance device such as a 6AS7G type discharge device is employed.

The invention thus provides an effective warm-up period control in a voltage regulated power supply and at the same time permits undisturbed high gain operation of the component control voltage amplifier so as to maintain the control substantially as effective at one output setting as at another.

In carrying out the invention it is, of course, apparent that variations in the embodiment shown may be made without departing from the spirit of the invention. It is contemplated by the appended claims to cover any such modifications as fall within the true spirit and scope of the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A voltage regulated power supply comprising a source of unidirectional voltage, a pair of output terminals for connection to a load, a variable resistance electric discharge device having an another, a cathode, a control grid, and heating means effective to bring said variable resistance device to conductivity within a relatively short period of time, said anode being connected to the positive terminal of said source and said cathode being conductively connected to one of said output terminals, and a control electric discharge device having heating means requiring a somewhat longer time than required for said first heating means to bring said control device to conductivity, said control device being responsive to variations in voltage across said output terminal and having an anode connected to said grid to apply said variations in inverse phase to said control grid to control the conductivity of said variable resistance device, a time delay circuit including a charging resistance and a capacitor joined and connected in series in the order recited between said cathode and the other of said output terminals respectively, another resistance connected between the positive terminal of said source and the anode of said control device, a gaseous discharge device having a pair of electrodes, one of said electrodes being connected to said grid and the other of said electrodes being connected to the junction of said charging resistance and said capacitor, the elements of said delay

circuit being proportioned to cause ionization of said gaseous discharge device from the time said power supply is energized up to the time said control device is rendered conductive and deionized thereafter whereby said grid is biased to reduce the conductivity of said variable resistance device during the time said control device is ineffective in controlling the conductivity of said variable resistance device and said control device is operated with optimum effectiveness thereafter.

2. In combination, a source of unidirectional voltage, a load, an electron discharge device including a cathode, a grid and an anode, the anode-cathode discharge path of said device being connected in circuit with said source and said load to permit current to flow between said source and said load, an amplifier including an output load resistance, said amplifier being energized from said source and said load resistance being connected between said anode and said grid, a voltage divider circuit connected in shunt with said load and in circuit with the input of said amplifier to supply variations in voltage across said load to said amplifier, whereby the potential of said grid is varied in a manner to maintain said load voltage substantially constant, another resistance and a capacitance being joined and connected in series in the order recited between said cathode and the negative terminal of said source, a gaseous discharge device having one terminal connected to said grid and the other terminal connected to the junction of said other resistance and capacitance, said resistance and capacitance being proportioned to cause a gradual rise in potential of said junction, said load resistance and gaseous discharge device being proportioned to cause ionization of said gaseous discharge when said unidirectional source is energized thereby limiting the potential of said grid and the voltage supplied to said load and to cause deionization of said gaseous discharge device as the potential of said junction rises to a predetermined value.

3. A voltage regulated power supply comprising a source of unidirectional potentials, a variable resistance electric discharge device having two principal electrodes for unidirectional conduction therein and a control element, output terminals for connection to a load energized by said source through a path including said principal electrodes, an amplifier discharge device having the anode thereof conductively connected to said control element and connected through a load resistance to the positive terminal of said source, said amplifier device being arranged to supply to said control element a voltage which varies inversely to the voltage at said output terminals, and a circuit for reducing the conductivity of said variable resistance device for an interval after said power supply is turned on, comprising a resistance and capacitance connected together and connected in

series in the order recited between the positive output terminal and the negative output terminal, and a gaseous discharge device coupled between said control element and the junction of said last recited resistance and capacitance.

4. A voltage regulated power supply comprising a source of unidirectional potentials, a variable resistance electric discharge device having two principal electrodes for unidirectional conduction therein and a control element, output terminals for connection to a load energized by said source through a path including said principal electrodes, an amplifier discharge device having the anode thereof conductively connected to said control element and connected through a load resistance to the positive terminal of said source, said amplifier device being arranged to supply to said control element a voltage which varies inversely to the voltage at said output terminals, and a circuit for reducing the conductivity of said variable resistance device for an interval after said power supply is turned on, comprising a resistance and capacitance connected together and connected in series in the order recited between the point in said path on the output side of said variable resistance device of positive potential and the negative terminal of said source, and a gaseous discharge device coupled between said control element and the junction of said last recited resistance and capacitance.

5. In combination, a source of unidirectional potentials, a variable resistance electric discharge device having an anode and a cathode for unidirectional conduction therein and a control element, said anode being coupled to the positive terminal of said source, an amplifier discharge device having the anode thereof conductively connected to said control element and connected through a load resistance to the positive terminal of said source, said amplifier device being arranged to supply to said control element a voltage which varies inversely with the voltage between said cathode and the negative terminal of said source, and a circuit for reducing the conductivity of said variable resistance device for an interval after energization of said power supply, comprising a resistance and capacitance connected together and connected in series in the order recited between said cathode and the negative terminal of said source, and a gaseous discharge device coupled between said control element and the junction of said last recited resistance and capacitance.

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