

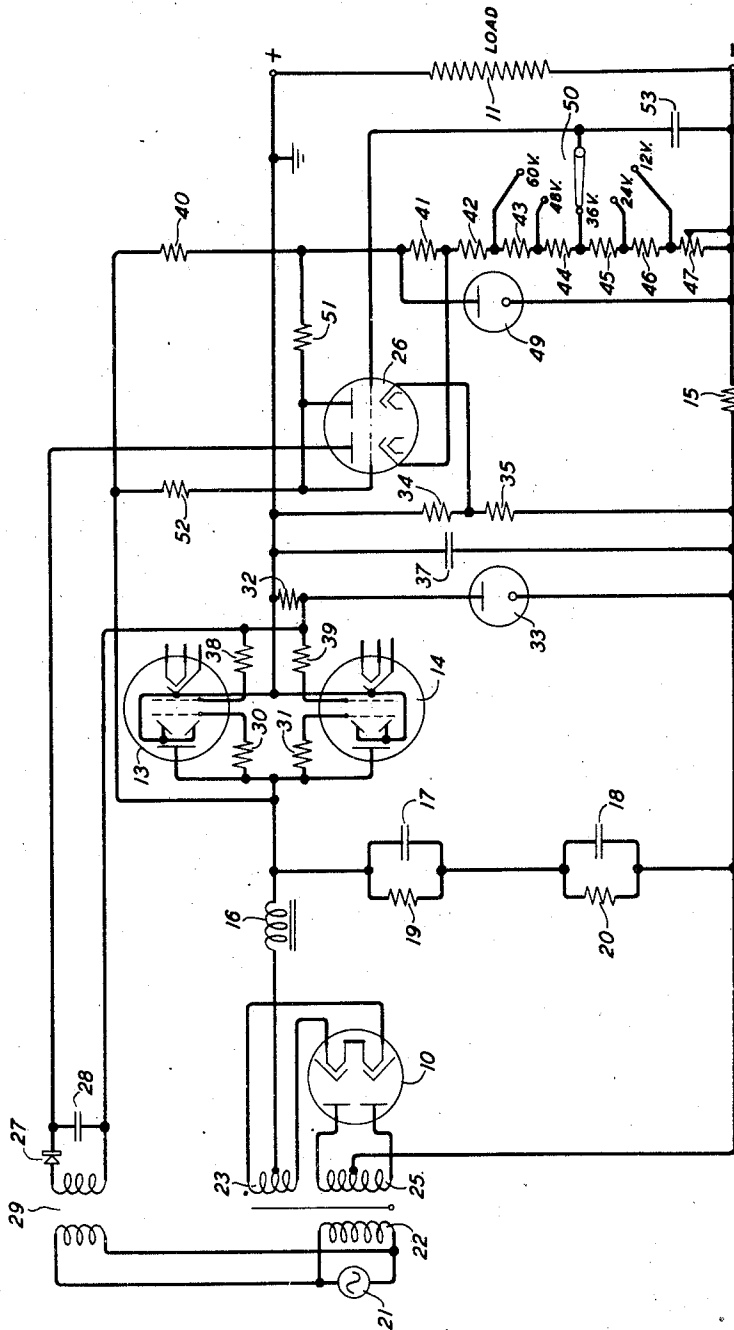
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VOLTAGE REGULATION

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VOLTAGE REGULATION

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This invention relates to voltage regulation and particularly to a regulated rectifier.

An object of the invention is to provide an improved regulator for maintaining substantially constant at a selected value within a certain voltage range the voltage across the load to which direct current is supplied.

In a specific embodiment of the invention herein shown and described for the purpose of illustration, there is provided a source of direct current, specifically a rectifier, for supplying current to a load through a circuit comprising in series the space current path of a space current device, or so-called series regulator tube, or a plurality of such tubes having their space current paths connect in parallel. The resistance of the space current path of the series regulator tube is controlled to control the current supplied to the load and thereby to control the load voltage by impressing upon the control circuit of the regulator tube a voltage derived from the output of a two-stage vacuum tube amplifier. Means are provided for deriving from the supply circuit and impressing upon the control circuit of the first amplifier stage a voltage having a first component proportional to the load voltage, a second component proportional to the load current and a third component having a selectable substantially fixed value, the second and third components being in opposition to said first component. The voltage amplified by the first amplifier stage together with a voltage component proportional to the voltage of the source is impressed upon the input circuit of the second amplifier stage.

The rectifier supplies current to a voltage divider circuit comprising a plurality of resistors in series, the voltage across the resistors or any portion of them being maintained substantially constant by means of a cold cathode, gas filled space current device connected across the resistors. A device of this type has the characteristic that its resistance decreases as the current flowing through it increases, and vice versa, at such a rate that the voltage across its terminals remains substantially constant. A multicontact switch is provided for varying the portion of the plurality of resistors connected in the control grid-cathode circuit of the first amplifier stage to thereby set the load voltage at 12, 24, 36, 48 or 60 volts. For any of these load voltages, there is required for supplying space current to the first amplifier

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stage a substantially constant voltage of greater magnitude than the load voltage, 150 volts, for example. There is therefore connected in the space current circuit of the first amplifier stage the plurality of resistors which are shunted by the cold cathode, gas filled, constant voltage tube. An auxiliary rectifier coupled to the alternating current supply source which also supplies current to the main rectifier is provided for supplying space current to the second amplifier stage.

The invention will now be described in connection with a drawing, the single figure of which is a diagrammatic view of a regulated rectifier embodying the invention.

There is provided a full wave rectifier comprising a rectifier tube 10 (type 5U4G) for supplying rectified current to a load 11 through a circuit comprising the anode-cathode paths of space discharge tubes 13 and 14 (type 350B) in parallel with each other connected in series in the lead going to the positive load terminal and a 6.2-ohm resistor 15 connected in series in the lead going to the negative load terminal. The rectified current is filtered by the series inductance element 16 and the shunt capacitance comprising in series condensers 17 and 18, each of 125 microfarads, condenser 17 being shunted by 1-megohm resistor 19 and condenser 18 being shunted by 1-megohm resistor 20. Current from an alternating current supply source 21 is connected to the primary winding 22 of a transformer having a secondary winding 23 for supplying heating current to the cathodes of tube 10 and a secondary winding 25 the end terminals of which are connected to the anodes respectively of tube 10. The positive output terminal of the rectifier is connected to a mid-tap of transformer winding 23 and the negative output terminal is connected to a mid-tap of winding 25.

A voltage regulating circuit comprising series regulator tubes 13 and 14 and a two-stage amplifier comprising the triodes of a twin triode tube 26 (type 6SL7GT) is provided for maintaining the load voltage substantially constant irrespective of changes of line voltage and changes of load at a selected voltage within a certain voltage range, namely, 12, 24, 36, 48 or 60 volts. An auxiliary rectifier comprising a metallic or a vacuum tube, rectifying element 27 and a shunt filtering condenser 28 of two microfarads capacity are provided for supplying space current to the tri-

ode of tube 26 which is in the second amplifier stage, as will be further described below, alternating current from the supply source 21 being supplied to the primary of a transformer 29 the secondary winding of which is connected to the auxiliary rectifying circuit. The anodes of tubes 13 and 14 are directly connected to a common terminal of inductance element 16 and condenser 17 of the ripple filter and the screen grids of the tubes are connected to the common terminal of the inductance element 16 and condenser 17 through resistors 20 and 31, respectively, each having a resistance of 33 ohms. Three parallel paths are connected across the load 11 and resistor 15 in series. One of the paths comprises resistor 32 of 100,000 ohms and a cold cathode, gas filled tube 33 in series, a second path comprises resistors 34 and 35 in series, each of 5100 ohms, and a third path comprises a two microfarad condenser 37. The control voltage for controlling the resistance of the space current paths of tubes 13 and 14 is the voltage drop across resistor 32, one terminal of resistor 32 being connected to the indirectly heated cathodes of tubes 13 and 14 and the other terminal of resistor 32 being connected to the control grids of tubes 13 and 14 through resistors 38 and 39, respectively, each of 2,200 ohms.

Current is supplied from the filtered output of rectifier 10 to a circuit which may be traced from a common terminal of inductance element 16 and condenser 17 through resistors 40, 41, 42, 43, 44, 45, 46, variable resistor 47 and the load compensating resistor 15, all in series. The resistors 41 to 47, inclusive, being shunted by a cold cathode, gas filled constant voltage tube 49 (type VR-150-30). As the current passing through the space current path of tube 49 increases, for example, its resistance decreases at a rate to maintain the voltage drop across the tube substantially constant irrespective of voltage changes at the output of the rectifier, the voltage variations appearing across the resistor 40. The resistances of resistors 40 to 47 are, respectively, 10,000 ohms, 22,000 ohms, 27,000 ohms, 2,400 ohms, 2,200 ohms, 2,400 ohms, 2,700 ohms and 5,000 ohms (variable). A multicontact switch 59 is provided for connecting the control grid of the first amplifier stage to such a point on the voltage divider comprising resistors 41 to 47 that a desired one of a plurality of values of voltage is obtained, that is, 12, 24, 36, 48 or 60 volts. The 12 volt switch contact is connected to a common terminal of resistors 46 and 47, the 24 volt switch contact is connected to a common terminal of resistors 45 and 46, the 36 volt contact is connected to a common terminal of resistors 44 and 45, the 48 volt contact is connected to the common terminal of resistors 43 and 44 and the 60 volt contact is connected to the common terminal of resistors 42 and 43. With the control grid connected to the 36 volt contact, for example, the load voltage will be set at 36 volts. A two microfarad condenser 53 is provided in a path connecting the movable arm of switch 50 and the negative load voltage terminal. The cathode of the triode of the first amplifier stage is connected to a common terminal of resistors 34 and 35. Thus the electromotive force in the grid-cathode circuit of the first amplifier stage is the algebraic sum of a portion of the constant voltage across tube 49 depending on the setting of switch 50, the voltage across resistor 15, and the voltage across resistor 35, the voltage across resistor 35 being in opposition to the remaining two voltage components. The

voltage across resistor 15 is substantially proportional to the load current while the voltage across resistor 35 is substantially proportional to the load voltage. Since the load voltage is variable and since its magnitude is within a relatively low voltage range, it is unsuitable for use as a source of space current for the amplifier triodes. It has been found satisfactory to complete a space current supply circuit for the first amplifier triode by connecting the common terminal of resistor 40 and cold cathode tube 49 through a one megohm resistor 51 to the anode of the triode. Thus for any desired setting of switch 50 the voltage impressed across the anode-cathode path of the triode and the resistor 51 in series is substantially constant.

The control grid of the triode of the second amplifier stage is connected directly to the anode of the triode of the first amplifier stage and the cathode of the triode of the second amplifier stage is connected to a common terminal of resistors 41 and 42. Anode current is supplied to the triode of the second amplifier stage from the auxiliary rectifier 27, 28, 29, through a circuit which may be traced from the positive output terminal of the rectifier to the anode and from the cathode through resistors 42 to 47, through the load 11 and through resistor 32 to the negative rectifier output terminal. A resistor 52 of 300,000 ohms is connected across resistors 40 and 51 in series so that voltage changes of the main rectifier, due to line voltage changes, for example appearing across resistor 40 cause the introduction of a corresponding voltage component in correct phase across resistor 51.

The space current of the second stage amplifier triode flowing through resistor 32 is small during an initial period while the indirectly heated cathodes of the triodes of tube 26 are being brought to operating temperature. During this initial period, therefore, the load voltage rises above its normal operating value. Excessive load voltage is prevented by means of the circuit comprising the cold cathode tube 33 which breaks down before an excessive load voltage is reached. The resulting increased current through resistor 32 sets up a biasing voltage for the series regulator tubes 13 and 14 to limit the current flowing in the load circuit and thereby to limit the load voltage to a safe maximum value.

In order to change the load voltage from one operating value to another, say from 36 volts to 48 volts, the arm of switch 50 is moved from the 36 volt contact to the 48 volt contact, thereby making the potential of the grid of the first amplifier triode relatively more positive with respect to its cathode. The anode of the first amplifier triode and, therefore, the control grid of the second amplifier triode are thus made relatively more negative with respect to the cathodes respectively, and, as a result, the space current of the second amplifier triode flowing through resistor 32 is reduced. The control electrodes of tubes 13 and 14 thus become relatively less negative with respect to the cathodes to cause the current supplied to the load to increase sufficiently to raise the load voltage to the desired value of 48 volts.

For any setting of switch 50, if the load voltage should increase slightly, the voltage across resistor 35 would increase to make the grid of the first amplifier triode relatively more negative with respect to its cathode. The control grid of the second amplifier triode would thus become relatively less negative with respect to its cath-

odes and the control grids of regulator tubes 13 and 14 would become relatively more negative with respect to their cathodes. The current supplied to the load would therefore decrease to bring the load voltage substantially to its correct voltage as determined by the setting of switch 50.

Any tendency of the load voltage to change in response to line voltage changes is substantially prevented by connecting the resistor 52 in series with resistor 51 across the resistor 40. When the voltage across the output of ripple filter 16, 17, 18, increases, for example, due to an increase of line voltage, the voltage drop across resistor 40 will increase proportionately and increased space current for the first amplifier triode will flow by way of resistor 52 to cause the voltage drop across the anode-cathode path of the first amplifier triode to increase. The component of the space current of the first amplifier triode flowing through resistor 51 will therefore decrease to reduce the voltage drop across resistor 51. The control grid of the triode of the second amplifier stage will thus become relatively more positive with respect to its cathode to cause the current flowing through resistor 32 to increase. As a result, the grids of regulator tubes 13 and 14 will become relatively more negative with respect to their cathodes to substantially prevent a rise of load voltage due to the assumed increase of line voltage. The control voltage across resistor 51 in the control circuit of the second amplifier stage and the control voltage across the resistor 32 in the control circuit of the regulator tubes 13 and 14, therefore, each have three components, namely, a first component proportional to the load voltage, a second component proportional to the line voltage and a third component proportional to the load, said third component being in opposition to each of the first and second components.

What is claimed is:

1. A voltage regulator for controlling the current supplied from a direct current source to a load to maintain the load voltage substantially constant comprising a regulator electronic device having an anode, a cathode and a control electrode and having its anode-cathode path connected in series in one side of the line connecting said source to a load terminal, an amplifier comprising a second electronic device having an anode, a cathode and a control electrode, means for deriving from said source a substantially constant voltage which is larger than the maximum load voltage, an anode current circuit connecting the anode and cathode of said second electronic device, means for obtaining a voltage proportional to the load voltage, means for obtaining a voltage proportional to the load current, means for impressing upon said anode current circuit a voltage having as components of opposite polarity therein said substantially constant voltage and said voltage proportional to load voltage a circuit connecting the control electrode and cathode of said second electronic device comprising in series a portion of said derived voltage, said voltage proportional to load voltage and said voltage proportional to load current, said voltage proportional to load current being in aiding relationship to one of said remaining voltages in said circuit and in opposing relationship to the other of said remaining voltages, and means for connecting the output voltage of said amplifier in a circuit connecting the control electrode and cathode of said regulator electronic device to control its anode-cathode resistance.

2. The combination with a circuit for supply-

ing current from a direct current source to a load of a regulator space current device having a space current path in series in said load circuit and having means responsive to a control voltage impressed thereon for varying the resistance of said space current path to control said load voltage, an amplifier comprising a first and a second amplifier space current device each having an anode, a cathode and a control electrode, a current path connected across said current source comprising in series a first resistor and a constant voltage device the resistance of which varies in response to current changes therethrough to maintain the voltage across said device substantially constant, a second resistor and a third resistor connected in series across said first resistor, a potentiometer connected across said constant voltage device, a common terminal of said first and third resistors being connected to the positive terminal of said direct current source, the common terminal of said first and second resistors being connected to a terminal of said constant voltage device, means for connecting the anode of said first amplifier device to a common terminal of said second and third resistors, a resistive path connected across said load, means for connecting the cathode of said first amplifier device to said resistive path, means for connecting the control electrode of said first amplifier device to a selectable point of said potentiometer, means for connecting the anode of said first amplifier device to the control electrode of said second amplifier device, means for connecting the cathode of said second amplifier device to said potentiometer, a source of space current for said second amplifier device and means responsive to the space current of said second amplifier device for setting up said control voltage.

3. A combination in accordance with claim 2 in which there is provided a fourth resistor connected in series in the control electrode-cathode circuit of said first amplifier device, said fourth resistor also being connected in series with said load with respect to said source.

4. A combination in accordance with claim 2 in which the voltage across the portion of said potentiometer connected in the control electrode-cathode circuit of said first amplifier device is such that the load voltage is less than half the voltage across said constant voltage device.

5. In combination, a space current device having an anode, a cathode and a control electrode, a direct current source the voltage of which may vary, a current path connected across said source comprising in series a first resistor and a constant voltage device having the characteristic that its resistance decreases when the current through the device increases, and vice versa, at such a rate that the voltage drop across the device remains substantially constant irrespective of the voltage of said source, voltage dividing resistance means conductively connected directly across said constant voltage device, a second resistor, a current path connecting said anode and said cathode comprising said second resistor and means for conductively connecting one terminal of said second resistor to said anode and the other terminal of said second resistor to a common terminal of said first resistor and said constant voltage device, a circuit connecting said control electrode and said cathode, means for including in said control electrode-cathode circuit a portion of said voltage dividing resistance means which portion may be varied to control the amplitude of the space current flowing in the anode-cathode path and thereby to control the voltage

across said second resistor means for supplying current from said direct current source to a load, and means responsive to the voltage across said second resistor for controlling the current supplied to said load.

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