May 11, 1943. E. A. TUBBS 2,318,644

VOLTAGE REGULATION AND SUPPLY

Filed Dec. 24, 1938 2 Sheets-Sheet 1

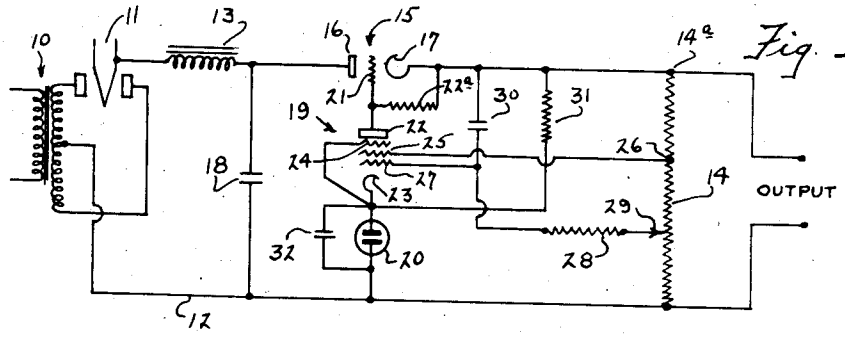


Fig. 1.

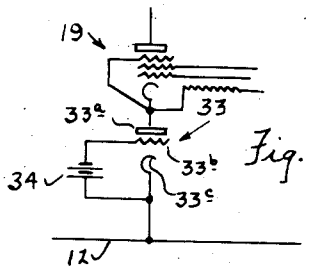


Fig. 2.

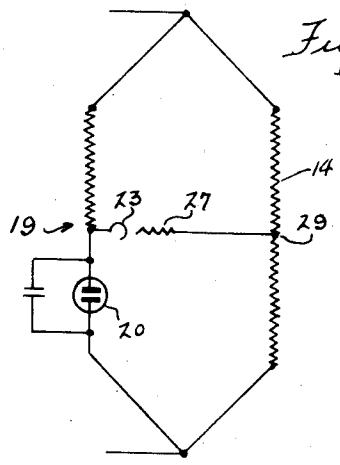


Fig. 3.

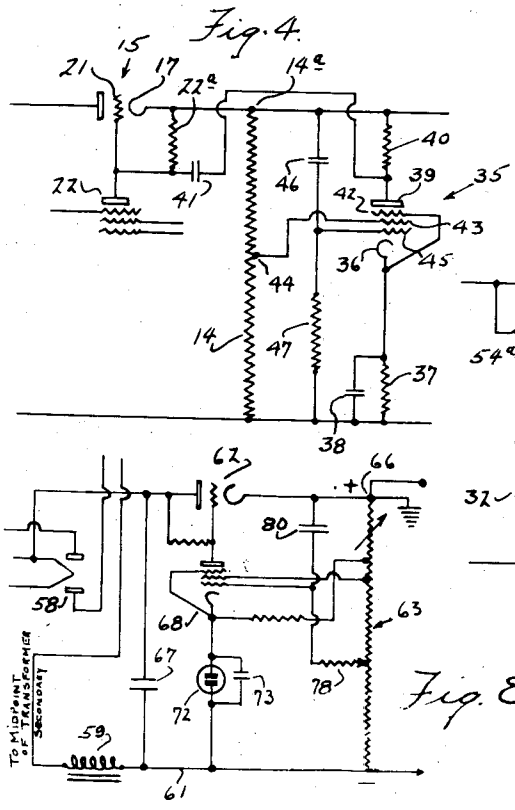


Fig. 4.

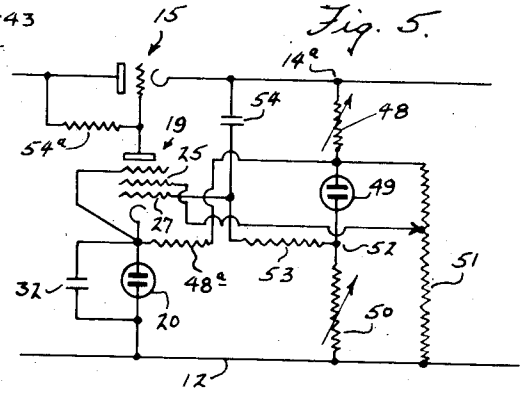


Fig. 5.

Fig. 8.

INVENTOR.
ERNEST A. TUBBS
BY Brueton, Whitcomb & Davis.
ATTORNEYS.

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VOLTAGE REGULATION AND SUPPLY

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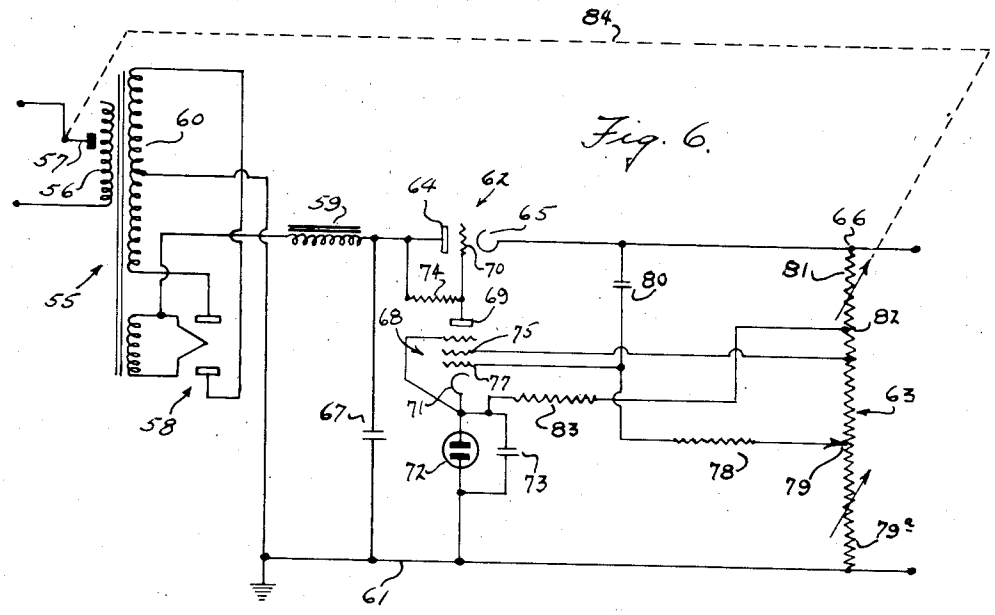


Fig. 6.

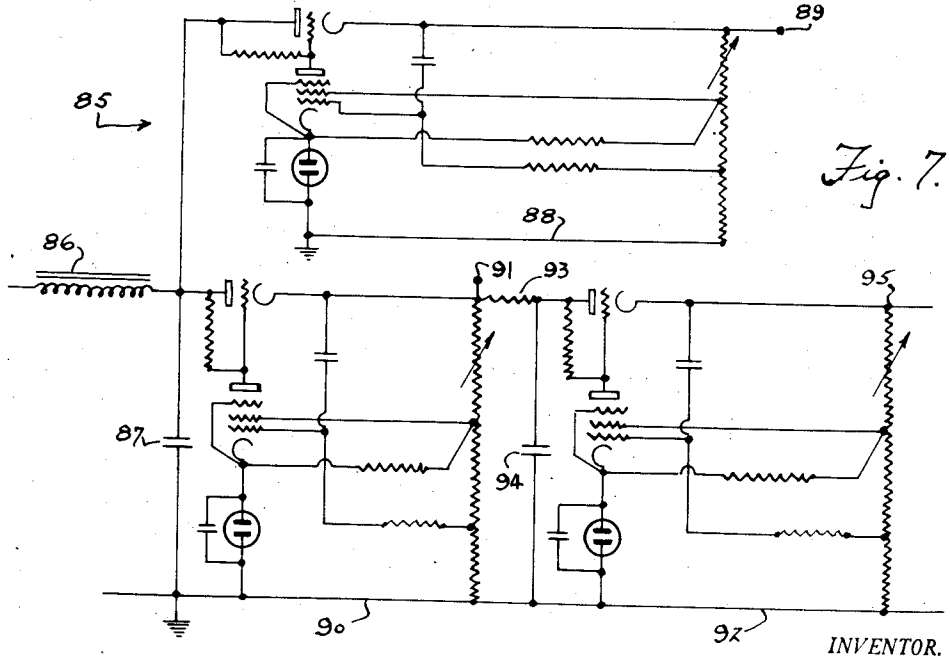


Fig. 7.

INVENTOR.
ERNEST A. TUBBS
BY Brascelton, Whittemore & Davis.
ATTORNEYS.

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UNITED STATES PATENT OFFICE

2,318,644

VOLTAGE REGULATION AND SUPPLY

Ernest A. Tubbs, Long Island City, N. Y., assignor to National Television and Manufacturing Corporation, a corporation of Delaware

Application December 24, 1938, Serial No. 247,721

7 Claims. (Cl. 171—312)

This invention relates to voltage regulation, and has, for is principal object, to provide a power supply having an extremely constant voltage which will not be appreciably disturbed by changes in load conditions or variations of the source.

Another object of the invention is to provide regulation for a power supply which will compensate for relatively rapid variations of the load requirements or power source, as well as relatively slow variations.

Still another object of the invention is to provide a regulating voltage network comprising a thermionic tube for amplifying slight changes in voltage to effect control of the output voltage with means to maintain maximum amplification of said tube regardless of input voltage variation or adjustment of the output voltage.

Another object of the invention is to provide a regulated power supply with an extremely low internal impedance.

Still another object of the invention is to provide a voltage regulation circuit comprising a gas discharge device with means to operate said device so that it always has its substantially maximum regulating effect.

Another object of the invention is to provide a voltage regulation network, including a pentode tube, with means to maintain a substantially constant potential difference between the screen and the cathode of the tube, while compensating action is provided by variations of the control grid.

Another object of the invention is to provide a regulated power supply with a wide voltage range.

Another object of the invention is to provide a voltage regulating circuit with an adjustable range of output voltage in which the effective regulation is substantially constant over the output voltage range.

Another object of the invention is to provide a regulated power supply with means to simultaneously vary the input voltage and the output voltage in a predetermined manner.

Still another object of the invention is to provide a regulated power supply with manually operated means to adjust the input voltage and additional manually operated means to adjust the output voltage.

Another object of the invention is to provide a regulated voltage supply comprising a plurality of regulating networks connected in series or parallel, or both, for providing several different voltages at the same time without the loads of either affecting the others.

The invention has been illustrated in the accompanying drawings, in which:

Fig. 1 is a circuit diagram of one form of the invention;

Fig. 2 is a diagram of a portion of the circuit of Fig. 1 showing a modified form of voltage regulation device;

Fig. 3 is a diagram of an equivalent circuit of a portion of the circuit of Fig. 1;

Fig. 4 is a circuit diagram of a modified form of the circuit of Fig. 1;

Fig. 5 is a circuit diagram of still another modified form of the circuit of Fig. 1;

Fig. 6 is a circuit diagram of a modified form of the circuit of Fig. 1 showing the simultaneous input and output voltage control;

Fig. 7 is a circuit diagram of a form of the invention adapted to permit several different output voltages; and

Fig. 8 is a circuit diagram of modified form of Fig. 6, arranged for a supply of negative voltage.

As will be understood, no power supply system can have zero internal impedance. Hence there must always exist across the terminals of the power supply device under load conditions a voltage which is somewhat less than the voltage which would exist for open circuit or zero load. If the load fluctuates, the terminal voltage will fluctuate also. A power supply system in which the drop in voltage under load is excessive is spoken of as having poor regulation; one in which the drop is small is said to have good regulation or to be "tight."

For the purposes of this application, applicant chooses the following definitions:

"Direct current" is considered to be a current flowing always in the same direction and having, over the entire period of time involved, the same value.

"Alternating current" is the current which is left after the direct current component, as above defined, is subtracted from the total current. Alternating current has a constant frequency only when its wave form is a mathematically pure sine wave. Any deviation from this condition may be shown to introduce frequencies other than the original frequency.

From the foregoing it follows that when a power supply system is supplying an alternating current load, the voltage at the terminals of the power supply fluctuates at the frequency drawn by the load and by an amount depending upon

the effective internal impedance of the supply. If the load draws current of a complex wave form, which would be the case for an audio or video frequency amplifier, the plate circuit of which is the load being supplied, then the voltage at the terminals fluctuates in a complex wave which can be shown to contain all of the frequencies appearing in the load.

Referring now more specifically to the drawings, the form of the regulated power supply shown in Fig. 1 comprises the usual transformer 10, the primary of which may be connected to a source of alternating current supply, as, for instance, the sixty cycle lighting mains, while the secondary is connected to the anodes of a full wave rectifier 11. Following the usual practice, the mid-point of the secondary of the transformer may be connected to the neutral side of the circuit, as represented by the wire 12, while the cathode of the rectifier 11 may be connected to the choke 13 which is placed in the high potential side of the circuit. The usual potentiometer resistance 14 may be connected between the high voltage side of the circuit and the neutral side, and in series with the choke 13 and the potentiometer resistance 14 I provide a thermionic tube 15, the anode 16 of which may be connected directly to the choke 13, while the cathode 17 may be connected to the potentiometer 14. This tube acts as a variable resistance in the circuit to automatically regulate the voltage output. The output voltage is taken off between the point 14*a* at the high potential end of the potentiometer 14 and the neutral wire 12.

I preferably use a three element tube with an independently heated cathode, although a tube with a filamentary cathode may be used if desired. The heater for the cathode 17 has been omitted in the drawing, and it will be understood that separate filament windings on the transformer 10 will be provided for energizing this heater and the heaters of other tubes in the circuit, or a separate filament transformer may be used for this purpose. The latter may be preferred as it provides a means to control the high voltage supply independently of the filaments of the tubes used in the circuit.

A filter condenser 18 may be connected across the high and low sides of the circuit between the choke and tube 15, following ordinary practice. However, the regulating effect of the circuit is such that no particular care need be taken in filtering the voltage supply up to the tube 15, and hence a single sixteen microfarad condenser has been found to be sufficient for this purpose.

A second thermionic tube 19 and a voltage regulating device 20 may be connected in series between the grid 21 of the tube 15 and the neutral wire 12. The tube is preferably a pentode tube, with the plate 22 being connected directly to the grid 21 of the tube 15, and the cathode 23 being connected directly to one terminal of the regulating device 20, the other terminal of which is connected to the wire 12. The plate potential may be supplied through a resistance 22*a* from the high side of the circuit. The suppressor grid 24 of the tube 19 may be connected directly to the cathode. The screen grid 25 of the tube 19 may be connected to a point 26 on the potentiometer 14, which will give it a suitable operating potential. The control grid 27 of the tube 19 may be connected through a resistance 28 to a movable contact arm 29, which may be adjusted along the potentiometer 14 to give the grid 27 a potential slightly negative with respect to the cathode 23, which is given a potential by the operating voltage of the regulating device.

A condenser 30 may also be connected between the grid 27 and the high side of the line at the cathode of the tube 15. The cathode 23 of the tube 19 may also be connected through a resistance 31 to the high potential end of the potentiometer 14, to insure sufficient operating current for the regulating device 20. Across the particular regulating device 20, used in Fig. 1, I preferably connect a condenser 32 for the purpose of insuring better regulation for alternating current components.

I have found that the action of any device in regulating the voltage depends on the favorable ratio of its equivalent direct current resistance to its incremental resistance. If the equivalent direct current resistance is very high in comparison to the incremental resistance, a good regulating effect will be obtained when the device is connected in series with a large resistance. The voltage drop across the device may be used as a reference voltage in the control network.

One device in which the above mentioned ratio may be made high enough for good regulating effects is a gaseous discharge device in which a pair of electrodes are arranged in spaced relation immersed in an inert gas under reduced pressure. Neon, argon, helium, krypton, and zenon might be used in such a device with gas pressures somewhere around 10 millimeters of mercury, depending on the particular gas used and the positioning and character of the electrodes. For such a device I prefer to have a ratio over 300 for conditions of stable operation.

In Fig. 1 a gas discharge lamp has been used for the regulating device 20. The condenser 32 across the lamp decreases the incremental resistance between the terminals of the device and therefore has the effect of improving the ratio.

Another device which might be used in place of the device 20 in Fig. 1 for producing the desired high ratio of equivalent direct current resistance to incremental resistance is a high vacuum tube in which the plate-cathode circuit has the desired ratio. Such a voltage regulating device is illustrated in Fig. 2 where the triode 33, having an anode 33*a*, a grid 33*b*, and a cathode 33*c* may be connected in the cathode circuit of the tube 19 in place of the gas discharge device 20. A battery 34 is provided between the grid 33*b* and the cathode 33*c* to maintain the grid at a fixed potential with respect to the cathode to insure zero plate current up to a predetermined potential on the plate.

In order to understand the operation of the circuit of Fig. 1, the discharge lamp 20 and resistance 31 may be considered as one arm of a bridge circuit, the other arm of which is composed of the potentiometer 14. This simple equivalent circuit is shown for convenience in Fig. 3, where it will be seen that the neutral points of the circuit are the point 29 on the potentiometer and the cathode 23 of the tube. This bridge circuit is so balanced that there is a certain normal predetermined potential difference between the points 29 and 23 for a given voltage across the bridge. It is desired to have a maximum of unbalance for voltage changes. If the voltage changes, the action of the regulating device upsets the balance of the circuit with the result that the potential difference between points 29 and 23 changes, and this means that the potential of the grid 27 will change with respect to the cathode 23. This change in potential is then amplified by

the tube 19, and as the plate current of that tube passes through the resistance 22a, the amplified voltage variation will take place across this resistance. The resistance 22a, however, is also between the cathode 17 and grid 21 of the tube 15, and hence the plate cathode resistance of this tube is varied, thus varying the potential across the entire circuit. It will be seen that as the voltage across the bridge rises there will be a rise in the resistance of the tube 15, so that the action of this tube compensates for the original change in voltage. This tends to maintain the voltage constant across the entire circuit.

I have found that maximum regulating effect of the circuit will be obtained when the following equation is a maximum:

$$\frac{\Delta E_g}{\Delta E_t}=\frac{E_n}{E_t}\left[\frac{R-1}{R+\frac{E_n}{E_t-E_n}}\right]$$

where

ΔE_g=the change in the potential of the grid of the tube 19 with respect to the cathode.

ΔE_t=the change in voltage across the potentiometer 14.

E_n=the direct current voltage across the regulating device.

E_t=the direct current voltage across the potentiometer 14.

R=the ratio of effective direct current resistance of the regulating device to incremental resistance.

It will be seen that as R is increased, the ratio of the change on the grid of the screen grid tube to the total voltage change is also increased.

I have found that one method of unbalancing the bridge circuit for changes is the use of the condenser 30 and resistance 28. When the resistance 28 is very large compared to the reactance of the condenser 30, for the frequency components present in the voltage change, the grid 27 will be effectively directly tied to the point 14a for these frequencies.

In determining the respective sizes of the condenser and resistance consideration should of course be given to the fact that the change in grid voltage (ΔE_g) should be as nearly in phase with the total change (ΔE_t) as possible. I prefer to use a resistance of at least a half million ohms, with which, for even relatively rapid variations, the condenser can be relatively small. With only .1 mfd. condenser and this resistance value, improved regulation is insured for changes down to at least one cycle per second.

This grid leak and condenser arrangement enables the circuit to effectively compensate for surges and other objectionable transients coming in over the power lines. The internal impedance (the impedance looking back into the output terminals 14a and 12 of the circuit) is also greatly reduced for alternating currents.

The potential output of the system of Fig. 1 may be adjusted within certain limits by adjusting the arm 29 on the potentiometer 14.

With the circuit of Fig. 1 the tube 19 will not always operate with maximum amplification, and to improve this condition I may use the arrangement shown in Fig. 4. The same circuit as shown in Fig. 1 is used including the tube 19, and in addition another tube, 35, is connected in parallel with the tube 19. This may be a pentode tube with its cathode 36 connected directly to the neutral wire 12 through a biasing resistance 37, by-passed by a condenser 38. The anode 39 of this tube may receive its operating potential through a resistance 40, which may be connected to the high end 14a of the potentiometer 14, and the anode may be directly connected to the grid 21 of the tube 15 through a condenser 41. The suppressor grid 42 of the tube 35 may be connected to the cathode as shown, while the screen grid 43 may receive a suitable potential from a point 44 on the potentiometer 14. The control grid 45 of the tube 35 may be connected directly to the high side of the potentiometer 14 through a condenser 46, while a grid leak 47 may be inserted between the grid and the neutral wire 12.

When adjusting for low voltage output the grid of the tube 19 may be backed off to such an extent that this tube is no longer an efficient amplifier for voltage changes. It will be seen that the grid 45 of the tube 35 receives its potential changes through the condenser 46 from the high side 14a of the potentiometer 14. Therefore the tube 35 is more effective than the tube 19 for changes under these conditions.

Another modified form of the arrangement of Fig. 1 is shown in Fig. 5, in which the tubes 15 and 19 are the same as in Fig. 1, but in place of the potentiometer 14, I provide a variable resistance 48 connected to the high point 14a, and a parallel circuit connected between the variable resistance and the neutral wire 12. The parallel circuit may comprise in one leg a voltage regulating device, such as the gas discharge lamp 49, in series with a resistance 50, and in the other leg a resistance 51.

The discharge lamp, together with the resistance 48, preferably has the same voltage drop as the upper part of the potentiometer 14 of Fig. 1, from the point 29 to the point 14a, so that the point 52 in Fig. 5 provides the grid 27 of the tube 19 with the same average potential as in the case of Fig. 1. The screen grid 25 of the tube 19, however, is given its potential from a point on the resistance 51.

In order to provide higher operating plate potential for the tube 19 I connect the plate of the tube through a resistance 54a to the plate of the tube 15 instead of to the cathode, as in the previous figures. Also the cathode of the tube 19 is preferably connected through a resistance 48a to the junction of the resistance 48 and the gas discharge tube 49.

In this arrangement the equivalent bridge circuit has the gas discharge lamp 20 and the cathode-anode circuit of the tube 19 forming one arm, while the resistance 50, the gas discharge lamp 49, and the resistance 48 forms the other arm. The cathode and the grid of the tube 19 form the neutral or balance points of the bridge. When the potential across the bridge changes, the two gas discharge lamps being diagonally opposite each other, will tend to upset the balance of the bridge in the same direction, so that they will both tend to make the grid of the tube 19 more positive or more negative, depending on the change in potential across the bridge. The gas device being inherently a requisite for extremely slow variations, becoming less effective at relatively rapid variations, therefore cooperates with the condenser and resistance which is increasingly effective for variations of higher frequencies, to increase the regulation for any and all variations regardless of their rapidity.

Two important advantages are obtained by the variable resistance 48 which is used for adjusting the output potential within certain predetermined limits. It has already been stated that it is important have a voltage regulating device with

a high ratio of equivalent direct current resistance to incremental resistance. However, in many gas discharge devices this ratio will change with the voltage applied to the device, as the operation takes place on a different portion of the voltage-current characteristic curve. Thus it may be possible to have a high ratio for one part of the curve and a very low ratio for another part of the curve. As the regulating action of the discharge device is a function of this ratio, poorer regulation will take place when the voltage has been changed to shift the operation to the part of the curve having the lower ratio.

I have found that with the adjusting arrangement of Fig. 1, where the arm 29 adjusts the output potential, the current through the gas discharge lamp 20 is also changed, which changes the ratio, with the result that the regulation of the circuit is changed for different adjusted values of output potential. In the arrangement of Fig. 5 this defect is overcome, because the adjustment of the resistance 46, for making the adjustment of output potential, makes relatively no change in the current through the gas discharge lamps and therefore keeps the ratio constant. This permits the adjustment of the circuit for different output potentials, within certain limits, without changing the regulation, which remains substantially constant.

The other important fact which also insures constancy of regulation through various adjustments of the output potential, is that the circuit provides substantially constant potentials for the elements of the tube 19. In Fig. 1 adjustment of the arm 29 toward the neutral end of the potentiometer, to give the control grid a more negative potential, will also give the screen grid a more positive potential, because it is connected to the same potentiometer, which tends to compensate for the change in potential on the grid. The grid, therefore, has to be made more negative by moving the arm 29 still farther down on the potentiometer. This change in the potential of the screen grid with respect to the cathode and control grid changes the amplification factor of the tube, and hence variations impressed on the grid will not be amplified as much under one condition as under another. Therefore the regulating ability of the circuit is different for different adjustments of the output potential. In the circuit of Fig. 5, where the adjustment is made by changing the resistance 46, the screen grid potential remains substantially constant with respect to the cathode, so that amplification of the tube 19 is kept substantially constant and the regulation is therefore substantially constant for various adjustments of the output voltage.

The above two facts, acting together, give greatly improved regulation over the circuit of Fig. 1. The grid leak 53 and condenser 54 act in the same way as the corresponding parts of Fig. 1 to make the circuit faithfully respond to surges and other sudden changes of input voltage, as well as load variations, which tend to reflect back into the circuit.

In certain cases, especially where low voltages are required, I may substitute a resistance for the regulating device 20 of Fig. 5 and depend on the voltage regulation of the device 49.

In some instances I may prefer to insert in place of the resistance 50 or the resistance 43*a*, or both, the plate-cathode circuit of a screen grid tube or some kind of a ballast tube, such as a tube with an iron wire filament which has a ratio of equivalent direct current resistance to incremental resistance of less than unity. Either of these devices will act opposite to the action of the device 20 by still further unbalancing the equivalent bridge circuit.

The resistance 50 or the screen grid tap on the resistance 51, may be varied to initially insure the grid 27 being negative with respect to its cathode, a condition which should always obtain.

In Fig. 6 I have shown a modification of the invention which may have certain advantages over the circuits of the previous figures. A transformer 55 may be used as a source of high alternating voltage. This transformer may have a primary winding 56 which may be connected to the source of alternating current power, and this primary may be provided with a control device 57 for adjusting the voltage applied to the primary. This control device may be any device suitable for this purpose, and it may be either incorporated in the primary winding of this transformer, or provided as a separate unit in series with the primary winding. As shown, an arm provided with a carbon contact is arranged to sweep across certain of the primary turns, thus regulating the number of turns in the primary coil. The carbon contact is provided so that no turn of the primary can be completely short-circuited.

Otherwise the transformer 55 may be the same as the transformer 10 of Fig. 1, and may be provided with a similar rectifier tube 58, which may feed the high voltage rectified current into the choke 59, which may be similar to the choke of Fig. 1. The mid-point of the high voltage secondary 60 of the transformer may be connected to ground, as indicated, and to the wire 61, forming the neutral wire of the system.

A control tube 62 may be connected in series with the potentiometer system 63, the anode 64 of the tube 62 being connected to the choke, while the cathode 65 is connected to the point 66 on the high voltage side of the potentiometer. The other end of the potentiometer is connected to the neutral wire 61. A filter condenser 67 may be connected across the system between the choke 59 and the neutral wire 61, for the same purpose as the condenser 18 of Fig. 1, to filter out extreme variations in the voltage supply.

Also in this modified form I provide a tube 68, which may be similar to the tube 19 of Fig. 1, and connect it in the same way, with the anode 69 connected directly to the grid 70 of the tube 62, and the cathode 71 connected through a gas discharge tube 72 to the neutral wire 61. A condenser 73 may be connected across the gas discharge lamp 72. The operating potential for the anode 69 in this case, similar to Fig. 3, may be provided directly from the choke 59 through a resistance 74. The screen grid 75 may be connected to a point 76 on the potentiometer 63 to provide it with a suitable potential, and the control grid 77 may be given its suitable potential through a resistance 78 at the point 79 on the potentiometer 63. A condenser 80 may also be used to connect the grid 77 directly to the point 66 at the high side of the potentiometer.

Similar to the arrangement of Fig. 5, I use a variable resistance 81 for the upper end of the potentiometer and connect the cathode 71 to the point 82 between that resistance and the potentiometer through a resistance 83. The variable resistance 81 is used, as in Fig. 5, for adjusting the output voltage of the system.

With the arrangement shown in Fig. 6 I have many of the advantages explained in connection

with Fig. 5. In fact the circuit of Fig. 5 could be substituted for the right hand side of Fig. 6, where good regulation for slow change is desired.

I have found that if I couple the control of the resistance 81 with the control 57 of the input voltage, as indicated by the dotted line 84, I am able to produce a wide range of voltage output for the particular circuit arrangement.

It can be appreciated that the output voltage can be adjusted only within certain limits by the adjustment of the variable resistance 81. These limits are chiefly determined by the allowable plate dissipation of the tube 62 and the voltage between its cathode 65 and the cathode 71 of the tube 68, which is the voltage available for negatively biasing the grid 70 of the tube 62. It will be seen, therefore, that the voltage of the point 66 cannot be lowered beyond a certain value for a given voltage on the plate 64. If it is desired to lower it still further, this may be accomplished by lowering the voltage on the plate 64, which I may conveniently do by including more turns in the primary 56 of the transformer 55, or the equivalent. I have found that by suitable design of the variable resistance 81 and the adjustable device at the primary 56, I can make these units track, so that the direct current voltage on the plate 64 is always at such a value that the desired output voltage is within the limit of automatic regulation of the circuit.

In some cases it may be desirable to have a regulated voltage supply which will provide several different voltages, ranging say, from 80 to 300 volts. In order to provide several points at which the different voltages may be taken off, I may use the circuit arrangement of Fig. 7 which may have the power supply transformer and rectifier the same as is shown for Fig. 1 or 6, although these have not been shown in Fig. 7. The transformer, of course, should be designed to have a high voltage output in excess of 300 volts. With this arrangement I may provide three separate circuits similar to the regulating circuit of Fig. 6.

The circuit indicated at 85 may be exactly the same as the regulating circuit of Fig. 6, without the primary adjustment feature, and may be connected to the output side of the filter choke 86, there being a filter condenser 87 connected between this point and ground, the arrangement being similar to the arrangement of the choke and filter of the previous figures. The circuit 85 may have its neutral side 88 connected to ground, and the various components may be so chosen that a maximum voltage of 300 volts may be provided at the point 89, which is the high side of that particular circuit.

The circuit 90 may also be exactly similar to the circuit 85, and may be connected to the same side of the choke 86. This circuit may have its components so chosen that a potential of about 200 volts will be found at the tap 91, which is connected to the high side of the circuit 90.

The circuit 92 may also be exactly the same as the two circuits 85 and 90, but may be connected to the tap 91 of the circuit 90 through a resistance 93, a condenser 94 being connected between the output side of this resistance and ground. This circuit 92 may also be provided with a tap 95 from which a potential of 80 volts may be obtained by suitably choosing the components of the circuit.

In the arrangement shown the two circuits 85 and 90 are in parallel with each other, while the circuit 92 is in series with the circuit 90. Any desirable combination of circuits may be used in this manner for producing different potentials, and the range may be still further increased by using the variable input arrangement as shown in Fig. 6.

Wherever the voltage regulating devices are used in the circuits it will be understood that two or more may be connected in series if a greater voltage drop across the device is desired. I have discovered that connecting such circuits in series has the result of decreasing the internal resistance.

If it is desired to obtain a regulated supply of negative voltage, any one of the circuits may be used, with the choke inserted in the lead to the mid point of the high voltage winding of the transformer, instead of the location shown, and with the positive side of the output connected to ground instead of the low side. The arrangement is indicated in Fig. 8, which shows the circuit of Fig. 6 arranged for a negative supply.

Under certain conditions I have found it desirable to provide a variable resistance at the lower end of the potentiometer which may be used for adjusting the voltage. Such a resistance, indicated at 79a in Fig. 6, may preferably be used in place of the variable contact 79 to initially adjust the grid of the tube 68 to insure its being negative with respect to the cathode.

Various combinations of the circuit arrangements shown in the different figures may be made to obtain certain results, as desired. The circuit of Fig. 5 is particularly advantageous for holding a constant voltage output for slow variations in the voltage of the alternating current source.

From the above description it will be seen that I have provided a regulating system for a voltage supply circuit which may be adjusted to supply various potentials, and which, when so adjusted, will produce an extremely constant potential which cannot appreciably change by line voltage variation or surges, or variation of the load conditions. In all of the figures the arrangement permits less attention to the ordinary power supply filter circuit, so that a cheap filter circuit may be used. I have found that when properly adjusted, the regulating circuits shown in Figs. 5, 6 and 7 may be made to have an internal resistance of less than one ohm.

Having thus described my invention, what I desire to secure by Letters Patent and claim is:

1. A voltage regulating system comprising, in combination, a rectified supply circuit, an electronic relay having a cathode, an anode, and a control electrode, and having a variable resistance space path connected in series in the current supply path, means for controlling the resistance of said path in a manner to maintain a substantially constant output voltage, said means comprising a circuit having a pair of branches across said supply circuit, one branch having therein a portion having different impedances for direct and alternating current, the other branch having in parallel with a portion thereof, a resistance and condenser in series, the values of said resistance and condenser being such that the impedance of said condenser is low relative to said resistance at low frequencies, a second electronic relay having a cathode, an anode and a control electrode, said cathode being connected to an intermediate point in the first branch, and the control electrode being connected between said resistance and condenser in said second branch, and a connection between

said anode and the control electrode of the first relay.

2. The combination claimed in claim 1, having a resistance in series between the junction of said branches and the cathode of the first said relay.

3. The combination claimed in claim 1, and having a variable resistance in series between the junction of said branches and the cathode of the first said relay, whereby variation of said variable resistance varies the output voltage without substantially varying the voltage across said branches.

4. A voltage regulating system comprising, in combination, a rectified supply circuit, an electronic relay having a cathode, an anode, and a control electrode, and having a variable resistance space path connected in series in the current supply path, means for controlling the resistance of said path in a manner to maintain a substantially constant output voltage, said means comprising a circuit having a pair of branches across said supply circuit, one branch having therein a portion having different impedances for direct and alternating current, a second electronic relay having a cathode, an anode, and a control electrode, said cathode being connected to a point in one branch, and said control electrode being connected to a point in the other branch, means for supplying changes of voltage from said anode to the control electrode of the first relay, a resistance in series between the junction of said branches and the cathode of the said first relay, and means for varying said resistance, to vary the output voltage while maintaining a substantially constant voltage across said branches.

5. A voltage regulating system comprising, in combination, a supply circuit including a transformer and a rectifier connected to the secondary of said transformer, an electronic relay having a cathode, an anode, and a control electrode, and having a variable resistance space path connected in series in the output current supply path, means for controlling the resistance of said path in a manner to maintain a substantially constant output voltage, said means comprising a circuit having a pair of branches across said supply circuit, one branch having therein a portion having different impedance for direct and alternating current, a second electronic relay having a cathode, an anode, and a control electrode, said cathode being connected to a point in one branch and said control electrode being connected to a point in the other branch, means for supplying changes of voltage from said anode to the control electrode of the first relay, a resistance in series between the junction of said branches and the cathode of the said first relay, means for varying said resistance, means for varying the effective turns ratio of said transformer, and a single means for operating both said last mentioned means simultaneously.

6. A voltage regulating system comprising, in combination, a rectified supply circuit, an electronic relay having a cathode, an anode and a control electrode, and having a variable resistance space path connected in series in the current supply path, means for controlling the resistance of said path in a manner to maintain a substantially constant output voltage, said means comprising a circuit having a pair of branches across said supply circuit, one branch having therein a portion having different incremental and direct current resistances, the other branch having therein a portion having different incremental and direct current resistances, a second electronic relay having a cathode, an anode and a control electrode, said cathode being connected to a point on one of said branches and the control electrode being connected to a point on the other branch, and means for supplying changes of voltage from the anode of said second electronic relay to the control electrode of the first relay.

7. A voltage regulating system comprising, in combination, a rectified supply circuit, an electronic relay having a cathode, an anode and a control electrode, and having a variable resistance space path connected in series in the current supply path, means for controlling the resistance of said path in a manner to maintain a substantially constant output voltage, said means comprising a circuit having a pair of branches across said supply circuit, one branch having therein a portion having different incremental and direct current resistances, the other branch having therein a portion having different incremental and direct current resistances, and including in parallel with a portion thereof a resistance and condenser in series, the value of said resistance and condenser being such that the impedance of said condenser is low relative to said resistance at low frequencies, a second electronic relay having a cathode, an anode and a control electrode, said cathode being connected to a point on one of said branches and the control electrode being connected to a point on the other branch, and means for supplying changes of voltage from the anode of said second electronic relay to the control electrode of the first relay.

ERNEST A. TUBBS.