

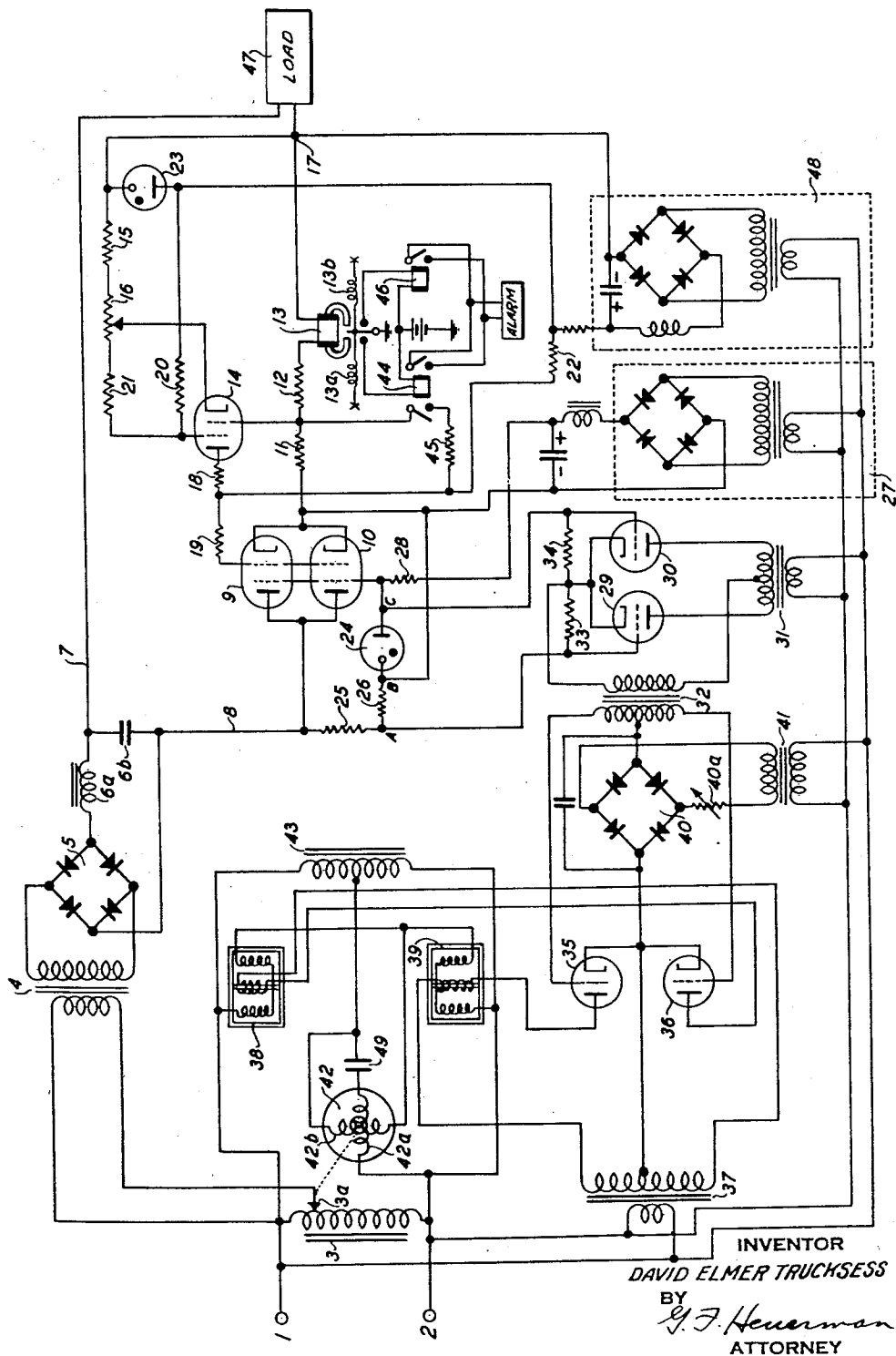
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REGULATED CURRENT SUPPLY APPARATUS

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REGULATED CURRENT SUPPLY APPARATUS

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This invention relates to power supply apparatus, and more particularly, to certain improvements in current regulated power supplies. The invention is particularly applicable for the rectification of alternating current, providing a closely regulated constant current output.

Throughout the description of the invention, reference will be made generally to rectifiers; it is to be understood that such rectifiers may be of the metallic disc type, employing semiconductive materials such as selenium or copper oxide, or may be of the thermionic discharge or vacuum tube type. In either case, either half or full wave rectification may be employed. Other types and systems of rectifiers may be employed in accordance with the invention without departing from the spirit and scope thereof.

With reference to communications apparatus, it is often desirable to employ a direct-current power supply wherein the output current is maintained at an amount constant within certain defined limits. To obtain such constant current output, the use of a thermionic discharge tube having its electron path in series with the output of the rectifier has been shown, for example, in United States Patent No. 2,075,966 to A. W. Vance, granted April 6, 1937. Means are employed responsive to the output current to modulate the electron flow in the thermionic discharge tube, thus varying the resistance resultant from the plate resistance of the discharge tube and maintaining the current at a constant value within the limits of tube operation. When wide variations of plate resistance are required of a series-regulating discharge tube arrangement, operation becomes less satisfactory because of the limited operating range of the discharge tube employed.

According to one mode of the invention, series-regulator thermionic discharge tubes are employed in series with the output of a rectifier. The operation of the series-regulator tube is maintained at its optimum operating point by varying the alternating voltage impressed upon the rectifier in response to the voltage drop existent across the series-regulator tubes. The alternating voltage is varied by means of a servo-system including a motor-driven, continuously tapped transformer; the energization of the servomotor is controlled by apparatus responsive to the voltage drop across the series-regulator tubes. The main object of this invention is to provide a rectifier having a substantially constant current output over a wide range of applied loads, unlimited by the margins of operation of the series-regulator discharge tubes.

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The invention is described in detail in the following specification:

Fig. 1, the sole figure, shows a schematic diagram of a circuit in accordance with a preferred embodiment of the invention.

Referring now to the figure, a source of alternating-current supply is applied to terminals 1 and 2. This alternating current is supplied to an autotransformer 3, having a variable tap 3-a; the output of the autotransformer is between terminal 1 of the alternating-current supply and variable tap 3-a. Voltages between zero and the line voltage between terminals 1 and 2 may be obtained by adjusting the variable tap along the winding of the autotransformer. The output of autotransformer 3 is supplied to the primary of a transformer 4.

Transformer 4 and bridge rectifier 5 comprise the main rectifier system; the transformer 4 is used to elevate or depress the line voltage supply, providing a rectifier output voltage having a value as may be required by the load. Transformer 4 may be dispensed with if the required rectifier output voltage is in the region of the voltage of the alternating supply. Rectifier 5 is shown as a metallic disc bridge rectifier, but as previously stated, many types of rectifiers may be used. A smoothing filter, comprising inductance 6-a and capacitance 6-b, is employed to aid in eliminating the output ripple resulting from the rectification of the alternating current. One output lead 7 of the rectifier is supplied directly to a load 47; the remaining output lead 8 is supplied to the anodes of thermionic discharge tubes 9 and 10.

Thermionic discharge tubes 9 and 10 are the series regulator tubes and their function is substantially similar to that of a comparable tube shown in the United States Patent No. 2,075,966 to A. W. Vance previously alluded to. While two tubes 9 and 10 are shown, any number of tubes may be employed depending upon the relative load current and tube capacity. The anode-cathode resistance of the series-regulator tubes will be varied in a manner responsive to the load current; by varying this anode-cathode resistance, the load current may be maintained constant within the marginal limits of series-regulator tube operation. To provide the variable resistance operation heretofore mentioned, the polarity of the voltage supplied to the anodes of the tubes on lead 8 must be positive with respect to the cathodes of tubes 9 and 10. This latter requirement means that for the circuit shown, the lead 8 must have a positive potential with respect to lead 7. However, the situation

of the anode-cathode circuit with regard to the output leads of the rectifier 5 is not material to the invention as long as the anodes of the series-regulator tubes 9 and 10 are maintained at a more positive voltage than the cathodes.

In the circuit shown, the current passes from the cathode of the series-regulator tube through resistive elements 11 and 12, and through the windings of a polarized relay 13 to the load 47. The voltage drop occurring across resistive element 12 and the winding of the polarized relay 13 will depend upon the load current.

A thermionic discharge tube 14 is employed as a direct coupled amplifier. The control grid-cathode circuit of tube 14 is connected in a series circuit with resistance 12; the winding of polarized relay 13; a resistive element 15; and a portion of the resistance of potentiometer 16, depending upon the position of the arm of this potentiometer. Although an auxiliary rectifier supply 48 is shown, providing a direct-current voltage between point 17 and the junction of resistances 18 and 19, a battery or other suitable means of providing direct-current potential may be utilized. In any event, the junction of resistances 18 and 19 is provided with a positive voltage with respect to point 17; a current will flow from the cathode to the anode of amplifier tube 14 in accordance with the potential of its control grid-cathode circuit.

The potentiometer 16 will be at a potential positive with respect to point 17 because of the positive voltage applied from the output of rectifier 48 through resistance 20 and 21 to the potentiometer 16. Alone, therefore, the resistance 15 and potentiometer 16 would provide a negative bias to the control grid of the amplifier tube 14. The resistance 12 and the polarized relay 13 will develop a voltage drop dependent upon the magnitude of the load current as previously shown and this voltage will be applied to the control grid-cathode circuit of amplifier tube 14, added with the negative bias developed by 15 and 16. Recalling the polarity of the rectifier with regard to the flow of output current, it will be seen that a voltage opposed to the negative bias voltage of potentiometer 16 and resistance 15 will be developed; increasing load current will make this opposing voltage larger in magnitude. Assuming that the load current has an optimum value at some given point, the voltage across 12 and 13 resultant from such an optimum flow of current can be made to have a given magnitude relative to the opposing negative bias voltage offered by resistance 15 and potentiometer 16, by adjustment of the tap of potentiometer 16. As a result, the operating point of amplifier tube 14 may be adjusted at the optimum load current condition.

The anode of the amplifier tube is direct coupled to the control grid of the series-regulator tubes 9 and 10. The cathodes of the series-regulator tubes 9 and 10 are operated at a potential sufficiently high to provide the proper relationship between their control grids and the anode of amplifier tube 14. The auxiliary rectifier system 48 has that portion of its voltage output from resistor 20 to point 17 maintained at a virtually constant level through the use of a gaseous discharge regulator tube 23. This will maintain the bias voltage for amplifier tube 14 and series-regulator tubes 9 and 10 at substantially constant values.

Assuming for the sake of illustration that the load current from the main rectifier 5 rises from

the optimum, the magnitude of the voltage drop across resistance 12 and polarized relay 13 will increase and the control grid of the amplifier tube 14 will become relatively more positive, or less negative. The increased positive control grid voltage will cause an increased flow of anode current in the amplifier tube. This increased anode current flow will provide a larger drop of voltage across resistance 22 and the point of the junction of resistances 18 and 19 will be depressed in voltage. In turn, this depressed voltage is supplied through resistance 19 to the control grid of the series-regulator tubes 9 and 10. By a suitable choice for the value of resistance 11 and of the other circuit constants, the series-regulator tubes 9 and 10 may be adjusted to have a given anode-cathode resistance at the optimum given value of load current. The more negative voltage at the control grids of series-regulator tubes 9 and 10 will, in turn, modulate the electron flow from the cathode to anode of the series-regulator tubes to restrict current flow. Such a restricted current flow will act as a resistance in series with the output lead 3 of the rectifier 5, reducing the voltage supplied to the load and tending to return the rectifier load current to the optimum value. Similarly, it can be shown that an assumed decrease in load current from optimum will cause a decrease of resistance of the series-regulator tubes 9 and 10, tending to restore the output current to the optimum amount.

As stated in the summary of the invention, the use of series-regulator tubes such as 9 and 10 to control the magnitude of the load current is rendered difficult over wide ranges of load, as the series-regulator tubes approach limits of operation. In order to keep the series-regulator tubes operating within reasonable limits of operating margin, a circuit according to the invention is employed to assist in regulating load current.

A gaseous discharge tube 24 is employed as a reference voltage standard. Resistances 25 and 26 are connected to each other in series and together in the paralleled anode-cathode circuits of series-regulator tubes 9 and 10. The gaseous discharge tube 24 is supplied with an operating potential from a second auxiliary rectifier 27 through the ballast resistance 28. The voltage between points B and C will be maintained at the regulated value of the gaseous discharge tube substantially independent of line voltage and component variations. The voltage drop across resistances 25 and 26, and thus between points A and B will be determined, in turn, by the voltage drop across series-regulator tubes 9 and 10. It has been shown that the value of resistance developed across series-regulator tubes 9 and 10 depends upon the load current; e. g., as the load current increases, the resistance offered by series-regulator tubes 9 and 10 will tend to increase and the voltage drop across the series-regulator tubes will be increased. Similarly, as the load current decreases, the resistance offered by tubes 9 and 10 will tend to decrease, and the voltage drop across tubes 9 and 10 will be decreased. It may therefore be said that the voltage existing between points A and B will depend ultimately upon the load current when the output voltage of rectifier 5 is constant. By properly proportioning resistances 25 and 26, the voltage developed between points A and B can be made substantially equal to the voltage across points B and C for that value of series-regulator tube voltage drop

corresponding to the optimum value of load current.

When series-regulator tubes 9 and 10 have a voltage drop reflecting the optimum value of load current, the voltage developed between points A and B, and B and C being made equal and opposite, the voltage between A and C will be zero. Optimum conditions of load current may well refer to the mid-point of operation of the series-regulator tubes. Assuming an increase in the load current, the voltage between A and B will increase correspondingly, but the voltage between B and C will remain constant. Thus, the sum of these two voltages at A and C will rise from zero to some value of given polarity. Conversely, a depression in the voltage drop across the series-regulator tubes 9 and 10, reflecting a decrease in load current, will produce a corresponding decrease in the voltage across A and B. As the voltage across B and C still remains constant, a voltage of opposite polarity to that resulting from an increasing load current will be derived at points A and C. It will be seen that the magnitude of the voltages developed across A and C depends upon the magnitude of the displacement of the voltage drop across series-regulator tubes 9 and 10 from the optimum value.

The signals derived at points A and C are supplied to a phase detector including thermionic discharge tubes 29 and 30. A transformer 31, having its primary connected to a particular source of alternating current, has its secondary connected between the anodes of phase detector tubes 29 and 30. A center tap of the secondary of transformer 31 is connected through the primary of a transformer 32 to the cathodes of phase detector tubes 29 and 30. The control grids of the phase detector tubes 29 and 30 are returned to their cathodes through resistances 33 and 34; points A and C, previously described, are connected respectively to the control grids of these phase detector tubes. Assuming that the circuits of the phase detector tubes 29 and 30 are intrabanced when points A and C are at the no-voltage condition, no alternating current will be drawn through the primary of transformer 32. When a voltage is derived between A and C, one of the phase detector tubes will have a negative grid-cathode voltage applied thereto and the other phase detector tube will have a positive grid-cathode voltage applied thereto; the relative polarity of the depression or elevation of the control grid voltage depends upon the polarity of the voltage at A and C. As the control grid voltage of phase detector tubes 29 and 30 changes, the one of the tubes having a positive grid-cathode voltage will draw more current; conversely, the tube having a negative grid-cathode voltage draws less current. An alternating voltage is applied to the anode circuits of these tubes by transformer 31; a resulting pulsating current will be drawn through the primary of transformer 32 dependent in phase upon the polarity of the voltage at A and C.

At such times as the currents drawn by the phase detector tubes 29 and 30, respectively, are equal, the secondary of transformer 32 will have substantially no voltage induced therein. However, a voltage will be induced in the secondary of transformer 32 at the other conditions of the phase detector tubes as described, having a phase dependent upon which of the phase detector tubes is more conductive. This voltage can be called the servocontrol voltage. The phase shift for the two possible unbalance conditions respectively,

of the phase detector tubes is substantially 180 degrees.

A phase sensitive servosystem is shown employing two thermionic discharge servotubes 35 and 36. Transformer 37 has its primary connected to an alternating-current supply having the same phase as supplied to transformer 31. The secondary of transformer 37 is coupled through the "direct-current control" windings of saturable reactors 38 and 39, later to be described, to the respective anodes of the servotubes 35 and 36. The center tap of the secondary of transformer 37 provides a return path from the anodes to the cathodes of these tubes. The grid-cathode circuits of tubes 35 and 36 comprise the halves, respectively, of the secondary of transformer 32. Interposed in the circuits between the secondary center tap of transformer 32 and the common cathodes of tubes 35 and 36, is a bias supply comprising: a rectifier 40, a rheostat 40-a and a transformer 41, the latter connected to an alternating-current supply. While such a rectifier, rheostat and transformer may be employed to supply the negative bias required for servotubes 35 and 36, other bias means, such as a battery, may be employed with equal success.

The saturable reactors 38 and 39 have been alluded to. One mode of construction for these reactors comprises the use of two windings on each reactor, one being a "variable impedance" winding and the other a "direct-current control" winding. It has been found convenient to employ a core of magnetic material having three legs: the outer two legs having the variable impedance winding thereon, while the center leg has the direct-current control winding thereon. By varying the unidirectional or direct current passing through the latter control winding, it will be possible to vary the saturation of the magnetic core of the reactor. A change in saturation of the magnetic core reflects as a change of reluctance of the core and ultimately, therefore, as a change in the reactance of the variable impedance winding. It can be seen that the impedance of the latter winding will vary in accordance with the flow of current through the direct-current control winding. While one form of construction for the saturable reactor has been described, many modes of construction are applicable to the circuit of the invention.

Depending upon the phase of the current drawn through the primary of transformer 32, one only of the servotubes 35 and 36 will draw plate current. For example, if the grid-cathode voltage and the anode-cathode voltage of tube 35 are in phase, tube 35 will draw space current. Similarly, if the voltage across the secondary of transformer 32 is shifted in phase by 180 degrees, the grid-cathode voltage of tube 35 will be 180 degrees out of phase with its anode-cathode voltage and the grid-cathode voltage of tube 36 will be in phase with the anode-cathode voltage of tube 36. Servotube 36 will then draw space current and tube 35 will draw no space current. During the periods of time when the primary of transformer 32 has substantially no pulsating current flowing through it, the bias supply from the auxiliary direct-current rectifier system 40, 40-a and 41 will normally bias the servotubes 35 and 36 to minimize the flow of current; only when a current of the proper phase is drawn through the primary of transformer 32, will the appropriate servotube 35 or 36 draw a current. It can be seen that the relative impedances of the impedance winding of reactances 38 and 39 will

depend upon the magnitude and phase of current drawn through the primary of transformer 32. The current drawn through the primary of transformer 32 has been shown to depend upon the magnitude and polarity of the voltage at points A and C, which, in turn, depends upon displacement of the series-regulator tubes 9 and 10 from the voltage drop corresponding to optimum load current.

A two-phased servomotor 42 has one phase winding 42-a connected between the alternating-current supply terminal 2 and the tap of a supply reactor 43 through a phase correcting capacitance 49. Supply reactor 43 is coupled across the alternating-current supply terminals 1 and 2; if tapped at its mid-point, it will provide an electrical mid-point of the alternating-current supply source. The variable impedance winding of the saturable reactors 38 and 39 are, in effect, connected together in series across the alternating-current supply terminals 1 and 2. In normal periods of quiescence, i. e., when the voltage drop across tubes 9 and 10 is at a predetermined value, the variable impedance windings of the saturable reactors 38 and 39 will have substantially equal values. The junction of the two reactors will, therefore, be located at an electrical mid-point of the alternating-current supply source. Winding 42-b is connected between mid-point tap of the supply reactor 43 and the junction of the saturable reactors 38 and 39. Thus, at the time that the regulating system is in the quiescent condition, both ends of winding 42-b will be at an electrical mid-point of the alternating-current supply line; no current will flow through winding 42-b. Although winding 42-a of the motor will remain excited, it alone will not cause servomotor 42 to operate; as long as the junction of saturable reactors 38 and 39 provide an electrical mid-point of the alternating-current supply source, winding 42-b will remain unenergized.

As the voltage across the series-regulator tubes 9 and 10 changes from the optimum value, the impedance of the impedance windings of saturable reactors 38 or 39 will change in accordance with the direction and magnitude of the displacement from optimum, in the manner described. As the ratio of these impedances varies, the junction of the two reactors 38 and 39 will provide a new electrical point displaced from the electrical mid-point of the alternating-current supply. As the electrical position of the mid-point of the supply reactor 43 remains invariable, a voltage will be developed across the winding 42-b of the servomotor. Winding 42-a is constantly energized, the phase of this winding being appropriate to cause servomotor 42 to rotate by proper selection of the phasing condenser 49; the current through winding 42-a will be substantially in quadrature with the current drawn through winding 42-b.

A mechanical linkage couples the rotatable shaft of motor 42 with the variable tap 3-a of autotransformer 3. The rotation of the servomotor drives the variable tap 3-a to some new position on the winding of autotransformer 3, thus varying the alternating supply voltage to the transformer 4 and main rectifier 5. This change in voltage will be such as to affect the output of the main rectifier 5, compensating for whatever displacement in voltage drop across tubes 9 and 10 from optimum originally caused the change in the variable impedance windings of saturable reactors 38 and 39. Whenever the

position of the variable tap 3-a has moved sufficiently so that the output voltage of the main rectifier 5 has attained a position returning the voltage drop across tubes 9 and 10 to optimum, the regulating system will again become quiescent and the relative impedances of the variable impedance winding of the saturable reactors 38 and 39 again become equal and the servomotor 42 ceases to operate.

It has been assumed that the center tap of supply reactor 43 is at its mid-point and that the impedance windings of the saturable reactors are substantially equal at the quiescent point, but this is not essential. As long as the ratio between the arms of saturable reactors 43 is proportional to the relative quiescent impedance of the saturable reactors 38 and 39, the system will operate in the manner described.

Turning now to the protective circuits, as the normal condition of circuit operation presumes that the load current will remain at a constant value, a load current condition having a wide variation from the optimum amount denotes a condition which should provide warning. Furthermore, if the load current should continue increasing, a point of load current output may be reached which will endanger the load 47, series-regulator tubes 9 and 10 and rectifier 5. To provide a warning or alarm device and to protect the series-regulator tubes and rectifier from overload, a polarized relay 13 has its winding inserted in series with load 47. The armature of relay 13 will remain clear of both contacts during the times that the load current is maintained within predetermined limits surrounding the optimum point. Centering of the armature may be accomplished by suitable spring linkages 13-a and 13-b attached thereto. In the event that the load current should exceed the maximum predetermined amount, polarized relay 13 will draw the armature over to make with its left-hand contact, thereby operating relay 44. The operation of relay 44 will close the right-hand armature and contacts to an alarm circuit which may include audible or other means of warning. The left-hand armature will also close against its associated contact; the control grids of the series-regulator tubes 9 and 10 will then be connected through resistances 19 and 45 to the junction of resistances 11 and 12. The latter junction is at a point considerably more negative than the cathodes of the series-regulator tubes and will, in effect, place a negative bias on these control grids, reducing or cutting off the flow of load current through the series regulator tubes.

In the event that the load current decreases beyond the predetermined underload amount, the polarized relay 13 will attract its armature to make with its right-hand contact. This will cause relay 46 to operate, closing its right-hand armature and contact, thus operating the alarm circuit. With the underload condition, the problems of series-regulator tube and rectifier overload are not significant.

It is obvious that the scope of the invention is not limited to the specific embodiment described, and that the invention may be employed in arrangements other than as given by way of example.

What is claimed is:

1. An electric power supply circuit arrangement for providing unidirectional current to a load circuit comprising, a rectifier for rectifying current from an alternating-current source, and for

supplying said rectified current to the load circuit, variable current conducting means in said load circuit, means for varying the conductance of said conducting means in response to changes of current flowing to the load for controlling at least in part the current in said load circuit, and means responsive to a portion at least of the voltage drop across the said variable current conducting means for controlling the alternating voltage impressed upon the said rectifier from the alternating-current source, said last-mentioned means comprising a variable reactor and means for varying the reactance of said variable reactor in response to changes of said voltage drop across said variable current conducting means.

2. A current regulating power supply system having a rectifier to derive a rectified current output from a source of alternating current comprising, a load circuit having an optimum value of load current, a space charge path to couple the rectified current to the said load circuit, means to vary the resistance of the said space charge path in accordance with the magnitude of the rectified current supplied to the said load, means to derive a unidirectional control voltage from a portion of the voltage drop across said space charge path having a polarity and magnitude proportional respectively to the direction and magnitude of the displacement of the rectified current from the said optimum value of load current, and means for controlling the alternating voltage supplied to the rectifier responsive to the polarity and magnitude of the said unidirectional control voltage.

3. In combination, a space current device having a space current path, a rectifier for rectifying current from an alternating-current source, means for supplying rectified current from said rectifier through said space current path to a load, means responsive to the magnitude of the said rectified current for controlling the resistance of said space current path, a variable reactor, and means responsive to resistance changes of said space current path for controlling the alternating voltage impressed on the said rectifier from the said alternating-current source comprising means coupled across the said space current path and energized by current from the said rectifier for controlling the reactance of said variable reactor, said energization varying in response to resistance changes of the said space current path.

4. In a constant current power supply system including a rectifier to derive a rectified current output from an alternating-current supply, a load circuit having an optimum value of load current, the circuit comprising, a variable resistance space charge path coupling the rectified current to the load circuit, said resistance of said space charge path being responsive to the magnitude of the rectified current supplied to the load, means to derive a unidirectional control voltage from a portion of the voltage drop across said space charge path having a polarity and magnitude proportional respectively to the direction and magnitude of the displacement of the rectified current from the optimum value of load current, a mechanically variable multiratio transformer interposed between the rectifier and the alternating-current supply, an electric servomotor having its mechanical output coupled to the said variable ratio transformer, and polarity sensitive means to energize the said electric motor in accordance with the polarity and magnitude of the said unidirectional control voltage.

5. A system according to claim 4 characterized in that the polarity sensitive means comprises a phase detector having first and second thermionic discharge tubes each with a cathode, grid and anode, means to apply an alternating voltage of given phase to the anode-cathode circuits of the said first and second thermionic discharge tubes in push-pull, means to couple the said unidirectional control voltage to the grid-cathode circuits of the said first and second thermionic discharge tubes, a regulatory circuit having third and fourth thermionic discharge tubes each with cathode, grid and anode, means to apply the said alternating voltage of given phase to the anode-cathode circuit of the said third and fourth thermionic discharge tubes in push-pull, means to couple the anode-cathode circuits of the said first and second thermionic discharge tubes to the grid-cathode circuits of the said third and fourth thermionic discharge tubes in push pull, and means to energize the said electric servomotor in accordance with the ratio of anode-cathode currents of the said third and fourth thermionic discharge tubes.

6. In a system according to claim 5 characterized in that the means to energize the said electric servomotor comprises first and second magnetically saturable reactors having each an impedance winding and a control winding, means to energize the said servomotor through the impedance windings of the said first and second impedance windings, and means to couple the control windings of the said first and second reactors in the anode-cathode circuits of the said third and fourth thermionic discharge tubes respectively.

7. In a constant current power supply system including a rectifier to derive a rectified current output from a source of alternating current, a load circuit having an optimum value of load current, a space charge path of variable resistance coupling the rectifier to the load circuit, means to vary the resistance of the space charge path in accordance with the magnitude of the rectified current supplied to the said load, a source of substantially constant direct voltage, means to derive a comparison voltage from the voltage drop of the said space charge path and the source of constant direct voltage, said derived comparison voltage having a polarity and magnitude proportional respectively to the direction and magnitude of the displacement of the rectified current from the said optimum value of load current, and means for controlling the alternating voltage supplied to the rectifier responsive to the polarity and magnitude of the said unidirectional control voltage.

8. In a constant current power supply system including a rectifier to derive a rectified current output from an alternating-current supply, a load circuit having an optimum value of load current, a space charge path of variable resistance coupling the rectifier to the load circuit, means to vary the resistance of the space charge path in accordance with the magnitude of the rectified current supplied to the said load, a source of substantially constant direct voltage, means to derive a comparison voltage from the voltage drop of the said space charge path and the source of constant direct voltage, said derived comparison voltage having a polarity and magnitude proportional respectively to the sense and magnitude of the displacement of the rectified current from the said optimum value of load current, a mechanically variable multiratio transformer interposed between the rectifier and the alternating-current

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supply, an electric motor having its mechanical output coupled to the said variable ratio transformer, and polarity sensitive means to energize the said electric motor in accordance with the polarity and magnitude of the said derived comparison voltage.

9. In a power supply system including a rectifier to derive a substantially constant rectified current output from a source of alternating current and a load circuit having a given desired load current value, the combination of a plurality of thermionic discharge tubes each having an anode, a cathode and a grid, means to couple the anode-cathode circuits of the said thermionic discharge tubes in series with the rectified current output to the load circuit, means to vary the grid-cathode circuit voltage of the said thermionic discharge tube in accordance with the magnitude of the rectified current supplied to the said load, a source of substantially constant voltage, means to derive a comparison voltage from the anode-cathode voltage drop of the said thermionic discharge tubes and the source of constant voltage, said derived comparison voltage having a vectorial composition proportional to the vectorial displacement of the rectified current from the given desired load current value, a variable tap output autotransformer coupling the source of alternating current and the rectifier, an amplifier responsive to the vectorial composition of the said derived comparison voltage, and a servosystem energized by the said amplifier and an electric servomotor mechanically linked to the variable tap of the said autotransformer, whereby the alternating voltage supplied to the rectifier is maintained at values providing the given desired load current.

10. In a power supply system for providing a direct current of optimum constant magnitude to a load including a rectifier for rectifying current from an alternating-current source, said rectified current being supplied to the load, variable current conducting means responsive to the said rectified current flowing to the load and means responsive to the voltage drop of the said variable current conducting means for providing a control voltage having a vectorial composition in accordance with the vectorial displacement of the rectified current from the optimum constant amount, a first and a second thermionic discharge tube each having a cathode, grid and anode, means to energize the anode-cathode circuits of the said thermionic discharge tubes in push-pull with a given alternating voltage, means to impress the control voltage differentially upon the grid-cathode circuits of the said first and second thermionic discharge tubes, means to derive an alternating servocontrol voltage from the anode-cathode circuits of the said first and second thermionic discharge tubes, and means to control the alternating current source supplied to the rectifier in accordance with the said derived alternating servocontrol voltage.

11. In a power supply system for providing a direct current of optimum constant magnitude to a load comprising, a rectifier for rectifying current from an alternating-current source, said rectified current being supplied to the load, variable current conducting means responsive to the said rectified current flowing to the load and means responsive to the voltage drop of the said variable current conducting means for providing an alternating servocontrol voltage having a phase and magnitude dependent upon the polarity and magnitude of the displacement of the

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rectified current from an optimum constant magnitude, a first and a second thermionic discharge tube each having a cathode, a grid and an anode, means to impress the alternating servocontrol voltage upon the grid-cathode circuits of the said thermionic discharge tubes, a variable tap autotransformer interposed between the alternating-current source and the said rectifier, a servomotor linked mechanically to the variable tap of the said autotransformer, and means to energize the said servomotor from the anode-cathode circuit of the said first and second thermionic discharge tubes.

12. In a power supply system according to claim 11, characterized in that the means to energize the said servomotor comprises first and second reactors having each a magnetically saturable core, an impedance winding and a control winding, means to energize the said servomotor from the impedance windings of the said first and second reactors in opposition, and means to couple the control windings of the said first and second reactors in the anode-cathode circuit of the said first and second thermionic discharge tubes.

13. In a power supply system, a space current device having a space current path, a rectifier for rectifying current from an alternating-current source, means for supplying rectified load current from said rectifier through said space current path to a load, means responsive to the magnitude of the said rectified load current for controlling the resistance of said space current path, means responsive to resistance changes of said space current path for controlling the alternating voltage impressed on the said rectifier from the said alternating-current source including means coupled in parallel with the said space current path and energized by the said load current from the said rectifier, said energization varying in response to resistance changes of the said space current path, and a relay energized by at least a portion of the said load current at a predetermined maximum of said load current, said relay controlling the said means responsive to the magnitude of the said rectified current whereby the said rectified current is limited to the said predetermined maximum.

14. In a power supply system according to claim 13, wherein the said relay is energized by at least a portion of the said load current at a predetermined minimum of said load current, and a warning indication device activated by the energization of the said relay.

15. In combination, a rectifier for rectifying current from an alternating-current supply source and for supplying rectified current to a load circuit, variable current conducting means in said load circuit, means for decreasing the conductance of said conducting means in response to an increase of current in said load circuit, and vice versa, and means responsive to a portion at least of the voltage drop across said variable current conducting means for controlling the alternating voltage impressed upon said rectifier from said supply source, said last-mentioned means comprising a motor, variable reactance means for controlling the energization of said motor, and means responsive to said portion at least of the voltage drop across said variable current conducting means for controlling the reactance of said variable reactance means.

16. In combination, a space current device having a space current path, a rectifier for rectifying current from an alternating-current supply source, means for supplying rectified current from said rectifier through said space current path to

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a load, means responsive to said rectified current for controlling the resistance of said space current path, and means responsive to resistance changes of said space current path for controlling the alternating voltage impressed upon said rectifier 5 from said supply source, said last-mentioned means comprising means having a movable element for changing said alternating voltage, a motor for driving said movable element, variable reacting means for controlling the energization 10 of said motor and means responsive to said resistance changes of said space current path for

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controlling the reactance of said variable reactance means.

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The following references are of record in the file of this patent:

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