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RECTIFYING APPARATUS

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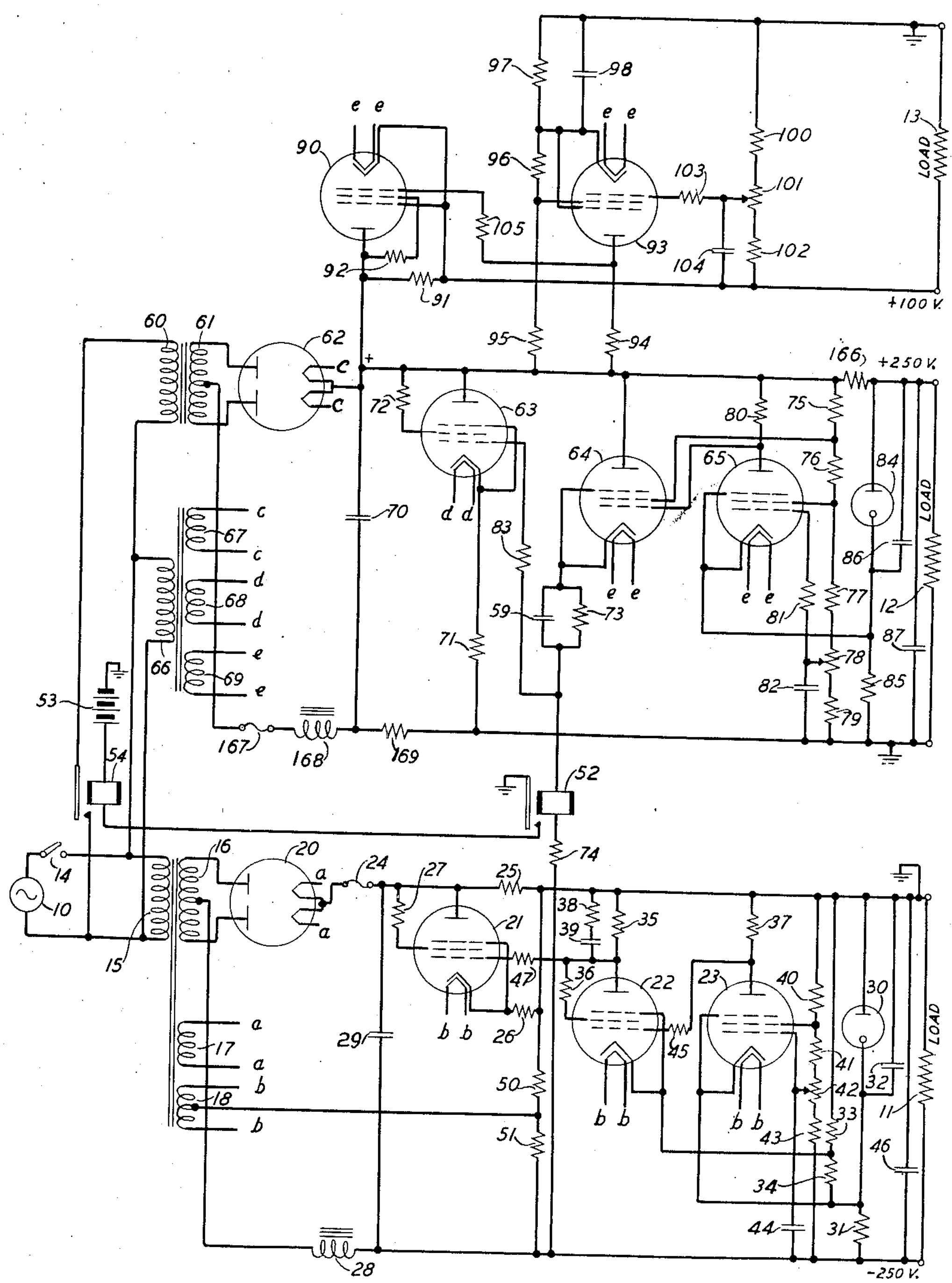

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RECTIFYING APPARATUS

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This invention relates to rectifying apparatus and particularly to regulated rectifying apparatus having protective means.

An object of the invention is to provide means responsive to the energization of a first current supply circuit for controlling the energization of a second current supply circuit.

A further object is to provide improved means for delaying the application of anode voltage to a thermionic space discharge device for a period during which heating current is being supplied to the cathode of the device.

In an embodiment of the invention herein shown an described for the purpose of illustration, there are provided two rectifiers each for supplying rectified current to a load and two voltage regulators for minimizing voltage change across the respective loads. Each voltage regulator comprises a space discharge amplifier for amplifying load voltage changes to set up a control voltage and space discharge means under control of the control voltage for controlling the current supplied to the load to minimize load voltage changes.

When initiating the supply of current to the loads, it is desired that current be supplied to a first of the loads before current is supplied to a second of the loads and, if the supply of current to the first load is interrupted for some reason, it is desired that the supply of current to the second load be also interrupted. Moreover, it is often desirable to supply cathode heating current to space discharge tubes prior to the time that voltage is applied to the anode-cathode paths of the tubes so as to prevent damage to the cathodes especially when relatively high anode-cathode voltages are applied to the tubes. To accomplish these purposes, there is provided switching means, which operates subsequent to the time that current is supplied to the circuit for supplying current to one of the loads, for causing energizing current to be supplied to the second current supply circuit. The switching means comprises an electro-magnetic relay having a winding which is included in a circuit comprising in series the space current path of a space discharge device in the voltage regulator of the second current supply circuit and the two load voltages in aiding relationship. When current from a supply source is supplied to a first of the supply circuits, the current in the relay energizing circuit increases, during a delay period in which the cathode temperature of the space discharge device is increasing, to an amplitude which is sufficiently high to cause the relay to operate, thereby causing current from the supply source to be supplied

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to the second current supply circuit. Current is supplied to the cathodes or the cathode heating elements of space discharge devices of the second supply circuit at the same time that current is supplied to the first current supply circuit. A portion of the circuit through which energizing current is supplied to the relay winding is included in the control electrode-cathode circuit of a regulator space discharge device which controls the current supplied to the second load and therefore the voltage across the second load. Therefore, when the current supplied to the first load is interrupted for some reason, the current in the relay circuit is reduced to produce a sudden large change in the control electrode-cathode voltage of the regulator tube in such a direction as to reduce the voltage across the second load. As a result the current through the relay energizing circuit is further reduced to such an amplitude that the relay armature is released, thereby causing the supply of current to the second supply circuit to be interrupted.

There is also provided a third current supply circuit comprising space discharge voltage regulating apparatus for supplying current from the load circuit of the second current supply circuit to a third load.

The invention will now be described with reference to the accompanying drawing, the single figure of which is a schematic view of current supply apparatus embodying the invention.

Referring to the drawing, there is disclosed apparatus for rectifying current from a 110-volt, 400 to 2400-cycle alternating current supply source **10**, for supplying rectified currents to loads **11**, **12** and **13** and for controlling the currents supplied to the loads, respectively, to minimize load voltage changes. When switch **14** is closed, alternating current is supplied to a first of the supply circuits through a transformer having a primary winding **15** and secondary windings **16**, **17** and **18**. This supply circuit comprises a twin-diode rectifier space discharge device **20**, a pentode series regulator space discharge device **21** and two pentode amplifier space discharge devices **22** and **23**. The cathodes of diodes **20** are supplied with heating current from the transformer winding **17** and the cathode heater of regulator tube **21** and the cathodes of amplifier tubes **22** and **23** are supplied with heating current from transformer winding **18**. The cathodes of rectifier diodes **20** are connected to one of the load terminals, which is grounded, through a fuse **24** and in series therewith a path having 5,000-ohm resistor **25** in one of its two parallel branches and, in the other parallel branch, the anode-cathode path of series regulator tube 21 and 30-ohm resistor 26 in series. The rectifier cathodes are connected through fuse 24 and through a 47-ohm resistor 27 to the screen grid of tube 21. The end terminals of transformer winding 16 are connected to the anodes of diodes 20 and the midtap of winding 16 is connected through filter choke coil 28 to the negative terminal of load 11. A filter condenser 29 is in a shunt path connecting the common terminal of fuse 24, resistor 25 and the anode of tube 21 to the negative load terminal.

There is provided in a shunt path across the load 11 a cold cathode gas-filled voltage regulating tube 30 and an 11,200-ohm resistor 31 in series, the anode of tube 30 being connected to the grounded load terminal. The voltage regulating tube 30 has the characteristic that its resistance changes in response to a change of current flowing through the tube at such a rate that the voltage drop across the tube remains substantially constant. A condenser 32 is connected across the tube 30. Resistors 33 and 34 of 33,000 ohms and 68,000 ohms, respectively, are connected in series in a second shunt path across the tube 30. The common terminal of resistors 33 and 34 is connected to the cathode of tube 22 and the common terminal of resistors 31 and 34 is connected to the cathode of tube 23. The anode of tube 22 is connected through 0.47-megohm resistor 35 to ground and the screen grid of tube 22 is connected through 47-ohm resistor 36 and resistor 35 to ground. Resistor 38 of 27,000 ohms and condenser 39 of 240 micromicrofarads in series are connected across the anode resistor 35 to prevent singing. The anode of tube 23 is connected through 0.47-megohm resistor 37 to ground. There is provided a shunt path across the load 11 comprising in series 10,000-ohm resistor 40, 15,000-ohm resistor 41, 5,000-ohm potentiometer 42 and 15,000-ohm resistor 43. The common terminal of resistors 40 and 41 is connected to the screen grid of tube 23. The variable tap of potentiometer 42 is connected to the control grid of tube 23 and, through a condenser 44, to the negative load terminal. The anode of tube 23 is connected through 2,200-ohm resistor 45 to the control grid of tube 22. The anode of tube 22 is connected through 2,200-ohm resistor 47 to the control electrode of tube 21. A filter condenser 46 is connected across the load. There is provided a shunt path across the load 11 comprising in series 0.47-megohm resistor 50 and 1.0-megohm resistor 51, a mid-terminal of transformer winding 18 being connected to the common terminal of resistors 50 and 51.

Due to the action of the voltage regulator tube 30, the cathodes of tubes 22 and 23 are maintained at substantially fixed potentials, each being negative with respect to ground. The potential of the control electrode of tube 23 is negative with respect to ground and varies in accordance with load voltage changes. When a small increase in load voltage occurs, for example, the potential of the control electrode of tube 23 becomes more negative to reduce the anode current of tube 23. The control grid of tube 22 thus becomes less negative with respect to ground to increase the anode current of tube 22. As a result the potential of the control electrode of tube 21 becomes relatively more negative with respect to the cathode of tube 21 to cause the anode-cathode resistance of tube 21, and therefore the voltage drop across the anode-cathode path, to increase, thereby restoring the output load voltage substantially to its normal value. A plurality of tubes having their anode-cathode paths in parallel may be used if desired in place of the single tube 21 for controlling current supplied to the load. By supplying a portion of the load current through the resistor 25, the amount of current which must be supplied to the load through the space current path or paths of the series regulator tube or tubes, such as tube 21, is correspondingly decreased, thereby permitting fewer tubes or tubes of smaller space current capacity to be used. The use of such a resistor however has the effect of lowering the sensitivity of the rgulator circuit.

There is provided a relay 52 which, when operated, as will be explained below, completes a circuit for supplying current from a battery 53 to the winding of a relay 54, causing the relay to operate. The operation of relay 54 completes a circuit for supplying alternating current from source 10 to a second current supply circuit through a transformer having a primary winding 60 and a secondary winding 61. This supply circuit comprises a twin-diode rectifier space discharge device 62, a pentode shunt regulator space discharge device 63 and two pentode amplifier space discharge devices 64 and 65. There is provided a transformer having a primary winding 66 and secondary windings 67, 68 and 69. The cathodes of diodes 62 are connected to transformer winding 67, the cathode heater of tube 63 is connected to winding 68 and the cathodes of tubes 64 and 65 are connected to winding 69. Primary transformer winding 66 is connected to the supply source 10 when the switch 14 is closed. The operation of relay 52 occurs after the switch 14 has been closed for a certain delay interval as will be explained below. Therefore, the heating of the cathodes or cathode heaters of tubes 62, 63, 64 and 65 occurs prior to the time that alternating current is supplied to the supply circuit through transformer 60, 61. For supplying rectified current to load 12, there are provided a conductive path from the cathodes of diodes 62 through 0.3-ohm resistor 166 to the positive load terminal and a path from a midtap of transformer winding 61 through a fuse 167, filter choke coil 168 and 100-ohm resistor 169 in series to the other load terminal which is grounded, the end terminals of transformer winding 61 being connected to the anodes of rectifier diodes 62. A filter condenser 70 is provided in a path connecting the cathodes of diodes 62 and the common terminal of choke coil 168 and resistor 169.

The anode of shunt regulator tube 63 is connected to the positive output terminal of rectifier 62 and its cathode is connected through 30-ohm resistor 71 to ground. While a single shunt path comprising a resistor 71 and the anode-cathode path of shunt regulator tube 63 is shown, a plurality of such paths in parallel may be provided. The screen grid of tube 63 is connected through 47-ohm resistor 72 to the positive output terminal of the rectifier. The anode of amplifier tube 64 is connected to the positive output terminal of rectifier 62 and its cathode is connected through 50,000-ohm resistor 73, the winding of relay 52 and 60,000-ohm resistor 74, in series, to the negative terminal of load 11. A 240-micromicrofarad condenser 59 is connected across the resistor 73 to prevent singing. There is provided a shunt path from the positive output terminal of rectifier 62 to ground comprising in series 5,000-ohm resistor 75, 20,000-ohm resistor

76, 5,000-ohm resistor 77, 5,000-ohm potentiometer 78 and 20,000-ohm resistor 79. The common terminal of resistors 75 and 76 is connected to the screen grid of tube 64. The anode of tube 65 is connected through 3.3-megohm resistor 80 to the positive output terminal of rectifier 62. The screen grid of tube 65 is connected to the common terminal of resistors 76 and 77. The control electrode of tube 65 is connected through 33,000-ohm resistor 81 to the variable tap of potentiometer 78, the potentiometer tap being connected through condenser 82 to ground. The control grid of tube 64 is connected to the anode of tube 65. The control grid of tube 63 is connected through 2,200-ohm resistor 83 to the common terminal of resistor 73 and the winding of relay 52. There is connected across the load 12 a shunt path comprising cold cathode gas-filled voltage regulator tube 84 and 11,200-ohm resistor 85 in series. A condenser 86 is connected across the tube 84 and a filter condenser 87 is connected in a second shunt path across the load. The common terminal of tube 84 and resistor 85 is connected to the cathode of tube 65.

Due to the action of voltage regulator tube 84, the cathode of tube 65 is maintained at a potential which is substantially fixed with respect to the positive terminal of load 12. If the voltage across load 12 increases by a small amount for example, the control electrode of tube 65 becomes relatively more negative with respect to its cathode to cause the current in the anode-cathode path of the tube to decrease. The control electrode of tube 64 thus becomes relatively more positive with respect to its cathode to cause the current flowing in the anode-cathode path of tube 64 to increase. The control electrode of tube 63 thus becomes relatively less negative with respect to its cathode to cause the current flowing through the anode-cathode path of shunt regulator tube 63 to increase. The voltage drop across resistor 69 thus increases to cause the increase of load voltage to be minimized.

In initiating the supply of rectified currents to the loads 11 and 12, switch 14 is closed for causing heating current to be supplied through secondary transformer windings 17, 18, 67, 68 and 69 to the cathodes and cathode heaters of space discharge devices 20, 21, 22, 23, 62, 63, 64 and 65. Space current is also supplied to rectifier diodes 20 through secondary transformer winding 16. Current is caused to flow in a circuit which may be traced from ground through the load 12, the anode-cathode and screen grid-cathode path of tube 64, resistor 73, winding of relay 52, resistor 74 to the negative terminal of load 11. The current in this circuit flows due to the voltage across load 11. The current increases as the cathode temperature of tube 64 increases until, after a delay period of about eight seconds from the time that switch 14 is closed, the current has reached a sufficient amplitude to cause relay 52 to operate. Relay 54 thus becomes energized to cause a circuit to be completed for supplying through transformer 60, 61 space current to the rectifier diodes 62, thereby causing rectified current to be supplied to the load 12.

When current is supplied to load 12, the voltage, and therefore the current, in the circuit including the winding of relay 52 is increased sufficiently to increase the magnetic pull on the relay armature and thereby prevent the release of the armature of relay 52 due to vibration. If subsequently the supply of current to load 11 is interrupted, as the result of a short circuit across the load and the blowing of fuse 24, the supply of current to load 12 will also be interrupted. This is explained as follows: The normal voltage across each of loads 11 and 12 is 250 volts so that the voltage across the current path comprising in series the anode-cathode path of tube 64, resistor 73, winding of relay 52 and resistor 74 is normally 500 volts. For this condition the potential with respect to ground at the common terminal of resistor 73 and winding of relay 52, which is connected through resistor 83 to the control grid of tube 63, will be of the order of −20 volts. When the voltage across load 11 is removed from the circuit by short-circuiting load 11, for example, the potential with respect to ground of the common terminal of resistor 73 and winding of relay 52 is equal to the voltage drop across the winding of relay 52 and resistor 74 in series which may be of the order of +150 volts. As a result of this change of potential of the control grid of tube 63 with respect to the potential of its cathode, the space current flowing through the anode-cathode path of tube 63 is greatly increased to cause a corresponding increase in the voltage drop across resistor 69. The voltage across load 12 thus decreases suddenly, thereby further decreasing the voltage in the circuit including the winding of relay 52. The resulting reduction of current through the relay winding causes its armature to release, thereby opening the energizing circuit for relay 54 which, in turn, releases to open the circuit for supplying current to transformer winding 60. The supply of current to load 12 is thereby interrupted.

A third current supply circuit is provided for supplying rectified current to the load 13 and for maintaining the voltages across this load substantially constant at 100 volts. Current is supplied to load 13 by the rectifier 62 through a circuit which may be traced from the positive terminal of the rectifier output through the parallel paths having the anode-cathode path of a series-regulator space discharge tube 90 in one of its branches and an 8,000-ohm resistor 91 in a second branch to the positive load terminal, the other load terminal being grounded. The screen grid of tube 90 is connected through 47-ohm resistor 92 to the positive output terminal of rectifier 62. There is also provided an amplifier space discharge tube 93, the anode of which is connected through 4.7-megohm resistor 94 to the positive output terminal of rectifier 62. There is provided a current path which may be traced from the positive output terminal of rectifier 62 through 50,000-ohm resistor 95, 4,000-ohm resistor 96 and 15,000-ohm resistor 97 to ground. The common terminal of resistors 95 and 96 is connected to the screen grid of tube 93 and the common terminal of resistors 96 and 97 is connected to the cathode of tube 93. The cathode of tube 93 is also connected through a condenser 98 to ground. There is connected across the load 13, a path comprising in series 30,000-ohm resistor 100, 5,000-ohm potentiometer 101 and 25,000-ohm resistor 102. The variable tap of potentiometer 101 is connected through a 1,500-ohm resistor 103 to the control grid of tube 93 and through a condenser 104 to the positive output terminal of load 13. The anode of tube 93 is connected through a 2,200-ohm resistor 105 to the control electrode of series regulator tube 90.

The voltage impressed upon the input of the circuit for supplying current to the load 13 is the voltage across the load 12 minus the small voltage drop across the 0.3-ohm resistor 106. This impressed voltage is therefore relatively constant. Voltage variations across the load 13 are further minimized due to the action of the regulator circuit comprising space discharge tubes 90 and 93. If the voltage across the load 13 should rise due to a decrease in load, the control grid of tube 93 would become relatively less negative with respect to the relatively fixed potential of the cathode. The space current through tube 93 would therefore increase to make the potential of the grid of series regulator tube 90 relatively more negative with respect to the potential of its cathode. The resistance of the anode-cathode path of tube 90 is thus increased, thus tending to reduce the current supplied to the load 13. The increase of voltage across load 13 is thus minimized.

What is claimed is:

1. In combination, a first rectifier for supplying direct current to a first load when current from an alternating current supply source is supplied to said rectifier, a second rectifier for supplying direct current to a second load when current from said supply source is supplied to said second rectifier, means for operatively connecting said first rectifier to said supply source to cause direct current to be supplied to said first load, means for operatively connecting said second rectifier to said supply source and slow-acting means, comprising a switching relay in series with a space discharge device having an anode and a cathode, under control of current supplied thereto through said second load by said first rectifier, for controlling said last-mentioned means for connecting said second rectifier to said supply source to cause direct current to be supplied from said second rectifier to said second load.

2. A combination in accordance with claim 1 in which cathode of said space discharge device is supplied with heating current from said supply source in response to the operation of said means for connecting said first rectifier to said supply source.

3. Regulated rectifying apparatus comprising a first rectifier for rectifying current supplied thereto from an alternating current supply source and for supplying rectified current to a first load, a first voltage regulating means responsive to voltage changes across said first load for minimizing said load voltage changes, a second rectifier for rectifying current supplied thereto from an alternating current supply source and for supplying rectified current to a second load, a second voltage regulating means responsive to voltage changes across said second load for minimizing said load voltage changes, said second regulating means comprising a space current device having an anode and a thermionic cathode, means for operatively connecting said first rectifier to said supply source to cause direct current to be supplied to said first load and for substantially simultaneously connecting said cathode to said supply source, switching means having an operating winding, a switching circuit extending from the positive terminal of the second load to the anode of said space current device; and then from the thermionic cathode of said space current device through the winding of said switching means to the negative terminal of the first load, said switching means including a normally open circuit closer between the source and the second rectifier and operating to cause said second rectifier to be operatively connected to said supply source after a delay period during which the current in said switching circuit is increasing due to the increase in temperature of said cathode, thereby causing current to be supplied from said second rectifier to said second load, the voltages across said first and second loads being in aiding relationship in said switching circuit and thereby increasing the current in said circuit, and means included in said second voltage regulating means for causing the voltage across said second load to decrease in response to an interruption of the voltage across said first load, thereby causing the current in said switching circuit to decrease sufficiently to cause the release of said switching means and thereby to cause said second rectifier to be disconnected from said supply source.

4. In combination, an alternating current supply source, a first rectifying means and a first load connected in tandem thereto, a second rectifying means and a second load also connected in tandem thereto, a direct electrical connection between respective points in the loads, a thermionic device having an anode and a cathode, a normally open circuit closer in the connection between the alternating current supply source and the second rectifying means provided with an operating winding, a path extending between respective points in the two loads which are electrically remote from the directly connected points, said path including in series the discharge path of said thermionic device and the winding of said circuit closer, whereby, upon application of an alternating electromotive force from said source to said first rectifier, current is supplied to said path to energize the winding therein, to operate the circuit closer and connect the source to the second rectifier and second load.

5. In combination, an alternating current supply source, a line switch, a first rectifying means and a first load connected thereto, a second rectifying means with a second load connected thereto, a direct ground connection common to both loads, a path extending from the ungrounded end of the second load through a thermionic device having an anode and a cathode, and thence through the operating winding of a normally open relay to the ungrounded end of the first load, a second relay connected in a series circuit from ground through the contacts of said normally open relay, the winding of said second relay and a source of potential back to ground, means for supplying heating energy to the cathode of said thermionic device simultaneously with the application of alternating current from said source through the line switch to said first rectifier, whereby current is supplied to said path from the first rectifying means to energize said normally open relay which becomes operative when the current in said path reaches a predetermined minimum amplitude thereby sequentially operating the said second relay and causing the said second rectifying means and its associated second load to be operatively connected to said alternating current supply source.

6. Rectifier apparatus in accordance with claim 5 in which said second rectifying means includes a thermionic shunt regulating discharge device, having an anode, a grid and a cathode, the grid being connected to a point in the said path from which it obtains its operating bias, said bias therefore being responsive to a reduction of the voltage across said first load for causing said thermionic shunt regulating space discharge device to draw a greatly increased current which reduces the voltage across said second load to such magnitude as to cause the release of the two relays in

turn and thereby the interruption of the connection of the second rectifying means to the alternating current supply source.

7. Rectifier apparatus in accordance with claim 5 in which the current in the said path increases as the temperature of the cathode of said thermionic device increases, thereby causing a time delay in the operation of the relay switching means after the line switch is operated.

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REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
1,791,327	Seeley	Feb. 3, 1931
2,299,942	Trevor	Oct. 27, 1942
2,301,343	Tarr	Nov. 10, 1942
2,377,500	Johnson	June 5, 1945