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REGULATED POWER SUPPLY

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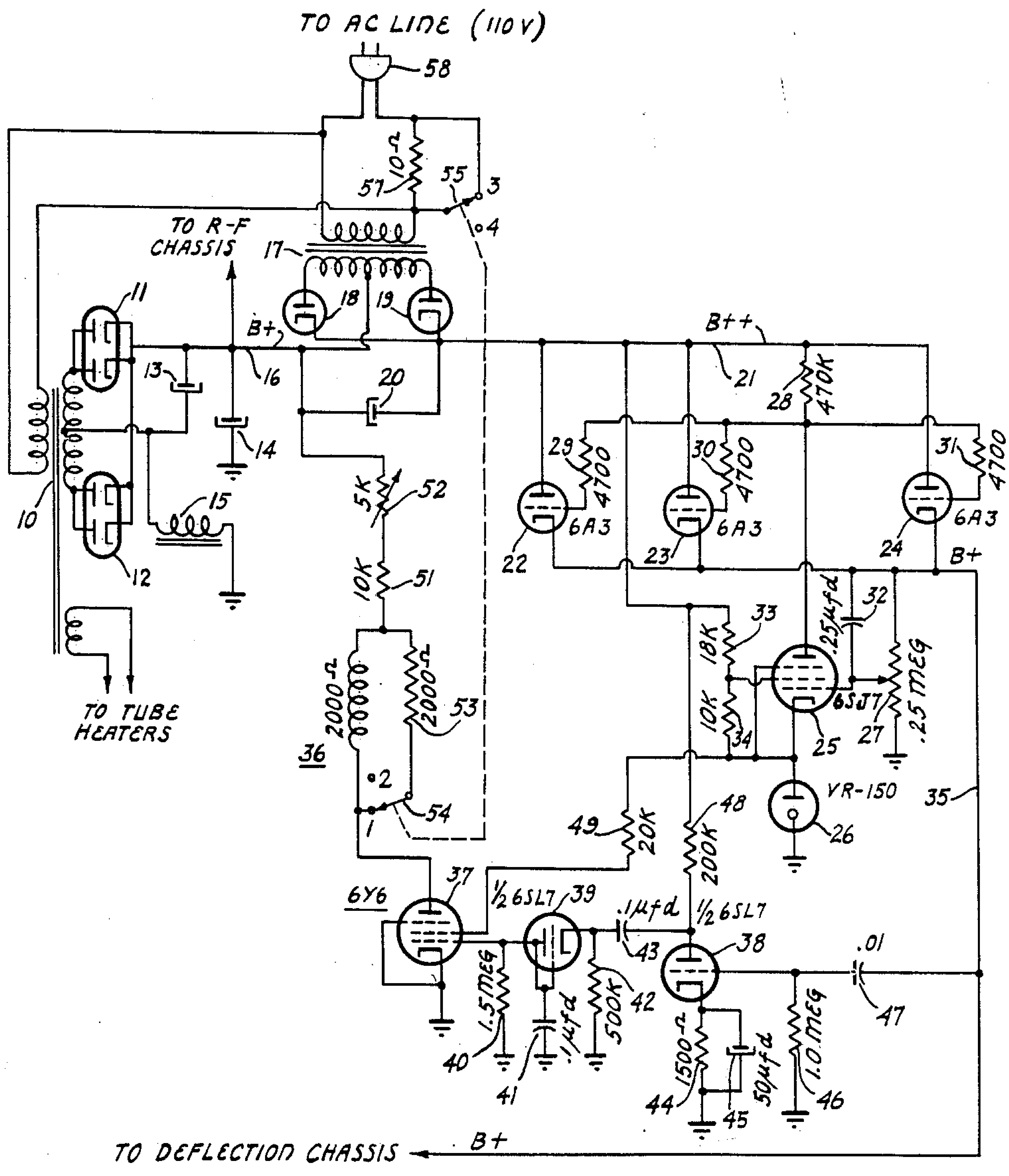

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REGULATED POWER SUPPLY

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The invention herein described and claimed relates to regulated power supplies and in particular to a power supply having an extended range of regulation. The term "power supply" is employed throughout this specification to denote a local system for deriving a D.-C. supply voltage (i. g. B+) from an A.-C. power line.

In some localities, notably foreign countries, regulation of power line voltage is relatively poor and as loads are added to or removed from the distribution system line voltages vary over wide ranges. For example, in many foreign countries it is not unusual for the line voltage of a nominal 110-volt A.-C. power line to vary over a range of from 90 to 130 volts; sometimes, the variation range is even wider.

It is, of course, well known to include at the local power supply a regulator circuit to maintain substantially constant the D.-C. voltage derived from the A.-C. line voltage. However, the conventional regulator circuit is unable to maintain regulation over a range of line voltages as wide as may be encountered in foreign countries.

In those cases where line voltages are subject to variation beyond the limits of the conventional regulator circuit, the prior art has employed a relay or other electrically operated switch whereby when the line voltage increases to a predetermined value the relay operates and a reducd portion of the line voltage is impressed upon the rectifier, or alternatively, a reduced portion of the rectified voltage is applied to the regulator circuit. However, prior-art power supplies of this type have not been entirely satisfactory due to the fact that, after an increase in line voltage has actuated the relay, when the line voltage thereafter decreases the relay does not release soon enough to avoid having the power supply fall out of regulation. For, a relay will ordinarily not release until the coil current has decreased to a value substantially less than the pull-in value. This is due to residual magnetism and to the increase which occurs in the magnetic flux when the reluctance of the magnetic circuit is reduced by the closing of the air gap. The release value may, for example, be of the order of twenty per cent or so of the pull-in value. In addition, the release value seems to vary from relay to relay and from operation to operation. It is generally conceded, then, that while relays will pull in at a predetermined definite value of coil current, they cannot be depended upon to release at a predetermined definite value.

In view of the above, it is the primary object

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of the present invention to provide a regulated power supply capable of maintaining a source of substantially constant D.-C. voltage at the local equipment despite wide variations in A.-C. line voltage.

The foregoing object is achieved by means of a regulated power supply which includes an electrically operated relay for limiting the range of the voltages applied to the regulator circuit, preferably by limiting the range of line voltages applied to the rectifier. The prior-art difficulties with respect to release of relay are overcome, according to the present invention, by means responsive to an early indication that the power supply is falling or is about to fall out of regulation for effecting positive release of the relay, thereby to apply an increased voltage to the regulator circuit, as by applying an increased portion of line voltage across the power-supply transformer. Thus, the power supply is prevented from falling out of regulation at a supply voltage which, if applied in full, is well within the range of the regulator circuit.

The invention will be most readily understood from a consideration of the following detailed description of a preferred embodiment illustrated in the accompanying single figure of drawing.

Referring now to the drawing, there is shown a regulated power supply particularly adapted for use in a modified domestic television receiver intended for use in foreign countries or other localities where the A.-C. line voltage is subject to wide variations. Included in the power supply are the power transformer 10, the double-diode rectifiers 11 and 12, the filter capacitors 13 and 14, and the choke 15. These elements comprise the normal unregulated power supply of a conventional domestic television receiver and function in well known manner to derive from the A.-C. line voltage an unregulated positive D.-C. supply voltage, B+, which appears at lead 16. In the circuit shown in the drawing, this voltage is used to supply the R.-F. chassis of the television receiver.

For use in foreign countries, the television receiver should have a regulated power supply, and to compensate for the voltage drop across the regulator circuit, the circuit shown in the drawing includes a voltage booster comprising the power transformer 17, the diode rectifiers 18 and 19, and the filter capacitor 20. These elements function to develop an additional positive D.-C. voltage which, when added to the unregulated D.-C. supply voltage, B+, produces a boosted unregulated D.-C. supply voltage, B++, on lead 21. It is to be understood, of course, that so far as the present invention is concerned, a single rectifier circuit could be employed and that the booster arrangement shown in the drawing is merely used to avoid replacing transformer 10 with a transformer of larger rating when modifying the television receiver for foreign use.

The regulator circuit is comprised of the parallel-connected triodes 22, 23 and 24, the pentode 25, the gas tube 26, the potentiometer 27, and the various associated resistance and capacitance elements shown in the drawing identified by reference numerals 28 to 34. Three parallel-connected tubes (22, 23, 24) are used in lieu of the single tube found in the more conventional circuit to increase the current capacity of the regulator.

The regulator circuit functions to maintain a substantially constant positive D.-C. voltage, B+, on lead 35 in a manner which is largely conventional and need be but briefly described. When variations occur in the unregulated B++ voltage appearing on lead 21, in-phase variations tend to appear on the cathode lead 35 and at the grid of tube 25. The cathode potential of tube 25 is, however, held substantially constant by the action of the gas tube 26 which maintains a substantially constant voltage drop thereacross even though the current through the tube 26 varies over a relatively wide range. Thus, when the potential at the grid of tube 25 varies, the grid-to-cathode potential of the tube varies and so does the plate current through the tube. The plate potential of tube 25 then varies in the opposite direction, and so do the grid potential of the parallel-connected tubes 22, 23, 24. Thus, when the plate potential of tubes 22, 23, 24 varies, the voltage drop across these three tubes varies in such direction as to prevent any change in their cathode potential. It will be seen, then, that the potential on lead 35 remains constant despite variations in the B++ voltage on lead 21. This assumes, of course, that the A.-C. line voltage does not drop to such an extent that the regulator circuit is unable to mainain regulation.

To widen the range over which the A.-C. line voltage may deviate without having the power supply fall out of regulation, an automatic switching arrangement is provided comprising a relay 36 controlling a pair of switches 54 and 55, and, in accordance with the present invention, a relay-release control circuit comprised of the tubes 37, 38, 39 and the various resistance and capacitance elements associated therewith identified by reference numerals 40 to 48 and connected as shown in the drawing. Tube 37 functions as the relay-release control tube. Tube 38 functions as an amplifier of a control signal which is derived from the regulated B+ lead 35 as will later be described. Tube 39 functions as a diode-rectifier of the amplified control signal to produce a negative D.-C. control signal which is then applied to the grid of the relay-release control tube 37.

As will be seen from the drawing, relay-release control tube 37 is connected in series with the coil of relay 36, fixed resistor 51, and variable resistor 52, between the unregulated B+ lead 16 and ground. An anti-chatter resistor 53, discussed more fully later, shunts the relay coil when the relay is not in actuated condition.

The operation of the automatic switching arrangement, including the means added by the present invention, may be most readily understood by assuming certain values of voltages for discussion purposes. Assume that the A.-C. line voltage is nominally 110 volts but is subject to wide variations and that it is desired to provide a regulated power supply capable of maintaining the derived D.-C. supply voltage substantially constant over a range of A.-C. line voltages extending from 90 to 145 volts. Assume an instant when the line voltage is low, say about 90 volts. The D.-C. current through the coil of relay 36 is then insufficient to operate the relay, and relay switch arms 54 and 55 are then at positions 1 and 3, respectively. Observe that with switch arm 55 at position 3, the voltage-dropping resistor 57, which is series-connected in the lead from the line plug 58 to the parallel-connected transformers 10 and 17, is shorted out. Thus the full A.-C. line voltage is applied to the primaries of the transformers. The variable resistor 52 in the relay circuit is so adjusted that when the A.-C. line voltage rises to a predetermined value, say 120 volts, the current through the relay coil increases sufficiently to actuate the relay and switch arms 54 and 55 then move to positions 2 and 4, respectively. When this occurs, the voltage-dropping resistor 57 is no longer shorted and a voltage drop, say of 10 volts, occurs thereacross. Thus, when relay 36 operates, the A.-C. voltage impressed upon the primaries of the parallel-connected transformers 10 and 17 drops suddenly, in the present example by 10 volts, from 120 volts to 110 volts.

Though not a part of the improvement contributed by the present invention, it may be helpful at this point to discuss briefly the manner in which resistor 53 functions to prevent relay chatter. When the relay starts to operate and the relay switch arms 54 and 55 break contact at positions 1 and 3, respectively, the line voltage impressed upon the primaries of transformers 10 and 17 drops suddenly, as just mentioned hereinabove, and as a result a sudden decrease occurs in the unregulated D.-C. voltage on lead 16. Hence, in the absence of resistor 53, as soon as the relay began to operate, the current through the relay coil would decrease and the switch arms, instead of continuing on to the operate positions 2 and 4, would return to the release positions 1 and 3. Thus, the relay contacts would chatter. However, with a resistor 53 of suitable value connected as shown in the drawing, when the switch arm 54 breaks contact at position 1, the resistive shunt across the relay coil is removed and all of the current flowing in the relay circuit now flows through the coil, whereas prior to the opening of the contacts at position 1, only a portion of the total relay-circuit current passed through the coil. Hence, by effecting an increase in the relay-coil current in lieu of the decrease which would otherwise occur when the relay began to operate, the resistor 53 prevents contact chatter.

Returning now to the discussion of the operation of the automatic switching arrangement shown in the drawing, if after the relay has operated the line voltage continues to rise, the voltage impressed upon the primaries of transformers 10 and 17 will continue to be less than the actual A.-C. line voltage by the amount of voltage drop in resistor 57. In the exemplary case being discussed, if the A.-C. line voltage should rise to 145 volts, the drop in resistor 57 may be of the order of 25 volts, and the voltage impressed upon the primaries of transformers 10 and 17 will be about 120 volts.

It will be seen, then, that if the line voltage should rise from a low of 90 volts to a high of 145 volts, the voltage impressed upon the primaries of transformers 16 and 17 will rise from 90 volts to only about 120 volts, due to the action of the automatic switching arrangement described thus far, and the requirements imposed upon the regulator portion of the power supply will be no greater than they would be if the line-voltage variations themselves were from 90 volts to 120 volts.

Thus far we have considered how the automatic switching system operates when the line voltage increases. Consider now what happens when the line voltage decreases, say from a high value of 145 volts down to a low value of 90 volts. It will be recalled that, in the illustrative situation being discussed, when the rising line voltage reached 120 volts, the current through the relay coil became sufficient to operate the relay. However, as stated previously hereinabove, before relay 36 will release, the current through the relay coil must decrease to a value substantially lower than that which caused the relay to operate. Hence, in the absence of the means provided by the present invention, the probability would be that, as the line voltage decreased from a high value, relay 36 would hold too long in the actuated position. In other words, there would be the danger that before the relay released, and before the voltage-dropping resistor 57 was shorted out, the line voltage would drop to such an extent that the unregulated D.-C. voltage on lead 21 would fall to such a low value that the regulator circuit would be unable to maintain regulation of the D.-C. voltage on lead 35.

The above danger is obviated, in accordance with my invention, by the provision of means which, in response to an early indication that the power supply is falling or is about to fall out of regulation, effects positive release of relay 36, thus shorting out the voltage-dropping resistor 57 and increasing the amount of line voltage applied to the power supply circuit. The indication to which the relay-release control means is responsive is a significant increase in hum or ripple voltage. For, I have observed that so long as regulation is maintained, the amount of ripple appearing on the regulated B+ lead 35 is very small but that, when the power supply starts to fall or is about to fall out of regulation, the ripple voltage increases very appreciably, even before there is any change in the measured D.-C. voltage on the regulated B+ lead. In a particular case, for example, with a regulated D.-C. voltage of 315 volts on B+ lead 35, the root-mean-square value of hum or ripple voltage appearing on the lead, during regulation, was less than 0.1 volt. However, when the power supply was about to fall out of regulation, the root-mean-square value of ripple voltage rose rapidly to 5.0 volts, though the D.-C. voltage still measured 315 volts as before. The present invention takes advantage of this observed phenomenon, and uses the hum or ripple voltage to trigger relay 36 into the released condition.

In the arrangement shown in the drawing, the ripple voltage appearing on the regulated B+ lead 35 is applied by way of RC network 46, 47 to the grid of amplifier tube 38 whose plate voltage is supplied from lead 21, and the amplified ripple signal developed on the plate of tube 38 is applied by way of RC network 42, 43 to the rectifier tube 39 which is shown to be a triode connected as a diode. Rectifier 39 and filter 40, 41 function to produce a negative D.-C. control signal which is applied to the control grid of the relay-release control tube 37. The substantially constant positive voltage developed across the gas regulator tube 26 is applied to the screen grid of the tube 37 by way of resistor 48. During regulation, the ripple voltage is small, the negative D.-C. signal applied to the control grid of tube 37 is small, and tube 37 conducts. When, however, the power supply is about to fall out of regulation, the ripple voltage increases in a substantial and significant manner, and the negative D.-C. control signal developed on the grid of relay-release control tube 37 is sufficient to cut the tube off. When this occurs, the current in the relay coil is suddenly reduced to zero and relay 36 releases. Switch arms 54 and 55 thereupon return to positions 1 and 3, respectively, and the voltage-dropping resistor 57 is shorted out. The full line voltage is now applied across the primaries of transformers 16 and 17, and the unregulated D.-C. voltage appearing on lead 21 is suddenly increased to a value which is within the limits of the regulator circuit. Thus, regulation is maintained.

Component values for a typical system have been shown in the drawing. It is to be understood, of course, that the values shown are merely illustrative and not limiting.

In a particular case, a system employing values similar to those shown in the drawing developed about 75 volts D.-C. at the grid of relay-release control tube 37 with about 2.0 volts input to the grid of amplifier tube 38. Only about 30 volts D.-C. was required to cut tube 37 off.

The point at which the relay pulls in is, of course, largely determined by the total impedance of the series-connected components of the relay circuit, which is adjustable by means of the variable resistor 52. It is advantageous to keep the impedance of relay-release control tube 37 low, relative to the other relay-circuit series impedances, so that tube variations and aging effects are minimized. In the particular case referred to above, the voltage drop across relay-release control tube 37 at the time the relay operated was only about fifty volts.

Also, since the relay circuit loads the power supply, the current drawn by the relay circuit should be kept low. In the particular case being discussed, the total current in the relay circuit was 30 milliamperes. This was deemed to be a good compromise between relay cost and extra load.

The particular system above referred to is also designed to have the relay pull in at a line voltage about 10 volts higher than the line voltage at which the power supply would fall out of regulation. More particularly, the relay pulls in when the line voltage reaches 120 volts, and, with the relay in the operated condition, the power supply starts to fall out of regulation when the line voltage drops to 110 volts. A voltage difference of this order of magnitude is desirable in order to prevent relay chatter and hunting in the event the line voltage hovers about the relay pull-in value.

It is to be understood that, instead of being connected in the primary side of the transformers, the series voltage-dropping resistor 57 and the shorting-out relay switch 55 could be connected in the unregulated B++ lead 21. This alternate arrangement is, however, less satisfactory than that shown in the drawing since the tube heaters, which are fed directly from the secondary of the power transformer, would then be subjected to the full range of line-voltage variations. The preferred arrangement, shown in the drawing, limits the range of the voltage variations in the heater circuit as well as on the unregulated B++ lead 21.

It should also be understood that, instead of employing a series voltage-dropping resistance, the portion of line voltage applied to the transformer primary could be varied by switching between primary taps. However, in this case, there is a momentary loss of regulated B+ during relay operation. In the arrangement shown and described, using a series voltage-dropping resistor, there is no loss of regulation as the shunt across the resistor is removed or connected.

Having described my invention, I claim:

1. A power supply for deriving a regulated D.-C. voltage from an A.-C. line whose line voltage is subject to relatively wide variation, said power supply comprising: rectifier means; means for applying at least a portion of said A.-C. line voltage to said rectifier means to develop an unregulated D.-C. voltage; a regulator circuit for deriving a regulated D.-C. voltage from said unregulated D.-C. voltage; a relay operative in response to an increase in said line voltage for effecting a decrease in the unregulated voltage applied to said regulator circuit; and means responsive, when said line voltage decreases, to an increase in the ripple component of said regulated voltage for releasing said relay to increase the unregulated voltage applied to said regulator circuit, thereby to prevent said power supply from falling out of regulation.

2. Apparatus as claimed in claim 2 characterized by the fact that said means responsive to an increase in the ripple component of said regulated voltage for releasing said relay comprises a normally conductive control tube connected in series with said relay, and A.-C. coupling and rectifying means for applying rectified ripple voltage to the grid of said control tube to cut said control tube off when said ripple voltage increases to a predetermined value.

3. A power supply for deriving a regulated D.-C. voltage from an A.-C. line whose line voltage is subject to relatively wide variation, said power supply comprising: rectifier means; means for applying at least a portion of said A.-C. line voltage to said rectifier means to develop an unregulated D.-C. voltage; a regulator circuit for deriving a regulated D.-C. voltage from said unregulated D.-C. voltage; a relay operative in response to an increase in said A.-C. line voltage for effecting a reduction in the portion of said line voltage applied to said rectifier circuit; and means responsive to an increase in the ripple component of said regulated D.-C. voltage for releasing said relay to increase the portion of said A.-C. line voltage applied to said rectifier means, thereby to prevent said power supply from falling out of regulation when said line voltage decreases to such an extent that said regulator circuit is unable to maintain regulation of said reduced portion thereof.

4. Apparatus as claimed in claim 3 characterized by the fact that said means responsive to an increase in the ripple component of said regulated voltage for releasing said relay comprises a normally conductive control tube connected in series with said relay, and A.-C. coupling and rectifying means for applying rectified ripple voltage to the grid of said control tube to cut said control tube off when said ripple voltage increases to a predetermined value.

5. A power supply for deriving a regulated D.-C. voltage from an A.-C. line whose line voltage is subject to relatively wide variation, said power supply comprising: rectifier means; means for applying at least a portion of said A.-C. line voltage to said rectifier means to develop an unregulated D.-C. voltage whose value tends to vary in accordance with variations in said line voltage; a regulator circuit; means for applying said unregulated D.-C. voltage to said regulator circuit to derive a regulated D.-C. voltage; switching means responsive to an increase in said unregulated D.-C. voltage beyond a predetermined upper control limit of said regulator and operative to reduce to a substantially lower base value the unregulated D.-C. voltage applied to said regulator circuit; and means effective when said unregulated lower-base-value D.-C. voltage decreases to a value substantially equal to a lower control limit of said regulator circuit for operating said switch means to increase to a substantially higher base value the unregulated D.-C. voltage applied to said regulator circuit, said last-named means being responsive to an increase in the ripple component of said regulated D.-C. voltage.

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