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A RADIO CORPORATION OF AMERICA SUBSIDIARY
Harrison, New Jersey

RCA RADIOTRON
DIVISION

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APPLICATIONNOTES

APPLICATION NOTE ON A VOLTAGE REGULATOR FOR D-C POWER SUPPLIES

It is desirable to use a well-regulated source of d-c voltage when the performance of associated equipment is critically dependent on the value of the d-c voltage. For example, laboratory test equipment using vacuum tubes often employs a regulated B-supply unit to improve performance; the plate voltage of oscillator tubes may be obtained from a regulated power-supply unit to increase frequency stability; plate, screen, and bias voltages may be obtained from a regulated power-supply unit to reduce distortion and to increase power output; and a regulated power-supply unit may also find wide application in the laboratory as a suitable substitute for batteries. This Note describes a voltage-regulator circuit that has been used for some time. The performance of the circuit under various line-voltage and load conditions is given and output current limitations are pointed out.

The circuit of the regulator is shown in Fig.1. It consists essentially of a regulator tube (T_1), a control tube (T_2), a neon glow lamp (T_3), and several resistors. The unregulated d-c voltage from a conventional power-supply unit is fed to the plate of the regulator tube; the regulated d-c voltage is obtained from the cathode of the regulator tube. In normal operation of the regulator, current from the unregulated source flows through the regulator tube to its cathode; at the cathode, this current divides into three branches: (1) R_3, T_2, T_3 to ground; (2) R_1, R_2, to ground; and (3) the external load (R_L). Because the resistance of T_3 is non-linear, its voltage drop (E_3) is substantially independent of current through it over a wide range of current values. It is this property of T_3 that accounts for the good regulation of the system.

Operation of Circuit

From the circuit of Fig.1, it is seen that T_2 has a bias equal to $-(E_3 - E_1)$, a screen voltage equal to $(E_2 - E_3)$, and a plate voltage equal to $(E_o - E_4 - E_3)$. Assume, now, that the load current is increased from rated value, at which rated output voltage is obtained. Any increase in load current tends to decrease the output voltage. Because E_3 is substantially independent of current, a decrease in E_o causes a proportional increase in the negative bias of T_2, which reduces the plate current of T_2; consequently, the bias of T_1 decreases. A reduction in the bias of T_1

reduces the voltage drop across T_1, which tends to increase E_o. The net result is a small change in the value of E_o. In other words, voltage is stored across T_1 and is released by the action of the control tube, which, in turn, is actuated by a change in the value of E_o. Should the load current decrease and tend to cause a rise in the value of E_o, the action of the control tube increases the voltage drop across T_1 to reduce the change in E_o.

Changes in the value of E_o due to changes in line voltage or to hum-voltage input are also reduced. An increase in the value of the unregulated voltage (E_i) due to an increase in line voltage or to hum voltage causes an increase in E_o; however, this increase in the value of E_o is small because of the action of the regulator. For example, in one test, the ratio of hum voltage to d-c voltage was reduced by a factor of 4 by the regulator.

The voltage drop across the neon lamp (E_3) may be regarded as a standard voltage with which the fraction E_1/E_o of the total change in output voltage (ΔE_o) is compared. Because the change in voltage that actuates the control tube is $\Delta E_o E_1/E_o$, it is desirable to use as high a value of E_1 as possible. However, an increase in the value of E_1 without a corresponding increase in the value of E_3 causes a very high voltage drop across T_1. When the voltage drop across T_1 is high, its dissipation is high and the recommended maximum value of load current is correspondingly low.

It is desirable to use a high ratio of screen voltage to plate voltage on T_2 in order to obtain a high ratio of cathode current to plate current. The plate current of T_2 determines the initial bias on T_1, which, in turn, controls the voltage drop across T_1. The cathode current of T_2 flows through the neon lamp and should have a sufficiently high value under full load and minimum line-voltage conditions to permit of stable operation.

With the values of components suggested in the circuit of Fig.1, the cathode current of the control tube should be approximately 25 microamperes under full load and minimum line-voltage conditions; the voltage drop across the neon lamp is approximately 50 volts. In making the adjustments, set E_2 to 200 volts and then adjust E_1 for a cathode current of approximately 25 microamperes under full load and minimum line-voltage conditions; the screen voltage is then 200 - 50, or 150 volts.

Performance of Circuit

The curves of Fig.2 depict the performance of the regulated power-supply unit when T_1 is a single type 2A3. The data show, for three values of line voltage, the relations between input voltage to the regulator, dissipation of 2A3, and d-c output voltage of the regulated power-supply unit for various values of load current. Thus, with the unregulated power supply used in this test and with a line voltage of 115 volts, E_1 increased from 370 volts to 460 volts as the load current changed from 70 milliamperes to 10 milliamperes; the change in E_1 of 90 volts corresponds to an internal resistance of 90/0.06, or 1500 ohms for the unregulated power-supply unit. Now, referring to the curve of E_o corresponding to a line voltage of 115 volts, it will be noted that the total change in output voltage is approximately 5 volts for a 60 milliampere change in load current; the internal resistance of the regulated supply unit is thus approximately 5/0.06, or 86 ohms. It is seen from the curves that the value of internal resistance for small changes in load current at high values of current is considerably less than 83 ohms.

The curves are not shown for values of load current greater than 70 milliamperes, because the recommended maximum value of dissipation (15 watts) for the type 2A3 is reached at this value of load current when the line voltage is 125 volts. At low line voltage, 105 volts, and at 70 milliamperes load current, regulation is just beginning, because the current through the neon lamp is at approximately the minimum value that permits of stable operation.

The curve showing the input voltage to the regulator for a line voltage of 105 volts is important because it shows the minimum voltage that is necessary to obtain 200 volts output under full load conditions. The unregulated power-supply unit must furnish this value of voltage. As the value of load current decreases or the line voltage increases, the input voltage to the regulator increases, as shown.

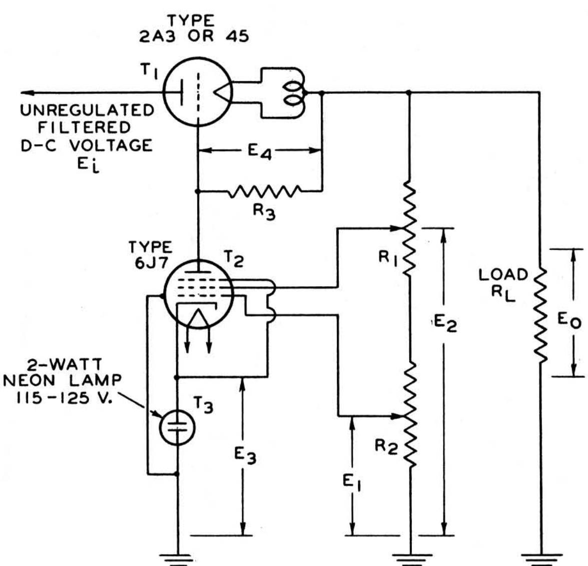
Values of output voltage greater than 200 volts can be obtained by increasing the input voltage to the regulator by an amount equal to the difference between the desired output voltage and 200 volts. However, because the input voltage (E_1) may be several hundred volts under maximum line-voltage and low load conditions, it may be necessary to use paper or oil-filled condensers in the unregulated power-supply unit. The data shown in this Note were taken with low-cost electrolytic condensers. The curves of Fig.3 show the performance of the regulated power-supply unit when T_1 consists of two type 2A3 tubes connected in parallel. The recommended maximum value of load current is twice that of the single-tube regulator of Fig.2 and the regulation characteristic remains substantially constant.

Fig.4 shows the performance of the regulated power-supply unit when T_1 is a single type 45. In this case, the recommended maximum value of load current is 45 milliamperes, at which current value the recommended maximum value of dissipation (10 watts) of the type 45 is reached with a line-voltage of 125 volts. Fig.5 shows the performance of the regulated power-supply unit when T_1 consists of two type 45 tubes connected in parallel. The type 2A3 or 45 is suitable for use in a regulator circuit because high current is obtained with comparatively low voltage drop. Other triode types are suitable, but the input voltage to the regulator should be increased above the values shown by the curves to obtain 200 volts output.

The stability of the regulator depends to a large extent on the constancy of the voltage drop across the neon lamp. Determination of the stability of the type of neon lamp recommended in Fig.1 at low current values was made by measuring the voltage drop across each of a number of lamps periodically for several weeks. It was found that after the lamps had been operated for two days, the voltage drop across the majority of them remained substantially constant with time, although the drop changed appreciably during the first day of operation. When it is important to have stability with time, therefore, it is suggested that the neon lamp be aged for about 30 hours.

The neon lamp recommended for use in this circuit has a series resistor mounted in the base of the lamp. When the current through the lamp is high (several milliamperes), some improvement in performance is obtained by removing this resistor. However, because the current through the lamp is low in this circuit, the neon lamp may be used as purchased--with the resistor connected.

CIRCUIT OF D-C VOLTAGE REGULATOR



$R_1 + R_2 = 0.2$ MEGOHM
$R_3 = 0.5$ MEGOHM

FIG. 1

CHARACTERISTICS OF REGULATED POWER SUPPLY
WHEN T_1 (SEE FIG.1) IS A SINGLE TYPE 2A3

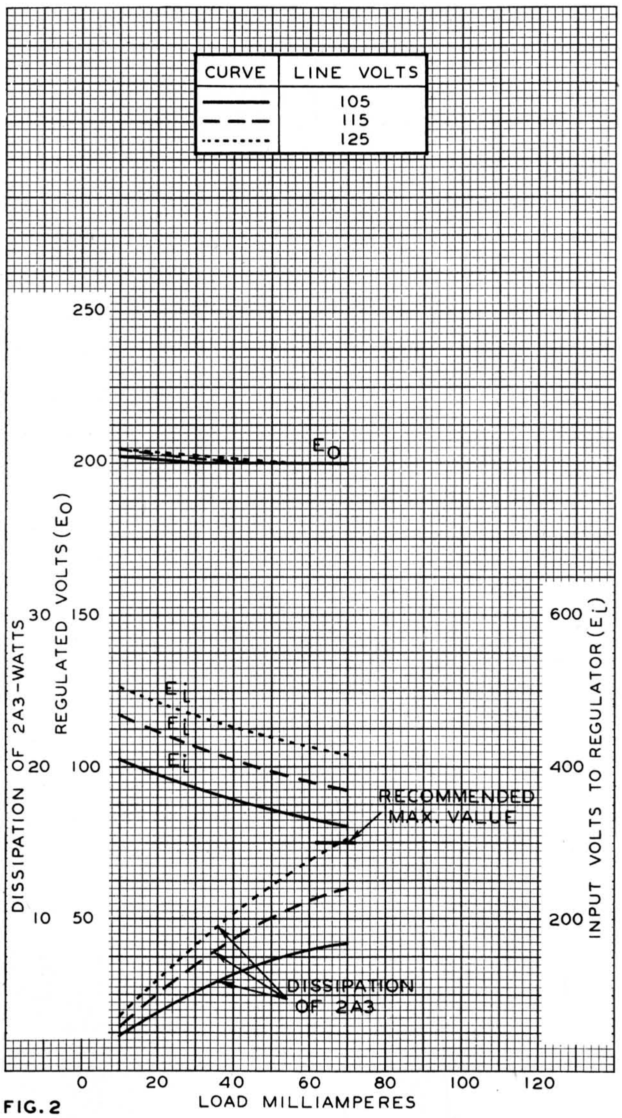


FIG. 2

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CHARACTERISTICS OF REGULATED POWER SUPPLY
WHEN T_1 (SEE FIG.1) CONSISTS OF TWO TYPE 2A3'S CONNECTED IN PARALLEL

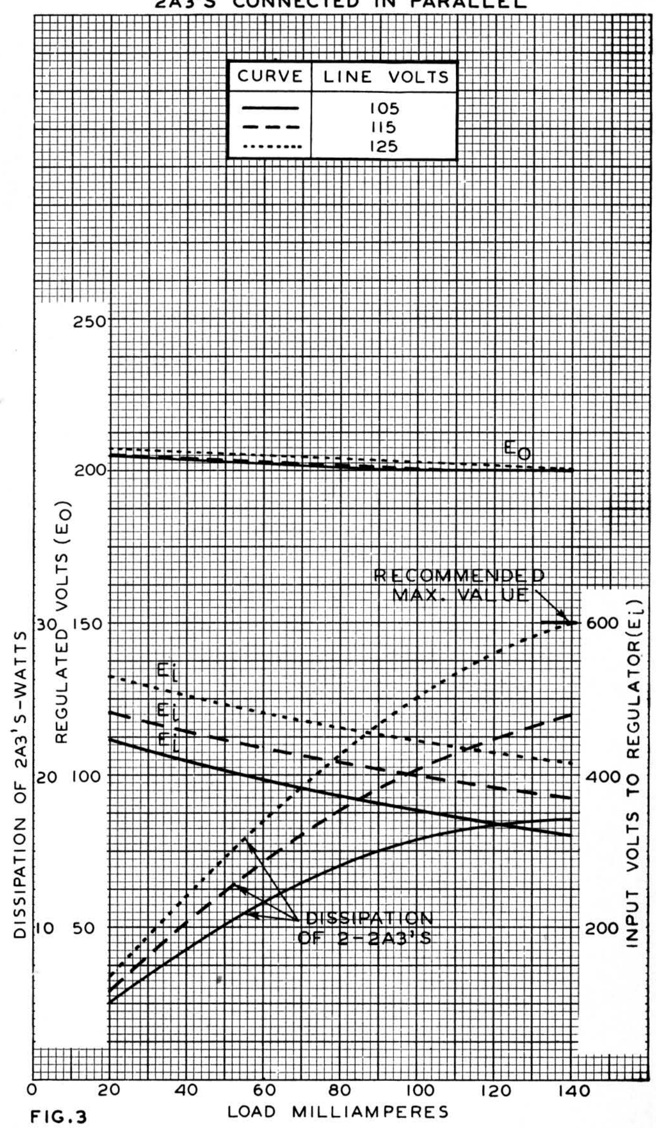

FIG. 3

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CHARACTERISTICS OF REGULATED POWER SUPPLY
WHEN T_1 (SEE FIG.1) IS A SINGLE TYPE 45

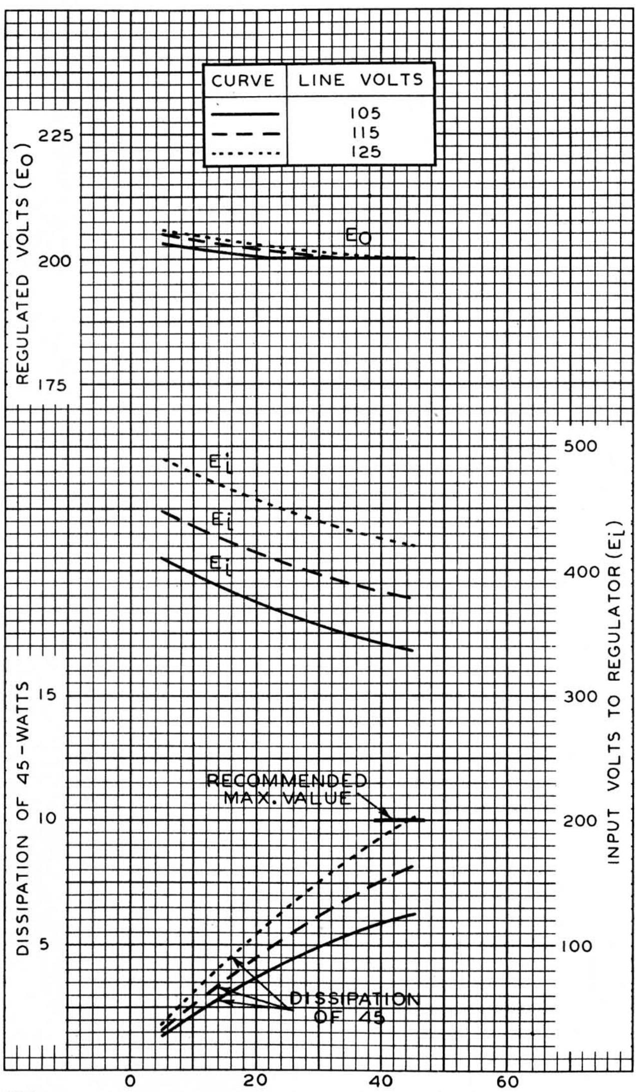

FIG. 4

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CHARACTERISTICS OF REGULATED POWER SUPPLY
WHEN T_1 (SEE FIG.1) CONSISTS OF TWO TYPE 45'S CONNECTED IN PARALLEL

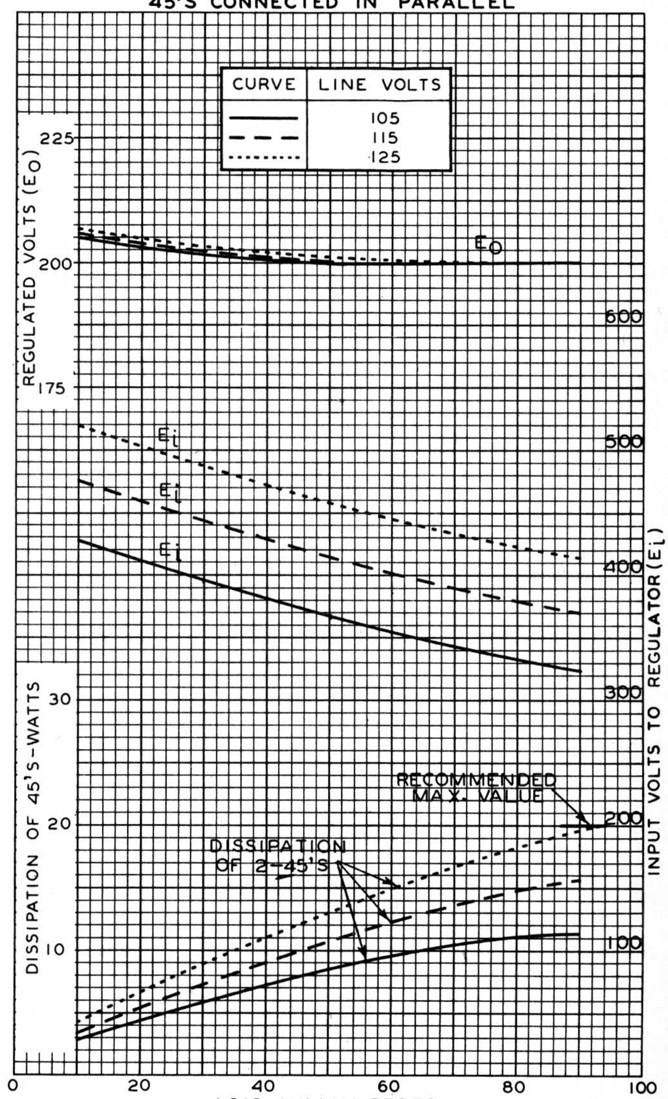

FIG. 5

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