July 13, 1937. C. W. HANSELL 2,086,910

VOLTAGE REGULATOR

Filed Feb. 8, 1934

Fig. 1

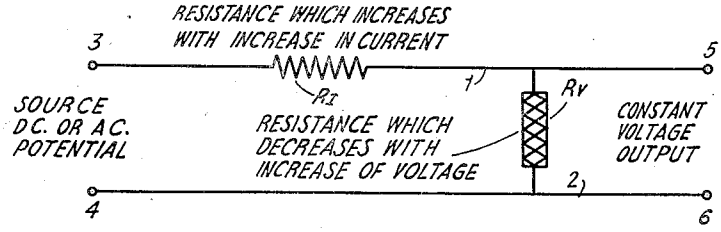


Fig. 4

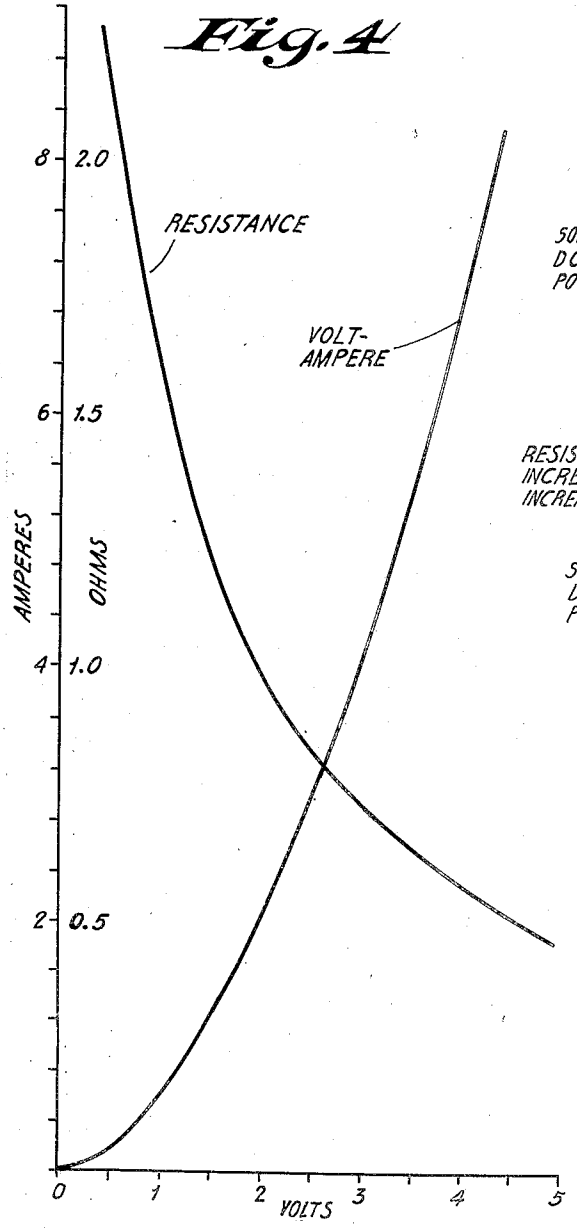


Fig. 2

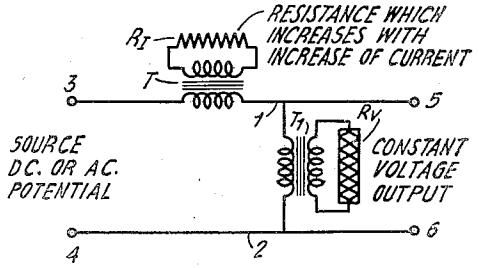
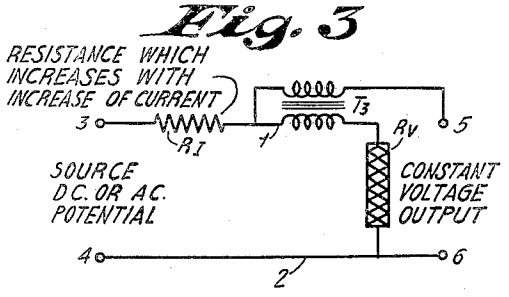


Fig. 3



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2,086,910

VOLTAGE REGULATOR

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8 Claims. (Cl. 171—229)

A new type of resistance material has been recently developed in the electrical arts. This material is permanent and has the property of rapidly decreasing its electrical resistance when the voltage across it is increased. The characteristic of this resistance is non-linear. That is to say, the current flow through the resistance increases at a rate faster than linear with respect to the increases of applied voltage which causes such current change. Although the relation between the changes in current flow and changes in applied voltage is not linear, said changes are continuous over the effective range of the resistance material which range is considerable. The characteristics of this resistance material, which are described in the General Electric Review, February, 1930, vol. 33, No. 2, page 92, and has been called "Thyrite", are such that doubling the voltage upon it will decrease its resistance to less than one-sixth of its initial value. The resistance of this material is relatively high, and the material is well adapted to high voltages and small current requirements such as for example anode circuits of thermionic tubes.

Cuprous oxide rectifiers, photo cells, cesium oxide photo cells, rectifiers and similar devices have this non-linear characteristic of decreasing resistance when the applied voltage is increased. These devices, however, are well adapted to low voltage and heavy current circuit requirements.

In my invention this property of these devices and material is made use of to regulate the voltage applied to any load as, for example, the heating elements of radio tubes or the anodes or any other electrodes of said tubes. The decrease in the cell or resistance or rectifier which occurs with an increase of applied voltage causes a change in the current flow therethrough which may be used to prevent the change of voltage causing said change in current flow and consequently the change of voltage in or across the useful load circuit.

My novel invention also contemplates the use of a resistance, the character of which is such that the resistance thereof increases rapidly with the increase of current flowing therethrough. The use of this resistance element properly placed in the circuit with the resistance element described above greatly increases the effectiveness of the voltage regulation.

The novel features of my invention have been pointed out with particularity in the claims appended hereto.

The nature of my invention and the manner in which the same is carried out will be better understood from the following description thereof and therefrom when read in connection with the attached drawing in which Figures 1 to 3 inclusive show circuits arranged in accordance with my present invention including a resistance, the current flow through which is non-linear with respect to the applied voltage, for applying constant potentials from a direct current source which may vary to a load circuit; while Figure 4 is a curve indicating the relation between the applied voltage and the current.

Figure 1 shows one of the simplest possible methods of and circuits for regulating voltages in accordance with my invention. This regulator is suitable for use either with direct current or alternating current sources. In Figure 1 a resistance R_I is connected between the source of variable voltage and the load or constant voltage output. A resistance R_V of suitable dimensions in which the current flow increases non-linear with respect to the applied voltage, is connected across the leads 1 and 2 as shown. As the potential from the source connected to the terminals 3, 4 increases the current through the resistance R_V increases at a faster rate than the voltage and causes a variation in the voltage drop in the resistance R_V which counteracts the increase in voltage from the source to insure a more constant voltage output at 5 and 6 which may be applied to any load. The regulation described above will be improved if the series resistance R_I is made of a tungsten filament such as a lamp, or of any other material the resistance of which increases rapidly with increasing current. Of course, where power consumption is of great importance the series resistance R_I may be replaced by a reactance for alternating current voltage control. This reactance may have a magnetic core in which the permeability increases with increasing current to obtain better regulation of the voltage at the terminals 5, 6 and on the load.

Figure 2 shows a circuit somewhat similar to the circuit of Figure 1. In the circuit of Figure 2, however, I provide transformers T and T_1 interposed as shown between the resistance R_I and the resistance R_V. These transformers permit adjustment of the voltages on the resistance R_I and on the resistance R_V in order to obtain suitable relation between the constants or values of the respective resistances or regulating elements and the circuit to be regulated.

In the circuit of Figure 3 the resistance R_I is connected to the primary winding of a trans-

former T_3. The resistance Rv connects the other terminal of this transformer winding to lead 2. One winding of the transformer is connected as shown to the output terminal 5 so that an autotransformer effect is obtained which permits regulating the constants of the circuit with respect to the load circuit which is to utilize the voltages from 5 and 6. The autotransformer makes it possible to obtain a circuit combination which completely suppresses voltage variations to a constant impedance load when the line voltage varies.

To simplify the description of my invention I have assumed that the resistance Rv is of the Thyrite type. However, my invention contemplates the use of any material or device to replace Rv provided said material or device has the required non-linearity relation between the applied voltage and the resistance. For example Rv may be replaced by a rectifying device of the oxide type. These rectifiers have current and resistance and voltage characteristics as indicated in Figure 4. The element Rv may also be replaced by photo cells or other cells which have the required characteristics.

Having thus described my invention and the operation thereof, what I claim is:

1. The voltage regulating circuit comprising, a pair of leads each having a terminal which may be connected to a source of voltage which may vary, and another terminal which may be connected to a load circuit, an inductive reactance, a resistance the value of which increases rapidly as the current therethrough increases connected in series with said reactance in one of said leads, a second inductive reactance and a rectifier of the oxide type the current through which increases rapidly as the voltage across the terminals thereof increases connected in series with said second inductive reactance between said leads.

2. A voltage regulating circuit comprising, a pair of leads each having a terminal which may be connected to a source of voltage which may vary, and another terminal which may be connected to a load circuit, a resistance the value of which increases rapidly as the current therethrough increases connected in series with one of said leads, a cesium oxide photo cell the current through which increases rapidly as the voltage across the terminals thereof increases connected between said leads, an inductance in series with said resistance, and an inductance in series with said cell.

3. A voltage regulating circuit comprising, a pair of leads each having a terminal which may be connected to a source of voltage which may vary, and another terminal which may be connected to a load circuit, an inductive reactance, a resistance the value of which increases rapidly as the current therethrough increases connected in series with said inductive reactance in one of said leads, and an element the current through which increases rapidly as the voltage across the terminals thereof increases connected between the juncture between said resistance and inductive reactance and the other of said leads.

4. A voltage regulating circuit comprising, a pair of leads each having a terminal which may be connected to a source of voltage which may vary, and another terminal which may be connected to a load circuit, a transformer winding, a resistance the value of which increases rapidly and continuously as the current therethrough increases connected in series with said winding in one of said leads, a second transformer winding coupled to said first named winding, and a second resistance the current through which increases rapidly and continuously as the voltage across the terminals thereof increases connected in series with said second transformer winding between said leads.

5. A voltage regulating circuit comprising, a pair of leads each having a terminal which may be connected to a source of voltage which may vary, a second terminal which may be connected to a load circuit, a resistance the value of which increases rapidly as the current therethrough increases, connected in series with one of said leads, an inductance connected in series with said resistance, a photo cell the current through which increases rapidly as the voltage across the terminals thereof increases connected between said leads and a second inductance connected in series with said photo cell to which said inductances are coupled.

6. A voltage regulating circuit comprising, a pair of leads each having a terminal which may be connected to a source of voltage which may vary, and another terminal which may be connected to a load circuit, an inductive reactance, a resistance the value of which increases rapidly as the current therethrough increases connected in series with said reactance in one of said leads, a second inductive reactance, and a resistance the value of which decreases rapidly as the voltage across the terminals increases connected in series with said second inductive reactance.

7. A voltage regulating circuit comprising, a pair of leads each having a terminal which may be connected to a source of voltage which may vary, and another terminal which may be connected to a load circuit, a resistance in series with one of the leads, the value of which increases rapidly with increasing current, a first transformer winding connected in series with the source of voltage, the resistance and the load circuit, a second transformer winding coupled to the first mentioned transformer winding, said second transformer winding being connected across said pair of leads, one terminal being connected between the junction points of the first mentioned transformer winding and said resistance, said second transformer winding having in series therewith a resistance, the value of which decreases rapidly with increasing voltage.

8. A voltage regulating circuit comprising, a pair of leads each having a terminal which may be connected to a source of voltage which may vary, and another terminal which may be connected to a load circuit, a transformer having a primary winding in series with said pair of leads, said transformer having a secondary winding across which is connected a resistance the value of which increases rapidly with increasing voltage, a second transformer having a primary winding connected between said pair of leads on the load side of said first mentioned transformer, said second transformer having a secondary winding across which is connected a resistance the value of which decreases rapidly with increasing voltage.

CLARENCE W. HANSELL.