Feb. 14, 1933. T. E. FOULKE 1,897,471

REGULATOR

Filed Sept. 11, 1926

Fig. 1

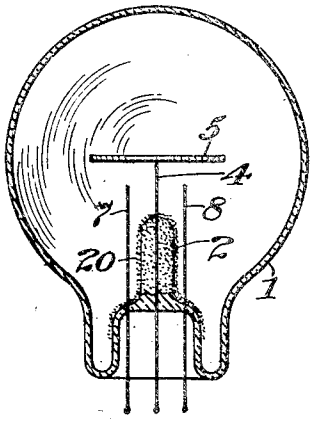


Fig. 2

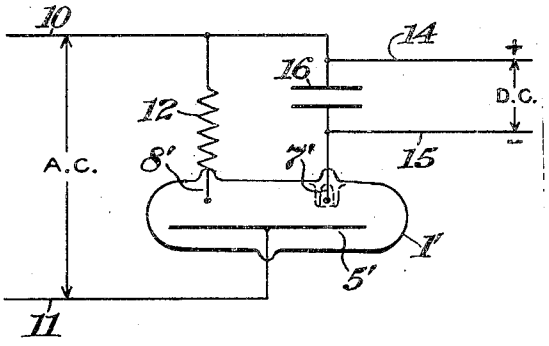


Fig. 3

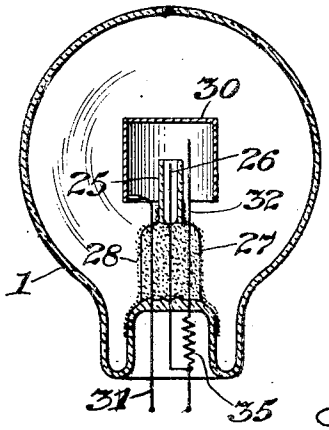


Fig. 4

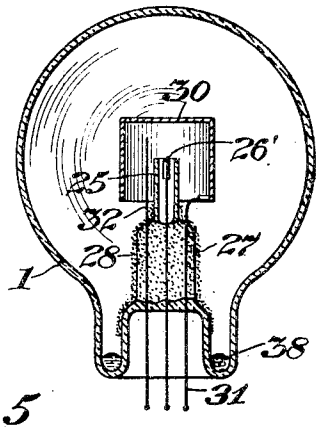
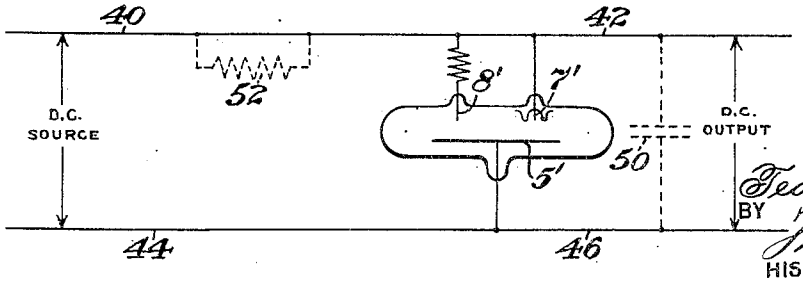


Fig. 5



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Patented Feb. 14, 1933 1,897,471

UNITED STATES PATENT OFFICE

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REGULATOR

Application filed September 11, 1926. Serial No. 134,936.

My present invention relates to electric current valves of the one way flow type and particularly to such devices in which electrodes of different areas are used for maintaining current flow by electronic discharge through a gas. The invention more particularly relates to such a device having means for facilitating commencement of current flow in one direction and for preventing current flow in the opposite direction or for limiting the flow in the opposite direction to a minimum. The invention further relates to such a device having a constant voltage characteristic between a considerable range of current flow values.

In the following description and in the claims parts will be identified by specific names for convenience, but they are intended to be as generic in their application to similar parts as the art will permit.

Various other objects and advantages of the invention will be obvious from the following particular description of forms of mechanism embodying the invention or from an inspection of the accompanying drawing; and the invention also consists in certain new and novel features of construction and combinations of parts hereinafter set forth and claimed.

In the accompanying drawing there is shown for purposes of illustration one form of valve with certain modifications thereof embodying the invention, in which

Fig. 1 is an elevational sectional view illustrating somewhat diagrammatically a current rectifying valve embodying the invention.

Fig. 2 is a diagrammatic representation of the valve of the invention connected between an alternating current supply circuit and a direct current work circuit.

Figs. 3 and 4 are vertical sectional views illustrating somewhat diagrammatically alternative embodiments of the invention, and

Fig. 5 is a diagram showing connections of the device of the invention in a direct current circuit for regulating or controlling the voltage thereof.

In Fig. 1 of the drawing is shown for illustrative purposes a valve embodying the invention comprising the sealed envelope 1 which is of glass or other suitable material and which carries on the interior thereof the stem 2 through which is sealed the lead-in 4 which in turn carries the cathode plate 5 which is of considerable area compared with the size of the bulb. Through the envelope are sealed two anodes 7 and 8 in the form of wires which terminate not far from one of the lateral surfaces of plate 5. Over the stem 2 and about the sealed-in ends of the wires 4, 7 and 8 is a coating of an easily dissociated compound such as a hydroxide, oxide, or carbonate of any of the alkali or alkaline earth metals. These metals will be designated in the claims by the term "alkaline metals." In the envelope 1 is provided a filling of gas such as krypton, helium, neon, argon or a mixture of any or all of these gases; for example, a mixture of three parts neon to one part of helium at a pressure of about 3 to 15 mm. of mercury, and preferably with about 0.25% of argon.

In Fig. 2 is shown a diagram of connections for the use of the valve of Fig. 1 in a rectifying circuit in which the mains 10 and 11 serve to connect to a source of alternating current, the cathode 5′ is connected to the lead 11, the electrode 8′ which is an auxiliary anode is connected through the resistances 12 to the main 10, and a direct current output main 14 is connected to supply main 10, the direct current output main 15 is connected to the anode 7′ and a condenser 16 is connected across direct current mains 14 and 15. A filling of a rare gas or mixture of rare gases such as is above described is supplied in the envelope 1′.

In the operation of this device upon the connection to a source of alternating current through the mains 10 and 11 current will not flow at once to anode 7′ from cathode 5′ because the characteristics of the device are so chosen that the applied voltage cannot break down the space resistance between anode 7′ and cathode 5′ when the work circuit is connected in series therebetween. However, the characteristics of the parts and elements of the circuit are so chosen that current will flow from main 11 to the cathode 5′ thence through the gas filling of the device to the

anode 8′ and thence back through the resistor 12 and alternating current main 10 whereupon the gas filling of the device will sustain an increase in conductivity due to the multiplication of the number of electrons therein through ionization by collision. Upon the ionization of the gas filling of the device and the increase in conductivity thereof to or above a given value discharge will take place from cathode 5′ to anode 7′ when the said given value is such that the combined impedance of the work circuit and the space resistance between electrodes 5′ and 7′ is less than the combined impedance of resistor 12 and space resistance between electrodes 5′ and 8′, and a rectified current flow will be maintained between the main anode 7′ and cathode 5′. Return flow to cathode 5′ is maintained at a minimum which is practically nil because the small area of the anodes limit the number of electrons which can be emitted therefrom in a given unit of time. To accentuate this differential in current flow whereby the return flow is kept practically nil while the flow from the cathode to the anode is increased the cathode or a coating over the cathode is formed of such a metal that positive ion bombardment will free a comparatively large number of electrons from this surface for a given unit of current flow.

For producing a coating of a metal on a cathode of the same or another metal there is provided over a portion of the surface within the envelope a coating of an oxide or hydroxide of a metal of low atomic weight such as, lithium, calcium, magnesium, sodium, potassium or the like. Such an alkaline coating 20 is shown in Fig. 1 as being placed on the stem 2 about the electrode lead-ins of the device. Metal from the oxide or hydroxide of the coating is transferred to the surface of the cathode 5 by maintaining a discharge between the electrodes of the device at a high enough energy to cause molecular dissociation of the alkaline compounds by electron bombardment thereof and subsequently to sputter the reduced metal by positive ion bombardment onto all parts contained within the envelope. A part of the sputtered metal will reach the surface of the cathode and lodge there. The sputtering discharge is maintained until a coating is obtained to give the device desired current operating characteristics. It is of course to be understood that the device can be put into actual operation before sputtering is started or completed and the positive ion bombardment occurring during the operation of the device utilized to sputter the metal onto the cathode.

An alternative and for some purposes preferable method is to form the metal coating on the cathode with an intermediate layer of a chemical compound which is easily dissociated. Such a compound is preferably one of the metal of the "activating" layer and is produced by painting onto the cathode a solution or light sludge of one of the compounds more or less specifically mentioned above. This paint is dried and is bombarded in the manner above described to dissociate the outer layer thereof and produce over the layer of the metal compound a layer of the metal about a molecule deep. An active coating of this type on the cathode will have a long life because should the metal of the outer layer be sputtered off it will be quickly replaced by subsequent dissociation of the compound exposed by the sputtering.

As noted above current will flow in comparatively large quantities from the cathode to the anode while flow in the opposite direction will be practically nil. This is due as explained, to the fact that under positive ion bombardment the cathode with the alkaline metal surface is a prolific source of electrons while the construction of the anode is such that little or no electron emission occurs therefrom. After the space resistance between the electrodes has been overcome the voltage of the device will remain practically constant between comparatively wide limits of current flow values because a slight increase in positive ion bombardment of the cathode surface will greatly increase electron emission from the cathode. The emission of electrons per positive ion may not exceed more than one for every ten but the electron emitted can increase by ionization by collision so that by the time the anode is reached the original one is increased to one hundred electrons in a typical low voltage operating tube of this type.

To further maintain the return flow practically nil while maintaining the direct or rectified flow a shield of insulating material or an insulated metal shield is placed partially surrounding the anode. This shield is spaced apart from the anode at a short distance and extends parallel thereto throughout its length in the direction of the line of potential difference in the device. The shield acquires a negative charge from the electron bombardment thereof and when upon voltage reversal the "anode" becomes the "negative electrode" this negative charge neutralizes the charge at the "anode" throughout the length of the shield so that electrons will not have potential difference to move them from the "anode". As a consequence substantially only those residual electrons which happen to be in the space between the shield and the "cathode" will be moved and accelerated toward the "cathode". As a consequence practically no current will flow from the "cathode" to the "anode". Such a shield is illustrated in Figs. 2, 3 and 4.

In Fig. 3, which illustrates a preferred form of the invention, such a shield is shown in the form of a glass tube 25 positioned about anode 26 and fused to the seal-in stem 27.

The said tube 25 has its upper end open to provide current flow passageway between the anode 26 and the cathode 30. This cathode 30 is in the form of a hollow cylinder positioned about the anode 26 and shield 25 with the upper end thereof closed to increase the discharge area. Lead-in 31 sealed through stem 27 serves to support cathode 30. An auxiliary anode 32 sealed through stem 27 and extending to or into cylinder 30 is connected to the main anode 26 through the resistor 35. An alkaline coating 28 is provided on stem 27 and a filling of a suitable gas is provided in the envelope 1.

The valve of Fig. 4 is similar to that of Fig. 3 except that the main and auxiliary anodes are not connected and the series resistor for the auxiliary is not shown, and further that the terminal portion of anode 26' is shown as having an increased or enlarged area. A small quantity of mercury 38 is also enclosed within the envelope 1.

In the circuit shown in Fig. 5 the device is used as a voltage regulator for direct current. The electrodes 7' and 8' are both connected to an input main 40 and an output main 42. The cathode 5' is connected to the other input main 44 and the corresponding output main 46, and a condenser 50 is connected across the output mains 42 and 46. Due to the characteristic of the device by virtue of which the current increases exponentially with the voltage, a very small change in voltage corresponds with a marked change in current flowing therethrough thereby tending to stabilize ordinary voltage fluctuations and keep them between narrow limits in a given circuit. The use of the condenser emphasizes this action and is of use particularly in circuits in which the voltage has marked variations. In circuits in which the voltage varies comparatively slightly the condenser is when desired not used, in which case a resistance or impedance 52 is preferably used in series in the input line.

While I have shown and described and have pointed out in the annexed claims certain novel features of the invention, it will be understood that various omissions, substitutions and changes in the forms and details of the device illustrated and in its operation may be made by those skilled in the art without departing from the spirit of the invention.

I claim:

1. An electrical current valve of the one way flow type, comprising a sealed envelope having therein a gaseous atmosphere, an electrode of large area, two electrodes of small area, and a shield having a small opening therein about one only of said electrodes, and a getter of alkaline oxide in a position facing the surface of said electrode of large area.

2. An electrical current valve of the one way flow type, comprising a sealed envelope having therein a gaseous atmosphere, an electrode of large area, another electrode of small area and a getter of alkaline oxide in a position apart from either of said electrodes and facing the surface of said electrode of large area.

3. An electrical current valve of the one way flow type, comprising a sealed envelope having therein a gaseous atmosphere, a stem, an electrode of large area, two electrodes of small area, and a shield having a small opening therein about one only of said electrodes, and a getter of lithium oxide on said stem facing the surface of said electrode of large area.

4. An electrical current valve of the one way flow type, comprising a sealed envelope, a gaseous atmosphere therein, a negative electrode of large area, a positive electrode of small area, a shield having a small opening therein about the latter electrode, and another positive electrode connected through a resistance to the first named positive electrode and positioned between said negative electrode and said shield.

Signed at Hoboken in the county of Hudson and State of New Jersey this 26th day of August A. D. 1926.

TED E. FOULKE.