Dec. 12, 1933. D. D. KNOWLES 1,939,063

SHIELD ANODE GRID GLOW TUBE

Filed Sept. 22, 1931

Fig. 1.

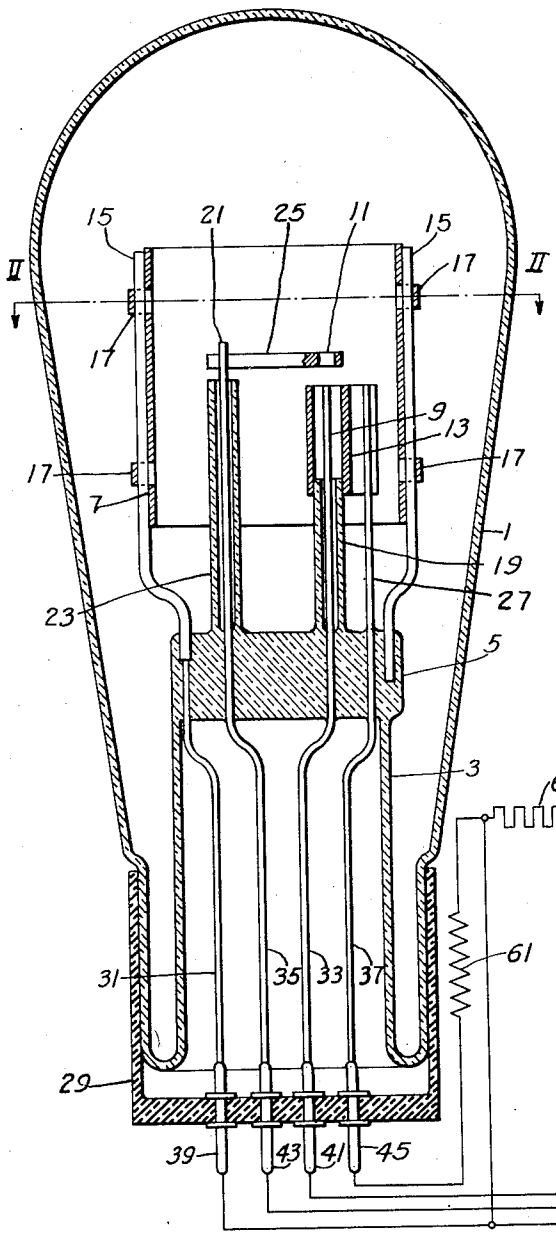
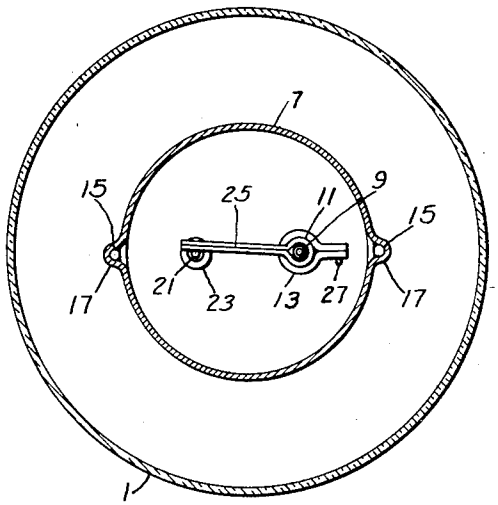
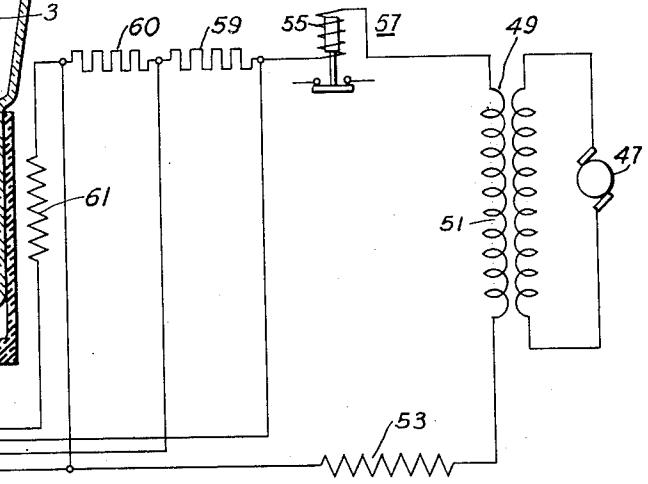



Fig. 2.




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Patented Dec. 12, 1933

1,939,063

# UNITED STATES PATENT OFFICE

1,939,063

## SHIELD ANODE GRID GLOW TUBE

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Application September 22, 1931
Serial No. 564,267

9 Claims. (Cl. 250—27.5)

My invention relates to electric-discharge devices and has particular relation to gas-filled electric-discharge devices, particularly of the plural electrode type.

An electric discharge device of the gas-filled type ordinarily comprises a cathode of a predetermined type, an anode properly disposed relative to the cathode and a control electrode preferably disposed adjacent to the anode. Specifically, in devices of the prior art which are related to the apparatus constituting the subject of the present invention, the cathode is a cylindrical shell, the anode is a wire projecting into the region bounded by the shell and the control electrode is a hollow cap having an opening in its base. The control electrode is displaced from the anode by a distance substantially equivalent to the mean path of an electron in the gaseous medium in which the electrodes are immersed.

Potentials are ordinarily impressed between the cathode and the anode, and between the control electrode and the anode. When the latter potential attains a predetermined value relative to the former potential, a disruptive discharge takes place between the principal electrodes of the device and the device is said to be in an ionized or an energized condition.

It is apparent that the condition of the electric discharge device is, in all cases, dependent on the relation between the potentials between the electrodes. As the potential of the control electrode approaches the potential of the anode, the electro-motive force between the cathode and the anode which is required to produce an energized condition in the electric discharge device decreases. Consequently, if a short circuit is established between the control electrode and the anode, the electric discharge device has a property of an ordinary glow device and a comparatively small potential is required between the cathode and the anode to produce a discharge.

On the other hand, when the device is in energized condition, sputtering, to a certain degree, takes place at the anode. Moreover, the sputtered particles as they are projected into the region around the electrode become charged, and are drawn to the nearest electrode, that is to say, to the control electrode. When the tube has operated for a certain time, a string of sputtered metal is built up between the control electrode and the anode, short circuiting the control electrode, and reverting the device to a condition in which its state is not dependent on the electrical condition of the control electrode.

In electric discharge devices of the prior art, the above described condition has existed in the past and has given rise to a number of difficulties in certain of the fields to which the electric discharge device was applied. Thus the electric discharge device was applied to the control of the fuel-feeding elements of fuel burners. In this application, the control electrode is associated with the fuel of the fuel burner, and when a flame is ignited in the burner, the electric discharge device becomes energized by reason of the ionizing action of the flame. The current through the electric discharge device energizes a relay, which, in turn, produces the necessary changes that render the fuel supply system properly operative.

It is to be noted that in this application of the electric discharge device the continuous control of the condition of the device is a matter of extreme importance. If the flame in the burners is choked out for one reason or another it is highly desirable that the fuel supply should be shut off. This object can only be accomplished automatically if the control electrode retains its controlling function with regard to the electric discharge device. As a result, the short circuiting of the control electrode by the sputtered metal as has been set forth hereinabove is, in this application of the electric discharge device, rather aggravating.

Another matter which is of extreme importance with regard to the electric discharge device of the type described herein is a matter of the life of the device. It is apparent that the reliability and the usefulness of the device is dependent to a great extent on the length of its life. A device which has a life of only a few hours can hardly be applied to fuel burner control, for example, with any degree of success. One difficulty with the electric discharge device in the form in which it exists in the prior art is that its life is decreased by reason of the sputtering of the metal from the anode to the control electrode and the consequent short-circuiting of the electrodes.

Finally, in experimenting with apparatus of the type described herein, I have noted that the operating characteristic of the electric discharge devices of the type constructed according to the teachings of the prior art is comparatively unstable. In making life tests of these devices, I have noted that under certain circumstances the unstable characteristic is manifested by a flicker of the glow which is produced in the device when it is energized. On further investigating the

flicker, I have found that it is produced by reason of the electrical charge which accumulates on the insulators that is associated in particular with the wire electrodes such as the anode.

In the electric discharge devices as they are most generally constructed, certain of the leads project from the press through a plurality of insulating sleeves which are commonly integral with the press. By reason of the presence of the sleeves, the leakage path between the various leads which are necessarily at different potentials is considerably increased and, consequently, deleterious results occasioned by leakage are minimized. However, I have found that the insulating sleeves become charged and that it is the charge on the sleeves which produces the instability in the characteristic of the device as it exists in the prior art.

It is accordingly an object of my invention to provide a plural-electrode electric discharge device that shall have a stable characteristic.

Another object of my invention is to provide a plural-electrode electric discharge device that shall have a comparatively long life.

A further object of my invention is to provide a plural-electrode electric discharge device wherein the metal sputtered from any of the electrodes when the device is energized shall be deflected in a predetermined direction.

A still further object of my invention is to provide a plural-electrode electric discharge device of the type incorporating a control electrode that shall fail to pass current when it has been rendered irresponsive to the condition of the control electrode.

More specifically stated, it is an object of my invention to provide for an electric discharge device of the type incorporating attenuated electrodes and control electrodes disposed adjacent to the attenuated electrodes, a shield for deflecting the sputtered metal from the attenuated electrodes away from the control electrodes.

Another specific object of my invention is to provide for an electric discharge device of the type incorporating insulating sleeves for increasing the leakage path between the electrode leads of different potential, a device for preventing the electrical charge from accumulating on the sleeves.

A further specific object of my invention is to provide for an electric discharge device of a type including a control electrode, a contrivance for preventing the other electrodes of the electric discharge device from becoming connected to the control electrode by reason of the metal sputtered from the electrodes during the energized condition of the control electrode.

More concisely stated, it is an object of my invention to provide a plural-electrode electric discharge device, of a type incorporating a control electrode, that shall have a stable characteristic, and a long life and that shall become deenergized when it fails.

According to my invention I provide a shield for the electrodes particularly operative in producing the difficulties which have been set forth hereinabove. In a specific embodiment of my invention, the cathode is a cylindrical shell of compartively large diameter; the anode is a wire projecting into the region of the electrode through a glass sleeve which, in turn, projects from the press; and the control electrode is a metallic ring disposed above the anode and secured to a rod projecting from the press through a glass sleeve. The contrivance which I have provided for eliminating the difficulties discussed hereinabove comprises a metallic shell enclosing the anode and supported from the press in a manner similar to that in which the control electrode is supported.

In its most common use, the shielding electrode of the specific embodiment of my invention described herein is connected to the cathode through a resistor. By reason of the difference in potential between the shielding electrode and the anode, the particles sputtered from the anode are drawn to the shielding electrode and are deflected away from the control electrode.

Moreover, in spite of the fact that to prevent a discharge from taking place between the shielding electrode and the anode, the two electrodes are displaced from each other by a distance of the order of a mean free path of an electron from the gaseous medium in which the electrodes are immersed; a comparatively large volume of space ordinarily exists between the anode and the shielding electrode. In consequence of the comparatively large volume of space, the particles sputtered from the anode may ordinarily take a number of paths to flow to the shielding electrode. Hence, the time required for a short circuiting string of sputtered metal to be established between the shielding electrode and the anode is considerably increased over the period which would be required for the control electrode in devices of the prior art to become short circuited at the anode.

When a connection is established between the anode and the shielding electrode, the anode and cathode are short-circuited through the impedances that connect the shield to the cathode. When the short circuit occurs the electric discharge device is prevented from becoming energized and if it is energized at the time, it becomes immediately deenergized. The impedance between the shield and the anode may be made so great that the current which now flows through the principal circuit of the system incorporating the device is too small to energize the relay which is commonly associated with the circuit.

It should be noted however that in general the large impedance is not essential. Customarily, the device is operated from an alternating current source and the relays utilized in the principal circuit are of the direct current type which are normally responsive to the rectified current passing through the tube. However when the connection is established between the shield and the anode an ordinary ohmic circuit is provided for the current and it is no longer rectified. The direct current relays are not responsive to the alternating current which now passes through the circuit and the system loses its controlling effect.

On the other hand it may happen that a sputtered string of metal connects the control electrode to the shield. In such a case the tube cannot become energized since the control electrode is at cathode potential.

Finally, the shielding electrode is ordinarily in contact with the insulating sleeve associated with the electrode for which it is provided. Hence, any charge deposited on the insulating sleeve is conducted away by the shielding electrode. One of the principal causes of instability of the electric discharge device is thus removed.

The novel features that I consider characteristic of my invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and its

method of operation, together with additional objects and advantages thereof will best be understood from the following description of a specific embodiment when read in connection with the accompanying drawing in which:

Figure 1 is a view, partly in section and partly diagrammatic, showing the structure of the preferred embodiment of my invention, and a preferred circuit that is commonly utilized in connection therewith, and

Fig. 2 is a view in section, taken along the line II—II of Fig. 1.

The apparatus shown in the drawing comprises an envelope 1 of insulating material such as glass, which has been completely evacuated and preferably refilled with gas at a pressure of from several microns to several millimeters of mercury. The gas enclosed in the envelope may be of any desired type but is preferably of an inert type, or at least of a type incapable of coacting with the metals which may be disposed within the envelope. I have found that in certain modifications of my invention the gas may be mercury vapor, and, to provide the vapor, my practice has been to deposit a small globule of mercury in the container.

The insulating envelope 1 is equipped with a reentrant stem 3 and a press 5 is molded integral with the stem 3. The electrodes 7, 9, 11 and 13 of the device project from the press 5.

The cathode 7 is a metallic cylindrical shell and it is secured to a plurality of supporting rods 15 which project from the press 5 and which pass through a plurality of eyelets 17 formed in the shell. The anode 9 is a rod which projects through an insulating sleeve 19 molded integral with the press 5 and the control electrode 11 is a ring secured to a rod 21 projecting through a second insulating sleeve 23 that is also molded integral with the press 5.

As can be seen from Fig. 2, the ring 11 is formed by welding together two metallic strips 25 of proper configuration. The ring 9 may of course be formed in other ways and I do not wish to restrict myself to a control electrode of the specific structure shown. The strips 25 are welded to the rod 21.

The auxiliary electrode 13 provided for shielding the anode 9 is a tube formed in a manner similar to that in which the control electrode 11 is formed. It is secured to a rod 27 projecting from the press 5 and is disposed substantially coaxial with the anode 9 and with the sleeve 19 enclosing the anode.

To prevent a discharge from taking place between the anode 9 and the control electrode 11 or between the anode and the shielding electrode 13, the anode 9 is ordinarily disposed at a distance away from the electrodes 11 and 13 that is of the order of the mean free path of electrons in the gaseous medium. By so displacing the electrodes in the medium, ionization in the region between the anode 9 and its associated electrodes 11 and 13 is prevented, and thus it becomes possible to impress a comparatively large potential between the anode 9 and its associated electrodes without producing a discharge therebetween.

A base 29 of proper structure is secured to the stem 3 of the envelope 1. A plurality of leads 31, 33, 35 and 37 properly welded in the press 5 are connected to the pins 39, 41, 43 and 45 of the base 29. In practice the pins 39, 41, 43 and 45 engage the contact elements of a socket (not shown) and are thus properly connected in an electrical circuit. For purposes of clarity the socket has been omitted in the illustration of my invention.

The circuit which is commonly associated with an electric discharge device of the type described herein is symbolically shown in Fig. 1. It comprises a source of supply of electrical energy 47 and a transformer 49, the secondary 51 of which is connected between the anode 9 and the cathode 7 of the electric discharge device through a current-limiting impedance 53 and the coil 55 of relay 57 of any desirable structure.

Suitable impedances 59 and 60 are connected between the control electrode 11 and the anode 9 and between the control electrode and the cathode 7. The impedances 59 and 60 may take a form that varies in accordance with the system to which the electric discharge device is applied. Thus, in the various applications of the electric discharge device which have come to my attention, one or the other of the impedances 59 and 60 takes the form of a photo-electric cell, a flame, a transformer, the primary of which is associated with a transmission line in which variations are to be detected, a capacitor, such, for example, as that formed between the body of a burglar and a safe which he is about to open, a high resistor, which may be formed in the same connection when the burglar touches the safe, and other impedances of the same nature.

One or the other of the impedances 59 and 60 associated with the control electrode 11 may also be an ordinary variable impedance such as a resistor, a capacitor or an inductor. By varying such an impedance, the relative potentials of the electrodes of the electric discharge device at which the device becomes energized may be varied.

The shielding electrode 13 of the device is connected to the cathode 7 of the device, preferably through a resistor 61. As has been pointed out hereinabove, a difference in potential is thus applied between the shielding electrode 13 and the anode 9 of the electric discharge device and the particles sputtered from the anode 9 are thus prevented from impinging on the control electrode 11 and from short circuiting the control electrode. Moreover, a leakage path is thus provided for the charge accumulated on the insulating sleeve 19 associated with the anode 9.

The operation of a relay system incorporating an electric discharge device constructed according to my invention is apparent from the drawing. When the impedances 59 and 60 associated with the control electrode 11 of the electric discharge device attain the proper values, the potentials between the electrodes 7, 9 and 11 of the electric discharge device become so related that the device. Since the current passes through the between the cathode 7 and the anode 9 of the device. Since the current passes through the exciting coil 55 of the relay 57, the relay becomes energized and the proper circuits are closed or opened thereby.

On the other hand when a string of sputtered metal connects the anode 9 to the shield 13 a circuit is established from one terminal of the secondary 51 through the impedance 53, the impedance 61, the lead 37, the shield 13, the sputtered film, the anode 9, the lead 33, the exciting coil 55 of the relay 57 to the other terminal of the secondary 49. As has been explained hereinabove the current now traversing the coil 55 is too small to energize the relay 57, if the latter is of the alternating current type, by reason of

the magnitude of the impedance 61. On the other hand the current now passing through the circuit is of the alternating current type and a relay 57 of the direct current type cannot be energized thereby.

If a sputtered film connects the shield 13 to the control electrode 11 the control electrode attains the potential of the cathode and the device is prevented from being energized.

As shown and described hereinabove, my invention has been specifically applied to a cold cathode electric discharge device of the gaseous type. It is to be noted that my invention may also be applied to electric discharge devices of the hot cathode type, of the vacuum type or of the mercury vapor type.

Again, it is well to keep in mind that while in the embodiment of my invention described herein, the shielding electrode 13 has been illustrated as associated with the anode 9, it may equally as well be associated with other electrodes of the device if the necessity therefor arises. Thus, if necessary, an electrode may be provided to eliminate the charge which may accumulate on the insulating sleeve associated with the rod that supports the control electrode. Moreover, if the control electrode is found to sputter, a suitable shielding electrode may be provided to insure that the sputtering from the control electrode shall be in the proper direction.

It should also be noted that in a number of applications of the cold cathode electric discharge device, the cathode may be of an attenuated structure such as is the anode in the present device. In such a case, deleterious sputtering may, to a certain extent, exist at the cathode and the remedy provided for the sputtering, according to my invention, may be applied to the cathode, if the necessity therefor arises.

It is apparent also that the shielding electrode need not necessarily be connected to the cathode but may be connected in such manner that it has a predetermined potential relative to the other electrodes of the electric discharge device. I have found that a highly satisfactory system is produced by connecting the shielding electrode to the cathode. It is altogether possible that an equally suitable system may be produced by connecting the shielding electrode to a point of potential other than the cathode.

Finally it should be noted that I do not intend to restrict myself to the specific structure of the device shown herein. Other types of electric discharge devices are well known in the art and my invention is equally as well applicable to the structure of these devices. The control electrode while it is conveniently and with advantage given the configuration of a ring may be a screen or a simple wire or may have any other desired structure. In a similar manner the other electrodes may be modified to apply to a particular occasion.

Although I have shown and described certain specific embodiments of my invention, I am fully aware that many modifications thereof are possible. My invention, therefore, is not to be restricted except insofar as is necessitated by the prior art and by the spirit of the appended claims.

I claim as my invention:

1. In an electric discharge device of the type which comprises a plurality of principal electrodes and a control electrode juxtaposed to certain of said principal electrodes, an electrode adapted to have a potential applied thereto for deflecting the sputtered particles from said last named principal electrodes away from said control electrode.

2. In an electric discharge device of the type which comprises an anode, a cathode, and a control electrode, an electrode adapted to have a potential applied thereto for deflecting the sputtered particles from said anode out of the region of said control electrode.

3. In an electric discharge device of the type which comprises an anode, a cathode, and a control electrode, juxtaposed to said anode, an electrode adapted to have a potential applied thereto associated with said anode for deflecting the sputtered particles from said anode out of the region of said control electrode.

4. In an electric discharge device of the type which comprises an anode, a cathode, and a control electrode, an additional electrode for deflecting the particles sputtered from said anode away from the region of said control electrode.

5. An electric discharge device comprising a gaseous medium, a purality of principal electrodes immersed in said medium, one of said principal electrodes having the form of an attenuated cylinder, a shielding shell associated with said cylinder and displaced therefrom a distance substantially equivalent to the mean-free-path of an electron in said gaseous medium and a ring-shaped control electrode associated with said cylindrical electrode and displaced from said shell and said cylindrical electrodes by a distance substantially equivalent to the mean-free-path of an electron in said gaseous medium.

6. In an electric discharge device of the type which comprises a plurality of principal electrodes, one of said electrodes having substantially the form of an attenuated cylinder, tube shaped shielding means for said cylindrical electrode and a ring-shaped control electrode juxtaposed to said cylindrical electrode.

7. In an electric discharge device of the type which comprises a cathode of comparatively large surface area and an anode of comparatively small surface area, a shielding electrode associated with said anode, said shielding electrode having the form of a shell, and a control electrode associated with said anode, said control electrode having the form of a ring.

8. An electric discharge device comprising a gaseous medium, a plurality of principal electrodes immersed in said medium, shielding means associated with at least one of said principal electrodes, and displaced therefrom a distance substantially equivalent to the mean-free-path of an electron in said gaseous medium and a control electrode associated with said principal electrode and displaced from said shielding means and from said electrode by a distance substantially equivalent to the mean-free-path of an electron in said gaseous medium.

9. An electric discharge device comprising a shell, a wire insulated from said shell and projecting into the region enclosed thereby, a second shell of diameter smaller than said first-named shell and enclosing said wire, a second wire displaced from said first-named wire and projecting into the region enclosed by said first-named shell and a ring secured to said second-named wire and juxtaposed to said first-named wire and said second-named shell.

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