Aug. 27, 1940. C. M. SLACK ET AL 2,212,849

HIGH VOLTAGE GASEOUS RECTIFIER

Filed Nov. 25, 1938 2 Sheets-Sheet 1

Fig. 1.

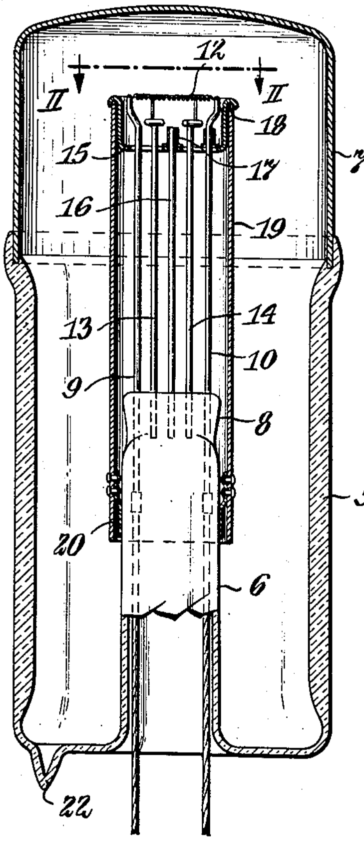


Fig. 3.

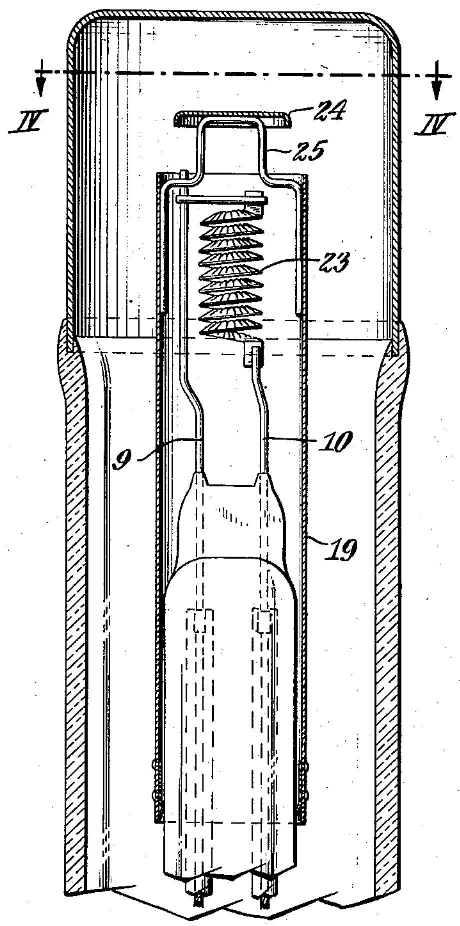
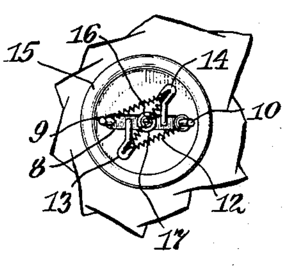


Fig. 2.



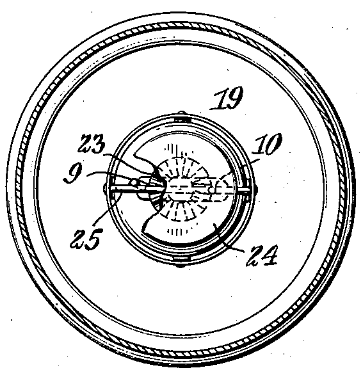


Fig. 4.

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Fig. 5.

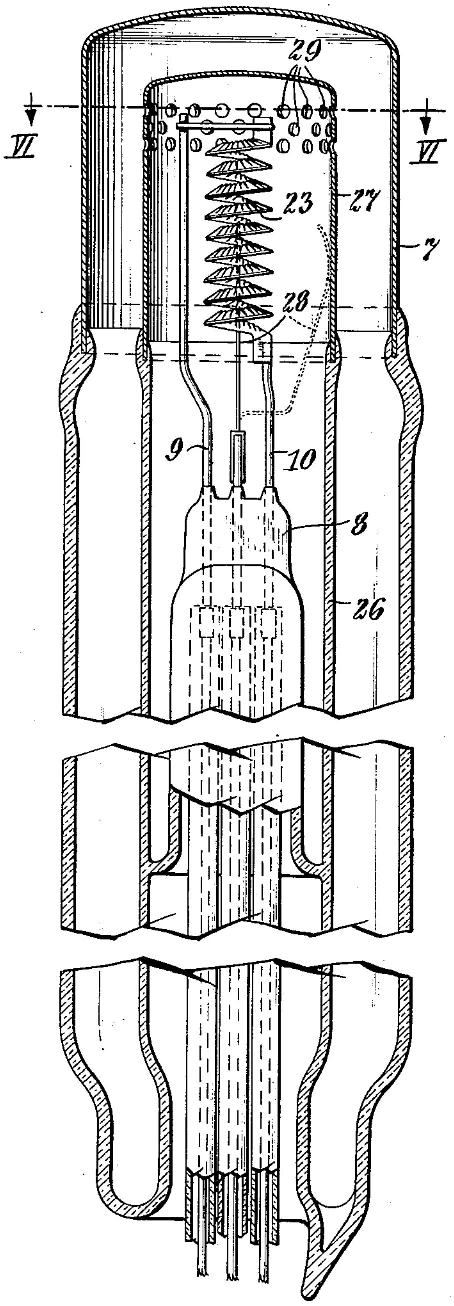


Fig. 6.

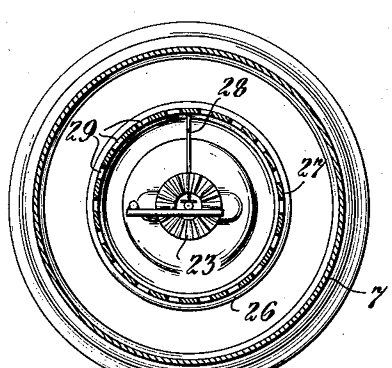
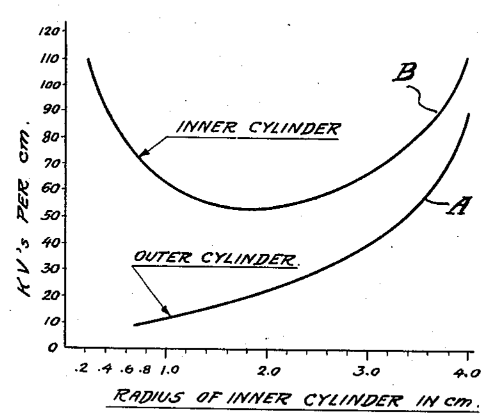


Fig. 7.



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UNITED STATES PATENT OFFICE

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HIGH VOLTAGE GASEOUS RECTIFIER

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Application November 25, 1938, Serial No. 242,210

8 Claims. (Cl. 250—27.5)

The present invention relates to discharge devices and more particularly to a gaseous discharge device capable of transmitting relatively large currents and withstanding a high inverse potential.

Gaseous discharge devices are now employed extensively in the art as rectifiers, inverters and control devices; but although capable of passing relatively large currents, they have been restricted to voltages within the range of a few thousand volts. Efforts have also been made to construct high potential gaseous discharge devices employing mercury vapor as the discharge supporting medium and in some instances such mercury vapor devices when used as rectifiers are operable at voltages as high as 20,000 volts.

One type of high potential gaseous discharge device at present known to the art is what may be termed a multi-section tube which employs mercury as the discharge supporting medium, but the disadvantage of such a device resides in its size, which makes it cumbersome and expensive to construct inasmuch as the voltage has to be distributed between the various parts.

It has also been suggested to construct a single section high potential gaseous discharge device wherein the peak voltage applied between the electrodes is alleged to be of the order of 100,000 volts and in which mercury vapor is utilized as the discharge supporting medium. The recognized difficulty with devices of this character has been the inherent phenomenon of autoelectronic emission. This phenomenon has heretofore been attributed solely to the heating of the anode by bombardment, during the half wave of the alternating current cycle when the anode is positive, and the potential gradient at the anode. During the reverse half wave when the anode is impressed with a high negative polarity, electrons are emitted due to the intensive field at the anode, which must be prevented from impinging on the glass envelope, cathode, or other insulated parts of the device. Otherwise, deleterious results ensue such as disruption of the cathode, liberation of the occluded gases, or puncture of the envelope. To prevent the effect of autoelectronic emission in which the electrons are emitted normal to the surface, it has heretofore been the practice to so position an electrode of the device that the autoelectronic electrons are intercepted before impinging upon the glass envelope or other insulated parts of the device. A further suggestion has been that of giving the anode surface such a contour or configuration that the electrostatic field at certain points is altered, thereby precluding autoelectronic emission at these points. This field intensity is, however, independent of the nature of the gaseous medium and its pressure and is equally applicable to high vacuum devices as to gaseous discharge devices.

Actual tests made on high potential gaseous discharge devices wherein the effect of autoelectronic emission is reduced to a minimum in the manner above noted are definitely limited in maximum voltage which can be impressed upon the electrodes without erratic performance, particularly when operating as a rectifier, which maximum voltages have actually been found to be materially less than 100,000 volts. Heretofore autoelectronic emission, as before noted, has been attributed solely to field emission at the anode; but in addition to the field at the anode contributing largely to autoelectronic emission, there are other phenomena which contribute to such emission. For example, autoelectronic emission may result from the impinging of gamma rays or cosmic rays upon the anode of the tube. These being so few in number may be ignored in vacuum devices. In gas filled high voltage devices, definite structure must be provided, as here disclosed, to prevent these few autoelectrons from building up thru ionization to a destructive discharge commonly called "flash back" in the art. The same conditions hold true for positive ion bombardment of the anode with subsequent emission of electrons whether the positive ions have their origin at the cathode or within the gas.

In so far as we are aware, no high potential gaseous discharge device has been constructed wherein the inherent phenomena of autoelectronic emission is substantially eliminated and wherein consideration has been given to the fact that such occurs by all of the phenomena above noted. On the contrary, in the construction of prior art, high potential gaseous discharge devices, consideration has been given only to the inherent autoelectronic emission due to the field effect and, in lieu of eliminating such emission, the effect thereof has been compensated for in some manner. We have found that by substantially eliminating autoelectronic emission when caused by all of the above noted phenomena we can construct and operate a gaseous discharge device at voltages far in excess of 100,000 volts, using either a metallic vapor or an inert gas as the discharge supporting medium.

For example, by employing an anode of high work function having a smooth surface and free of all edges and points having small radii of curvature, concentration of an electrostatic field at the anode is prevented which thus contributes to the elimination of autoelectronic emission. In addition, the pressure of the gaseous medium within the envelope is maintained within a definite range so that the mean free path of electrons in the gas is not too small.

To still further minimize autoelectronic emission, the electrodes are formed as concentric cylinders to maintain minimum potential gradients at their respective surfaces. Coupled with the above, the spacing of the electrodes is made relatively small so that even in the event inappreciable autoelectronic emission occurs, the actual path of electron travel between the electrodes is always below or of the same magnitude as the mean free path of the electrons in the gas, thus minimizing collision with gas molecules and preventing positive ion bombardment from reaching a value where "flash back" occurs when the anode is subjected to a high negative potential.

It is accordingly an object of the present invention to provide a high potential gaseous discharge device capable of passing or blocking voltages in excess of 100,000 volts and wherein either a metallic vapor or an inert gas may be utilized with equal facility as the discharge supporting medium.

Another object of the present invention is the provision of a high potential gaseous discharge device wherein autoelectronic emission at the anode is substantially eliminated.

Another object of the present invention is the provision of a high potential gaseous rectifier device capable of withstanding a high potential in excess of 100,000 volts in the inverse or no-load portion of the alternating current cycle which passes relatively high current with a low voltage drop across the device in the useful or loaded portion of the cycle.

Another object of the present invention is the provision of a high potential gaseous inverter or interrupter tube capable of preventing the flow of current at relatively high voltage and wherein either mercury vapor or an inert gas is utilized as the discharge supporting medium.

A further object of the present invention is the provision of a high potential gaseous discharge device wherein the electrodes are so constructed and spaced within critical limits that autoelectronic emission is substantially eliminated, thus enabling operation of the device for long periods of time at voltages in excess of 100,000 volts.

Still further objects of the present invention will become obvious to those skilled in the art by reference to the accompanying drawings wherein:

Fig. 1 is a cross-sectional view of one form of high potential gaseous discharge device which the present invention may take for rectifying alternating current and wherein a filamentary cathode is utilized;

Fig. 2 is a cross-sectional view taken on the line II—II of Fig. 1;

Fig. 3 is a cross-sectional view of another modification of a high potential gaseous rectifier which the present invention may take and wherein a cathode in the form of a corrugated edgewise-wound helical ribbon is utilized;

Fig. 4 is a cross-sectional view taken on the line IV—IV of Fig. 3;

Fig. 5 is a cross-sectional view of a high potential gaseous inverter or interrupter tube constructed in accordance with the present invention;

Fig. 6 is a cross-sectional view taken on the line VI—VI of Fig. 5, and

Fig. 7 is a graphic illustration showing the relationship of potential gradient on outer cylindrical electrode and inner cylindrical electrode for a given voltage and radius of outer electrode.

Referring now to the drawings in detail, we have shown in Fig. 1 a high potential gaseous rectifier comprising a vitreous envelope 5 having a reentrant stem 6. Sealed to the envelope 5 is a metal cup 7 which constitutes the anode electrode of the device and forms a closure member for the envelope. In the employment of a device as shown in Fig. 1 as a rectifier tube it is essential that it be capable of withstanding a high potential in the inverse or no-load portion of the alternating current cycle and passing current with a relatively low voltage drop across the tube in the useful or loaded portion of the cycle.

As previously noted, one of the inherent disadvantages of high potential gaseous rectifiers has heretofore been that of autoelectronic emission, which phenomenon results from too intense fields at the anode or the combination of an intense field and a low work function anode material enabling the passage of inverse current. In order to substantially eliminate autoelectronic emission, according to the present invention the anode 7 is made of a high work function material. One such material we have found to be admirably suited for this purpose is an iron-base alloy containing cobalt and nickel, as shown and described in the patents to Howard Scott, #1,942,260, issued January 2, 1934, and #2,062,335, issued December 1, 1936, and known under the trade name of "Kovar," which alloy can be readily sealed to the vitreous envelope 5.

As shown in the several figures, the anode 7 is of cylindrical form and sealed to the envelope 5, thus forming an integral part of the tube wall. The edge of the anode is protected by the glass seal for a distance of approximately ⅛ of an inch so that autoelectronic emission due to intense field concentration at this point is eliminated.

To accomplish this it is essential that the glass seal completely covers the edge of the anode and at the same time does not extend too far inside the anode, otherwise internal puncture through the glass occurs. In addition, the inner surface of the anode is smooth and free of all edges and points having small radii of curvature, which prevents the formation of field concentration otherwise occurring at such points, and since the edge which has a sharp curvature is insulated by the vitreous envelope, autoelectronic emission is eliminated thereat even under high electrical stress.

The reentrant stem 6 has sealed into the press portion 8 thereof a pair of leading-in and supporting rods 9 and 10 which are connected to the extremities of a filamentary cathode 12 of tungsten or other refractory metal. As will be seen from Fig. 2, this latter electrode is of a substantially N-shape configuration and at its intermediate points is supported by a further pair of supporting rods 13 and 14 sealed into the press 8.

The filamentary cathode 12 is disposed within a metallic cup 15 of suitable refractory metal, such as molybdenum, nickel, "Kovar," or the like, which is supported by a further supporting rod 16 sealed into the press 8 and connected to the cathode by a bushing 17. The periphery of this cup 15 is rolled to form a flanged recess 18. To protect the leading-in and supporting rods as well as to assist in supporting the cup 15, a metallic shield 19, which may be of the same material as the cup 15, is supported by a band 20 surrounding the reentrant stem 8 with its upper extremity seating in the flange recess 18.

This shield 19 is thus coaxially located with respect to the anode and so proportioned relative to the latter which, as shown, constitutes an outer concentric cylinder, as to assist in keeping low the electrostatic field or potential gradient at the anode. Inasmuch as the shield 19 surrounds the reentrant stem 6 and is connected thereto, a discharge from any of the leading-in and supporting rods 9, 10, 13, 14, and 16 is prevented and the reentrant stem is protected from any bombardment as well as from excessive heat of the filament, which prevents or minimizes sputtering of the filament. Moreover, this complete shielding thus equalizes the spacing between parts of opposite instantaneous polarity so that the electrons in general follow the shortest path between such parts, which we have found is one of the salient features that contributes to the high operating voltages possible with our device.

It is also essential that the spacing between the cathode 12 (and the shield 19 which is connected thereto and may accordingly be considered as an integral part of the cathode) and the surrounding concentric anode 7 be such that the paths of electron travel between the anode 7 and cathode 12 are less than, or of the same order of magnitude as, the mean free path of electrons in the gas. The effect of this is that the distance from any point on the anode 7 to the nearest point on the cathode 12 (and shield 19) is relatively small. This results in a lowering of the potential gradient at the anode to a value at which autoelectronic emission is inappreciable. Should some autoelectronic emission occur despite the low potential gradient at the anode, the electrons may not follow the absolute shortest path between the anode and cathode. Nevertheless, the electrons are confined to substantially the shortest path with their actual path of travel being below or of the same magnitude as the mean free path of the electrons in the gas. This means that due to the field effect the electrons may describe an arcuate path rather than traverse the shortest straight line distance between the electrodes. In so doing such path, being maintained below the mean free path of the electrons in the gas, will minimize collision with atoms of gas. Since collision is thus minimized, no appreciable ionization takes place, which would otherwise cause a deleterious discharge during that portion of the alternating current cycle when a high inverse potential is impressed between the electrodes.

The envelope 5 is exhausted and filled with a discharge supporting medium, such as mercury, or an inert gas, such as argon, neon, krypton, etc., after which it may be sealed off at the point 22. The gas pressure within the envelope is kept within a definite range so that with predetermined spacings between the anode and cathode, the mean free path of electrons in the gas will not be too small. We have found that in the case of mercury vapor where an excess is used, the ambient temperature must be maintained between 15° C. and 40° C. Also, when an inert gas is utilized in lieu of mercury vapor, it is preferable to keep the pressure such that all electron paths between anode 7 and cathode 12 are below the mean free path of the electrons in the gas, as before mentioned.

The range of pressure naturally depends on the voltage and currrent requirements and ranges from one to forty microns, depending also on the nature of the gas. For example, at one micron pressure the mean free path of an electron in argon is 38.0 centimeters; that of neon, 72.0 centimeters; and in the case of krypton, 40.0 centimeters. If ten microns of argon be considered a typical pressure, the mean free path is 3.8 centimeters and the preferable maximum spacing for voltages above 50 kilovolts is 3.0 centimeters.

Thus, depending upon the particular inert gas utilized, the mean free path of which is known at one micron pressure, the spacing of the electrodes is made such that, at any given pressure ranging from one micron to forty microns, the pressure of the inert gas is maintained below that of the mean free path of the electrons in that particular gas and for a given spacing between the electrodes.

In general, we have found that for carrying current, the lower the ionizing potential and the heavier the gas, the better; but for standing high voltage, just the reverse of this condition holds true, so that a compromise must be arrived at to satisfy the characteristics demanded in any given tube. Accordingly, by keeping the pressure of the gas within the range above noted and the spacing of electrodes such that the actual electron paths are below the mean free path of the electrons in the particular gas utilized, together with maintaining a low potential gradient at the anode, cleanup of the inert gas during operation is prevented and in the case where mercury vapor is utilized as the discharge supporting medium in lieu of the inert gas, too radical a change in the mercury vapor pressure is prevented by maintaining the ambient temperature of the device during operation within a definite temperature range.

Also, by proper positioning of the cathode 12 in the cup 15 and properly spacing it from the anode, the voltage drop across the tube during the useful or full-load portion of the alternating current cycle is maintained under 30 volts and preferably below 20 volts. Because of this low voltage drop, high energy positive ion bombardment of the cathode is precluded which, together with the fact that the discharge cannot strike the glass envelope, contributes to the absence of appreciable clean-up of the gas.

In Fig. 7 a typical example of the potential gradient at the surface of the concentric electrodes is shown for a given size outer cylinder of 5 centimeters radius of curvature and for a desired voltage of 100 k. v. The abscissa indicates radius in centimeters required for the inner cylindrical cathode, and the ordinate, kilovolts per centimeter. Curve A shows the potential gradient at the surface of the outer cylinder or anode 7 which increases as the radius of the inner cylinder or cathode 12—19 is increased.

On the other hand, it will be noted from curve B that the potential gradient at the surface of the inner cylinder or cathode decreases with an increase in radius up to a maximum of approximately 2 centimeters, after which, it again increases with an increase in radius.

It will thus be seen that for a device operable at 100 k. v. and with an outer cylindrical anode of 5 centimeters, the preferable radius of curvature for the inner cylindrical cathode is 2 centimeters. This gives a potential gradient at the cathode of approximately 50 kilovolts per centimeter and a gradient of approximately 23 kilovolts per centimeter at the anode. Furthermore, the spacing between the adjacent surfaces of the anode and cathode is but 3 centimeters, which is thus below the mean free path of the electrons in the space. In the case of a rectifier, the diameter of the inner cylinder may vary somewhat since the potential gradient at the cathode is not as important as at the anode but when the device is used to block current flow as in an interrupter tube, the diameter of the inner cylinder is very important and consequently must be more precise.

Referring now more specifically to Fig. 3, the structure therein shown is very similar to that above described with respect to Figs. 1 and 2, but differs therefrom in the construction of the cathode. In this particular modification, the filamentary cathode has been eliminated and a corrugated helically wound ribbon **23** is employed. As shown, the helix is coaxial with the longitudinal axis of the device with the extremities thereof connected to the leading-in and supporting wires **9** and **10** in the same manner as that previously described with respect to the filamentary cathode **12** of Fig. 1.

The cathode **23**, which is recessed within the metallic shield **19**, is coated with an electron emitting material, such as the oxides of barium, strontium, etc., which gives off a copious flow of electrons when heated. The metallic disc **24**, having a slightly smaller diameter than that of the shield **19**, is supported immediately above the open end of the shield **19** by a supporting rod or the like **25** welded to the interior walls of the cylinder **19** and to the disc **24** and also electrically and mechanically connected to the leading-in and supporting rod **9** so that the shield **19** and disc **24** have the same potential as that of the cathode **23** during operation of the device.

Since the cathode **23** in the modification shown in Fig. 3 is coated with an electron emitting material, it is preferable to recess the same within the shield **19** so as to prevent undue deterioration of the cathode by positive ion bombardment which problem is not present with pure refractory metal emitters such as shown in Fig. 1. The shield **19**, as well as the metallic disc **24**, serves to almost entirely intercept positive ion bombardment originating outside the shield, and those ions originating in the field-free space within the shield do not have sufficient velocity to cause any damage when they strike the cathode, thus serving to prevent sputtering of the cathode electrode. In all other respects, particularly with regard to spacing of the electrodes, gas pressure, or temperature of operation when a metallic vapor is utilized, this modification is identical to that previously described.

By the construction of a rectifier tube in the manner above described with reference to Figs. 1 to 4, inclusive, we have found that the voltage drop across the tube is exceedingly low, being of the order of 20 to 30 volts or less, while passing currents of as high as ten amperes, and blocking during inverse half waves at a voltage of 100 kilovolts and utilizing either mercury vapor or an inert gas as the discharge supporting medium. During actual tests of such devices, they have withstood an inverse potential of as high as 250 kilovolts.

Moreover, the discharge between the electrodes is effectively confined within the metal portions of the tube since the electrodes are concentric cylinders, with the anode forming a closure member for the tube. This contributes to the effective passage of comparatively large currents and the withstanding of high inverse voltages without impairment of tube life.

In addition, due to the low potential gradient at the electrodes and the spacing thereof at the gas pressure employed, autoelectronic emission which would otherwise be caused by the electrostatic field, gamma or cosmic rays, and positive ion bombardment, is substantially eliminated with any such emission being inappreciable and confined to the metal parts of the device.

In Figs. 5 and 6 we have shown a converter or interrupter tube which is substantially similar to the rectifier tube previously described. In this particular type of device the anode **7** forms a closure member for the tube in the manner previously described and the corrugated spiral ribbon cathode **23** is again concentrically disposed in the same manner as in Fig. 3. The envelope, however, is provided with an additional extension **26** on the reentrant portion thereof to the upper extremity of which is sealed a metallic grid structure **27**.

As noted in Fig. 5, this grid is in the form of a closed cylinder electrically connected to a leading-in conductor **28** sealed through the press portion **8** of the envelope, in the same manner as the leading-in and supporting conductors **9** and **10** for the cathode, which is offset and may frictionally contact the inner wall of the grid **27**. The grid is formed of any suitable metal, such as molybdenum, "Kovar," or the like having a high work function and which readily seals to glass, and is provided with a plurality of perforations **29**. In this case the grid **27** is completely insulated from the cathode and must accordingly stand high voltage.

Inasmuch as the grid is the inner of two cylinders, the gradients will necessarily be higher than in the case of the anode of the rectifier tube, with the result that for a given size tube it is not possible to control as high a voltage as that which can be rectified with the construction of the preceding figures. Again, however, there is a certain optimum diameter for the grid with respect to the diameter of the outer cylindrical anode which must follow the gradients as shown, for example, in Fig. 7, even more closely for blocking than when operating as a rectifier. Also, as to the relative spacing between the grid and the anode, it is necessary to keep the shortest distance from any point on the grid to the nearest point on the anode small.

Again, as in the case of the rectifier tube, the surface of the grid structure must be kept relatively smooth and sharp corners, points and edges must be avoided, which it will be noted is again accomplished by the edge of the grid being surrounded by the glass of the reentrant stem in the same manner as previously described with respect to the seal of the anode to the envelope.

By the application of suitable voltages between the grid and cathode, the flow of current between the cathode and anode is prevented until the desired potential has been built up across the tube and at the desired or preselected moment the potential of the grid can be altered to cause a discharge, after which the tube functions as a rectifier until the potential of the grid is again altered to prevent further discharge.

In utilizing an inert gas as the discharge supporting means in the application of the tube as an inverter or interrupter tube, the gas is more readily subject to clean-up because the current passes at considerably higher voltages than in the case of pure rectification. However, in various applications of the tube the actual passage of current at this high voltage occupies such a short period of time, even though it be assumed that a discharge occurs on alternate half waves of the alternating current cycle, the tube is able to withstand many successive operations extending over a relatively long period of time before clean-up of the gas becomes serious.

The utilization of mercury vapor in lieu of an inert gas naturally eliminates any disadvantage as to clean-up; but as is the case with a rectifier, mercury is subject to ambient temperature limitations. Also, for use as an inverter as distinguished from an interrupter tube, mercury vapor appears preferable due to the propensity toward clean-up of the inert gas, particularly under inverter tube operating conditions.

It thus becomes obvious to those skilled in the art that we have provided a high potential gaseous discharge device capable of passing relatively large currents and of withstanding high inverse potentials. Moreover, by the proper selection of an anode material having a high work function and the spacing of the electrodes, which are in the form of concentric cylinders, so that the spacing is preferably less than the mean free path of the electrons in the gas, and by the maintaining of minimum potential gradients at the surface of the electrodes, we have substantially eliminated autoelectronic emission even though due to field emission, positive ion bombardment and the effect of gamma and cosmic rays, is confined to a minimum.

The elimination of such emission enables operation of the device utilizing either a metallic vapor or an inert gas as the discharge supporting medium without clean-up of the inert gas or appreciable variation in the temperature of operation of the device. Furthermore, the surfaces of the electrodes being smooth and free of all points and edges, due to insulation thereof by the vitreous envelope itself, prevents the formation of electrostatic field concentration which would otherwise cause puncture and contributes to the passage of large currents at high potential without destruction of the tube or shortening its useful life.

Although we have shown and described several embodiments of our present invention, we do not desire to be limited thereto as various other modifications of the same may be made without departing from the spirit and scope of the appended claims.

We claim:

1. A high potential gaseous discharge device comprising a vitreous envelope having an ionizable medium therein and provided with electrodes energizable from a high potential source of electrical energy, said electrodes including an anode and a thermionic cathode disposed substantially concentric to said anode to produce a low electrostatic field at the anode and having a spacing therebetween such that at the pressure of the ionizable medium the distance between parts of opposite instantaneous polarity through which any electrons originating at the anode travel under the influence of the electrostatic field is below the mean free path of electrons in the ionizable medium, and said electrodes having such a radius of curvature at any point that autoelectronic emission from the electrode subjected to high negative potential is inappreciable.

2. A high potential gaseous discharge device comprising a vitreous envelope having an ionizable medium therein and provided with a thermionic cathode and a substantially concentrically disposed cylindrical anode of high work function forming a portion of said envelope and energizable from a high potential source of electrical energy, said anode and cathode having a spacing therebetween such that at the pressure of the ionizable medium the distance between parts of opposite instantaneous polarity through which any electrons originating at the anode travel under the influence of the electrostatic field is below the mean free path of electrons in the ionizable medium, and said electrodes having such a radius of curvature at any point that the potential gradient at the anode is maintained below a value at which appreciable autoelectronic emission occurs when the anode is subjected to a high negative potential.

3. A high potential gaseous discharge device comprising a vitreous envelope having an ionizable medium therein and provided with electrodes including an anode and a thermionic cathode energizable from a high potential source of electrical energy, said electrodes being in the form of concentric cylinders to produce a low electrostatic field at the anode and having a spacing therebetween such that at the pressure of the ionizable medium the distance between parts of opposite instantaneous polarity through which any electrons originating at the anode travel under the influence of the electrostatic field is below the mean free path of electrons in the ionizable medium and the discharge is restricted entirely between metal parts of the device, and said electrodes being void of all sharp points and edges having small radii of curvature to maintain the potential gradient at the electrode subjected to a high negative potential below a value at which appreciable autoelectronic emission occurs.

4. A high potential gaseous discharge device comprising a vitreous envelope having an ionizable medium therein and provided with a cylindrical anode of high work function and forming an integral part of the wall of said envelope, a cathode for supplying a copious flow of electrons when heated, and a cylindrical shield concentrically disposed relative to said anode surrounding said cathode and connected thereto to produce a low electrostatic field at said anode for restricting the direction of electron flow substantially to the shortest straight line path between said cathode and anode, said anode and cathode having a spacing therebetween such that at the pressure of the ionizable medium the distance between parts of opposite instantaneous polarity through which any electrons originating at the anode travel under the influence of the electrostatic field is below the mean free path of electrons in the ionizable medium, to prevent the origination of detrimental positive ion borbardment at the cathode or within the ionizable medium sufficient to cause flash back during operation of the device, and said anode and shield having such a radius of curvature at any point that the potential gradient at the anode is maintained below a value at which appreciable autoelectronic emission occurs when the anode is subjected to a high negative potential.

5. A high potential gaseous discharge device comprising a vitreous envelope having an ionizable medium therein and provided with a cylindrical anode of high work function and forming

an integral part of the wall of said envelope, a cathode for supplying a copious flow of electrons when heated, leading-in and supporting wires extending through a press in said envelope, and a cylindrical shield concentrically disposed relative to said anode and surrounding said cathode and leading-in conductors, and said shield being connected to said cathode and said press to produce a low electrostatic field at said anode for restricting the direction of travel of any electrons originating at the anode substantially to the shortest path between said cathode and anode, said anode and cathode having a spacing therebetween such that at the pressure of the ionizable medium the distance between parts of opposite instantaneous polarity through which any electrons originating at the anode travel under the influence of the electrostatic field is below the mean free path of electrons in the ionizable medium to prevent the origination of detrimental positive ion bombardment at the cathode or within the ionizable medium to cause flash back during operation of the device, and said anode and shield having such a radius with respect to each other that the potential gradient at the anode is maintained below a value at which appreciable autoelectronic emission occurs when the anode is subjected to a high negative potential.

6. A high potential gaseous discharge device comprising a vitreous envelope having an ionizable medium therein and provided with an anode, a cathode and a control electrode energizable from a high potential source of electrical energy for generating an electrostatic field at said anode, said anode and control electrode having a spacing therebetween such that at the pressure of the ionizable medium the distance between said anode and control electrode through which any electrons originating at the anode travel under the influence of the electrostatic field is below the mean free path of electrons in the ionizable medium, and said electrodes having such a radius of curvature at any point that electronic emission from the electrode subjected to high negative potential is inappreciable and the potential applied to the control electrode is normally of such value as to prevent the flow of electrons from the cathode to the anode, and said control electrode being operable upon a reversal of the polarity of the potential applied thereto to cause the flow of electrons from the cathode to the anode to be restricted to substantially the shortest path therebetween.

7. A high potential gaseous discharge device comprising a vitreous envelope having an ionizable medium therein and provided with a cathode, a cylindrical anode of high work function forming a portion of said envelope energizable from a high potential source of electrical energy for generating an electrostatic field at said anode, a grid electrode interposed between said anode and cathode and completely surrounding said cathode, and said grid having a spacing relative to the anode such that at the pressure of the ionizable medium, the distance therebetween through which any electrons originating at the anode travel under the influence of the electrostatic field is below the mean free path of electrons in the ionizable medium, and said anode and grid having such a radius of curvature at any point that the potential gradient at the anode is maintained below a value at which appreciable autoelectronic emission occurs when the anode is subjected to a high negative potential, and said grid being operable when impressed with a high negative potential to prevent the flow of electrons between the cathode and anode and thereafter causing the flow of electrons to be restricted substantially to the shortest path therebetween upon the reversal of the potential applied to said grid.

8. A high potential discharge device comprising a vitreous envelope having an ionizable medium therein and provided with an anode, cathode and grid energizable from a high potential source of electrical energy for creating an electrostatic field at said anode, said anode and grid being in the form of concentric cylinders having a spacing therebetween such that at the pressure of the ionizable medium, the distance therebetween through which any electrons originating at the anode travel under the influence of the electrostatic field is below the mean free path of electrons in the ionizable medium, said anode and grid being of a metal having a high work function, said anode being sealed to said envelope and forming a part thereof, and said grid forming a closure member for the thermionic cathode and being sealed to a reentrant portion of said envelope and provided with a plurality of openings through which the electrons flow from the cathode to the surrounding anode, and said grid being operable when impressed with a high negative potential to prevent the flow of electrons from the cathode to the anode and operable upon a reversal of the polarity to cause the flow of electrons from the cathode to the anode and to confine the same substantially to the shortest path therebetween.

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