

Aug. 12, 1952

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GAS FILLED DISCHARGE DEVICE

2,607,021

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2 SHEETS—SHEET 1

FIG. 1

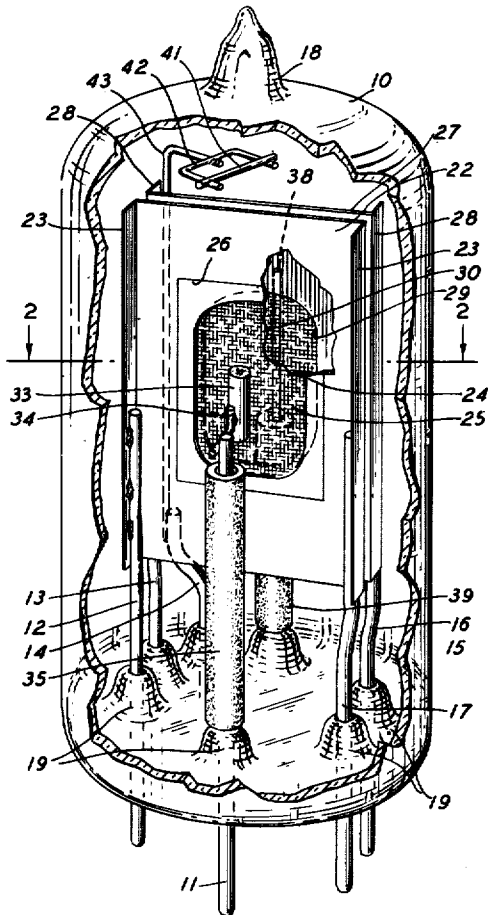


FIG. 2

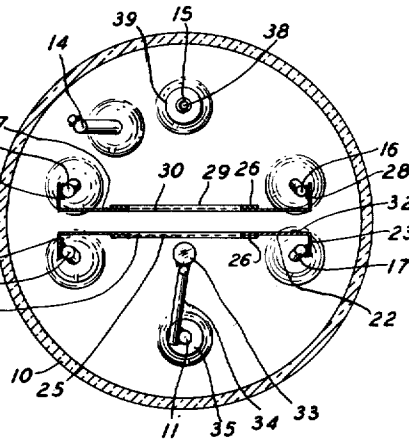


FIG. 3

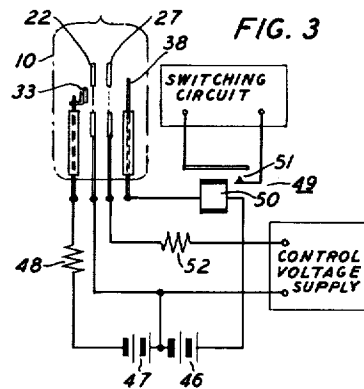
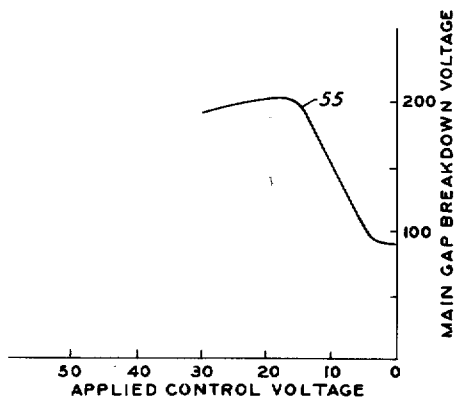


FIG. 4



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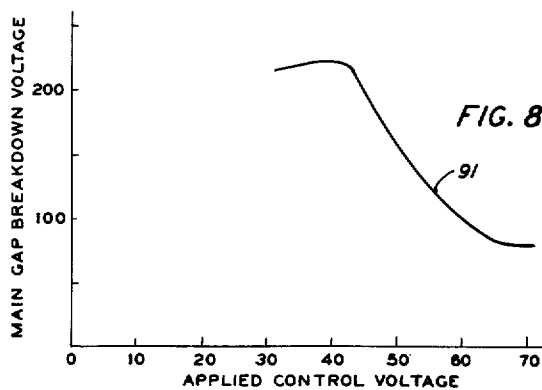
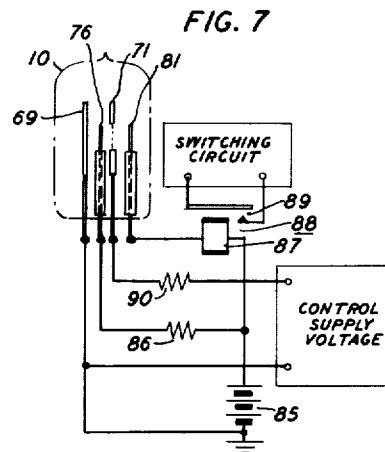
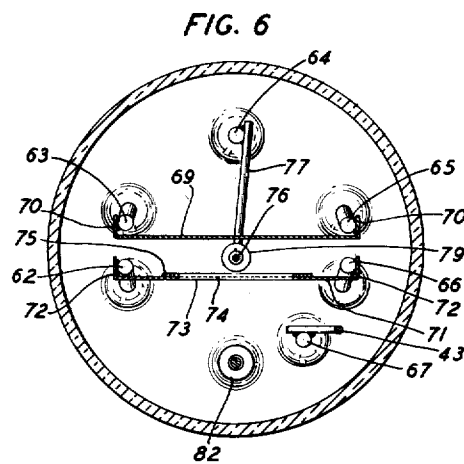
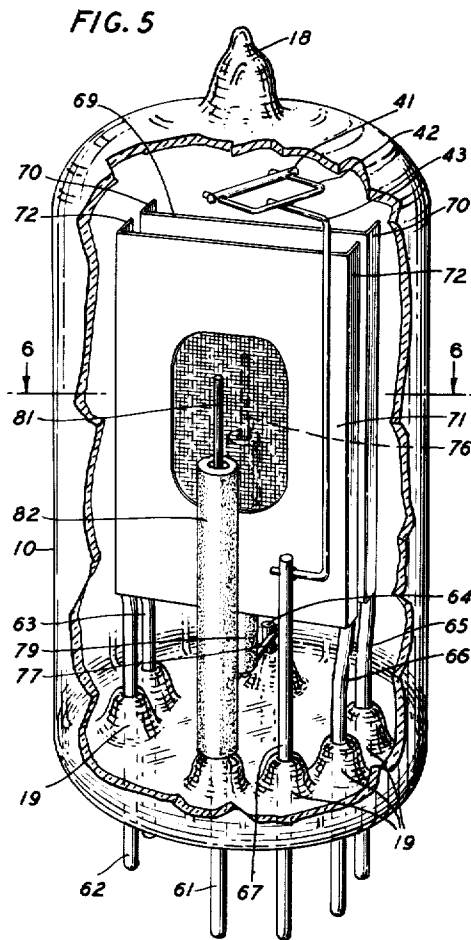
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GAS FILLED DISCHARGE DEVICE

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2 SHEETS—SHEET 2



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## UNITED STATES PATENT OFFICE

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## GAS FILLED DISCHARGE DEVICE

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14 Claims. (Cl. 315—167)

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This invention relates to gas filled discharge devices and more particularly to such devices of the cold cathode type and having auxiliary internal means for controlling the breakdown of the device.

In certain applications it is desirable to employ discharge devices having low control voltages and very short ionization times. In such applications it is also desirable that these devices be cold cathode glow discharge devices in order to obtain the advantages of low stand by power, longer life, and faster ionization. One such application is in switching circuits or telephone relay networks where circuits are intended to operate over a long life and over long periods of time without observation or maintenance.

In the past, difficulties have arisen because of the time required to initiate the ionization between the starter electrodes and to transfer the discharge to the main electrodes. Further difficulty has resulted from the relatively high voltages required to break down the starter gap. Prior devices have employed these high starter voltages and have then encountered several distinct delays. There is first the time lapse between the application of the starter breakdown voltage and the presence of the first charge carrier. There is then a second lapse after the presence of the first carrier during which collisions and ionization occur to build up the discharge. There is then a third time lapse while that discharge is transferred from the starter to the main electrodes.

An object of this invention is to provide a cold cathode gaseous discharge device having a low control voltage.

A further object of this device is to obtain, in a cold cathode gaseous discharge device, a shorter ionization time than priorly obtainable. Specifically it is an object of this invention to eliminate the time lapse until the presence of the first charge carriers and to substantially decrease the other time delays between the application of the control voltage and the main gap breakdown

In one specific illustrative embodiment of this invention, the continuous keep alive discharge is maintained between a small cathode and a large flat cathanode. The cathanode is apertured to permit the transfer of electrons through it and through a similar large flat control electrode to the region of a small wire anode, the various electrodes being positioned in alignment.

In another specific illustrative embodiment of this invention, the continuous keep alive dis-

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charge is maintained between a small wire keep alive anode and the main cathode, the keep alive anode being positioned between the large flat main cathode and a large flat control grid. The control grid has a central aperture therein to permit of the controlled injection of the keep alive electrons into the region of the main anode.

In accordance with one feature of this invention a constant auxiliary or keep alive discharge is present within the device.

In accordance with another feature of this invention, the breakdown of the main gap is controlled by the injection of carriers from this discharge into the main gap. The main gap in accordance with this invention is between a small area anode and a large area cathode, whereby a high current density is obtained adjacent the anode and a low current density adjacent the cathode. In accordance with this feature a steep slope at very low currents is obtained for the voltage-current characteristic of the main gap, as that slope is mainly controlled by the densities of the current in the gap. Such a slope also means that the gap has a steep breakdown voltage current characteristic. Therefore small injections of electrons or ions can cause a large decrease in the required breakdown voltage.

In accordance with another feature of this invention, the keep alive gap is separated from the region around the main anode. However, the keep alive gap is in alignment or coincident with a further part of the main gap so that electrons from the keep alive discharge can be directly injected into the main gap to cause ionizing collisions and gap breakdown without the subsequent transfer of the discharge to another gap.

In accordance with still another feature of this invention, the keep alive discharge is effectively separated from the region around the main anode and confined by large flat electrodes which prevent the appearance of other charge carriers, radiations, such as could produce photoelectrons, or metastable atoms in the vicinity of the main anode. Thus, the keep alive discharge may be boxed in by two or more of such electrodes or it may be positioned to one side away from the main anode and have such electrodes positioned between it and the main anode.

In accordance with still a further feature of this invention, such electrodes are apertured to allow the injection of electrons from the keep alive discharge through them into the vicinity of the main anode. Further a grid may be positioned across one aperture to control the injection

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tion of the electrons by slight variations in the bias on the control electrode. Further it is a feature in accordance with one specific embodiment of this invention that such an apertured electrode shall be a cathanode, acting as the anode of the keep alive discharge and the cathode of the main discharge.

The aforementioned and other features of the invention will be more readily understood by consideration of the following detailed description and the accompanying drawings, in which:

Fig. 1 is a perspective view of a glow discharge device illustrating one embodiment of this invention, a portion of the envelope having been broken away to show the internal elements of the device;

Fig. 2 is a cross sectional view of the device of Fig. 1 along the line 2—2;

Fig. 3 is a schematic representation of the device of Fig. 1 together with a partial circuit diagram illustrating one manner of utilization of this device;

Fig. 4 is a graph of the main gap breakdown voltage as a function of the applied control voltage for one value of control resistance for the device of Fig. 1.

Fig. 5 is a perspective view of a glow discharge device illustrating another embodiment of this invention, a portion of the envelope having been broken away to show the internal elements of the device;

Fig. 6 is a cross sectional view of the device of Fig. 5 along the lines 6—6;

Fig. 7 is a schematic representation of the device of Fig. 5 together with a partial circuit diagram illustrating one application of this device; and

Fig. 8 is a graph of the main gap breakdown voltage as a function of the applied control voltage for one value of control resistance for the device of Fig. 7.

Referring now to the drawings, the glow discharge device illustrated in Fig. 1 comprises an enclosing glass vessel 10 with pin conductors 11, 12, 13, 14, 15, 16 and 17 sealed in the base and an exhaust tubulation 18 at its top. The conductors are secured to the glass vessel 10 by seals 19. A large flat cathanode 22 having bent side stiffening portions or flanges 23 is supported by conductors 12 and 17 which are secured, as by welding, to the side portions 23. The cathanode 22 has a central aperture 24 across which a fine grid 25 is secured as by a thin plate or frame 26 having the same size aperture.

Closely adjacent the cathanode 22 and parallel thereto is a similar control electrode 27 having bent side portions 28 and an aperture 29 in alignment with aperture 24 of the cathanode 22. A fine wire grid 30 is secured across the aperture 29 by another metal plate 26 so that the grid 30 is between the electrode 27 and the plate 26. The use of a grid 30 with a fine mesh, rather than larger holes or slots, has been found advantageous in order to separate the different gaps and to more finely control the device. However other apertured control electrodes might be devised without departing from the scope of this invention. The control electrode 27 is similarly supported by conductors 13 and 16 which are secured, as by welding, to the side portions 28, the side portions of the two electrodes being bent away from each other so that the adjacent surfaces of the two electrodes are parallel. The surface 32 of the cathanode 22 adjacent the control electrode 27 may be coated with a material

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having a low work function such as barium and strontium oxides, or left clean, as is known in the art.

Adjacent the cathanode 22 on the other side thereof from the control electrode 27 is a keep alive cathode 33. The cathode 33 is attached, as by a short bent lead 34, to the conductor 11 and is positioned in alignment with the grids 25 and 30. A cylindrical ceramic insulator 35 is placed over the conductor 11 to prevent the glow discharge from spreading to the supporting leads. The keep alive cathode 33 may also have a similar low work function coating activated thereon.

To the other side of the grid electrode 27 and in alignment with the keep alive cathode 33 and the grids 25 and 30 is a small area, for example a thin wire, main anode 38 which is secured to the conductor 15. A ceramic insulator 39, similar to ceramic insulator 35, advantageously is placed over the conductor 15.

The glass vessel 10 may advantageously be filled with argon at a pressure of 16 millimeters of mercury, though other gases, such as neon, xenon, krypton, etc., at different pressures may be employed. A getter wire 41 is supported by a U-shaped wire 42 and lead 43 secured to the conductor 14.

In one specific and illustrative embodiment of this device the cathanode 22 and control electrode 27 are of  $\frac{7}{8}$  inch by  $\frac{1}{8}$  inch .010 inch nickel sheet, the keep alive cathode 33 a nickel cylinder  $\frac{1}{8}$  inch high and .0545 inch in diameter, the lead in conductors of a nickel-iron alloy, the main anode 38 of a .015 inch nickel wire, and the grids 25 and 30 of a .0015 inch nickel wire mesh. The cathode surfaces are coated with an activated barium oxide-strontium oxide coating. These materials and dimensions are to be considered as only exemplary of one embodiment as others may be employed in the application of this invention. Thus, the various elements may be of molybdenum with uncoated cathode surfaces. In this one illustrative embodiment the main anode 38 is spaced  $\frac{1}{8}$  inch from the control electrode 27 and the center line of the keep alive cathode 33 is  $\frac{1}{8}$  inch from the cathanode 22. There is  $\frac{1}{8}$  inch between the cathanode 22 and the control electrode 27.

Referring now to Fig. 3, wherein is represented schematically one application of this device in accordance with this invention, the keep alive cathode is connected through a limiting resistor 48 to the negative side of a voltage supply 47, the positive side of which is connected to ground. The main anode 38 is connected to the positive terminal of a voltage supply 46, the negative terminal of which is connected to ground, through the coil 50 of a relay 49. Contacts 51 cooperate with the coil 50 to open and close in a switching circuit which may be attached thereto. A control voltage is applied between the control electrode 27 and the cathanode 22, the control voltage supply being connected to the control electrode 27 through resistance 52. The protective resistance 52 may be omitted if the control voltage supply is incapable of causing a deleterious amount of current to flow to the control electrode; such would be the case if the control voltage supply were from a photoelectric cell or other low current device. However, if the control voltage supply is another section of a load circuit, such as another part of the switching circuit, the protective resistance should advantageously be employed.

In the operation of this device, a keep alive

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discharge is maintained between the keep alive cathode and the cathanode. The cathanode is at the same time the anode of this auxiliary discharge and the cathode of the main gap. The control electrode is normally kept at a potential negative with respect to the cathanode in order to prevent electrons from the keep alive discharge from coming through the grid 30 into the region of the main anode. By making the control electrode less negative with respect to ground, the electrons from the auxiliary discharge can then pass through the grid 27 of the cathanode and the grid 30 of the control electrode into the main gap region. This injection of electrons causes a sharp decrease in the voltage that need be applied to the main anode to cause the main gap to break down. Further, when the electrons have passed through the control electrode grid they are accelerated in the field of the main anode and thus give further ionization and electrons by their collisions with the gas in the main gap. Thus, because the electrons are present in the keep alive discharge there is no time delay between the decrease in the control grid voltage and the main gap breakdown due to the ionization delay for a discharge to commence.

In one specific illustration the resistance 48 may be 0.1 megohm and the voltage supplies each 130 volts. Then, the main gap breakdown voltage will be around 200 volts. However, with a continuous keep alive discharge of between 0.1 and 1.0 milliamperes, the applied voltage of 130 volts is able to break down the gap when the proper control voltage is applied to the control electrode.

Fig. 4 shows the value of main gap breakdown voltage as a function of the applied control voltage. Curve 55 shows the characteristic for a protective resistance of 0.1 megohm taken for an auxiliary keep alive current of 0.5 milliamperes. As is clearly apparent from curve 55, a very small change in control voltage, such as 10 volts, causes a very marked decrease in the required breakdown voltage, such as 100 volts. While typically the control electrode will be kept at about -15 volts to be at approximately the maximum gap breakdown voltage and then decreased to about -5 so as to allow a large injection of electrons and thus drop the required breakdown voltage well below that actually available, it is possible to obtain very fine control by a change of only a few volts on the control electrode. Thus by applying a control voltage of -10 volts to the control electrode a decrease of about 2 volts, to -8 volts, is sufficient to diminish the main gap breakdown voltage by 30 volts and to operate the tube with reasonable margins under the conditions of a control resistance of 0.1 megohm and a main gap voltage of 130 volts. The main gap breakdown is therefore controlled by the injection of electrons from a continuous keep alive discharge into the main gap. This injection in turn can be accurately controlled by a very slight change in a control voltage. It is thus apparent that high control voltages, such as have priorly been employed to break down starter gaps, may be dispensed with and circuit simplifications attained by this invention.

In the operation of these devices, it is further to be pointed out that the large flat area cathanode and grid electrodes are advantageously employed to almost fill the tube transversely, thereby preventing the appearance of metastable atoms, charge carriers or radiations from the keep alive discharge in the vicinity of the main anode. However, it is to be understood that other shaped

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electrodes might be devised by those skilled in the art. It is further to be understood that the main electrodes should advantageously be of such sizes as to obtain a very steep voltage current characteristic at very low currents whereby there is a very steep decrease in the breakdown voltage with slight increases in the current in the main gap. Thus, advantageously the anode is a small diameter wire while the cathode is a plate of considerably larger area. By this choice of sizes a large current density at the anode and in the anode field, which mainly determines the slope of the characteristic, is easily obtained with very low currents, while the cathode still has a size which enables it to carry a relatively large output current. The main gap should also have a sufficient difference between the breakdown and sustaining voltages to obtain favorable working conditions and the large slope of the voltage current characteristic.

It is further advantageous to align the various electrodes so that the keep alive electrons pass through the cathanode towards the main anode along the same path as the main discharge. By this alignment, the initial ionization collisions caused by the keep alive electrons in the region of the main anode are along the prerequisite path for the main gap breakdown, thereby obtaining a maximum efficiency of injection of the keep alive electrons into the main gap where their presence is desired.

Referring now to Fig. 5, there is shown another illustrative embodiment of this invention comprising a glass vessel 10 having an exhaust tubulation 18 and conductors 61, 62, 63, 64, 65, 66 and 67 secured to the base of vessel 10 in seals 19. A large flat cathode 69 having bent portions 70 is supported by the conductors 63 and 65 which are secured to the bent portions 70 as by welding. A control electrode 71, similar to electrode 27, and having bent side portions 72 is supported by the conductors 62 and 66 which may also be secured to the side portions 72. The electrode 71 has an aperture 73 centrally located opposite the cathode 69 and a fine wire grid 74 secured across the aperture by thin plate 75 similar to the plate 26 of Fig. 1. The electrode 71 is positioned so that the bent sides 72 extend towards the cathode 69. A keep alive anode 76 is positioned between the cathode 69 and the electrode 71. The anode 76 is attached to the conductor 64 by a transverse lead 77 extending from the conductor 64 beneath the cathode 69 and attached to an upright lead, not shown, to which the anode is secured. A cylindrical ceramic insulator 79 may be placed around the upright lead.

A main anode 81 is secured to the conductor 61 and is positioned in alignment with the keep alive anode 76 and the grid 74 to the other side of the electrode 71. The getter wire 41 is attached to the support leads 42 and 43 and to the conductor 67. The tube may be filled with argon or other advantageous gases as discussed with respect to the illustrative embodiment of Fig. 1. A ceramic cylinder 82 may also be placed around the conductor 61.

In one specific illustrative device, the lead conductors were of a nickel-iron alloy, the main anode 81 of .012 nickel wire and the auxiliary anode 76 of 0.15 nickel wire, the cathode 69 and electrode 71 of .010 nickel sheet  $\frac{3}{8}$  inch by  $\frac{7}{8}$  inch, and the cathode has an active coating of barium and strontium oxides on its surface towards the main and auxiliary anodes. The control electrode 71 was spaced  $\frac{1}{8}$  inch from the

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cathode 69 and the main anode 81  $\frac{1}{8}$  inch from the control electrode.

Referring now to Fig. 7, in one application of this device in a switching circuit and in accordance with this invention, the cathode 69 is connected to the grounded negative side of a voltage supply 85. The keep alive anode 76 is connected to the positive side of the voltage supply 85 through a limiting resistance 86. The main anode 81 is also connected to the positive side of the voltage supply 85 through the coil 87 of a relay 88 having cooperating contacts 89 in circuit in the switching circuit and similar in operation to the relay 49 of Fig. 3. A control voltage is applied between the grounded cathode 69 and the control electrode 71 which is connected to the control voltage supply through a protective resistance 90, which is similar in purpose and requirement to the protective resistance 52 of Fig. 3.

In the operation of this device, a continuous keep alive discharge is maintained between the main cathode 69 and the keep alive anode 76, the cathode 69 being both the main and auxiliary cathode. The control electrode then has a positive potential depending on the sustaining voltage of the main gap. Where this sustaining voltage is near 60 volts the electrons near the keep alive anode will have a potential of approximately 55 volts and in order to bring these electrons from the keep alive discharge near the main anode the control grid has to be at a positive voltage of substantially the same value. It is therefore advantageous to operate the control electrode with a bias of 40 volts and to apply a control voltage of about 20 volts or a little more to allow the injection of the keep alive electrons into the main gap. In one specific embodiment employing a 40-volt control electrode bias, a voltage supply 85 of 130 volts, a limiting resistor 0.5 megohm, a keep alive resistance of 0.1 megohm and a gas filling of argon at 16 millimeters of mercury, the main gap breakdown voltage characteristic shown in Fig. 8 was obtained, with a keep alive current of 0.1 milliampere. Curve 91 shows the main gap breakdown voltage plotted as a function of the applied control voltage. As was the case with the illustrative device of Fig. 1, a very small control voltage change, as of 20 volts, will cause a marked decrease in the main gap voltage necessary for breakdown, such as 100 volts. While, as noted before, it is desirable for most operations to employ a large control voltage change in order to obtain the most rapid breakdown in the main gap, it is to be understood that, if desired, the control electrode could be so biased that a change of only a few volts would cause the main gap to break down.

It is to be understood that the above-described arrangements are illustrative of the principles of the invention. Other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A gaseous discharge device comprising a large area cathode, a small area anode opposite said cathode and defining a gap therewith, a control electrode in said gap, means maintaining a continuous keep alive discharge in said device, means biasing said control electrode for injecting electrons from said keep alive discharge into the vicinity of said anode, and means biasing said anode to allow breakdown in the vicinity of said anode only following the injection of the electrons from said keep alive discharge.

2. A gaseous discharge device comprising a

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large area cathode, a small area anode opposite said cathode and defining a gap therewith, a large area control electrode in said gap and having an aperture therein, means maintaining a continuous keep alive discharge in said device, said discharge being in alignment with said main gap, means biasing said control electrode for injecting electrons from said keep alive discharge through said aperture into the vicinity of said anode, and means biasing said anode to allow breakdown in the vicinity of said anode only following the injection of the electrons from said keep alive discharge.

3. A gaseous discharge device comprising a large area main cathode, an electrode adjacent said main cathode, means biasing said electrode and cathode to maintain a keep alive discharge therebetween, a small area anode opposite said cathode and defining a gap therewith, means biasing said anode relative to said cathode at a potential above the sustaining potential of said gap but insufficient in itself to effect breakdown of the gap, a control electrode adjacent said anode in said gap, and means biasing said control electrode for effecting the controlled injection of electric carriers from said discharge into said gap.

4. A gaseous discharge device in accordance with claim 3 wherein said control electrode has a large area frame and a grid mounted by said frame and said keep alive discharge is in alignment with said main gap.

5. A gaseous discharge device comprising means including a cold cathode defining a main discharge gap having a steep current-breakdown voltage characteristic, means defining an auxiliary gap, means maintaining a keep alive discharge in said auxiliary gap, means substantially preventing any of the products of said discharge from appearing in said main gap, control electrode means effecting the controlled injection of electrons from said discharge into said main gap, and means for biasing said main discharge gap allowing breakdown in said gap only following said injection of electron.

6. A gaseous discharge device comprising a cold cathode and an anode defining a main discharge gap having a steep current-breakdown voltage characteristic, means biasing said anode at a potential above the sustaining but below the breakdown voltage of said main gap, means defining with said cold cathode an auxiliary gap, means maintaining a keep alive discharge in said auxiliary gap, control electrode means for substantially preventing the appearance of any products of said keep alive discharge in said main gap, and means biasing said control electrode effecting the controlled injection of electrons from said discharge into said main gap to initiate main gap breakdown.

7. A gaseous discharge device comprising a cold cathode having a frame portion and an aperture therein, a small area anode opposite one face of said cold cathode and defining a main gap therewith, an auxiliary cathode opposite the opposite face of said cold cathode and defining a keep alive gap therewith, and a control electrode between said cold cathode and said anode.

8. A gaseous discharge device comprising a cold cathode having an aperture therein, a small area anode opposite one face of said cold cathode, an auxiliary cathode opposite the opposite face of said cold cathode and defining a gap therewith, means biasing said cold and auxiliary cathodes relative to one another to maintain a discharge therebetween.

tween, means biasing said anode relative to said cold cathode at a potential sufficient to sustain a discharge across said gap but insufficient to effect breakdown of said gap, a control electrode between said cold cathode and said anode, and means biasing said control electrode controlling the injection of electrons from said discharge into the vicinity of said anode to effect breakdown of said gap.

9. A gaseous discharge device comprising an enclosing vessel, a cold cathode having a frame portion extending substantially entirely across said vessel and having also an aperture therein, a small area anode opposite one face of said cathode and defining a main gap therewith, an auxiliary cathode opposite the opposite face of said cold cathode and defining a keep-alive gap therewith, and a control electrode positioned in said main gap, said control electrode having a frame portion extending substantially entirely across said vessel and having also an aperture therein, said auxiliary cathode, said apertures, and said anode being in alignment.

10. A gaseous discharge device comprising an enclosing vessel, a cold cathode having a frame portion substantially filling said vessel and an aperture therein, a mesh grid across said aperture, a small area anode opposite one face of said cold cathode and defining a gap therewith, an auxiliary cathode opposite the opposite face of said cold cathode, a control electrode positioned in said gap, said control electrode having a frame portion substantially filling said vessel and an aperture therein, a mesh grid across said aperture, means biasing said cold cathode relative to said auxiliary cathode to maintain a discharge therebetween, means biasing said anode relative to said cold cathode at a potential below the breakdown but above the sustaining voltage of said gap, and means biasing said control electrode controlling the injection of electrons from said discharge through said control electrode grid into the vicinity of said anode to effect breakdown of said gap.

11. A gaseous discharge device comprising a large area cold cathode, a small area main anode opposite said cathode and defining a main gap therewith, an auxiliary anode in said gap adjacent said cathode and defining a keep-alive gap therewith, and a large area control electrode in said main gap adjacent said main anode.

12. A gaseous discharge device comprising a large area cathode, a small area main anode opposite said cathode and defining a gap therewith, an auxiliary anode in said gap adjacent said cathode, a control electrode in said gap adjacent

said main anode, means biasing said auxiliary anode with respect to said cathode to maintain a discharge therebetween, means biasing said main anode relative to said cathode at a potential sufficient to sustain a discharge across said gap but insufficient to effect breakdown of said gap, and means biasing said control electrode controlling the injection of electrons from said discharge into the vicinity of said main anode to effect breakdown of said gap.

13. A gaseous discharge device comprising an enclosing vessel, a cold cathode substantially filling said vessel, a small area main anode opposite said cathode and defining a gap therewith, an auxiliary anode in said gap adjacent said cathode, and a control electrode having a frame portion substantially filling said vessel and an aperture therein in said gap adjacent said main anode, said cathode, auxiliary anode, aperture, and main anode being in alignment.

14. A gaseous discharge device comprising an enclosing vessel, a cold cathode substantially filling said vessel, a small area main anode opposite said cathode and defining a gap therewith, means biasing said main anode relative to said cold cathode at a potential below the breakdown but above the sustaining voltage of said gap, an auxiliary anode in said gap adjacent said cold cathode, means biasing said auxiliary anode relative to said cold cathode to maintain a keep-alive discharge therebetween, a control electrode in said gap adjacent the main anode having a frame portion substantially filling said vessel and an aperture therein, a mesh grid across said aperture, and means biasing said control electrode controlling the injection of electrons from said discharge through said control electrode grid into the vicinity of said main anode to effect breakdown of said gap.

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