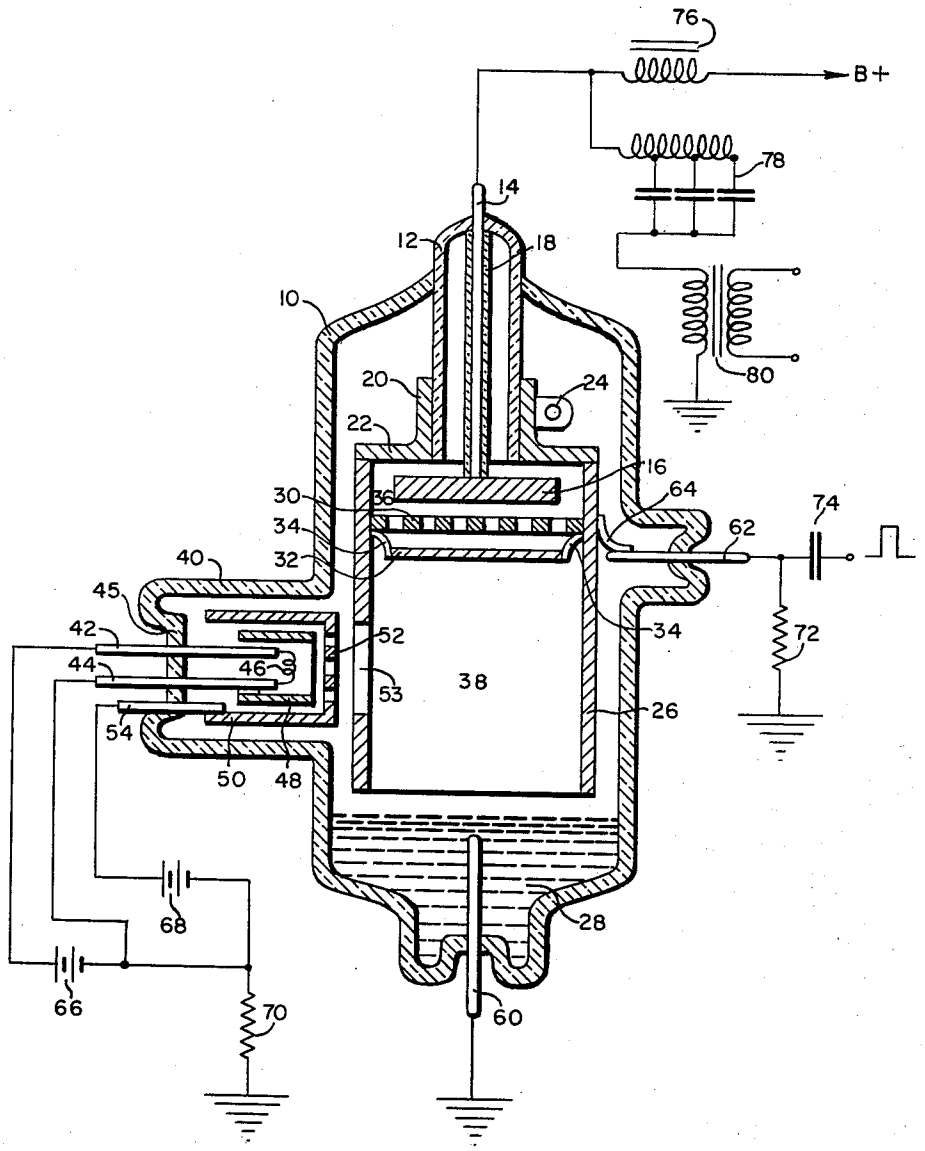
March 23, 1954 R. A. HERRING, JR 2,673,308

HIGH-VOLTAGE COLD CATHODE DISCHARGE DEVICE

Filed Jan. 10, 1952



INVENTOR
ROBERT A. HERRING JR.

BY O. B. Hayden
Howard White ATTORNEYS

Patented Mar. 23, 1954

2,673,308

UNITED STATES PATENT OFFICE

2,673,308

HIGH-VOLTAGE COLD CATHODE DISCHARGE DEVICE

Robert A. Herring, Jr., Washington, D. C.

Application January 10, 1952, Serial No. 265,910

9 Claims. (Cl. 315—339)

(Granted under Title 35, U. S. Code (1952), sec. 266)

1

This invention relates generally to cold cathode discharge devices and more particularly to a grid controlled, high voltage, cold cathode discharge device capable of extremely fast response to incoming grid signals.

Grid controlled, cold cathode discharge devices are known in the prior art which utilize an auxiliary electron emitting cathode to increase the sensitivity of the tube to a grid signal. In the prior art devices however the control grid is disposed to exert, during a quiescent period, a suppressing effect upon electron emission from the auxiliary cathode. Positive signals designed to trigger the main discharge are impressed upon this control grid as a result of which electrons emitted from the auxiliary cathode flood into the main discharge space and ionize the previously un-ionized gas therein. Due to the lack of quiescent ionization in the main discharge space a certain interval of time, of the order of milliseconds, is required for the main discharge to be initiated. As a result, in the prior art devices a time delay exists between the impingement of a signal on the grid and the occurrence of the main discharge through the device.

Attempts have also been made in the prior art, absent a control grid, to produce quiescent ionization of the gas in the main discharge chamber. Arrangements designed to create this quiescent ionization effect have taken either a first form of an auxiliary cathode connected through a resistance to the main cathode, or a second form of an auxiliary cathode externally connected to an auxiliary anode through a circuit isolated from the main discharge circuit. In the former case, during a quiescent period, the auxiliary cathode is subject to destructive positive ion bombardment due to the strong electric field existing between the auxiliary cathode and the main anode. In the latter arrangement the auxiliary cathode and anode are at a floating potential with respect to the main discharge electrodes with resultant erratic operation of the tube.

It is therefore an object of this invention to provide an arrangement for a grid controlled, high voltage, cold cathode discharge tube whereby in the absence of a grid signal the vapor in the main discharge path is maintained in a state of quiescent ionization with resultant elimination of the time delay between the occurrence of the grid signal and the occurrence of the main discharge.

It is a further object of this invention to provide an arrangement for a high voltage, grid controlled, cold cathode discharge tube whereby, during a quiescent ionization period, a non-floating, auxiliary, electron emitting cathode, is protected from the destructive effects of positive ion bombardment.

2

The above and other objects and features of the present invention will be made fully apparent to those skilled in the art from a consideration of the following detailed description taken in conjunction with the accompanying drawing in which the single figure depicts one embodiment of the present invention together with certain auxiliary elements which may be associated therewith.

Briefly this invention incorporates into a cold cathode discharge device having a tubular member acting as a control grid for the main discharge path a transverse baffle assembly which also may be considered part of the control grid, the baffle assembly dividing the tubular member into two chambers, and also incorporates into the cold cathode discharge device an auxiliary electron emitting cathode and an accelerating electrode. During a quiescent period the accelerating electrode draws electrons from the auxiliary cathode and directs them into the lower chamber where they ionize the gas therein. In the upper chamber, on the other hand, due to the close spacing of the chamber walls (formed respectively by the baffle assembly and the upper interior tubular member surface) to the main anode, no ionization of the gas occurs in spite of the high voltage field between the anode and the grid. The baffle assembly mentioned also shields the auxiliary cathode from the field of the main anode, thus deterring high velocity positive ion bombardment of the auxiliary cathode. The auxiliary cathode being tied in voltage level to the liquid cathode, the arrangement as a whole is freed from the problems which arise from the employment of a floating potential.

Referring now to the drawing, an evacuated glass envelope designated by 10 is arranged about a longitudinal axis extending in an up and down direction. At the apex of envelope 10 a downwardly extending hollow glass tube 12 is sealed into an envelope aperture concentric with the up and down axis. Similarly a downwardly extending conducting rod 14 is rigidly supported in the center of tube 12 from a point where it passes through a closure seal at the upper end of tube 12. Rod 14, which extends beyond the lower termination of tube 12, supports at its lower end a transverse disc-shaped main anode 16 disposed concentric with the tube axis. From its lower end to its upper sealing point the exterior of rod 14 is covered with a thin coating 18 of glass or similar insulating material. The purpose of coating

18 is to reduce the possibility of fortuitous discharges in the space enclosed by tube 12.

At the lower end of tube 12 a split collar 20, having a lower, transversely extending, circular flange 22, encircles the exterior of tube 12, the downward surface of the flange being flush with the lower end of the tube. Collar 20 is firmly clamped to tube 12 by a tightened bolt 24 which extends through tapped holes in two collar tabs. Spot welded or otherwise rigidly attached to the lower surface periphery of flange 22, a hollow metal cylinder 26 extends downwardly to a termination proximate to the surface of liquid cathode 28. Flange 22 and cylinder 26 form together a part of the control grid for the discharge path between main anode 16 and liquid cathode 28. It will be understood, of course, that flange 22 and cylinder 26 need not necessarily be fabricated from two sections and that any construction having a substantially similar form will be satisfactory.

Within the bore of cylinder 26 a transverse baffle assembly is supported below the main anode by a spot welding or other means to the interior of cylinder 26. The baffle assembly is constituted of two parts, namely, a first disc 30 perforate in its entirety and of the same diameter as the interior of the cylinder 26, and a second imperforate disc 32 of smaller diameter than the interior of the cylinder. Disc 30, extending transversely of the tube bore, is attached directly to the inner wall of cylinder 26. Disc 32 is supported concentrically, below, and closely spaced to disc 30 by a plurality of straps 34 attached at one of their ends by spot welding or other means to the periphery of disc 32 and similarly attached at their other end to the interior surface of cylinder 26. The perforate disc 30 and its baffle disc 32 together with cylinder 26 comprise the control grid of the device. Disregarding the space between discs 30 and 32, the baffle assembly divides the bore of cylinder 26 into an upper chamber 36 and a lower chamber 38. The baffle assembly serves to shield the lower chamber space from the electric field associated with the anode.

It is a familiar fact in the art that when an ionizable vapor fills the space between two electrodes, for a certain region of performance and for a constant pressure the length of gap necessary to resist breakdown from free electrons varies inversely with the potential applied between the two electrodes and the number of free electrons present. The present invention is designed to be capable of use with voltages between the main anode and cathode of 10 kilovolts or higher. Approximately the same voltage exists between the main anode and the control grid. Furthermore the number of free electrons in the upper chamber, due to the diffusion of electrons from the lower chamber through discs 30 and 32, even in the absence of acceleration by the anode field, exceeds by a considerable amount the number of free electrons which would exist in the absence of such diffusion. As a result the upper chamber 36 must be proportioned to avoid the possibility of a fortuitous discharge between the main anode and the control grid. In the embodiment shown, fortuitous discharges are prevented by so spacing disc 30, the upper interior surface of cylinder 26, and the lower surface of flange 22 that everywhere within upper chamber 36 a close spacing exists between points on main anode 16 and any points on the enclosing walls of chamber 36. By using close spacing in this manner, free electrons traveling within the vapor of chamber 36 will have an insufficient line of travel under the given pressure conditions to generate the avalanche effect necessary for a gaseous discharge.

At a level below that of the baffle assembly, envelope 10 protrudes outwardly in the form of a side arm 40. Parallel conducting rods 42 and 44 extend transversely from the exterior of the envelope into the space enclosed by side arm 40, rods 42 and 44 being supported in place by a sealed-in passage through the press 45. At the inboard ends of rods 42 and 44 an auxiliary filamentary cathode, typically comprised of tungsten, is supported by and electrically connected between the two rods. Rod 44 also supports, from a point of attachment slightly outboard of cathode 46, a transversely extending, cylindrical, conducting heat shield 48 which, in a manner familiar to the art, encircles auxiliary cathode 46. Heat shield 48 is in turn encircled by a concentric, conducting, accelerating electrode 50 having a closed but perforated inboard end 52. Accelerating electrode 50 is supported in place by an attachment to a transversely extending rod 54 which passes from the exterior of the envelope into the side arm space through a sealed passage in press 45. In operation accelerating electrode 50 performs the functions of drawing electrons away from auxiliary cathode 46 and of guiding electrons, escaping from perforated inboard end 52, through an aperture 53 in cylinder 26 and into lower chamber 38.

It will be appreciated of course that the auxiliary cathode 46 and accelerating electrode 50 need not be disposed in a side arm as described above. The auxiliary cathode may be located in any manner whereby it has an unobstructed field of view of at least part of the interior of the lower chamber, which is the equivalent of saying that there is an unobstructed path into the interior of the lower chamber for electrons emitted from the auxiliary cathode. Also the accelerating electrode may be located in any place where in effect it guides electrons into the lower chamber, and may assume any form suitable for the performance of the function. For example, the bottom of envelope 10 may be made reentrant to protrude as an island above the surface of liquid cathode 28, the auxiliary cathode may be mounted above this island, and the accelerating electrode may be disposed to guide emitted electrons upward or outward into the lower chamber.

Further, for example, the accelerating electrode may take the form of an auxiliary anode upon which electrons entering the chamber terminate their line of travel, rather than an electrode through which these same electrons pass in flight.

Cold cathode 28 may be comprised of any composition suitable for a vapour electric discharge device. Typically, a liquid cathode of pure mercury is utilized.

An electrical connection is made from the exterior to liquid cathode 28 by means of a rod 60 sealed into a lower stem of the envelope 10. In a similar manner an electrical connection is made from the exterior to the tubular member 26 by a rod 62 sealed into a side stem of the envelope 10, the rod 62 being electrically joined to cylinder 26 by a strap 64.

With respect to the external circuit connections, the exterior terminals of rods 42 and 44 are connected across a source of filament volt-

age, designated 66. This source of filament voltage may of course be any source satisfactory in the art. Accelerating electrode 50 is maintained at a positive potential with respect to the auxiliary cathode 46 by a connection of the exterior terminal of rod 54 to one end of filament voltage source 66 through a properly oriented positive bias supply 68. This mentioned end of filament voltage source 66 is in turn connected through a high impedance resistor 70 to ground. Cold cathode 28 is connected to ground through rod 60. Concerning the control grid, the exterior terminal of rod 62 is connected to ground through a high resistance 72. Positive voltages from a grid signal source are coupled to the control grid by a capacitor 74 connected to the exterior terminal of rod 62.

Where the discharge device is utilized to produce a pulse output, in one common form of plate connection, the exterior terminal of rod 14 is connected to a source of direct high voltage through a choke 76. The exterior terminal of rod 14 is also connected to ground through a series path including a pulse-forming line 78 and a pulse transformer 80. In operation, during a quiescent period, the full plate voltage is impressed between the upper and lower sides of pulse line 78. With the appearance of a positive voltage triggering signal upon the control grid of the discharge device, an extremely high current discharge takes place between main anode 16 and liquid cathode 28, the tube thereby effectively shorting the upper side of pulse line 78 to ground. As a result, pulse line 78 rapidly discharges, causing a short but heavy pulse of current through the primary of pulse transformer 80 which reappears as an induced pulse across the terminals of the secondary of pulse transformer 80. Choke 76 during the pulse formation period retards the flow of current from the high voltage source. Therefore, upon completion of the discharge of pulse line 78, the arc between main anode 16 and liquid cathode 28 is extinguished since there is insufficient current to maintain it.

Typical values used in conjunction with the present invention are as follows:

Positive bias supply 68.	20 volts.
Control grid signal	300 volts.
Anode supply voltage	10 to 15 kilovolts.
Choke 76	100 henries.
Pulse line 78	6 microseconds, 50 ohms, characteristic impedance.
Time of response	Less than one microsecond.

Considering now the action of the discharge device as it may be considered to operate, as mentioned heretofore, during a quiescent period the main anode 16 is maintained at a high potential, typically 10 kilovolts, with respect to ground. A strong field as a result is associated with the main anode. Due to the presence of the baffle assembly, however, substantially all of the lines of th s strong field terminate either upon the baffle assembly itself, or upon the surface of the control grid bounding upper chamber 36. Substantially, no field lines penetrate into lower chamber 38, and the space within this chamber can be considered to represent a ground potential field.

As has also been mentioned heretofore, both the surface of the control grid enclosing the main anode and the upper surface of the baffle assembly are spaced closely to the main anode. As a result, electrons produced within upper chamber 36 or diffusing into upper chamber 36 through the baffle assembly as a result of their random motion within the lower chamber 38, have so short a line of travel between opposite potential surfaces that the electrons do not, under the given pressure conditions, produce an avalanche effect. It is seen therefore, that during a quiescent period, the vapor in the upper chamber will remain in an un-ionized state, and the upper chamber will be free of fortuitous discharges in spite of the strong electric field running between the anode and the control grid.

While the electron discharge device is in operation, the auxiliary cathode 46 will be heated to an electron-emitting temperature by currents produced by filament voltage source 66. Accelerating electrode 50 is maintained by voltage supply 68 at a positive potential, typically 20 volts, with respect to cathode 46. As a result electrons are drawn from the auxiliary cathode to the accelerating electrode, and of these electrons a portion will pass through the perforations of the inboard end 52 of the accelerating electrode, continue through aperture 53 and flood the chamber 38. These flooding electrons travel with sufficient velocity to disassociate the mercury atoms of the vapor contained within the chamber 38. Since the flow of electrons from cathode 46 into chamber 38 is continuous, the gas contained within lower chamber 38 is maintained in a state of quiescent ionization. The flooding electrons at the end of their travel, migrate either to the surface of control grid 26 or to the surface of liquid cathode 28. In the former case, the electrons return to the auxiliary cathode through the path including resistance 72, ground, and resistance 70. In the latter case the same return flow occurs except that the electrons go directly from cold cathode 28 to ground. During a period of quiescence, since the total current flow through resistance 70 is very small, being measured in terms of microamperes, the auxiliay cathode 46 remains substantially at ground potential. The potential of cathode 46 is thus not a floating one, but is tied to one side of the main discharge circuit.

Positive ions are produced as a result of the bombardment of the mercury atoms in chamber 38 by the flooding electrons from auxiliary cathode 46. Of these positive ions so created, the great majority recombine with free electrons in the gas, these free electrons also being produced by the disassociation of the mercury atoms. It will be seen therefore, that there is maintained within the chamber 38 a substantial equilibrium between the continuing processes of disassociation and recombination which equilibrium is characterized by a blue glow which may be seen existing within chamber 38. Of the positive ions which may be thought to be permanently freed, most of them fail to reach auxiliary cathode 46 because of the repelling effect of the positive voltage on accelerating electrode 50. A small minority of the positive ions initially produced, however, will go to auxiliary cathode 46. Because of the presence of the baffle assembly which isolates the strong electric fields associated with the main anode 16 from the region of the lower chamber these positive ions are not accelerated towards cathode 46 through a strong potential field. The greatest potential through which they can move, in fact, is that existing between accelerating electrode 50 and auxiliary cathode 46. This potential which is typically on the order of about 20 volts, is not sufficient to cause the positive ions to

bombard the auxiliary cathode with destructive velocity. Thus, during the quiescent period, the auxiliary cathode 46 is protected from deterioration due to positive ion bombardment.

When a signal in the form of a positive voltage is impressed upon the control grid, the electrical level of the grid is raised sufficiently to allow the electric field lines from main anode 16 to penetrate through the perforations in the baffle assembly and extend into the lower chamber 38. Free electrons in the lower chamber 38 will be attracted at a high velocity upward through the perforations in the baffle assembly and, striking mercury atoms in the upper chamber 36, will cause substantially instantaneous ionization of the vapor contained in the upper space. A fully ionized path now exists between the main anode 16 and liquid cathode 28. By a phenomenon familiar to the art, but not yet completely explained, a cathode spot will form upon the surface of cold cathode 28 and the main discharge will now take place, building up to a full value at which it may conduct a current of thousands of amperes. The interval of time elapsing between the appearance of the signal on the grid and the appearance of the main discharge is so short that it may be considered negligible. This interval of time has been measured typically to be less than one microsecond.

During the interval of time between the creation of a fully ionized path between main anode 16 and liquid cathode 28, and the existence of the full main discharge a strong electric field exists between the main anode and the auxiliary cathode 46, and cathode 46, of course, will be subjected to a brief, high velocity, positive ion bombardment. This transient shower of high velocity particles, however, causes no appreciable damage to cathode 46 for the reasons that the interval of time is so short, that the positive ion current through cathode 46 is limited in value by the high impedance of resistance 70, that the auxiliary cathode is located in the side arm and that it is further shielded by accelerating electrode 50, and is thus removed from the full effect of the main anode field. When once the main discharge has reached its full value, auxiliary cathode 46 is once again substantially free from high velocity, positive ion bombardment due to the fact that the voltage between main anode 16 and liquid cathode 28 now is at a low value, typically, a hundred volts.

It is therefore seen that the present invention represents a grid controlled, high voltage, cold cathode discharge tube capable of handling heavy current and having a substantially instantaneous response to a signal impressed upon the control grid. In addition, the present invention represents a vapor discharge device having a long operating life since the auxiliary electron emitting cathode is almost completely protected from the deleterious effect of positive ion bombardment. Many applications of the present invention will occur to those familiar with the art. In particular, the present invention is ideally suited for the production of triggered, high voltage, high current pulses.

Although a single embodiment of this invention has been herein disclosed and described, it is to be understood that it is merely illustrative of this invention and various modifications may, of course, be made without departing from the spirit and scope of the invention as defined in the appended claims.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

What is claimed is:

1. A grid-controlled, fast response, cold cathode discharge device comprising, in combination, an evacuated envelope, a mutually spaced anode and cold cathode within said envelope, a control grid disposed to shield the lower portion of the discharge path between said anode and said cathode from electric fields associated with said anode, an auxiliary cathode adapted to emit electrons, and means separate from said control grid for continuously directing electrons from said auxiliary cathode into said lower portion of said path.

2. A grid-controlled, fast response, cold cathode discharge device comprising in combination an evacuated envelope, a mutually spaced upper anode and lower cold cathode within said envelope, a tubular member enclosing said main anode and extending almost to said cold cathode, a transverse perforate baffle assembly disposed in the tubular member bore below said anode and being divisive of said bore into upper and lower chambers, said tubular member and said baffle assembly forming a control grid, an auxiliary cathode disposed to have an unobstructed field of view of at least part of the interior of said lower chamber, and an accelerating electrode, separate from said grid, disposed to guide electrons emitted from said auxiliary cathode into said lower chamber.

3. The combination of claim 2 further provided with a source of voltage connected in a path between said auxiliary cathode and said accelerating electrode with its positive end towards the latter, and a direct current conducting, high impedance path between said auxiliary and cold cathodes.

4. A grid-controlled, fast response, cold cathode discharge device comprising, in combination, an evacuated envelope, a mutually spaced upper anode and lower cold cathode within said envelope, a tubular member with its upper end at all points closely enclosing said anode and its lower end located near said cold cathode, a transverse perforate baffle assembly disposed in the tubular member bore below and close to said anode and being divisive of said bore into upper and lower chambers, said tubular member and said baffle assembly forming a control grid, an auxiliary cathode disposed to have an unobstructed field of view of at least part of the interior of said lower chamber, and a perforate accelerating electrode, separate from said grid disposed proximate to said auxiliary cathode in the direction of the field of view.

5. A grid-controlled, fast response, cold cathode discharge device comprising, in combination, an evacuated envelope, a mutually spaced upper anode and cold lower cathode within said envelope, a control grid including an annular section and a tubular section attached thereunder to the periphery thereof, said sections being coaxially and closely spaced above and about, respectively, said anode, the latter section reaching almost to said liquid cathode and the lower portion of said tubular section having an aperture therein, a perforate baffle assembly, also a part of said control grid, extending transversely of the tubular section bore, closely below said anode and above said aperture, a side arm of said envelope spaced outward of and opposite to said aperture,

an auxiliary cathode spaced within the side arm bore, and a perforate accelerating electrode spaced between said aperture and said auxiliary cathode.

6. The combination of claim 5 further provided with a source of voltage connected in a path between said auxiliary cathode and said accelerating electrode with its positive end towards the latter, and a direct current conductive high impedance path between said auxiliary and cold cathodes.

7. A grid-controlled, fast response, cold cathode discharge device comprising, in combination, an evacuated envelope, a mutually spaced upper anode and lower cold cathode within said envelope, a control grid including a flat closure section closely spaced above and parallel with said anode and a tubular section closely spaced coaxially about said anode, said sections forming a continuous conductor, the latter section reaching almost to said cold cathode, a tranverse perforate baffle assembly, also a part of said control grid, disposed in the tubular section bore below and close to said anode and being divisive of said bore into upper and lower chambers, an auxiliary cathode adapted to emit electrons, and means for directing electrons emitted from said cathode during a quiescent period into said lower chamber.

8. A grid controlled, fast response, cold cathode discharge device comprising in combination, an

evacuated envelope, an anode, a cold cathode, and an auxiliary cathode within said envelope, a conducting means substantially enclosing said anode, and a shielding means electrically connected therewith disposed to protect the auxiliary cathode from deteriorating positive ion bombardment.

9. A grid controlled, fast response, cold cathode discharge device comprising, an evacuated envelope, an anode and a cold cathode disposed within said envelope, a conducting means substantially enclosing said anode, a transverse perforate baffle interposed between said anode and the cold cathode side of said conducting means, an auxiliary cathode and an accelerating electrode therefor disposed within said envelope for continuously directing electrons into the space separating said cold cathode and said conducting means, and shielding means for said auxiliary cathode connected to said conducting means and disposed to shield said auxiliary cathode from the main discharge path between said anode and cold cathode.

ROBERT A. HERRING, JR.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,263,958	Strobel	Nov. 25, 1941