Dec. 17, 1963 P. W. STUTSMAN 3,114,860

GASEOUS DISCHARGE INDICATOR DEVICES

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FIG. 1

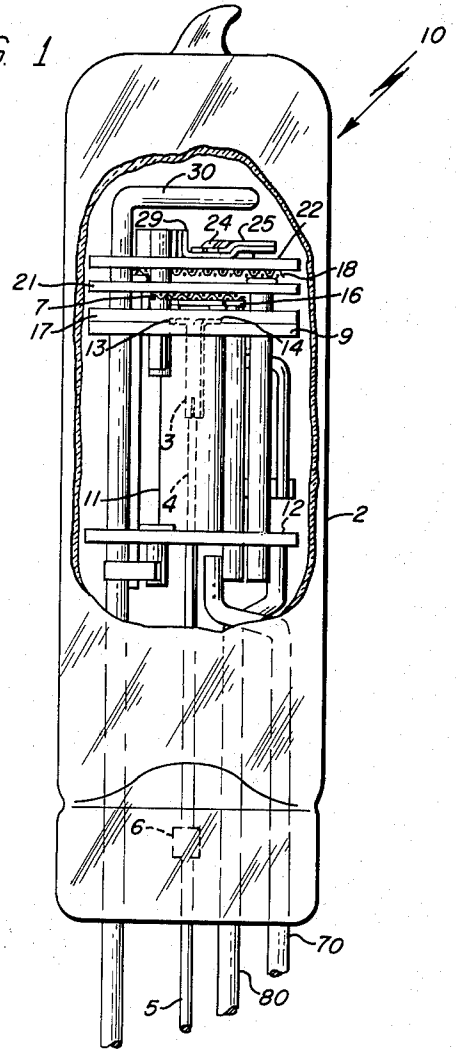


FIG. 2

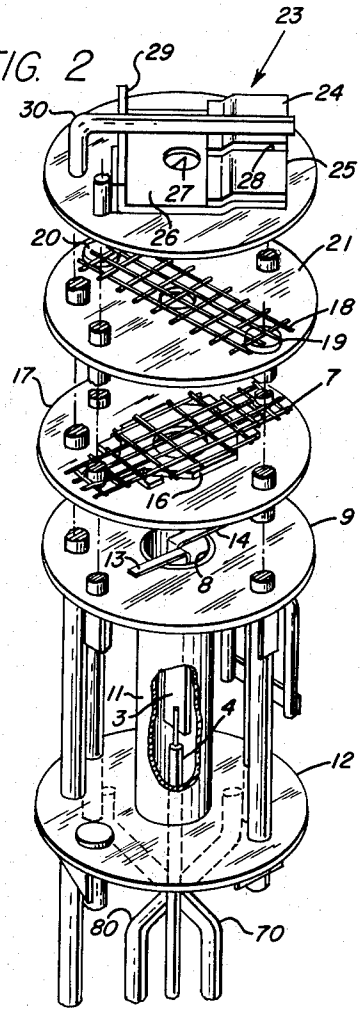


FIG. 3

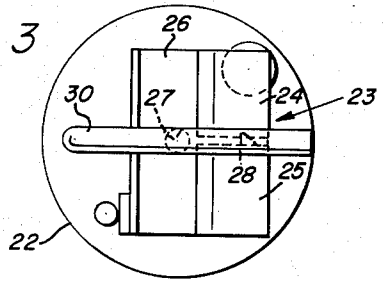
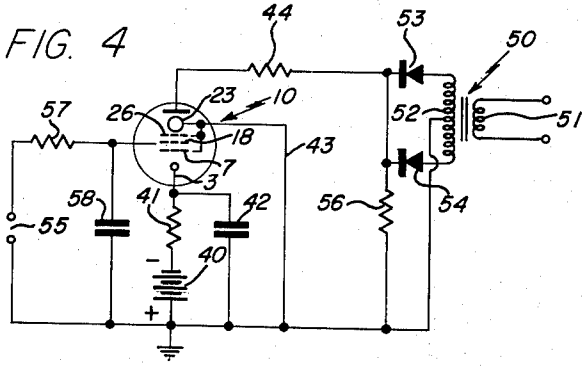


FIG. 4



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FIG. 5

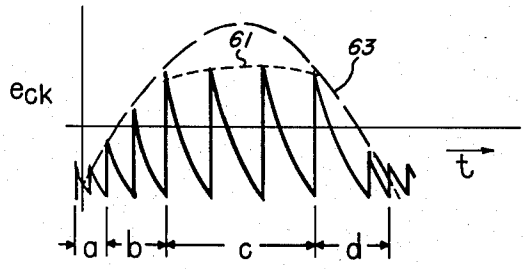


FIG. 6

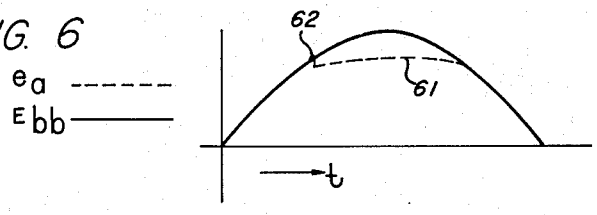


FIG. 7

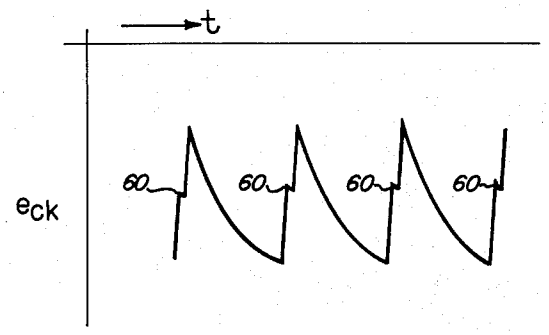
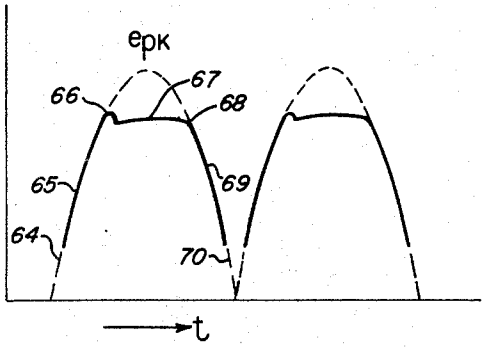


FIG. 8



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GASEOUS DISCHARGE INDICATOR DEVICES

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9 Claims. (Cl. 315—169)

This invention relates generally to electron discharge devices, and more particularly to a gaseous discharge device of the cold cathode type in which control may be achieved utilizing extremely low values of grid voltage, and at extremely low power levels.

Cold cathode gaseous tubes are known in the art in which conduction through the tube may be initiated and controlled by the application of suitable voltages to the grid electrode. However, known devices of this type operate with grid voltages ranging from 60 to 80 volts which are necessary in order to cause the tube to fire when the grid conduction process is initiated. Some gaseous discharge devices of this type may operate with signal voltages in the neighborhood of 12 volts as supplied, for example, by suitable transistor circuitry. However, a gaseous tube utilized for primarily indicating purposes, such as a neon glow lamp, will not fire with a voltage of this low value applied to its grid. Accordingly, gaseous indicator tubes for use particularly in conjunction with transistor circuitry are not presently readily available.

In accordance with the present invention, a grid-controlled cold cathode gaseous discharge device is provided in which the conduction process in the tube may be initiated by the application of voltage values to the grid which may be extremely low, that is, on the order of 2 volts. Additionally, a device in accordance with the present invention draws only an extremely low value of stand-by power, i.e., on the order of .005 watt. The low grid voltage value at which control may be effected makes it possible to utilize the indicator lamp in combination with transistors with all the attendant advantages gained by the use of transistor circuitry. Further, since the tube of the present invention uses only an extremely low stand-by power, it is particularly suited for applications where several hundred tubes may be required, as for example, in computer applications wherein the programming of the computer is ascertained by the pattern of indicator lights.

The invention will be better understood as the following description proceeds, taken in conjunction with the accompanying drawings wherein:

FIG. 1 is an elevation view, partially broken away, of a gaseous discharge device in accordance with the present invention;

FIG. 2 is an exploded view of the interior construction of the various electrodes of the tube shown in FIG. 1;

FIG. 3 is a plan view of the anode and cold cathode structure shown in FIGS. 1 and 2.

FIG. 4 is a circuit diagram of a typical circuit utilizing a gaseous discharge device in accordance with the present invention;

FIG. 5 is a waveform of the voltage present at the keep-alive cathode during operation of the tube of FIG. 1;

FIG. 6 is a waveform of the instantaneous anode voltage present at the anode of the device during operation;

FIG. 7 is another waveform of the keep-alive cathode voltage showing the point at which discharge transfers from the keep-alive cathode to the cold cathode; and

FIG. 8 represents a typical oscillograph of the anode waveform during each current pulse.

Referring now to the drawings, and more particularly to FIG. 1 thereof, there is shown generally at **10** a

gaseous discharge device in accordance with the present invention comprising a sealed outer envelope **2**, which may be glass, for example, containing the various electrodes of the device. The envelope **2** is filled with a suitable gas at a suitable pressure. For example, optimum results were achieved utilizing a mixture 99.9 percent neon and 0.1 percent argon at 30 centimeters of pressure mercury column.

A keep-alive cathode **3** is positioned within the envelope **2**, and is connected by an insulated lead-in wire **4** to a suitable conducting lead **5** at the point **6** positioned in the glass press of the envelope **2**. The keep-alive cathode **3** is suitably insulated so as to allow conduction to a first grid **7** by no other path except through the central hole **8** located in the insulating spacer **9**. To this end, the keep-alive cathode **3** is enclosed by a ceramic sleeve **11** and is isolated at the top and bottom by the spacers **9** and **12**. The keep-alive cathode **3** may be a zirconium ribbon, for example, which is split at its top, and along a portion of its length, so that each half of the split portion along this length may be bent at substantially right angles to form the projections **13** and **14**. The projections **13** and **14** rest on top surface of the spacer **9** adjacent the central hole **8** whereby a positive location of the keep-alive cathode **3** with respect to the first, or keep-alive grid **7**, is achieved. It will be noted that by thus structurally forming the keep-alive cathode **3** with projections **13** and **14**, only two entrance holes are left for the passage of the keep-alive discharge. Since during operation of the device, the keep-alive discharge causes material from the keep-alive cathode **3** to sputter from the cathode, it is essential that this sputtered material be prevented from disposing itself on the conducting elements of the tube and thereby causing leakage between the conducting elements should the insulation between them become sufficiently coated. With the keep-alive cathode structure of the present invention, the material which is sputtered off the keep-alive cathode is deposited mostly on the inside wall of ceramic sleeve **11** thereby eliminating the build-up of conducting paths between the various tube elements.

Positioned above the keep-alive cathode **3** is a keep-alive grid **7**. During tube operation, the grid **7** functions as an anode with respect to the keep-alive cathode **3**, and secondly provides a virtual cathode from which electrons are available for passage to the control grid **18**. Since faulty operation has been found to result from leakage when the grid **7** rested directly in contact with insulating spacer **17** due to stray sputtered deposits in the vicinity of the central hole in spacer **17**, the present invention provides an insulating element **16** for supporting grid **7**. The element **16** rests upon the spacer **17**, and provides a clearance between the grid **7** and the spacer **17**. Thus, sputtered material which may stray on to the surface of the spacer **17** will not effect the operation of the grid **7**. In a preferred embodiment of the present invention, the grid **7** was composed of a web-like structure made of 60×60 mesh of .005 inch nickel wire suitably welded to the support structure **16**. The top surface of element **16** is spaced from the surface of spacer **17** by a distance of approximately 0.01" due to the thickness of element **16**. Thus, keep-alive grid **7** which rests on element **16** is spaced from keep-alive cathode **3** at a distance greater than the minimum breakdown distance for the gaseous medium utilized in the embodiment being described. It has been found that variations in the gap distance between keep-alive cathode **3** and keep-alive grid **7** affects the virtual cathode at the keep-alive grid **7**, and hence the grid control characteristic. The preferred spacing of these two elements is on the order of 0.015" to 0.020".

Positioned above the keep-alive grid **7** is a second, or

control grid 18 which is supported on insulating heads 19 and 20 attached to the insulating spacer 21 to provide a clearance between the grid 18 and the top surface of the spacer 21 in the same manner as described with respect to the keep-alive grid 7. In the embodiment being described, the control grid 18 was constructed of the same mesh material as was used for the keep-alive grid 7.

A fifth insulating spacer 22 is positioned above the spacer 21 supporting the control grid 18, and carries a cathode structure indicated generally at 23. This second cathode is a cold cathode structure which is shown as comprising separate pieces 24 and 25 positioned on top of, and attached to, a shield grid 26. The shield grid 26 rests upon the insulating spacer 22 and is provided with a substantially central hole 27 to provide a path for the discharge. In this particular embodiment, shield grid 26 was constructed of a bright nickel plate having dimensions of approximately 0.109" x 0.125" x 0.005". The hole 27 had a diameter of 0.025". As shown, the cold cathode 23 is comprised of spaced pieces or plates 24 and 25 thereby providing a channel 28 which is positioned to be substantially perpendicular to an upraised fin 29 located at one end of the shield grid 26. The channel 28 is so formed that it lies substantially on the center line bisecting the central hole 27 is shield grid 26. The plates 24 and 25 are preferably of zirconium, and are positioned approximately 0.006" apart, i.e., channel 28 had a width of 0.006". The edges of plates 24 and 25 closest to central hole 27 were spaced about 0.0025" away from an imaginary line running tangent to the edge of hole 27 and parallel to a plane perpendicular to shield grid 26 containing these edges. By utilizing this particular geometry, it has been found that a beneficial reduction in the minimum anode starting voltage is achieved since the exact active region of the zirconium cathode is more precisely localized. The discharge will search out and become entrenched in the hollow cathode region provided by channel 28. Although once initiated the glow spreads over the zirconium in proportion to the current drawn, the most active portion of the cathode remains in the channel 28, thus reducing the spacing variation in the pick-up mechanism.

The shield grid structure shown has been found to perform several beneficial functions. In addition to decreasing by more than an order of magnitude the critical preconduction current to control grid 18, it also allows good visibility of the light produced on the cathode 23, reduces the magnitude of control grid noise occuring during anode conduction, and shields the upper tube structure from material which may be sputtered from the light-producing cathode 23. The reduction of critical preconduction current described above is believed to result when positive ions formed in the space between the shield grid 26 and anode 30 are largely screened from control grid 18 during the flow of critical control grid current. Reduction of control grid noise results from grid 26 shielding control grid 18 from the collections of positive ions which would otherwise occur at electrodes near the cathode and at cathode potential.

With the anode and cold cathode structure thus described, the light emanating from the glow discharge taking place between cathode structure 23 and anode 30 is readily visible. It will also be noted that no other electrode elements are interposed in the discharge path between the cold cathode structure 23 and the anode 30. As shown in FIG. 2, the anode is preferably constructed from a wire bent at a substantially 90° angle so that the active portion of the anode 30 extends over the active cathode region, i.e., over the channel 28. Anode 30 was made of 0.020" diameter nickel wire bent as described above so that the horizontal portion of the anode was approximately 0.045" above the hole 27. The anode lead and other leads to the grids further serve to clamp the assembly together, and to make electrical connection to the stem leads 70, 80.

Characteristic operation of the tube in accordance with this invention can be obtained when it is utilized in a circuit such as that shown in FIG. 4, by way of example. Where appropriate, the same reference numerals refer to like parts shown in FIGS. 1 and 2. The keep-alive cathode 3 of the tube 10 is connected to a suitable source of bias voltage 40 through the resistor 41. Source 40 and resistor 41 provide a D.C. potential sufficient to start and maintain a discharge between keep-alive cathode 3 and grid 7. As a typical illustration, and not by way of limitation, the value of source 40 may be on the order of 250 volts, while resistor 41 may have a value of 10 megohms. The keep-alive cathode 3 is also connected to condenser 42, the other side of which is connected to ground. Keep-alive grid 7 and shield grid 26 are connected to the cold cathode structure 23 which in turn is connected to ground through the wire 43. The anode 30 is connected to a source of appropriate D.C. voltage through the resistor 44. This direct current voltage is obtained by full wave rectification of alternating current voltage supplied to the primary winding 51 of the transformer 50. The secondary winding 52 has a pair of diodes 53 and 54 connected to opposite ends thereof which supply a pulsating direct voltage to the anode 30. The control signal is applied to the control grid 18 through the terminals 55, and grid resistor 57. A grid shunting capacitor 58 is connected between grid 18 and ground. In the illustration being described, grid resistor 57 may have a value of 0.1 megohm while capacitor 58 may have a value of 0.001 f.

In operation of the circuit of FIG. 4, a relaxation discharge is maintained between the keep-alive cathode 3 and the keep-alive grid 7. The keep-alive cathode 3 is connected through the resistance 41 to the negative terminal of a source of direct voltage in order to initiate and maintain the keep-alive discharge. The full wave rectified voltage obtained from the transformer 50 serves to extinguish the glow discharge occurring between the cold cathode 23 and the anode 30 after this conduction process is initiated by the signal voltage applied to the grid 18 through the terminals 55. For example, the critical D.C. control grid voltage may on the order of 2 volts negative with respect to ground, the control grid 18 ordinarily being biased more negative than this value. Since grid 18 is able to hold off discharge between cold cathode structure 23 and the anode 30, but cannot interrupt this discharge once it has started, control after discharge is obtained by reducing the anode voltage to less than the extinction voltage of the main gap between cold cathode 23 and anode 30. Accordingly, an appropriate bleeder resistance 56 is preferably connected across the rectified voltage source in order to insure that the voltage waveform essentially reaches zero at each minimum. The frequency of the voltage emanating from the transformer 50 may be on the order of 120 cycles per second.

With a negative voltage of sufficient magnitude applied to control grid 18, for example, on the order of 2 volts, no appreciative current flows through the tube to the anode 30. However, if the control grid 18 is swung positive toward zero, the critical 2 volt value toward zero, the field in the area of the anode 30 progressively gives more electrons sufficient energy to reach the anode 30 during each relaxation oscillation of the keep-alive cathode 3. When a sufficient number of electrons per second flow to the anode 30, a glow discharge is formed between the cathode 23 and the anode 30 in accordance with well-known cumulative ionization processes. In a particular description of the keep-alive discharge, the condenser 42 charges negatively through resistance 41 until the starting voltage of the gap between keep-alive cathode 3 and grid 7 is exceeded at which point this gap strikes. Condenser 42 then discharges very rapidly to the extinction voltage of this gap. The above-described process repeats periodically, and takes place at a rate on the order of 30 times that of the anode supply frequency, i.e., at 3.0 to 4.0 kilocycles. The relaxation fre-

quency rate of the keep-alive discharge is not synchronized with the rate of the frequency variation of the direct voltage being supplied to the anode **30**.

A reference to FIGS. 5 and 6 will demonstrate more clearly the relationship between the keep-alive voltage and the anode voltage plotted with respect to ground potential. For purposes of clarity the ratio of the periods of the anode and keep-alive phenomenon has been purposely distorted. As shown in FIG. 5, the oscillations applied to the cathode **3** which occur during the region *a* are not affected by the anode voltage. As soon as the anode voltage increases beyond a certain value related to the geometry and the bias on the control grid **18**, the discharge occurring between the keep-alive cathode **3** and the keep-alive grid **7** transfers from the keep-alive grid **7** to the anode **30**. This point of transfer is indicated by the bumps **60** shown on the waveform of FIG. 7. This curve represents approximately the voltage at the keep-alive cathode **3**. The transfer occurs during each cycle of the keep-alive oscillation indicated in the region *b* shown in FIG. 5. During region *b*, the extinction of the discharge is now dependent upon the extinction characteristic of the anode to keep-alive cathode gap. For practical purposes, this can be considered constant for a given control bias applied to the grid **18**. The voltage maxima of the relaxation oscillations trace an envelope which defines the value of the extinction voltage of the anode to keep-alive discharge. This envelope is indicated by the dotted line **61** in FIGS. 5 and 6. The long dashed line **63** in FIG. 5 indicates the trace envelope which would be reached if the main gap were not struck along the line **61**. There is a decrease in the keep-alive cathode relaxation frequency as the value of the anode voltage rises, and an increase in the average value of the current drawn by keep-alive cathode **3** while the average value of the current from the keep-alive cathode **3** to keep-alive grid **7** decreases. The instantaneous value of the voltage at the keep-alive cathode at the instant of extinction of the keep-alive discharge measured with respect to ground potential, thus will equal the instantaneous anode voltage minus the anode to keep-alive cathode gap extinction voltage.

When the anode supply voltage reaches a sufficiently high value as indicated by the point **62** in FIG. 6, the main gap between the cold cathode structure **23** and the anode **30** is ignited as a function of the ionization produced in the gap between the anode and the keep-alive cathode. After this main gap has been struck, the voltage applied to the anode is traced by the dotted line **61** in FIGS. 5 and 6. Because of the regulating characteristic of the main gap, the instantaneous anode voltage remains relatively constant during the region *c* in FIG. 5. The region *c* indicates the time period during which ignition has occurred between the anode **30** and the cold cathode **23**. During this region, the zirconium cathode **23** glows with a bright, readily visible light.

The main portion of the anode current is determined by the resistor **44**, while the portion supplied by the keep-alive cathode **3** is determined both by resistor **44** and resistor **41**. The main gap between anode **30** and the cold cathode structure **23**, once started, conducts continuously until the voltage applied to the anode is no longer high enough to maintain the discharge. Conduction between the anode and the keep-alive cathode occurs during the region *d* shown in FIG. 5 and is of a character similar to that which occurs in region *b* except that the peak amplitude decreases in successive cycles.

FIG. 8 illustrates a typical waveform of the voltage at the anode **30**. The dashed portion **64** of the curve represents the time period during which the anode **30** begins collecting electrons from the keep-alive cathode **3**. During the portion of the curve indicated at **65**, the average current to the keep-alive grid **7** changes sign and when the point **66** is reached, the anode has collected a sufficient number of electrons from the cold cathode structure on grid **26** to initiate a glow discharge between the cathode structure **23** and the anode **30**. At this point, the anode voltage breaks when the glow discharge has become established. During the region **67** of the curve shown in FIG. 8, a characteristic neon glow is maintained between the cold cathode **23** and the anode **30**. At point **68**, the anode voltage has fallen below that necessary to sustain the discharge between the anode **30** and the cold cathode **23** at which point this discharge is extinguished. The anode to keep-alive cathode discharge still persists, but with decreasing current. As the curve progresses downwardly through the portion **69**, the current to the keep-alive grid **7** again changes sign until the dashed portion **70** is reached at which time current flow between the keep-alive cathode **3** and the anode **30** ceases. The next cycle then repeats the process.

Due to the persistance of human vision, the tube appears to be continuously conducting even though it actually flickers at a rate of 120 times per second as controlled by the frequency of the voltage emanating from the transformer **50**.

Thus, it can be seen that the present invention provides a gaseous light indicator device in which no control electrodes are positioned between the main cathode **23** and the anode **30**. Since the third element keep-alive is hidden from view of the main discharge, the glow emanating from the end of the tube is readily visible and can be advantageously utilized to perform its indicating function. The further advantage is attained that ions are always maintained in the keep-alive region which speeds up the turn on time of the tube. The light indicator is capable of producing adequate light, and of being controlled by a small voltage at a low power level. The total efficiency of the tube is on the same order as that of a diode glow lamp. Although there has been described what is considered to be a preferred embodiment of the present invention, various adaptations and modifications may be made without departing from the scope of the invention as defined in the appended claims. For example, the percentage of argon in the gaseous medium may range from 0.1 percent to 1 percent and still produce satisfactory tube operation.

What is claimed is:

1. An electron discharge device comprising an envelope containing an ionizable gas, a cold cathode structure positioned in said envelope adjacent to an anode, the cold cathode structure comprising spaced plates providing a groove between them, which groove is positioned substantially directly beneath said anode.

2. An electron discharge device comprising an envelope containing an ionizable gas, a keep-alive cathode positioned at one end of said envelope, a keep-alive grid position adjacent said keep-alive cathode, a control grid positioned adjacent said keep-alive grid and on the side thereof opposite the keep-alive cathode, a cold cathode structure positioned adjacent said control grid and on the side thereof opposite the keep-alive grid, and an anode positioned adjacent said cold cathode structure and on the side thereof opposite the control grid.

3. An electron discharge device according to claim 2 wherein an insulating shield encloses the major portion of said keep-alive cathode.

4. An electron discharge device according to claim 2 in which said keep-alive cathode comprises a body of zirconium having a split portion at one end with the split portion being bent at substantially right angles to the remainder of the zirconium body.

5. An electron discharge device according to claim 2 in which said keep-alive cathode has an insulated lead wire attached thereto.

6. An electron discharge device comprising an envelope contianing an ionizable gaseous medium, a keep-alive cathode, a keep-alive grid carried by a first insulating spacer, said keep-alive grid being raised above said first

insulating spacer by an additional insulating member interposed between said keep-alive grid and said first insulating spacer, a control grid carried by a second insulating spacer, said control grid being raised above said second insulating spacer by an additional insulating member interposed between said control grid and said second insulating spacer, a cold cathode structure, and an anode.

7. An electrical system comprising a gaseous discharge tube having a first cathode, a first grid, an anode, and a second cathode, circuit means connected between said first grid and said first cathode for maintaining an intermittent discharge between said first grid and said first cathode, voltage means connected to said anode tending to cause a discharge between said anode and said second cathode, a control electrode interposed between said first and second cathodes and adapted to control the initiation of the discharge between said second cathode and said anode, and means connected to said control electrode for applying a signal to said control electrode to cause said discharge between said anode and said second cathode to be initiated during an impulse of said intermittent discharge.

8. An electrical system comprising a gaseous discharge tube having a first cathode, a first grid, a second cathode, and an anode, means connected between said first cathode and said first grid for causing an intermittent discharge between these two electrodes, circuit means connected between said anode and said first cathode for causing said discharge to transfer shortly after initiation to said anode, a control electrode interposed between said first and second cathodes and adapted to control the initiation of a second discharge between said anode and said second cathode, and means connected to said control electrode for applying a signal voltage to said control electrode to initiate said second discharge.

9. An electron discharge device comprising an envelope containing an ionizable gaseous medium, a keep-alive cathode in one portion of the envelope, a keep-alive grid adjacent said cathode, a control grid adjacent the keep-alive grid and on the side thereof opposite the keep-alive cathode, a shield grid adjacent the control grid and on the side thereof opposite the keep-alive grid, a cold cathode supported by the shield grid on the side thereof opposite the control grid, said cold cathode comprising a pair of spaced members having a channel between them, and an anode above the cold cathode.

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