Feb. 5, 1952 P. W. STUTSMAN 2,584,758

GASEOUS DISCHARGE DEVICE

Filed June 25, 1949 2 SHEETS--SHEET 1

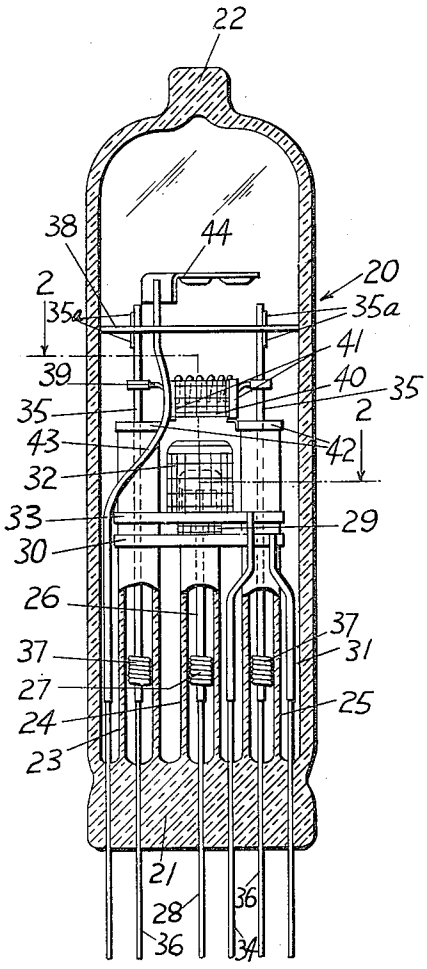


FIG. 1

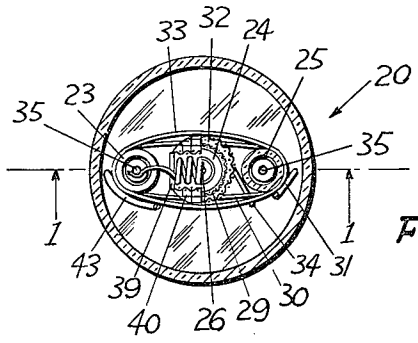


FIG. 2

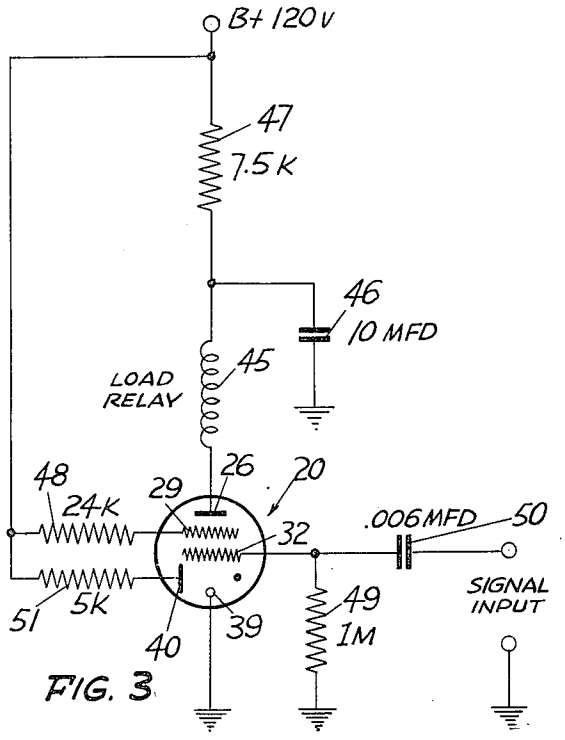


FIG. 3

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GASEOUS DISCHARGE DEVICE

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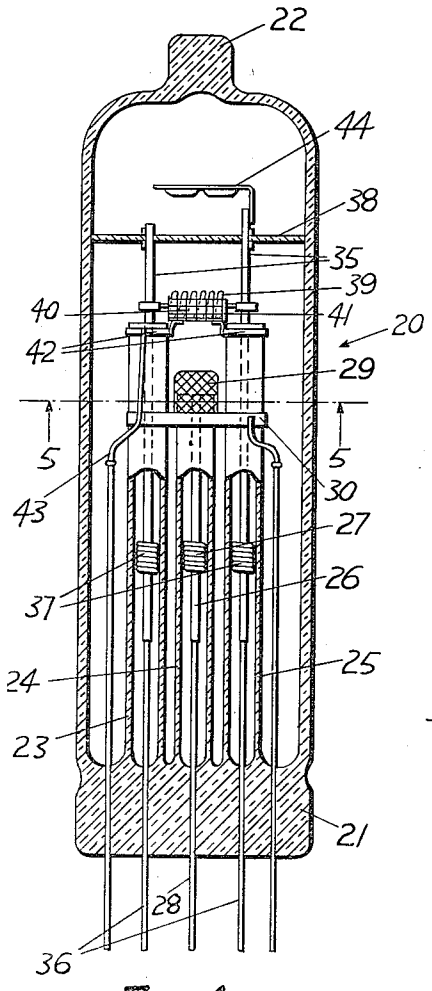


FIG. 4

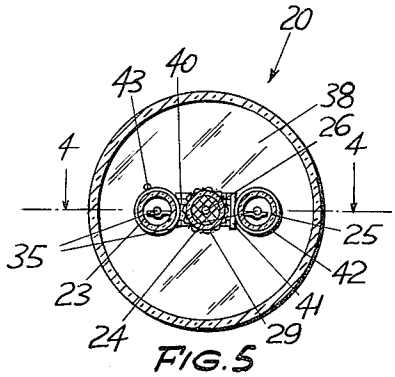


FIG. 5

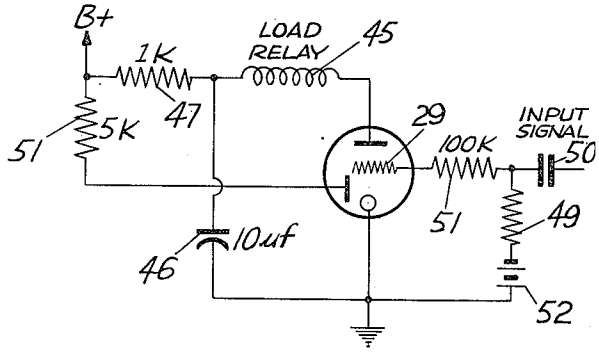


FIG. 6

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GASEOUS DISCHARGE DEVICE

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3 Claims. (Cl. 313—193)

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This application relates to electron discharge devices and more particularly to gas-filled discharge devices of small size.

Heretofore, it has been difficult to manufacture gas discharge devices of a small size which would carry heavy currents and operate for a long period of time without failure. This is due in part to a tearing off of particles of molecular size from the electron emissive coating of the cathode by high peak currents. The particles then occlude the gaseous filling of the tube and may be deposited on other elements of the device, thus depleting the store of electron emissive material on the cathode until ultimate failure of the device occurs. The occlusion of the gaseous medium by the electron emissive material detracts from the gaseous pressure, thus varying the operating characteristics of the tube and more particularly increasing the rate at which cathode deterioration takes place, since cathode deterioration in general varies inversely as a function of the pressure of the gas in the tube. This phenomenon is particularly true of gas discharge devices employing a cold cathode.

A further difficulty, encountered in producing gas discharge tubes of subminiature size, occurs from breakdown between the elements of the tube, for example, between the anode and cathode at relatively low voltages. It has been found that this difficulty can be overcome by placing adequate shielding grids between the anode and cathode.

Further, in cold cathode tubes it has heretofore been difficult, if not impossible, to fire the tube by the application of a suitable low potential to a control grid. This difficulty has been overcome by maintaining a keep-alive current between the cathode and a keep-alive electrode positioned adjacent the cathode. By positioning the keep-alive electrode at the minimum breakdown distance from the cathode, a keep-alive ionic discharge may be initiated with the lowest possible voltage applied between the keep-alive electrode and the cathode. If the spacing between the keep-alive electrode and the cathode is either increased or decreased, the necessary breakdown voltage which must be applied will be increased. For example, in the present tube having a spacing of approximately twenty thousandths of an inch between keep-alive electrode and the cathode and a particular gas filling described hereinafter, such that the voltage required to produce a glow discharge between the cathode and the keep-alive electrode is on the order of 60 volts, the initial voltage required to break down the space

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between the keep-alive electrode and the cathode into an ionic discharge will be, with good electrode design, in the range of 70–90 volts.

The close positioning of the keep-alive electrode to the cathode in this tube structure has been found to decrease the drop between the keep-alive electrode and the cathode to a point where it is approximately equal to the cathode fall. The positive column drop of the gaseous medium has been substantially eliminated with the result that there is a lower overall voltage drop between the cathode and keep-alive electrode and hence a minimum power required to maintain a keep-alive discharge. In this particular tube the keep-alive current may be within the range of 10–30 milliamperes. Since the positive column drop in the gaseous medium itself has been reduced to substantially zero, oscillations both of the high-frequency type due to electron interaction and of the lower audio-frequency type due to interaction of the heavier gaseous ions are substantially eliminated or, if present, reduced to a very low level.

Due to the keep-alive current which produces a positive ion bombardment of the cathode surface, thereby heating the same, a sufficient cloud of electrons is emitted from the cathode at all times. By the application of a relatively low positive signal potential to a grid shielding the anode, electrons will be drawn from this source through the grid structure and accelerated toward the anode. These electrons will attain a sufficient velocity due to the anode-to-grid potential to ionize the gaseous medium between the anode and grid thereby establishing conduction to the cathode and firing the tube.

As a result, it may be seen that applicant has produced a discharge device having relatively low stand-by power consumption, a large current discharge capacity, a low starting voltage and tube drop and a long cathode life, all these features being incorporated in a subminiature tube.

Further, applicant discloses herein, by way of example, circuits particularly adapted to utilize the discharge devices herein described.

The particular details of illustrative modifications of this invention whereby the foregoing results are obtained will now be described in detail, reference being had to the accompanying drawings wherein:

Fig. 1 represents one embodiment of the invention showing a cross-sectional view thereof taken along line 1—1 of Fig. 2;

Fig. 2 illustrates a cross-sectional view of the

device illustrated in Fig. 1 taken along line 2—2 of Fig. 1;

Fig. 3 illustrates a circuit utilizing the discharge device, shown in Figs. 1 and 2;

Fig. 4 represents a cross-sectional view of a second species of the invention taken along line 4—4 of Fig. 5;

Fig. 5 represents a cross-sectional view of my invention taken along line 5—5 of Fig. 4; and

Fig. 6 represents a circuit diagram illustrating one use of the species, shown in Figs. 4 and 5.

Referring now to Fig. 1, there is shown a glass envelope 20 consisting of a tube, one end of which is pressed together as at 21 and through which extend a plurality of lead-in wires. The other end of the glass tube 20 is curved together and contains at its center a mass of glass 22 which is used to seal the envelope after filling of the envelope with the correct gaseous medium. Extending upward from the glass press 21 inside envelope 20 are three glass tubes 23, 24 and 25 whose axes are all parallel and lying in the same plane and spaced an equal distance apart. The center glass tube 24 extends slightly less than half the length of envelope 20. Inside the glass tube 24, which is hollow, is an anode rod 26 which extends from the open end of the glass rod 24 toward the glass press 21 through a spacer 27 consisting of a wire spirally wrapped around anode rod 26. Anode rod 26 is then joined, for example, by welding to a lead-in wire 28 which extends through the glass press 21.

The end of the tube 24, which is open, is covered by a cup-shaped grid 29 of wire mesh which may be made of 60 x 60 strands per inch screening using .005 inch nickel wire. The diameter of the cup-shaped grid 29 is slightly larger than the diameter of the glass tube 24 and extends for somewhat more than one diameter of the glass tube over the end of said rod. The bottom of said cup-shaped grid 29 is in close proximity but not touching the end of the tube 24 and the anode element 26. Cup-shaped grid 29 is supported by being attached as by welding to a strap 30 at the lip of said cup-shaped grid. The strap 30 extends around the tubes 23 and 25 thereby rigidly supporting the grid 29. The tubes 23 and 25 are somewhat longer than the tube 24 and extend further into the envelope 20 past the end of tube 24 and the grid 29. A lead-in wire 31 is attached to the strap 30 as by welding and extends along the side of envelope 20 through the glass press 21.

Surrounding the grid 29 is a second cup-shaped grid 32 which is similar in shape to grid 29 but somewhat larger in diameter. The second grid 32 is supported by a strap 33 placed around the rods 23 and 25 similar to the support of grid 29, and a lead-in member 34 attached to strap 33 extends through the glass press 21. The bottoms of grids 32 and 29 are spaced somewhat from each other and the straps 33 and 30 are spaced from each other along the rods 23 and 25 with the result that the grid 32 is insulated from the grid 29. The glass rods 23 and 25 extend slightly beyond the bottom of cup-shaped grid 32.

Extending the length of rods 23 and 25, which are hollow, are a pair of support rods 35 which are butt-welded to lead-in members 36 extending through the glass press 21. The rods 35 contain spacers 37 thereon similar to the spacer 27 on anode rod 26. The rods 35 extend out of the open ends of the glass rods 23 and 25 for a distance equal to approximately half the diameter of envelope 20 and then pass through a mica plate 38. The mica plate 38 is flat and has a shape conforming to the inside contour of the envelope 20 at a section taken at right angles to the rods 35. Tabs 35a are welded to rods 35 on both sides of plate 38, thereby preventing movement of plate 38 on rods 35.

A cathode 39 is supported between the rods 35 in the space between the mica plate 38 and the bottom of the cup-shaped grid 32. This cathode consists of a helically-wound wire coated with electron emissive material, the diameter of said helix being approximately equal to the diameter of the glass tube 24. One end of said helically-wound wire is attached as by welding to one of the rods 35 and the other end to the other rod 35.

Between the cathode 39 and the cup-shaped grid 32 there is positioned a keep-alive grid 40. This grid is a semicylindrical piece of screening of the same type used to make grids 29 and 32. The axis of the semicylindrical screen is approximately concentric with the axis of the helical cathode 39. The diameter of the cylindrical screen 40 is slightly greater than the helix of the cathode 39 such that grid 40 is in close proximity with the cathode 39. The grid 40 is supported at each end by straps 41 welded thereto and which are attached to bands 42 mounted on the tubes 23 and 25. The grid 40 is connected to a lead-in wire 43 which extends along the side of envelope 20 through the glass press 21. Lead-in wire 43 also extends in the other direction through the mica plate 38 and is welded to a strap 44 containing getter material placed in two detents therein.

It may be seen that, by using grids which are cup-shaped, the anode is adequately shielded from other elements of the tube thereby preventing flashover at low anode to cathode voltages.

Referring now to Fig. 3, there is shown a circuit to be controlled by this discharge tube comprising a relay coil 45 attached to the anode 26 of the tube and to ground through a condenser 46, for example, of 10 microfarads. A junction between coil 45 and the condenser 46 is connected to B+ through a resistor 47 which may be, for example, 7½ kilohms. Grid 29 adjacent anode 26 is connected to B+ through a resistor 48 of, for example, 2400 ohms. Grid 32 is connected to ground through a 1 megohm grid-leak resistor 49 and to a source of signals through a D. C. blocking condenser 50 which may be, for example, .006 microfarad. The keep-alive grid 40 adjacent the cathode 39 is connected to B+ through a resistor 51 of, for example, 5 kilohms. The cathode 39 is connected to ground.

Due to the potential between keep-alive grid 40 and the cathode 39, an ionic discharge occurs therebetween causing current to flow through resistor 51 and the voltage of the keep-alive grid 40 to drop from the value of B+ which may be, for example, 120 volts to a lower voltage of, for example, 10 volts. This ionic discharge produces a source of electrons in the vicinity of the cathode.

With no signal on grid 32, said grid being tied to the cathode potential through resistor 49, no current will flow to the anode 25 since the anode 26 is effectively shielded from the cathode by the grid 32. However, if the grid 32 is driven positive by a signal, electrons will be attracted from the arc discharge existing between the keep-alive grid 40 and the cathode 49 and will pass through the space of grid 32 and the grid 29 striking the anode 26. As the electrons pass from the cathode 28 to

the anode 26, they strike molecules of the gaseous medium contained therein causing ionization of the molecules. The positive ions thus created are attracted to the cathode 39, due to its negative potential relative to the anode, and strike the cathode, thereby heating the cathode surface. This in turn causes a substantially increased electron emission from the cathode 39 whereby considerable current, for example, in the design illustrated in Fig. 1, 3½ amperes, may be drawn. This current surge through the relay coil 45 operates the relay to perform its function. The surge of current discharges the condenser 46 and causes the anode potential 26 to drop to a low value thereby extinguishing the discharge between the anode and cathode. The condenser then recharges through resistor 47 in preparation of the next discharge of the tube 20. By the use of the keep-alive grid 40 it is possible to eliminate a cathode heater and further to more easily control the discharge. The input signal to grid 32 required to fire the tube may be, for example, on the order of 20 volts at a current of 100 microamperes.

The gas used for this tube may be xenon at 20–40 millimeters pressure. Since xenon molecules have a low thermal conductivity, they act as a good heat insulator thus preserving the cathode heat. Furthermore, since the molecules have a large mass, they efficiently transfer energy from their momentum into heat upon striking the cathode. Due to the highe pressure, deterioration of the cathode is minimized, and due to the efficient heating, less power is required at the signal input grid to transfer the discharge from an ionic discharge between the cathode and the keep-alive grid to an arc discharge between the cathode and anode. By the use of the glass tubes 23 and 25, the leads 36 at cathode potential are shielded, as they pass near the anode and grid elements, thus further helping to prevent low anode to cathode discharges.

Referring now to Figs. 4 and 5, there is shown a modification of the species illustrated in Figs. 1 and 2, like parts of the different species being referred to by the same reference numerals. The species of Figs. 4 and 5 differ from the species of Figs. 1 and 2 in that the grid 32 and its supporting strap and lead-in member have been eliminated.

Referring to Fig. 6, there is shown the diagram of a circuit utilizing this modification. The anode and keep-alive grid circuits are simlar to Fig. 3. The signal input is now applied to the grid 29 through a 100 kilohm grid current limiting resistor 51 and the D. C. blocking condenser 50. The grid 29 is returned to ground by having the junction between the grid current limiting resistor 51 and the input D. C. blocking condenser 50 returned to ground through a grid load resistor 49 and a source of bias voltage 52. This bias voltage is necessary since in the absence of the second shield 32 a zero bias on grid 29 allows the tube to fire. Thus it may be seen that while the species of Figs. 4 and 5 eliminates one grid, it requires a bias source not required by the species of Figs. 1 and 2.

Since, in both Figs. 1 and 4, the cathode comprising the helical coil 39 is led out through two leads 36, an external voltage may be applied between leads 36 causing a current to flow through cathode coil 39 to heat the same. As a result, the cathode will operate as a directly heated thermionic emitter and if desired, the keep-alive current and electrode may be eliminated for this type of operation.

This completes the description of the details of the specific modifications of the invention illustrated herein. However, many variations thereof will be apparent to persons skilled in the art without departing from the spirit and scope of this invention. For example, additional grids of the types 29 and 32 could be added and the particular methods of support and connection of the various electrodes could be modified. Therefore, applicant does not wish to be limited to the specific details of the invention described herein except as defined by the appended claims.

What is claimed is:

1. An electron discharge device comprising an envelope containing a cathode, an anode surrounded by a sleeve of insulating material, a plurality of grids surrounding said insulating sleeve and said anode, and a keep-alive electrode positioned at substantially the minimum breakdown distance from said cathode.

2. An electron discharge device comprising an envelope containing an ionically heated cathode, an anode surrounded by a sleeve of insulating material, and a plurality of grids surrounding said insulating sleeve and said anode.

3. An electron discharge device comprising an envelope containing a cathode, an anode surrounded by a sleeve of insulating material, a cup-shaped grid surrounding said insulating sleeve and said anode, and a keep-alive electrode positioned at substantially the minimum breakdown distance from said cathode.

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