Feb. 1, 1944. W. A. DEPP 2,340,799

ELECTRONIC DISCHARGE DEVICE

Filed Oct. 19, 1942

FIG. 1

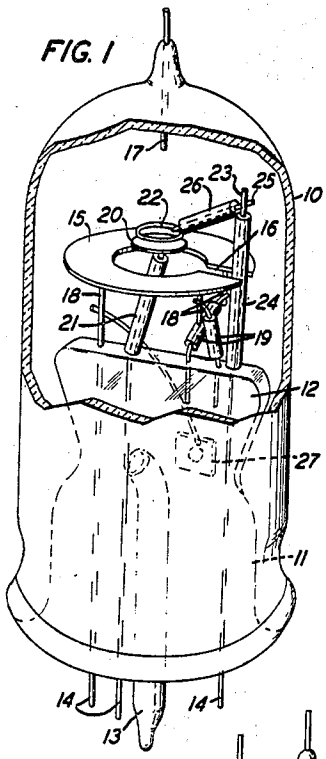


FIG. 2

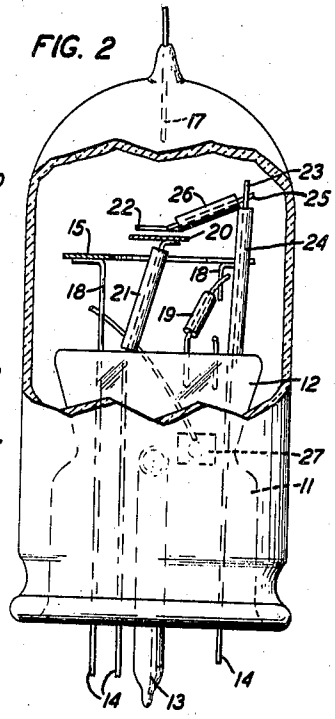


FIG. 3

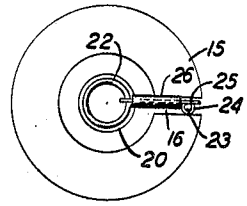


FIG. 4

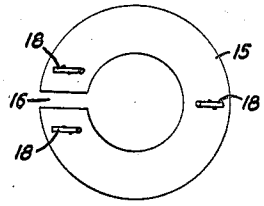


FIG. 5

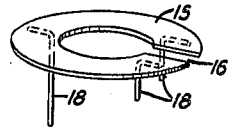


FIG. 7

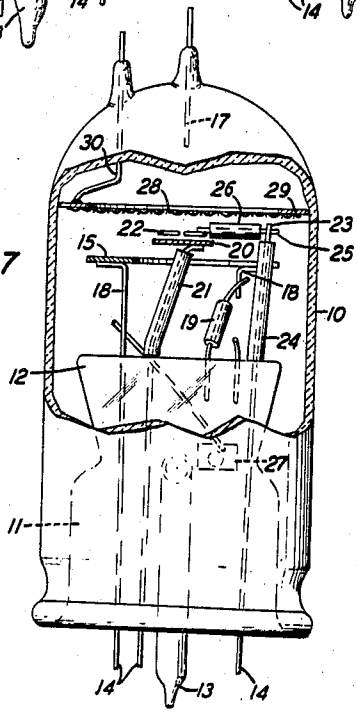
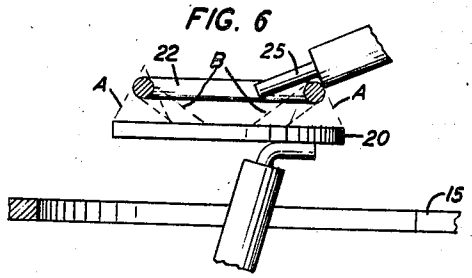


FIG. 6



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ELECTRONIC DISCHARGE DEVICE

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10 Claims. (Cl. 250—27.5)

This invention relates to electronic discharge devices and more particularly to such devices of the cathode glow type.

In devices of this type it is a common practice to provide a starting or ignition anode close to the cathode surface to initiate and sustain a glow discharge, whereby the discharge is readily transferred, or in other words, the main gap in the device breaks down more efficiently when critical potentials are applied to the control electrode. However, it has been found that variations in transfer current and, therefore, unstable operation usually occurs, due to the variability in the striking of the glow discharge on the surface of the cathode to initiate the starting discharge.

The difficulty in this construction is the inherent lack of control of the striking path of the discharge so that the initiating glow wanders over wide areas of the cathode, thereby varying the potential gradient in the initial glow discharge path in relation to the main discharge path. If attempts are made to overcome this difficulty by shielding the greater portion of the ignition anode to localize the striking path, a further difficulty arises in sustaining the glow discharge due to the limited contact surface of the starting anode in spaced relation to the cathode surface.

The principal object of this invention is to stabilize the initiating glow discharge whereby the main discharge path breaks down at a minimum limit of control potential.

Another object of the invention is to anchor the striking glow discharge in the device so that the glow forms at the same location each time whereby reproducibility is enhanced.

A further object of the invention is to facilitate efficient operation of the device as a relay or switching element by controlling the breakdown characteristics within a narrow range of operating voltages, whereby an extremely sensitive device is attained.

These objects are realized in accordance with this invention by providing an assembly of cooperating electrodes in a gas-filled vessel in which a cathode element is subdivided into major and minor proportions and separate anodes are associated with the several parts of the cathode element. In a specific arrangement, in accordance with this invention, the cathode is formed of a small disc member surrounded by an annular disc member with a main anode disposed opposite the cathode and an auxiliary anode, in the form of a ring, positioned close to and parallel with the small disc cathode member. This construction insures the localization of the starting or initiating discharge due to the symmetrical relation of the ring and small disc members whereby the glow discharge is always constant with respect to the striking point on the small disc so that the curve relating transfer current to main anode voltage remains constant and a low transfer current is obtained with regularity throughout the operating life of the device.

A feature of the invention relates to the space relation of the initiating discharge path involving the auxiliary anode ring and the small cathode disc section whereby the striking of the glow discharge is controlled. The auxiliary ring member is spaced above the small cathode disc a relatively short distance which is less than the minimum point in the sustaining volts versus distance curve so that the glow discharge is converged at the central portion of the disc cathode, thereby localizing the initiating discharge and controlling the constancy of the striking point and the density of current flow in the starting discharge.

Another feature of this construction relates to the isolation of the initiating discharge so that the direction of striking the glow on the central cathode surface is positively assured. This aspect of the invention is concerned with the geometric relation of the auxiliary anode ring and the small cathode disc so that the discharge is induced to converge towards the center of the adjacent disc and peripheral discharge is repulsed. This feature is contemplated in the diametrical relation of the ring and disc electrode both with respect to the minimum sustaining current and the power output of the device. The radius of the ring electrode should be substantially the same or not much greater than the distance for minimum sustaining current for the discharge and the control cathode disc should have a diameter only slightly greater than the auxiliary anode ring so that the possible paths from the periphery of the ring electrode to the periphery of the disc electrode are less than the optimum length for the establishment of a glow discharge path therebetween. Furthermore, the slightly larger area of the control cathode disc simplifies the problem of degassing the cathode disc by high frequency heating particularly when the electrodes are assembled in an enclosing vessel.

These and other features and advantages of the invention will be more clearly understood by referring to the following detail description which together with the accompanying drawing set forth the structural and functional characteristics of the device of this invention.

Fig. 1 is a perspective view of one embodiment of this invention with a portion of the enclosing vessel broken away to show the disposition of the internal electrode assembly;

Fig. 2 shows the device of Fig. 1 in elevation and partly in cross section to illustrate the interrelation of the cooperating electrodes;

Fig. 3 is a plan view of the cathode sections and the auxiliary anode to show the spatial relation thereof;

Fig. 4 illustrates in plan view the reverse side of the larger cathode section and the disposition of the supports for mounting it in the device of Fig. 1;

Fig. 5 is a perspective view of the electrode shown in Fig. 4 with the depending support extensions;

Fig. 6 shows the initiating discharge electrodes in elevation, on an enlarged scale, to clearly illustrate the diametrical and parallel spaced relation for accomplishing the controlling action in accordance with this invention; and

Fig. 7 illustrates a modified arrangement of the device of Fig. 2, partly in cross section, in which the auxiliary anode is made discontinuous and a screen grid is positioned between the main gap electrodes.

Referring to the drawing, and particularly to Fig. 1, the electronic glow discharge device of this invention includes a cylindrical enclosing vessel **10**, of vitreous material, having the lower end hermetically sealed to the flare of an inwardly projecting stem **11** which terminates within the vessel in a flat press **12**, and the stem is provided with a central outwardly extending tubulation **13** for evacuating the interior of the vessel and for injecting a suitable pressure of an ionizing gas therein. A plurality of leading-in conductors **14** extend within the vessel and are sealed in the stem **12** for connection to various electrodes mounted on the stem.

The electrode assembly of this invention for facilitating the transfer of a large current and in which the control of the transfer is highly stabilized, comprises a pair of main discharge electrodes, such as a large area cathode metallic ring **15** with a slot **16** provided therein to offset distortion due to high frequency heating of the electrode surface, and a main anode **17** separated from the main cathode by a large gap and mounted in coaxial relation therewith from the top of the enclosing vessel **10**. The cathode **15** is provided with an electron emitting coating on the upper surface, such as barium and strontium oxides, to produce an emissive glow discharge across the main discharge gap between the cathode and the anode. The reverse surface of the cathode is provided with a non-emissive coating, such as aluminum oxide, to prevent the glow spreading to the rear surface thereof. The cathode ring **15**, as shown in Figs. 4 and 5, is provided with a plurality of angle-shaped support wires **18** mounted in spaced relation on the reverse side of the electrode and depending therefrom. One of these support wires is attached to an extension of the leading-in conductor **14** projecting from the press **12**, other support wires being attached to stub wires (unnumbered) in the press which are covered by insulating sleeves **19**.

The large surface area of the cathode **15** and the large gap between the cathode and the anode constitute a high resistance path which requires a fairly high potential to create a glow discharge therebetween and the striking or initiating point is variable due to the numerous possible paths presented between the main electrodes. In order to overcome these defects and at the same time render the device highly sensitive to narrow limits of initiating and transfer control voltages, a separate control cathode surface **20** is provided so that the cathode is formed of two parts or portions, namely, the major portion **15** and the minor portion **20**. The control cathode **20** is a small diameter metallic disc coaxially mounted within the boundaries of the ring cathode **15** and spaced therefrom by a relatively large gap to prevent the initiating discharge of the control cathode from spreading to the main cathode until the critical transfer voltages are applied to the main discharge path in the device. The small disc cathode **20** is coated on opposite sides in the same manner as the main cathode **15** whereby the upper surface is electron emitting while the reverse surface inhibits the spreading of the glow discharge thereto. The control cathode disc **20** is mounted in a parallel plane slightly above the surface of the main cathode and is attached to an extension of one of the leading-in conductors **14**, the extension being covered by a glass sleeve **21** to prevent extraneous discharges between the extension and the main cathode **15**.

In order to localize or anchor the initiating discharge on the small diameter control cathode and thereby stabilize the transfer characteristics of the device, so that the operation is reproducible throughout the life of the device and also to make the potential gradient in the initiating discharge constant, an auxiliary anode is mounted close to the control cathode surface. This auxiliary control electrode is in the form of an annular ring member **22** which is mounted parallel and close to the periphery of the control cathode disc **20**. The annular ring **22** is mounted in rigid position by an upright wire **23** which extends from the press **12** through the slot **16** of the main cathode **15** and is surrounded by an insulating sleeve **24** to prevent false operation of the device, due to the short gap between the main cathode **15** and the wire **23**. A bridging wire **25** extends inwardly from the end of the upright wire **23** and is attached to the annular anode **22**, said wire being surrounded by an insulating sleeve **26**. The correlation of the electrodes mounted on the stem **12** and the space relation therebetween with the dimensional areas thereof can be realized from the showing in Fig. 3 of the drawing. This construction insures the concentration of the initiating glow striking the center of the control cathode **20** and prevents the glow from striking on the periphery of the control cathode. In view of the large gap between the control cathode and the main cathode surface **15**, the initiating glow is controlled until the critical potential is applied to the anode **17** to transfer the discharge to the main cathode whereupon the gap between the control cathode and the main cathode breaks down and a large flow of current ensues between the anode and the cathode in the main discharge path of the device.

Fig. 6 shows the initiating discharge electrodes on an enlarged scale in cooperating relation with the main cathode ring **15**, to illustrate the functional characteristics of the diametrical and elevational relation of the respective electrodes for directing the initiating discharge towards the center of the control cathode and preventing the dispersion of the glow to other areas of the control cathode which would introduce unstable operation due to wander-effect in striking the glow on the cathode surface. As a first consideration

it is desirable that the diameter of the control anode **22** is not too large and preferably the radius thereof should be comparable to the minimum sustaining voltage for striking the initiating glow discharge on the surface of the cathode **20**. The second consideration is that the control anode ring **22** should be spaced relatively close and parallel with the control cathode surface **20**, the spacing being much less than the minimum point in either the breakdown or sustaining voltage characteristics. The third consideration is that the diameter of the control cathode surface **20** should not be much greater than the diameter of the anode ring **22**. The close spacing of the control anode **22** with respect to the periphery of the cathode disc **20** provides an insulating path directly below the ring which is indicated by A as representing a shadow border defined by diagonals projected from the periphery of the cross-sectional area of the ring **22** which bisect the edge of the cathode disc **20** and an equal distance on the opposite side of an axial line drawn through the cross section of the ring. This area embraces paths of less than optimum length in which a striking of the glow cannot occur since the paths are too short to ionize the gap therebetween. The ions must therefore seek longer paths to ionize the gap between the anode and the cathode and these paths are indicated by B so that the discharge is directed towards the center of the cathode and is concentrated thereon to insure a potential gradient of constant value and stable characteristics. The control cathode disc **20** is preferably made slightly larger than the control anode diameter to facilitate high frequency heating thereof in the manufacturing process of the device to activate the emissive coating thereon. It is, of course, understood that the cathode surface may be made smaller with the same operational characteristics noted above if other methods are employed in activating the cathode surface. It should be understood that it is not essential to mount the control cathode **20** in a plane above the main cathode ring **15**.

In order that the critical relations of the electrode assembly employed in the device of this invention may be realized a typical example of the dimensional measurements of the electrodes and the spacing therebetween is given as follows: The main cathode ring **15** is formed of thin nickel sheeting having an outside diameter of ¾ inch and an inside diameter of ⅜ inch with the slot **16**, ⅛ inch. The anode **17** is a 30-mil diameter wire extending downwardly toward the main cathode with the inner end thereof spaced coaxially from the cathode a distance of $\frac{7}{16}$ inch. The control cathode **20** is a thin nickel disc $\frac{3}{16}$ inch in diameter and spaced coaxially with respect to the main cathode **15** and in a parallel plane therewith approximately $\frac{1}{16}$ inch above the main cathode, the insulating gap between the edge of the control cathode **20** and the inner edge of the main cathode **15** being substantially equal to the radius of the control cathode. The control anode ring **22** is formed of circular wire having a diameter of .020 inch and formed into a ring having an inner diameter of .140 inch. This ring is mounted in parallel relation to the control cathode **20** so that the ring is wholly within the boundary of the outer diameter of the disc **20** with a spacing therebetween of approximately 5 mils.

Since the peripheral edge of the control cathode disc **20** is slightly beyond the outer diameter of the ring **22**, the peripheral edge of the disc must be held within close limits in order to avoid the establishment of a path to produce a striking glow exterior to the anode ring **22**. The peripheral edge of the disc projecting beyond the outer diameter of the ring is approximately slightly more than ½ the distance between the ring and the surface of the control cathode **20**, the exact difference, in the typical example described, being an overhang of .00375 inch. This protrusion or extension of the disc beyond the control anode diameter is preferably not more than the spacing distance between the control anode ring and the surface of the cathode which is much less than the spacing corresponding to the point of minimum voltage on a curve relating either to the breakdown or sustaining voltage of a glow discharge to the distance between the electrodes. It will be readily seen that the initiating glow discharge is easily controlled to strike at substantially the central portion of the cathode surface **20** substantially at a constant rate so that the potential gradient of the initiating discharge is constant and reproducible transfer characteristics may be realized in the operation of the device.

After the electrodes are suitably mounted in their cooperative relation on the stem of the vessel in association with the main anode **17**, the vessel is highly evacuated through the tubulation **13**, the active coating on the bi-part cathode surfaces is activated by bombardment, for instance by high frequency heating, and, at a suitable stage of the processing of the device, a getter material supported on the mounting **27** is flashed, to absorb residual gases not easily removed by the pump system. The evacuated space of the vessel may be filled with an ionizing medium, for instance, an inert gas, such as argon or a mixture of gases, such as argon and neon, in the proportion of 95 per cent argon and 5 per cent neon, at a pressure of between .1 to 70 millimeters of mercury after which the tubulation **13** is sealed off and the device associated in a switching circuit in which critical relay action of the device is to be utilized in the transfer of large currents. Although the bi-part sections of the cathode surfaces **15** and **20** are shown connected to separate lead-in conductors **14** for functional operation in desired switching circuits, the control cathode surface **20** may be directly connected to the large cathode surface **15** within the vessel by a suitable strap wire.

A modification of the invention is shown in Fig. 7 in which the various electrodes, described in connection with Fig. 1, are cooperatively arranged in the same relation except that the control anode ring **22** is shown split to overcome high frequency heating thereof during the activation of the cathode surfaces **20** and **15**. In addition, the structure shown in Fig. 7 includes a screen grid electrode **28**, in the form of a circular member of wire mesh material, reinforced at the periphery by a ring **29** and supported by a conductor **30** extending through the top of the vessel. In this construction the switching function of the relay is accomplished in three steps depending on the critical voltages applied to the control electrodes in the device. Such operation is an advantage in interlocking circuits in the telephone plant in which the first critical voltage applied to the control anode **22** initiates the discharge on the center of the cathode surface **20**, then a critical potential applied to the grid **28** transfers the initiating discharge to the main cathode **15** and finally, the discharge breaks down to the main anode **17** when a suitable potential is applied thereto to

transfer the discharge to the main path between the main cathode 15 and the anode 17.

While the invention has been disclosed with respect to particular embodiments of the invention as heretofore described, it is, of course, understood that various modifications may be made in the detail structure of the electrode assembly without departing from the scope and spirit of the invention as defined in the appended claims.

What is claimed is:

1. An electronic discharge device comprising an enclosing vessel containing an ionizable medium, a plurality of electrodes therein including a cathode element formed of concentric surfaces with a relatively large gap therebetween, a small area output electrode spaced axially with respect to the outer concentric surface and forming therebetween a main discharge path in said vessel, and an annular auxiliary electrode closely adjacent the inner concentric surface and forming therewith an initiating discharge path in which the striking point of the discharge is localized near the axis of said inner surface.

2. An electronic discharge device comprising an enclosing vessel containing an ionizable medium, a plurality of electrodes therein including a cathode element formed of concentric surfaces with a relatively large gap therebetween, a main anode spaced axially with respect to the outer concentric surface and forming therebetween a main discharge path in said vessel, and a ring-shaped control anode substantially coextensive with the periphery of said inner concentric surface and spaced therefrom a distance less than the minimum sustaining point for establishing a glow discharge directly across the area between said ring anode and said inner surface.

3. An electronic discharge device comprising an enclosing vessel containing a gaseous medium, a plurality of electrodes therein including a cathode element formed of concentric surfaces with a relatively large gap therebetween, a main anode spaced axially with respect to the outer concentric surface and forming therebetween a main discharge path in said vessel, and an annular control anode closely adjacent the periphery of the inner concentric surface, said control anode being adapted to produce a border on said surface below it of an area defined by a shadow effect projected from the sides of said control anode to said surface, whereby the space relation therebetween inhibits the establishment of a glow discharge in said shadow and causes the discharge to strike over a longer path between said annular anode and an area of said surface surrounded by the shadow border.

4. An electronic discharge device comprising an enclosing vessel containing a gaseous medium, a plurality of electrodes therein including a cathode element formed of concentric surfaces with a relatively large gap therebetween, a small area output electrode spaced axially with respect to the outer concentric surface and forming therebetween a main discharge path in said vessel, and an electrode closely adjacent the inner concentric surface and forming therewith an initiating glow discharge, said electrode being so proportioned with respect to said inner surface that said glow discharge is projected and concentrated towards the center of said inner concentric surface and is inhibited from diverging outwardly to the periphery of said inner surface.

5. An electronic discharge device comprising an enclosing vessel containing an ionizable medium, a plurality of electrodes therein including a cathode, an anode, and an auxiliary electrode, said cathode being formed of a central disc member and a flat ring member, said anode being associated with said ring member and constituting a main discharge path, said auxiliary electrode being closely associated with said disc member and forming therewith an initiating discharge path, the space relation between said auxiliary electrode and the periphery of said disc member being much less than the minimum point of the breakdown voltage characteristic and the space relation between said disc and ring members being substantially equal to the breakdown voltage characteristic.

6. An electronic discharge device comprising an enclosing vessel containing an ionizable medium, a plurality of electrodes therein including a cathode, an anode, and an annular auxiliary anode, said cathode being formed of a central disc member and a flat ring member, said anode being associated with said ring member and constituting a main discharge path, said annular anode being disposed parallel with said disc member and substantially equal in diameter therewith, the space relation between them being less than the minimum point of the breakdown voltage characteristic and the space relation between said disc and ring members being substantially equal to the breakdown voltage characteristic.

7. An electronic discharge device comprising an enclosing vessel containing an ionizable medium, a plurality of electrodes therein including a cathode, an anode, and an auxiliary anode, said cathode being formed of a central disc member and a flat ring member in concentric relation, said anode being associated with said ring member and constituting a main discharge path, and said auxiliary anode being mounted parallel to said disc member, the space relation between them being less than the minimum point of the sustaining voltage characteristic, said disc member having its periphery extending beyond the outer diameter of said auxiliary anode slightly greater than one-half the spacing distance between said auxiliary anode and said disc member.

8. An electronic discharge device, according to claim 7, in which the auxiliary anode is in the form of a wire ring having a cross-sectional dimension of .020 inch, the space relation between the auxiliary anode and the disc member being .005 inch, and the peripheral edge of the disc member projecting a distance of .00375 inch beyond the outer diameter of said wire ring.

9. An electronic discharge device comprising an enclosing vessel containing a gaseous medium, a plurality of electrodes therein including a bi-part cathode consisting of a small disc section and a flat ring section disposed in concentric relation, said sections being in different planes, a main anode disposed opposite said cathode and forming with said ring section a main discharge path, and a split wire ring mounted parallel to and close to the edge of said disc section, said wire ring and disc section forming an initiating discharge path in said vessel, said flat ring section being spaced from said disc section by an insulated gap more than five times the space relation between said wire ring and said disc section.

10. A gaseous electronic relay device comprising an enclosing vessel having a stem, an inert gas filled therein, a plurality of electrodes mounted in said vessel and capable of producing an ionizing glow discharge in distinct steps de-

pending on the initiating, sustaining and breakdown periods of the device, said electrodes involving a control cathode, a control anode, a main anode, and a main cathode, said control cathode being a small metallic disc axially mounted on said stem, said main cathode surrounding said control cathode and being formed of a flat metallic ring having a slot therein, said main cathode being electrically connected to said control cathode, a plurality of supports extending from said stem to said flat ring, said control anode being a wire ring closely adjacent and parallel to the periphery of said control cathode, a support extending from said stem through said slot to said wire ring, and said main anode being mounted in the top of said vessel and projecting axially toward said control cathode and main cathode.

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