

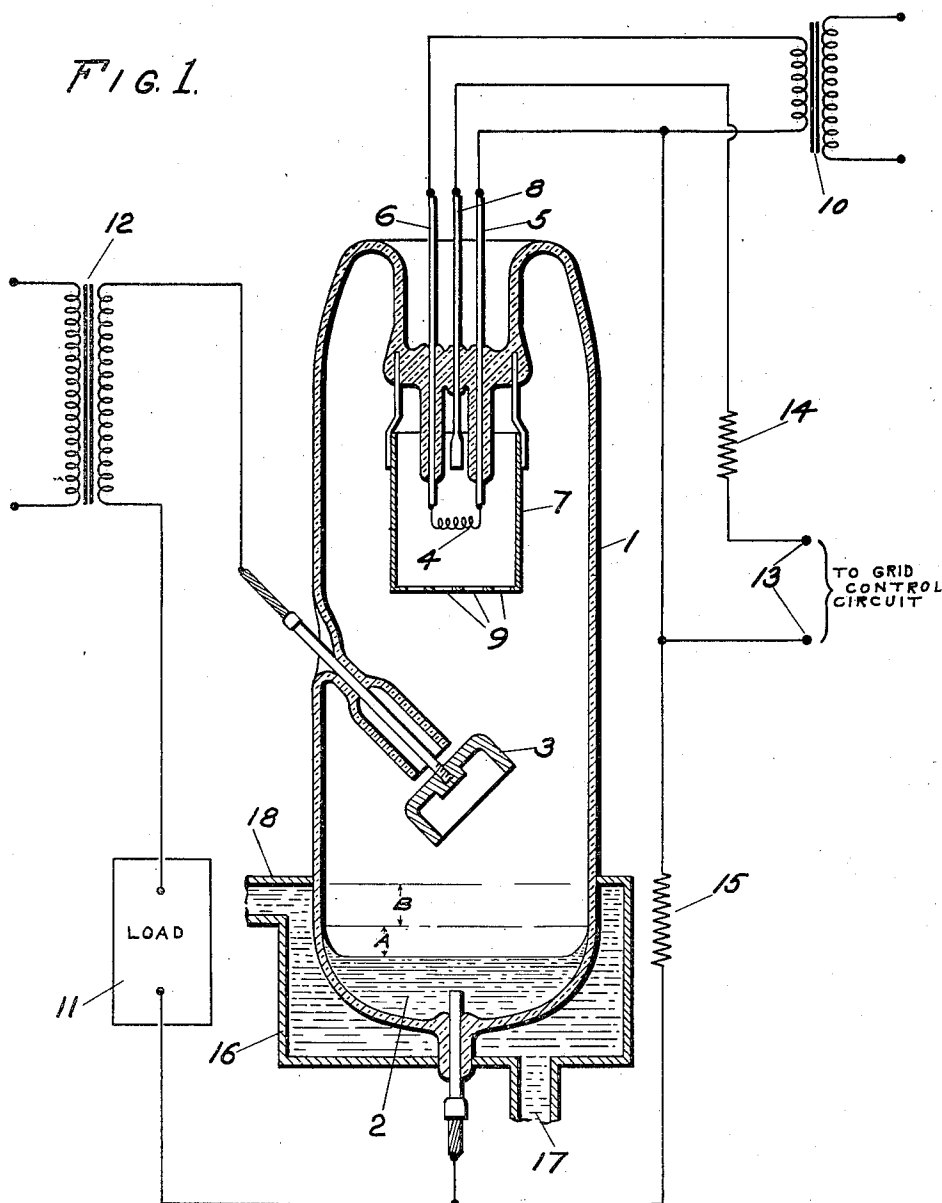
Jan. 18, 1949.

P. W. STUTSMAN
ARC DISCHARGE DEVICE

2,459,199

Filed May 22 1943

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

FIG. 2.

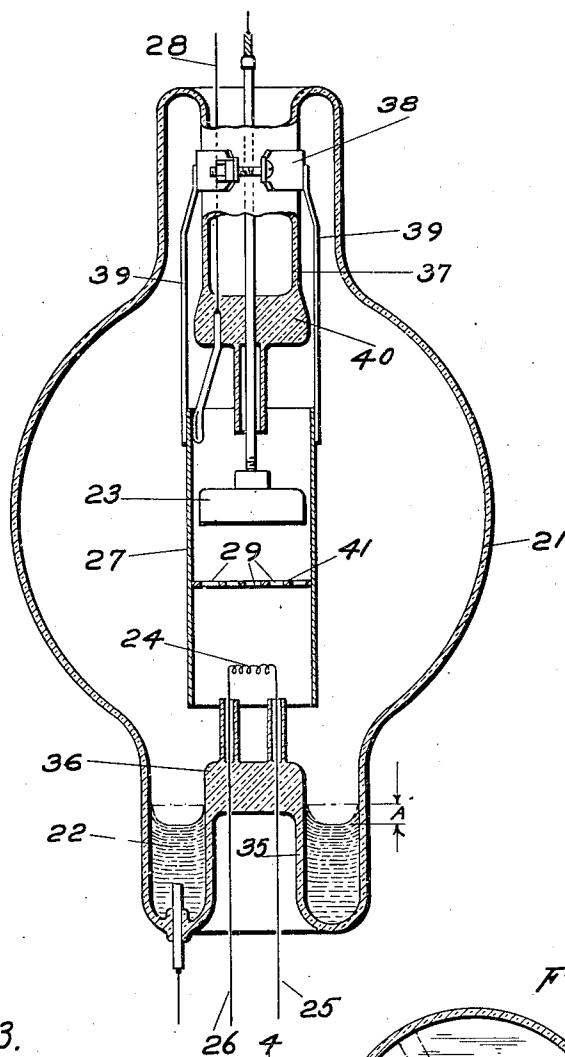


FIG. 3.

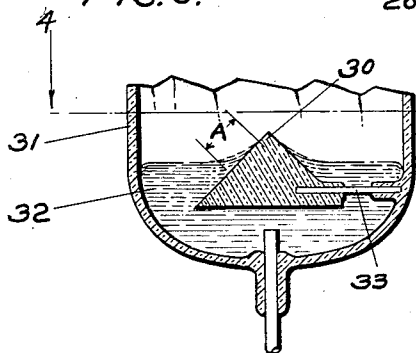
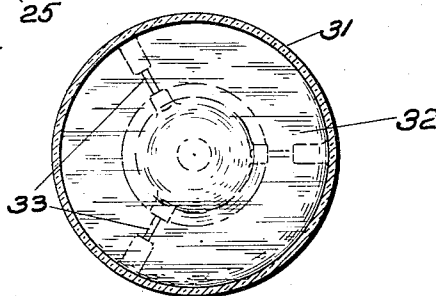


FIG. 4.



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ARC DISCHARGE DEVICE

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7 Claims. (Cl. 250—27.5)

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This invention relates to an arrangement and a method for initiating an arc spot on the cathode of a pool type discharge tube.

In discharge tubes of the type to which the invention relates it has been a common practice to initiate the arc by impressing a high voltage between the cathode pool and an igniting electrode. While tubes of this type can be controlled, with respect to the initiation of the discharge, this control requires the use of high ignition voltages greatly complicating the system and increasing the number of tubes involved in a given control circuit.

It is a primary object of the present invention to overcome the above-mentioned defects of the prior art devices and provide a pool type cathode tube in which the discharge may be quickly initiated without the application of high igniting voltages. To this end the invention contemplates the provision of a thin film of the liquid, preferably mercury constituting the cathode pool, which film extends from the surface of the pool along the side walls of the containing vessel or upon the wall of any other nonconducting surface projecting from the pool and the bombardment of this film by ionized gases. I have discovered that if such a film, extending from the surface of the pool, is bombarded by particles originating from ionization of gases or vapors within the envelope of the tube, then the familiar cathode spot may be made to appear upon the surface of this film and particularly at the point or line of conjunction between the film and the surface of the pool. I have found that this cathode spot may be initiated much more readily upon such a film than upon the surface of a pool where such film is not provided.

It is a further object of this invention to provide a tube in which the initiation of the arc spot may be controlled by the application of relatively small control voltages. Accordingly, the invention provides a means whereby the high currents, which the tube is capable of carrying, may be controlled by energy impulses which are much weaker than those required to control present tubes of similar current-carrying capacity, such as ignitrons.

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 drawings in which:

Fig. 1 is a longitudinal section of a tube embodying the invention, together with a diagrammatic representation of a circuit with which said tube may be used;

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Fig. 2 is a longitudinal section, with parts in side elevation, of a second embodiment of the invention;

Fig. 3 shows in longitudinal section a fragment of a third embodiment; and

Fig. 4 shows a transverse section taken on the line 4—4 of Fig. 3.

Referring to the drawing, reference numeral 1 indicates a sealed envelope having a pool type cathode 2 preferably consisting of a pool of mercury. It is well known that the surface of a pool of mercury curves downwardly where the liquid is in contact with ordinary glass. The purposes of this invention, however, require that a portion of the liquid of the pool be attenuated upon the side wall of the envelope 1, or upon some other surface projecting from the surface of the pool 2, preferably in the form of a thin film indicated in the drawing by the zone A. One means of attaining this end is to alter the capillary properties of either the glass or the mercury to the extent that there will be a strong capillary attraction between the surface of the glass and the mercury, instead of a strong capillary repulsion. By this means the desired film is created through capillary attraction.

One means of altering the capillary effects exhibited between common glass and mercury and providing a capillary attraction therebetween, so that the liquid will curve upwardly at the line of contact between the glass and the mercury, consists in the addition to the mercury of small quantities of material, such as barium, strontium, or similar dispersing agents. Such materials may be called "wetting agents" since they cause the mercury to wet the glass walls of the containing vessel along the line of contact between the surface of the liquid and the surface of the wall. Thus, the addition of these agents changes the molecular properties of the mercury from those exhibited by capillary repulsion to those of capillary attraction, and the desired film, zone A, is created.

The envelope 1 also contains an anode 3, which may be of conventional construction, and a thermionic cathode 4. The thermionic cathode 4 may be of either the directly heated type shown, or may be of the indirectly heated type if desired, and preferably is provided with a suitable coating of some highly emissive substance in a manner well known in the art. Conductors 5 and 6, which extend through and are properly sealed in the wall of the envelope 1, provide lead-in connections for supplying heating current to the cathode 4.

While not essential to many uses of the tube,

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a grid 7, having a suitable lead-in connection 8 for supplying electrical impulses thereto, is preferably provided in the space between the thermionic cathode 4 and the anode 3. Perforations 9 in the end portion of the grid 7 permit a copious flow of electrons from the thermionic cathode 4 to the anode 3 whenever suitable operating conditions exist, which conditions will be hereinafter more fully set forth.

The operation of the device as above described is as follows: Heating current is supplied to the thermionic cathode 4 from any suitable source. As shown, an alternating current is supplied from a transformer 10. A suitable potential difference is applied between the pool type cathode 2 and the anode 3, which potential difference may be from any source, of either a direct or alternating current, which it is desired to supply to the load 11. In the instance shown, the transformer 12 provides a source of alternating current. Energy impulses are supplied to the grid 7 from any suitable control circuit by way of terminals 13 and grid resistance 14. The pool cathode 2 is connected to the thermionic cathode 4 and to the grid control circuit by way of a resistance 15.

It will be understood that the critical grid break-down voltage for any given positive anode voltage will depend upon the temperature of the tube and the geometry of the grid. In this respect the operation of the grid resembles that of the thyatron, and the grid control circuit will resemble the grid circuit for such thyatron, depending upon the use to which the tube is to be put. Assuming that a suitable energy impulse has been supplied to the grid 7, electrons emitted by the thermionic cathode 4 will be permitted to pass through the perforations 9 into the space between the grid 7 and the anode 3. In flowing toward the anode 3, the electrons from the thermionic cathode 4 ionize the mercury vapor within the envelope, and the positive ions in the region between the cathode 2 and the anode 3 are repelled by said anode and attracted toward the pool cathode 2. These ions strike the thin layer of mercury, zone A, drawn upwardly along the side walls of the envelope by the capillary attraction of the mercury, as modified by the dispersing agent. While the ions also strike the plane surface of the cathode pool itself, this bombardment of the plane surface of the cathode pool seems to be of little importance in the initiation of the cathode spot. However, that portion of the positive ions which bombards the thin layer of mercury which curves upwardly upon the surface of the glass wall of the envelope 1 affects this portion of the pool in a number of ways. One effect appears to be that a flow of electrons must pass from the main body of the pool to the thin layer of mercury upon the wall in order to neutralize the positive charge received by the ion bombardment, and the resulting current flow in passing through the attenuated film provides a portion of the energy necessary to create the cathode spot, this cathode spot appearing always on the surface of the pool immediately adjacent the envelope 1, or upon the film itself. It also appears that the current flowing between the surface of the cathode pool and the attenuated film on the surface of the wall results not only from the flow of positive ions from the space of the tube to the film, but also the bombardment of this film possibly results in an electronic emission therefrom.

Although ionic bombardment of the attenuated film is essential, since the arc spot will not appear

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without such ionic bombardment of the film, it may be that other factors tend to augment the conditions favorable to the formation of the arc spot by the ionic bombardment of the film. The tendency of electrons to escape from an attenuated projection on the surface of the negatively charged body may augment the electron discharge from the thin film on the wall surface, which film constitutes such a projection from the surface of the pool. The electrons discharged, due to these causes, flow with considerable velocity toward the anode 3, increasing the ionization of the mercury vapor in the space between the pool type cathode and the anode 3. This electron flow greatly augments the flow of current through the attenuated film, thereby increasing the temperature thereof and augmenting the various other forces which facilitate the formation of the cathode spot.

It will be understood that while the above statement of the theory of operation of the tube with respect to the formation of cathode spots may not be correct in detail, nevertheless, the fact that such cathode spots are readily and quickly formed upon the film or at its edges by the means described may be utilized by those skilled in the art, regardless of whether or not the theory accounting for the phenomena is fully understood.

In practice, if the grid 7 is not used, the cathode spots are formed and the tube becomes conductive instantly when a suitable potential difference is impressed between the pool cathode 2 and the anode 3, assuming that the thermionic cathode 4 is heated. Thus an alternating current may be applied between the anode 3 and the cathode 2, and the tube will discharge regularly once every cycle. Under these conditions, the tube is completely extinguished by the reversal of potential between the anode and cathode once each cycle, and yet it is capable of discharging instantly upon the next half wave of the cycle during which a positive potential is applied to the anode 3 and a negative potential applied to the pool cathode 2.

Where a control grid, such as 7, is used, the thermionic cathode 4 may be continuously heated, and although a high potential difference may exist between the anode 3 and the pool cathode 2, yet the tube will not fire if a bias sufficient to prevent the escape of electrons from the thermionic cathode 4 through the perforations 9 is applied to grid 7; but if an energy impulse exceeding the critical break-down voltage is applied to the grid 7, under the same conditions then electrons flow freely through the perforation 9 and the tube fires within a few milliseconds. Thus, very small potential variations applied to the grid are capable of controlling heavy currents. For example, with a grid input of 200 microamperes, and a grid resistance of 250,000 ohms, the tube has controlled currents of 1,000 amperes.

It will be obvious that the invention may be applied, either with or without the control grid 7, to many purposes. Its uses correspond to those of both the thyatron and the ignitron, in that it has a power capacity comparable to that of the latter and is susceptible to a degree of control comparable to that of the former.

While not essential to the practice of the invention as above described, I prefer to provide a cooling jacket 16 having an inlet 17 and an outlet 18 for cooling the lower portion of the envelope 1. The cooling jacket 16 extends above the surface of the pool cathode 2 and somewhat above the

upper limit of the attenuated portion forming zone A on the side walls of the envelope 1. This provides a cooled area, indicated as zone B, above the upper limit of the zone A. In operation, the mercury or other vapors from the pool 2 tend to condense upon this portion of the wall of the envelope 1 and, unlike pure mercury, tend to wet this portion of the wall, forming a thin film of mercury above the attenuated portion formed by the capillary action of the modified mercury. The mercury does not tend to condense upon the uncooled portion of the walls of the envelope 1 above the cooling jacket 16. Accordingly, a well defined zone B is provided having a thin film of mercury condensed thereon and spread out in wetting relationship thereto due to the admixed content of the wetting agent. This zone B therefore tends to augment the area of the attenuated film A resulting from capillary attraction alone, thus providing a greater surface area upon which the various forces tending to produce a cathode spot may act, and tends somewhat to facilitate the formation of such spots and accordingly increases the ease with which the discharge of the tube may be initiated.

Instead of disposing the anode 3 between the pool cathode 2 and the thermionic cathode 4, the electrodes may be arranged to advantage as shown in Fig. 2. In the modification shown in this figure, reference numeral 21 indicates an envelope having a pool type cathode 22 in which the liquid forming the pool has been modified by the addition of a dispersing agent as was described in connection with the pool 2 of Fig. 1. In this case the anode 23 is provided above the thermionic cathode 24 so that the latter is positioned closer to the pool 22 and between this pool and the anode. The pool 22 is formed in an annular space between the outer envelope 21 and a reentrant stem 35, which reentrant stem terminates in a press 36 through which leads 25 and 26 extend to supply heating current to the filament 24.

As shown, a grid 27 is provided, although it will be understood that this grid may be omitted and the tube would still be suitable for many purposes. The grid 27 in this instance is formed of a tubular member into the open ends of which the anode 23 and thermionic cathode 24 project. A suitable grid lead 28 extends through a reentrant stem 37 at the upper end of the tube, which reentrant stem provides a support for the grid 27 by means of a collar 38 which is clamped to the reentrant stem and supports the grid by suitable rods 39. The reentrant stem 37 is provided with a sealing press 40 at its inner end in which the grid and anode leads are sealed. A partition 41 is provided in the mid portion of the grid 27 at a point between the anode 23 and the thermionic cathode 24. The partition is provided with perforations 29 which permit a flow of electrons from the thermionic cathode 24 toward the anode 23 in the same manner as has been previously described in connection with the perforations 9 of the grid 7 in the form shown in Fig. 1.

The operation of this form of the device is similar to the operation previously described in connection with the construction shown in Fig. 1. The positioning of the electrodes in this latter construction provides a more favorable geometry for ion bombardment than that of the former, and the annular form of the liquid pool cathode results not only in a thin attenuated portion A of the pool extending upwardly upon the wall of

the envelope 21, but also in a similar attenuated portion extending upwardly along the surface of the reentrant stem 35. Thus a relatively large film area is provided, which area functions the same as the area provided by zone A in the form shown in Fig. 1.

Figs. 3 and 4 represent a further modified form of the invention. In these figures only the lower portion of the tube is shown. It will be understood that the remainder of the tube may be of any suitable construction, for example, as shown in Fig. 1. In this modification, however, the mercury forming the pool type cathode 32 need not be modified to change its capillary properties with respect to the side walls of the envelope 31, and hence, in the instance shown, the mercury forming the pool 32 exhibits the usual capillary repulsion in the area immediately adjacent these side walls. A thin film or attenuated portion, corresponding to the zone A of Fig. 1, is in this instance obtained by means of a member 30, of conical or equivalent shape, which is formed of some suitable insulating material and which is so supported in the pool 32 that its peaked upper end projects above the surface of the pool and its gradually sloping sides extend below the surface. If the material forming the member 30 is such that the mercury does not have a capillary repulsion therewith, but is either neutral or exhibits a capillary attraction therefor, there will be a thin film formed around the projecting portion of the member, which film is sufficiently attenuated to provide the necessary zone A which will function to facilitate ignition in a manner analogous to the zone A of Fig. 1. As shown, the mercury exhibits some capillary attraction for the surface of the member 30 and therefore extends upwardly upon this surface somewhat above the normal surface of the mercury pool. Common glass is not a suitable material from which to construct the member 30. However, some specially treated glass, such as that having a metallic content high enough to alter its surface properties without altering its insulating characteristics to a harmful degree, or any other insulating material which exhibits some capillary attraction for, or at least does not repel the unmodified mercury, is suitable for this purpose. For example, the member 30 may be formed by painting the upper surfaces thereof with a platinum paint and thereafter heating the glass to a temperature sufficient to soften the glass and to drive off the inert constituents of paint leaving a thin film of platinum which becomes incorporated with the molten surface of the member. The member 30 is maintained in the desired position by brackets 33 extending outwardly from the side walls of the envelope 1.

Other embodiments, particularly other means of securing an attenuated portion corresponding to the zone A, will be readily apparent to those skilled in the art from the various modifications herein shown. Furthermore, since there are many means already known for securing the ionization of gases for other purposes, it will be obvious that, for some of the purposes of this invention, such other means may be substituted for the thermionic cathode, used in the embodiments herein disclosed, to secure the desired ionization of gases within the envelope, and thereby to provide for the ion bombardment of the attenuated portion of the mercury pool.

What is claimed is:

1. An arc discharge device comprising a member of non-conducting material, an anode, a

liquid pool cathode consisting of mercury having a metal of the alkaline earth group incorporated therewith to thereby attenuate a portion of said mercury upon a surface of said non-conducting material projecting from said pool, a gaseous medium adjacent said cathode and means for ionizing said gaseous medium to cause ionic bombardment of said attenuated portion and thereby initiate an arc spot.

2. An arc discharge device comprising a member of non-conducting material, an anode, a liquid pool cathode consisting of mercury having a member of the group comprising barium and strontium incorporated therewith to thereby attenuate a portion of said mercury upon a surface of said non-conducting material projecting from said pool, a gaseous medium adjacent said cathode, and means for ionizing said gaseous medium to cause ionic bombardment of said attenuated portion and thereby initiate an arc spot.

3. An arc discharge device comprising a member of non-conducting material, an anode, a liquid pool cathode consisting of mercury containing a sufficient quantity of barium to cause said mercury to disperse upon and wet the wall of said member to thereby attenuate a portion of said mercury upon a surface of said non-conducting material projecting from said pool, a gaseous medium adjacent said cathode, and means for ionizing said gaseous medium to cause ionic bombardment of said attenuated portion and thereby initiate an arc spot.

4. An arc discharge device comprising a sealed envelope having a portion of non-conducting material, an anode, a liquid pool cathode, and an electrode separate from said anode and cathode for ionizing the gaseous contents of said envelope, said liquid pool cathode consisting of mercury containing a sufficient quantity of barium to cause said mercury to disperse upon and wet said non-conducting portion of said envelope.

5. An arc discharge device comprising a mem-

ber of non-conducting material, an anode, a liquid pool cathode, a thermionic cathode, and a control grid partially enclosing said thermionic cathode, said liquid pool cathode consisting of a liquid exhibiting capillary attraction with a surface of said non-conducting material projecting therefrom.

6. An arc discharge device comprising a sealed envelope having a portion of non-conducting material, an anode, a liquid pool cathode, a thermionic cathode, and means to control the flow of electrons from said thermionic cathode to said anode, said liquid pool cathode consisting of mercury containing a sufficient quantity of barium to cause said mercury to disperse upon and wet said non-conducting portion of said envelope.

7. An arc discharge device comprising a sealed envelope having a portion of non-conducting material, an anode, a liquid pool cathode, a thermionic cathode, and a control grid partially enclosing said thermionic cathode, said liquid pool cathode consisting of mercury containing a sufficient quantity of barium to cause said mercury to disperse upon and wet said non-conducting portion of said envelope.

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