

March 28, 1939.

L. D. MILES

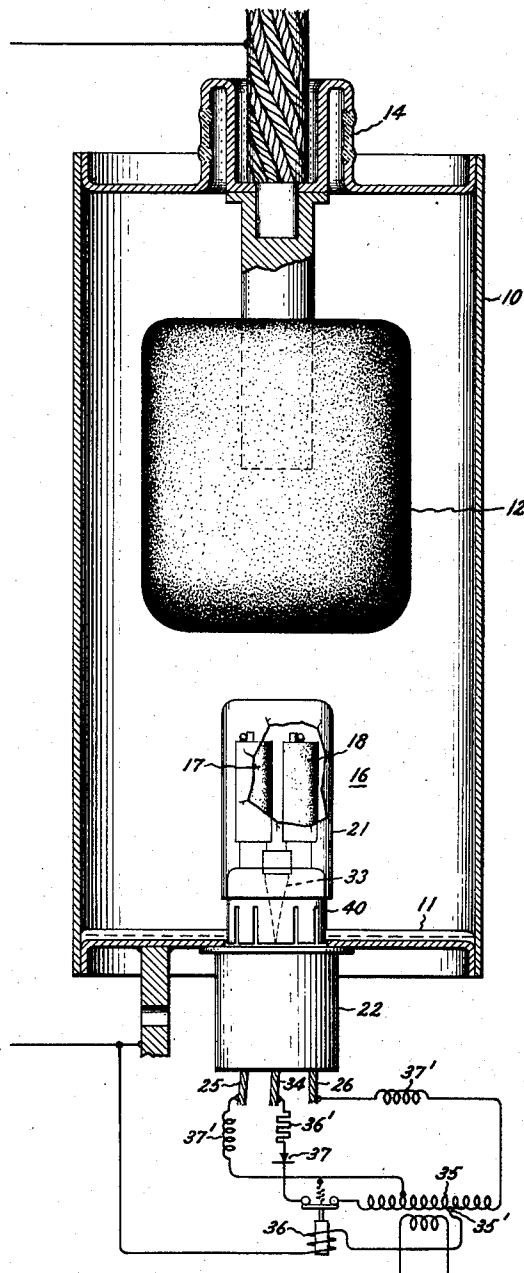
2,152,201

DISCHARGE DEVICE

Filed Oct. 9, 1937

5 Sheets-Sheet 1

Fig. 1.



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Fig. 2.

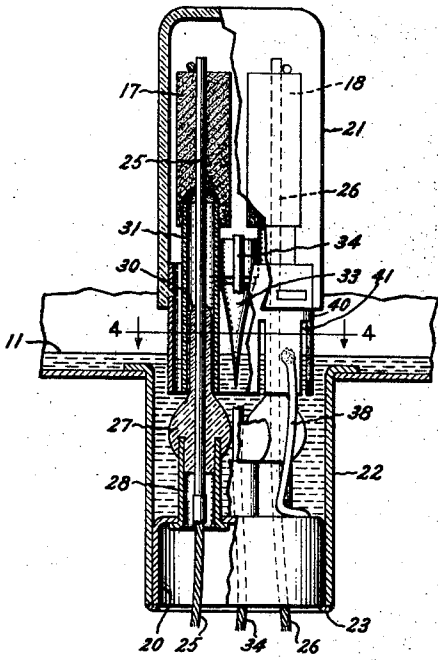


Fig. 3.

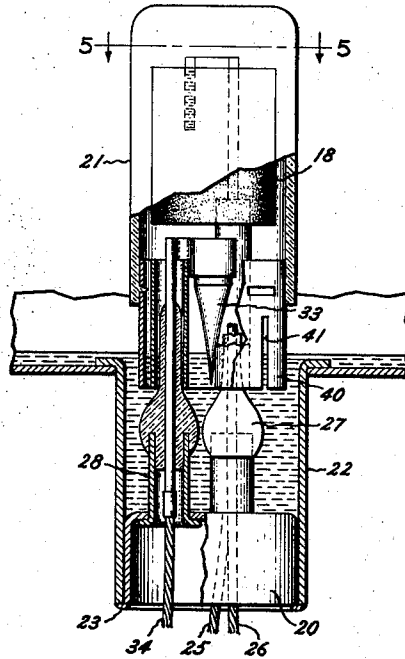


Fig. 4.

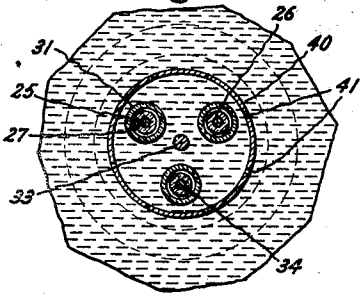
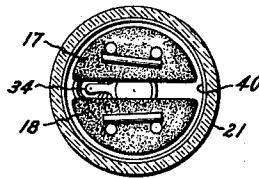


Fig. 5.



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Fig. 9.

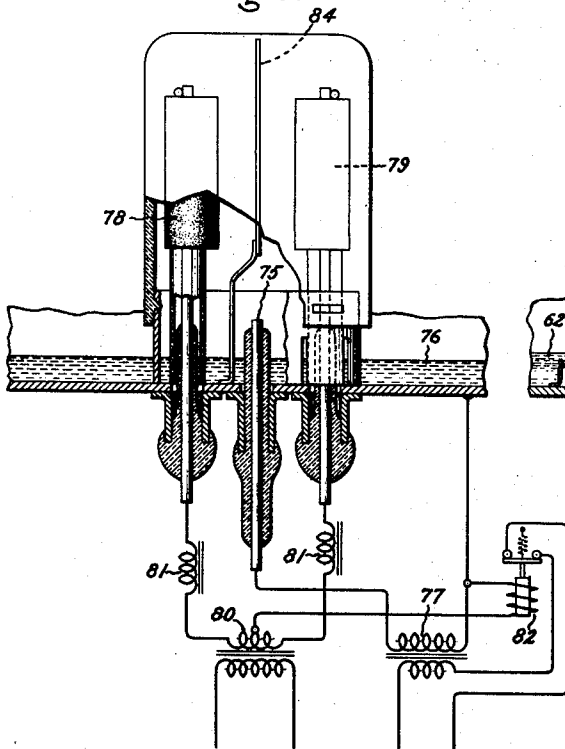


Fig. 8.

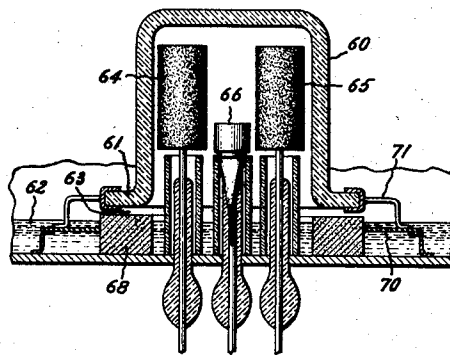


Fig. 6.

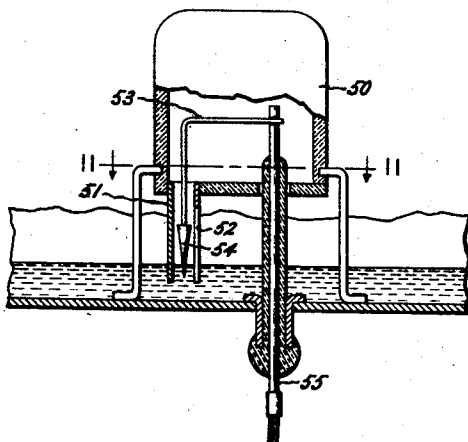
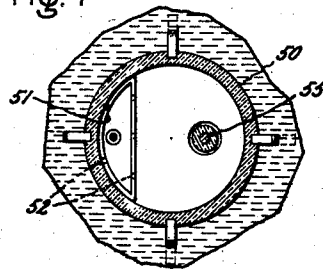


Fig. 7.



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DISCHARGE DEVICE

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Fig. 10.

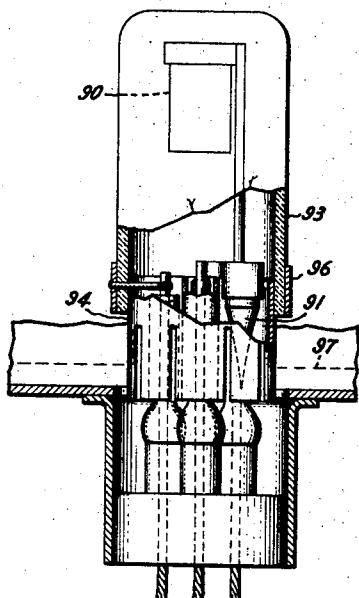


Fig. 12.

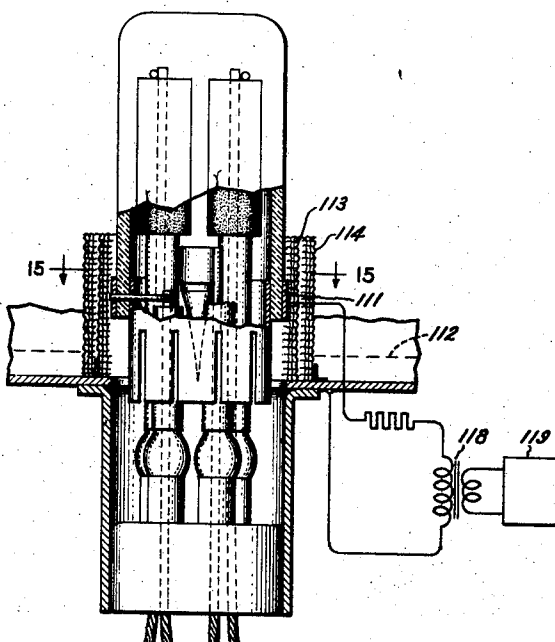


Fig. 11.

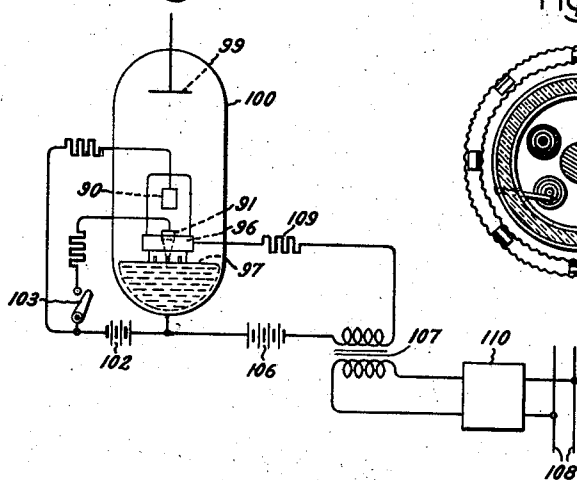
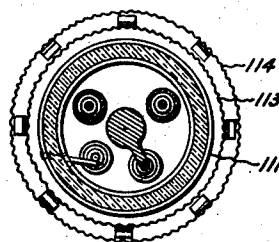


Fig. 13.



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Fig. 14.

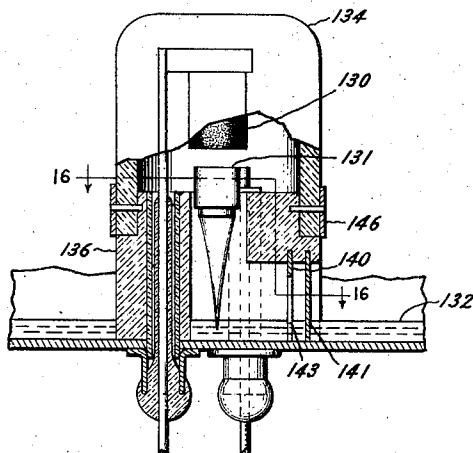


Fig. 16.

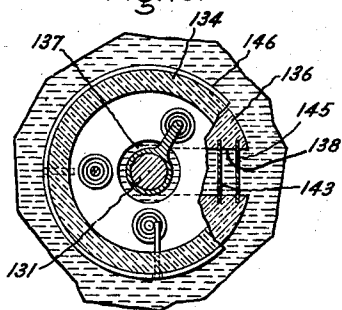
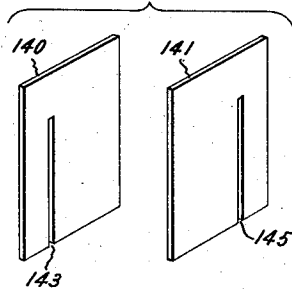


Fig. 15.



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UNITED STATES PATENT OFFICE

2,152,201

DISCHARGE DEVICE

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New York

Application October 9, 1937, Serial No. 168,197

9 Claims. (Cl. 250—27.5)

The present invention relates to improvements in discharge devices employing cathodes constituted of a material which is adapted to yield substantially unlimited electron emission in the presence of a favorable electrostatic field. Such cathodes are best exemplified by the mercury pool and for that reason are referred to in this application as "pool-type cathodes". It should be understood, however, that the term "pool-type" as used herein and in the appended claims is not limited to liquid metals such as mercury but is intended also to include solid substances which are capable of analogous use. Particular examples of such solid substances include cadmium and bismuth.

It is an object of the invention to provide an improved means for initiating a discharge between the principal electrodes of a discharge device of the class above specified. While not limited thereto, the invention is primarily applicable to single anode devices or other devices in which the main discharge requires to be re-initiated at cyclically recurrent intervals.

It is well known in this connection to utilize means for continuously maintaining a holding arc from which an intermittent main discharge may be ignited from time to time. It is, however, an objectionable characteristic of such systems as conventionally employed that the cathode spot is free to wander on to the walls of the discharge enclosure unless such walls are effectively insulated. It is one important object of this invention to provide a holding-arc assembly which may be used satisfactorily even where the metal parts of the discharge enclosure are electrically continuous with the cathode itself.

This is accomplished in one way by so enclosing or shielding the discharge space of the holding arc that it is substantially entirely separated from the main discharge space except for a restricted passage between them. By utilizing shielding means of appropriate character, as hereinafter explained, I obtain the result that the cathode spot of the holding arc is always confined to a restricted cathode region and always causes the main discharge to develop from such region. Consequently, even if a cathode spot attributable to the main discharge current reaches the enclosure wall during a portion of some given voltage cycle, it will necessarily be reborn in the vicinity of the holding arc assembly at the beginning of the next cycle.

Another advantage accruing from the use of means for shielding the holding arc lies in the fact that such means effectively protect the

holding arc from possible extinguishment by arc-back occurrences in the main discharge space. This is of considerable practical importance in that it assures immediate resumption of operation at the end of each arc-back period and eliminates the need for elaborate supervisory equipment for automatically restarting the holding arc.

It is frequently desirable in connection with pool-type discharge devices to control or vary the time of discharge initiation, and a further aspect of my invention consists in the combination with a shielded holding arc assembly of means for accomplishing such control.

The features of novelty which I desire to protect herein are pointed out with particularity in the appended claims. The invention itself, together with further objects and advantages thereof, may best be understood with reference to the following description taken in connection with the drawings in which Fig. 1 illustrates in section a pool-type discharge device suitably embodying the invention; Figs. 2-5 are various detailed views of a particular holding arc assembly according to the invention; Figs. 6 and 7 conjointly illustrate a possible modification of the holding arc assembly; Fig. 8 shows a further modification; Fig. 9 shows a variant means which may be used alternatively with the make-alive means of Figs. 1-8 for initially starting the holding arc; Fig. 10 shows the combination of a shielded holding arc assembly with means for controlling the time of initiation of the main discharge; Fig. 11 shows circuit connections suitable for use with the device of Fig. 10 and Figs. 12-16 illustrate two modifications of the controllable device of Fig. 10.

Referring particularly to Fig. 1, I have shown a metal envelope 10 forming an enclosed discharge space within which are arranged a cathode 11 and an anode 12, providing appropriate discharge terminals. As shown, the anode comprises a massive member of heat-resisting material, such as graphite, supported from the envelope and insulated from it by means of a glass ring 14. It should be understood, however, that in certain cases the anode may comprise a portion of the envelope itself. The cathode 11 is a pool-type cathode, as previously defined, and may consist of a liquid metal such as mercury or of an equivalent solid material such as cadmium. It is in direct contact with the main body of the metal envelope and is thus electrically continuous with it.

Devices such as that illustrated are ordinarily

used as asymmetrically conducting elements in connection with alternating current circuits, in which they may act as rectifiers or inverters. When they are so used, some means must be provided for facilitating the initiation of a main discharge upon the application of favorable potential between the discharge terminals. I have shown for this purpose a holding-arc assembly 16 having certain novel and improved features to be described in the following. Before proceeding to a full description of such features, it will be helpful to refer briefly to certain factors involved in the operation of devices of the type in question.

15 An arc discharge extending from a pool-type cathode results in the creation of a so-called "cathode spot" on the cathode surface. Actually such a "spot" comprises a multiplicity of separate "spots" or elements which grow by subdivision as the current increases until on a liquid mercury surface a minute spot exists for about each two amperes. Thus, 600 amperes come from about 300 spots which usually arrange themselves in further groups and all act in parallel. 20 In a discharge device comprising one main anode and holding anode, the cathode spot comprises a continuously maintained component, attributable to the holding arc, and an intermittent or cyclically recurrent component, attributable to the main discharge. The latter component grows or develops from the former in the presence of a favorable potential field in accordance with the process of subdivision previously referred to. 25 With an open holding arc as conventionally employed, the composite cathode spot, being continuously maintained although variable in size, travels rapidly from place to place, moves frequently on to the metal tube walls unless insulated from such walls, and when finally marooned upon the metal, gets its emission therefrom and disintegrates the metal in so doing. It may wander back to the cathode surface without serious consequences or it may wander into the seals and damage them. For this reason, 30 heretofore, the cathode has been conventionally insulated from the envelope side walls when a holding arc is employed.

However, a holding-arc assembly may satisfactorily be employed in connection with a discharge device in which the metal walls of the envelope are electrically continuous with the surface of the cathode provided the component of the cathode spot attributable to the holding arc is confined to a restricted region of the cathode surface. If this is done, the main discharge current will necessarily be initiated at a point adjacent to such region at the beginning of each voltage cycle. Consequently, no portion of the cathode spot will be able to lodge permanently or for a substantial length of time on any part of the discharge device other than the cathode surface.

Confinement of the holding arc cathode spot as proposed in the foregoing is accomplished in accordance with my invention by the use of shielding means adapted substantially to segregate the holding arc from the main discharge space except for the provision of a restricted passage between them. Referring again to Fig. 1, I have shown one example of such a shielding means as comprising a hollow enclosing member extending from the surface of the cathode 11 up to and around the keep-alive electrodes 17 and 18. This member is preferably constituted

throughout of refractory material adapted to withstand the effects of an arc discharge.

The details of construction of the holding-arc assembly are clearly illustrated in Figs. 2-5 in which parts corresponding to elements shown in Fig. 1 are similarly numbered. It is possible, of course, to mount the assembly in various ways as by supporting it from the top or lateral walls of the discharge envelope. However, I prefer an arrangement such as that shown, wherein the assembly as a whole is mounted on a demountable header 20 (Fig. 2) which is positioned within a conforming cylinder 22 depending from the bottom of the envelope. The header is secured in place by an externally accessible fillet 23 of appropriate sealing material such as glass or fused metal which may be broken or cut away to permit removal and replacement of the header whenever necessary.

The keep-alive electrodes 17 and 18 are supported on the upper surface of the header 20 by means of relatively rigid lead-in conductors 25 and 26 brought into the discharge device through the header. In order hermetically to seal the lead-in connections, one may employ a quantity of glass such as is illustrated at 27, this being fused to an eyelet 28 of iron-nickel-cobalt alloy or the like which is in turn welded or otherwise secured to the header.

In order to insulate the lead-in connections from the cathode material a portion of the sealing material may extend above the level of the cathode surface as indicated, for example, at 30. Since the sealing material is to a certain extent subject to erosion by the action of an arc discharge, its exposed portion may be further protected by the provision of a heat shield, for example, a sleeve 31 of metal, glass or quartz surrounding the same. Similar sleeves may be provided in connection with all the electrode connections.

The keep-alive electrodes themselves are preferably constituted of a heat resisting material of high thermal emissivity such, for example, as graphite, and may assume various configurations according to the circumstances of their use. The electrodes 17 and 18, of which various aspects are shown in Figs. 2, 3 and 5, comprise, in the case illustrated, elongated graphite members of generally oblong cross-section. Where it is desired to use the holding-arc assembly with an alternating current power supply, the holding arc may be continuously maintained by employing two or more keep-alive electrodes adapted to be energized during alternate periods. With a direct current supply only one such electrode is required.

In order to start the holding-arc during the initial functioning of the discharge device, one may employ a make-alive electrode such, for example, as a body of semi-conducting material 33 arranged in permanent contact with the cathode. Such an electrode preferably has a resistivity between the limits of from about 10^{-2} to about 10^5 ohms per centimeter cube and may consist, for example, of a short tapered rod of silicon carbide which has been treated superficially with a solution of iron nitrate according to the procedure described and claimed in J. M. Cage application, Serial Number 130,760, filed March 13, 1937, and assigned to the same assignee as the present application. As is well known in the art, the act of subjecting a make-alive electrode of the type specified to a positive potential during a period when one of the keep-alive electrodes

is also positive with respect to the cathode 11 will cause an arc discharge to such electrode to be initiated. A terminal connection for permitting the make-alive electrode 33 to be energized is shown at 34. It is shown partly broken away so as not to obscure the remaining details of the assembly.

An exemplary circuit for obtaining proper cooperation between the keep-alive and make-alive electrodes is shown diagrammatically in Fig. 1. In the illustrated circuit there is provided a transformer having a tapped secondary 35 connecting with the various electrodes. The keep-alive electrodes are alternately rendered positive with respect to the cathode 11 by means of a symmetrical circuit arrangement in which the cathode is connected at 35' to the mid-point of a section of the transformer 35, the terminals of such section being connected to the electrodes 17 and 18. Energization of the make-alive electrode 33 is controlled by a relay 36 which is so constructed as to be normally closed during periods of disuse of the discharge device. Under these circumstances application of potential to the transformer results in passage of current to the electrode 33. This current is caused to flow only in a desired direction (i. e. from the electrode 33 to the cathode 11) by the use of a rectifier 37. A current limiting resistor 36' is provided in series with the make-alive electrode and the reactors 37' in series with the keep-alive electrodes.

With the circuit illustrated, energization of the electrode 33 will result in the immediate establishment of an arc discharge to the keep-alive electrodes 17 and 18, which will thereafter conjointly maintain the arc. Furthermore, once current starts to flow in the cathode circuit, the relay 36 will act to open the connection to the make-alive electrode 33, thus maintaining it de-energized as long as the holding arc is in operation. If the holding arc is extinguished for any reason the relay 36 will automatically close and the starting operation will be repeated.

As previously stated, there is a tendency for the cathode spot maintained by a holding-arc to wander freely over the cathode surface and even to run on to the walls of the discharge container. In order to avoid this type of operation and its attendant difficulties, my invention provides a shielding means adapted to confine the holding arc cathode spot to a restricted region of the cathode surface. Such means preferably comprises a structure which is adapted substantially to segregate the holding arc space from the main discharge space except for the provision of a restricted passage between such space. Thus, with the particular electrode assembly shown, the shielding means consists of a hollow enclosing member extending from a point below the surface of the cathode to and around the keep-alive electrodes 17 and 18 and preferably also enclosing the make-alive electrode 33. Such an enclosing member (comprising parts to be described hereinafter) may be supported in various ways and in the particular arrangement shown is mounted on relatively rigid supports 38 extending from the upper surface of the header 20.

The shielding member should preferably be of a refractory material, for example, of metal or ceramic, which is adapted to withstand the destructive action of an arc discharge. It may comprise a unitary structure of a single material or may alternatively consist of an assembly of various parts of different materials. For at least the upper part of the enclosure 21 I prefer to use

refractory insulator such as quartz or alumina in view of the superior heat resisting qualities of these materials. I have found however, that if the insulator extends below the cathode surface so that it is frequently in contact with the cathode spot, there is some tendency for it to be eroded by the action of the arc at the cathode spot. For this reason, I prefer to construct the lower portion 40 of the shielding means of a refractory metal, for example, of molybdenum or tungsten. The metals last mentioned are particularly suitable in that they serve the additional function of anchoring the cathode spot rather than permitting such spot to play freely over the entire enclosed portion of the cathode surface.

In order that the cathode spot maintained by the holding arc may be effective to initiate a discharge upon the application of a favorable potential difference to the main anode and cathode, at least some communication must be provided between the holding arc space and the main discharge space. In accordance with my invention such communication is limited to a passage or passages of sufficiently small dimensions so that the flow therethrough of a current of the order of magnitude of the holding arc current will build up a substantial opposing voltage or voltage drop. The significance of the foregoing statement may best be understood by consideration of a particular structure such as that shown in Figs. 2 and 3. In the arrangement there illustrated, the passage between the holding arc space and the main discharge space comprises a plurality of slots 41 formed in the metal enclosure member 40. These slots 41 preferably extend normally from the cathode surface to a point appreciably above such surface.

During the inactive period of the discharge device, that is when no positive potential is applied between the main anode and the cathode, the holding arc cathode spot is readily retained within the region enclosed by member 40. However, when the main anode 12 (Fig. 1) becomes highly positive with respect to the cathode, a main discharge will be initiated which in the first instance derives electrons from the cathode spot referred to. As the main discharge current tends to increase, the limited area of the slots 41 hinders the passage of current therethrough and produces a tendency for the cathode spot to be forced outside the enclosing member. This tendency is opposed, however, by the fact that the current demanded by the keep-alive electrodes themselves will, assuming a sufficiently small slot area, build up a relatively high voltage drop in the slots if the cathode spot seeks to leave the enclosed region. This "constriction voltage drop" which is well-known in other connections, is comparable in many respects to the pressure drop required to force a stream of liquid at high velocity through a restricted tube or orifice.

Under the influence of these conflicting forces the cathode spot follows the only course left and divides. The component attributable to the holding arc remains within the confines of the member 41 whereas the component attributable to the main discharge space may wander over the free cathode area outside the enclosure. This latter component, however, extinguishes at the end of each positive half cycle of potential and must be reignited from the holding arc at the beginning of the next positive half cycle. In this way the cathode spot is always reinitiated at some point on the surface of the cathode 11 and is prevented from becoming fixed to a de-

structible element of the discharge device such as the wall of the enclosing envelope.

The slot area required to give the results stated in the foregoing is variable with the magnitude of the holding arc current and must be low enough with relation to the particular current employed so that the constriction effect will prevent the portion of the cathode spot attributable to the holding arc from leaving the shielded enclosure. This relationship does not lend itself to simple calculation but may be readily determined experimentally. It will be noted that if the slot area is too large, the "constriction voltage drop" may be inappreciable and will not prevent the spot from leaving the shield. On the other hand, if the slot area is decreased sufficiently this voltage drop will reach a substantial value, adequate to force a division of the spot so that one component remains within the shield while the other supplies the demands of the load current. In general, this division will occur whenever the voltage drop needed to force through the slots a current of the magnitude of the holding-arc current reaches a substantial fraction, say one-third to one-half, of the total voltage normally required to maintain the holding-arc.

Referring again to the particular construction of Fig. 2 it has been found that with a moderate holding arc current, such as 5 to 7 amperes eight slots provide too little shielding where each slot is .045 inch wide and extends as much as $\frac{1}{4}$ inch above the cathode surface or where each slot is .025 inch wide and extends $\frac{3}{4}$ inch above the cathode surface. The result is that not enough constriction occurs and the main anode attempts to get too much of its current from under the cup, resulting in excessive heating. Further, the constriction is insufficient to force a division of the cathode spot so that the spot frequently leaves the shield during the conduction period. Under these conditions, the cathode spot is sometimes "recaptured" when the load current ceases, but more frequently extinguishes. However, the .045 inch slots have been found to be satisfactory if limited to about $\frac{1}{4}$ inch length while .025 inch slots prove satisfactory if limited to about $\frac{1}{4}$ inch length. It should be understood, however, that these exemplary figures refer to a particular construction of the shielding enclosure and to a particular value of the holding-arc current. Widely different dimensions may prove suitable with enclosures of different form and materials and with other electrode arrangements.

The precise type of shielding enclosure shown in Figs. 2 and 3 is in no way essential to the purposes of the invention, and in Figs. 6 and 7 I have shown one alternative form which the shield may take. In this case, as in that previously described, the upper part of the enclosure 50 is preferably of an insulating material such as quartz alumina or glass while the lower part 51 is of a refractory metal such as molybdenum having slots 52 therein (Fig. 7). However, the lower part and particularly that portion in contact with the cathode surface has a relatively constricted configuration for a purpose to be stated in the following.

The nature of this configuration is most clearly shown in Fig. 7 wherein it appears that the metallic shield portion 51 comprises a substantially continuous enclosure having a long and narrow outline. It is a particular advantage of this construction that the holding-arc cathode spot, even though it may occasionally escape from anchor-

age on the inner surface of the member 51, is never very far removed from one of the slots 52. For this reason, more uniform starting will be obtained than is possible if the cathode spot may be at a relatively great distance from the slot openings.

The arrangement of Fig. 6 also represents a further departure from the construction previously described in that the make-alive and keep-alive functions are combined in a single electrode structure. This structure comprises a heat-resisting conducting member 53, suitably of tungsten, having depending therefrom a semi-conducting make-alive electrode 54 in contact with the cathode surface. During the initial starting period of the device, a positive potential is impressed on the member 53 through the lead-in conductor 55. The current flowing through the semi-conducting electrode member 54 will initiate an arc, the positive terminal of which will be immediately transferred to the conducting member 53 or to some portion thereof. Due to the high resistance of the member 54, it will be effectively shunted by the holding-arc and will play no further part in the operation of the device. The holding-arc itself may be maintained between the member 53 and the surface of the cathode material by the maintenance of a direct current potential between them.

The shape and character of the constricting passage may also be varied and in Fig. 8 I have shown one form which such variation may take. In this case, the shielding enclosure is formed by an inverted cup-like member 60, suitably of quartz, having a flattened rim 61 arranged parallel to the surface of the cathode 62. Within the shielding member 60, there are provided keep-alive electrodes 64 and 65 and a make-alive electrode 66 corresponding in essential particulars to the similar elements previously described. The narrow free space or passage 63 (preferably of the order of magnitude of $\frac{1}{4}$ of an inch in height) existing beneath the rim 61, serves by constriction to maintain the holding arc cathode spot within the region falling under the member 60 in accordance with the principles previously explained. It is clear, however, that if the passage 63 is defined only by the cathode surface and by the opposed surface of the rim 61, slight variations in the cathode level will produce relatively great variations in the operation of the holding-arc assembly. For this reason in order satisfactorily to employ the construction of Fig. 8 with a liquid cathode such as mercury, particularly in high current rectifiers, I consider it necessary to provide means for stabilizing the cathode at the constricted region. Such means may include, for example, an annular member 68 constituted of a porous wick-like substance adapted to be wet by the cathode material. Such a substance, suitable for use with mercury, may comprise in one instance, a sintered mass of coherent particles of carburized molybdenum such as is described and claimed in U. S. Letters Patent No. 2,128,861 granted August 30, 1938 to Lewi Tonks and assigned to the same assignee as the present invention. The annular member 68 may project slightly above the normal surface of the cathode, dependence being placed upon capillarity to maintain the upper surface of the member covered with cathode material so that it operates in effect as a raised extension of the cathode. Under these conditions, the dimensions of the passage existing between the rim 61 and the stabilizing member 68 will be substantially con-

stant and independent of variations in the cathode level. Still further means for preventing excessive agitation or wave motion of the cathode material in the region directly surrounding the holding-arc assembly is provided in the form of an annular baffle 70, suitably of metal, extending around the outer periphery of the member 68 and arranged slightly below the cathode surface. (It should also be noted that in many cases a baffle of this kind may advantageously be associated with holding-arc shielding other than the particular shielding means illustrated in Fig. 8.) Mounting brackets 71 serve to support the member 60 from the upper surface of the baffle 70.

In Fig. 9 I have shown a further modification which differs from the arrangements previously described mainly with respect to the means disclosed for initially starting the holding arc. In this figure, such means is illustrated in the form of a sparking electrode 75 although it may alternatively comprise a capacity make-alive device such as is shown, for example, in Patent 1,110,572 to Von Recklinghausen. During the initial starting of the device, a high potential may be impressed between the cathode 76 and the sparking electrode 75, for example, by means of a so-called "ignition" transformer 77. The sparking discharge thus produced will be effective to initiate a holding-arc to the keep-alive electrodes 78 and 79. These latter electrodes are energized by means of a transformer 80 which has a center tap connection to the cathode 76 and which is connected at its terminals to the keep-alive electrodes through stabilizing reactors 81. A series relay 82 in the holding arc circuit acts to break the connections to the starting electrode as soon as the holding-arc is in progress.

Another feature shown in connection with Fig. 9 comprises a baffle 84, suitably of metal, interposed between the keep-alive electrodes 78 and 79. Such a baffle may advantageously be employed with any holding-arc assembly in which a plurality of keep-alive electrodes are employed, and serves to prevent cross currents between the various electrodes during periods when a difference of potential exists between them.

The various embodiments of the invention so far described have been primarily applicable in facilitating or assuring the initiation of a discharge upon the application of a favorable potential between the main discharge electrodes. The devices of my invention may also be employed in connection with control means to determine the occurrence or non-occurrence of a discharge to a principal anode upon the establishment of conditions favorable to such discharge, or to vary the time of discharge initiation in a desired manner. In order to understand this aspect of the invention, it is desirable to refer briefly to some of the principles which govern the occurrence of a discharge in a vapor arc device of the type herein under consideration.

When a positive potential is impressed between an anode and a pool-type cathode on which a cathode spot exists, the occurrence of an arc discharge to such anode depends largely upon the presence in the discharge space of a supply of electrons sufficient to produce ionization of the vapor existing in the space. It is the usual function of a holding-arc and its cathode spot to provide and maintain such an electron supply in the main discharge space. However, in connection with shielded holding-arc assemblies such as those herein described this is not necessarily true. On the contrary, with such

assemblies the occurrence of a main discharge upon the application of a positive potential to the main anode depends in part upon the ability of the electrostatic field of the anode to reach into the shielded space and to draw electron current from the holding-arc cathode spot. It is therefore possible, and a part of my invention, to provide in operative relation to the restricted passage between the holding-arc and the main discharge space electrostatic means effective to control the penetration of the anode field into the shielded space.

Referring particularly to Fig. 10, I have shown a holding-arc assembly comprising a single keep-alive electrode 90, (to be energized from a direct current source), and a make-alive electrode 91. These electrodes are enclosed within a hollow shielding member comprising an upper insulating portion 93 and a lower slotted metal portion 94. In addition to the elements already described, there is provided an electrostatic control member or electrode in the form of a conducting band 96, for example, of metal mounted on the outer surface of the insulating member 93 in operative relation to the slots in the metal member 94.

Circuit connections for a device of the type described in the foregoing are illustrated diagrammatically in Fig. 11 which also illustrates schematically a complete discharge device comprising a cathode 97, an anode 99 and an enclosing envelope 100. The make-alive electrode 91 may be energized for initially starting the holding-arc by means of a direct current source of potential 102, controlled by a switch 103; while the holding-arc may be maintained by a connection between such source and the keep-alive electrode 90. As soon as the holding-arc is started, the occurrence of a main discharge will depend in part upon the application of a favorable potential difference between the anode 99 and the cathode 97 and in part on the potential applied to the control member 96. In this connection it will be understood that if the member 96 is strongly biased negatively, it may be made impossible for the positive field of the anode 99 to draw electrons from within the shielded space in sufficient quantity to initiate a main discharge. The magnitude of the negative potential which must be applied to the member 96 to accomplish this result will depend in part upon the geometry of the discharge device and of the shielding structure and in part upon the magnitude of the positive potential to be applied to the anode 99.

Assuming that the control electrode 96 is sufficiently negatively biased by means of a battery 106 so that the occurrence of a main discharge will be normally impossible, such a discharge can nevertheless be caused to occur by additionally applying to the control member another potential of such nature as to overcome its bias. Such a potential may be provided, for example, by means of an alternating current transformer 107 having its primary connected to a potential source 108 and its secondary in circuit with the control electrode through a series resistor 109. Interposed between the source and the transformer there may be provided a phase-shifting means, illustrated diagrammatically at 110, which is adapted to control the phase relation between the control potential applied to the electrode 96 and the main discharge potential applied between the anode 99 and the cathode 98. By properly selecting this phase relationship as by adjustment of the phase control means 110,

the main discharge may be made to occur cyclically and may also be limited as to duration to a selected fraction of each positive half cycle of the main potential. Other means of control will of course occur to those skilled in the art.

It is important to note that the control member of the combination just described acts only on the holding arc and exerts no direct influence on the main discharge current. It therefore has no tendency to increase the main arc drop, in which respect it differs fundamentally from the various grid structures and other electrostatic control means which have previously been employed in connection with the regulation of pool-type discharge devices.

In order somewhat to decrease the potential which must be applied to the control member for effective control operation and to decrease the necessary power consumption of the control circuit, I may also provide means for additionally shielding the holding-arc cathode spot from the field of the main positive electrode or anode. One means is shown in Fig. 12 wherein the holding-arc assembly itself closely resembles that already described in Fig. 2. In this figure, electrostatic shielding means in the form of a pair of cylindrical grids 113 and 114 are provided in a region closely surrounding the passage existing between the holding arc space and the main discharge space. These members are preferably of sufficient extent to encompass also the control member 111. They are shown as being in contact with the bottom of the discharge envelope and therefore with the cathode material (indicated in dotted outline at 112), but may alternatively be insulated therefrom and charged to different potentials. Under the conditions illustrated, they tend to maintain in the region surrounding the holding-arc shielding structure an equipotential zone having the same potential as the cathode itself. It is thus made relatively difficult for the positive field of the main anode to affect in any way conditions within the holding arc shielding structure. For this reason, the occurrence of a main discharge is more directly under the control of the control member 111 and may be regulated by the use of a control potential of relatively low value, applied, for example, by means of a transformer 118 in connection with a phase-shifting device 119.

A still further variation of structure in connection with a controllable discharge-initiating device is shown in Figs. 14-16. In the arrangement there illustrated, the electrode structure involved comprises a single keep-alive electrode 130 and a make-alive electrode 131 suitably supported above the surface of a pool-type cathode 122. A shielding member is provided in the form of an inverted cup-like member 134, of quartz or the like, which encloses the keep-alive electrode 130 and which is joined at its lower end to a body of refractory material 136, suitably of graphite or alumina. The member 136 is of such configuration that the cathode material within the shielding enclosure is confined to a relatively constricted well 137 (Fig. 16) communicating with a radially extending narrow channel 138. The channel itself is substantially closed by means of a pair of barriers 140 and 141, preferably of a refractory metal such as molybdenum and each having one or more slots therein. With this arrangement, the cathode spot within the shielded enclosure will be confined to a very limited portion of the cathode surface. Ordinarily it will be anchored to the inner face of the barrier

140 so as to be close to a slotted opening 143 provided in such barrier. In some cases I have found it advantageous to assist such anchoring by the use of means (not shown) for producing a magnetic field transverse to the holding arc and in a direction suitable for forcing the cathode spot against the barrier, thereby to localize the same. This feature is fully described and claimed in my copending application Serial No. 254,156, filed February 2, 1939. By virtue of such an arrangement, highly dependable results with respect to firing of the discharge device may be obtained whenever conditions external to the shielded enclosure are favorable to such firing.

In order to shield the holding arc cathode spot most effectively from the field of the main anode, the second barrier 141 has an opening 145 which is offset from the opening 143 in the barrier 140 (see Figs. 15 and 16). In order to control the discharge initiation, an electrostatic control electrode 146 is provided in operative relation to the channel 138. This control electrode may be energized in a desired manner, as has previously been explained and when properly charged will be effective to prevent firing of the discharge device in spite of the occurrence of a favorable potential difference between the main discharge electrodes. When differently charged, on the other hand, it may permit such firing. It will be understood that the particular arrangement of the electrode 146 shown in Fig. 14 is not essential. In some cases the control member may advantageously be placed between the barriers 140 and 141, or even within the shielded enclosure. With the last mentioned arrangement, it can be made to affect the magnitude of the holding-arc current and in this way to control the number of electrons supplied to the main discharge space.

It will be seen from the foregoing that I have provided in connection with a pool-type discharge device an improved discharge-initiating device by means of which the cathode spot may be positively confined to the cathode surface. Furthermore such confinement is accomplished without the use of an electrode member in continuous contact with the cathode surface so that the limitations on life ordinarily associated with such electrodes are not involved.

By shielding the holding-arc assembly in the manner specified, I also obtain the result that the operation of the holding arc is substantially independent of events occurring in the main discharge space. In particular, there is little or no tendency for the holding arc to be extinguished by arc-back or excessive forward currents occurring between the main electrodes. For this reason, an extremely low holding arc current, of the order of a few amperes, may be employed satisfactorily. Also, because of the inherent reliability of my improved system, very little auxiliary and supervisory equipment is required.

While I have in the foregoing exemplified my invention by reference to particular constructions, materials, and dimensions, it will be understood that any or all of these may be varied substantially by those skilled in the art without departure from the invention. I, therefore, aim in the appended claims to cover all modifications which come within the true spirit and scope of the foregoing disclosure.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A discharge device comprising an anode and a pool-type cathode having a discharge space therebetween and means for facilitating the ini-

5 tiation of a discharge through said space upon the application of a favorable difference of potential between said anode and cathode, said means comprising one or more keep-alive electrodes effective to maintain a continuous holding arc to the cathode surface throughout the normal operation of the device and a shielding member extending from a point below the cathode surface to and around the keep-alive electrode, said shielding member substantially completely enclosing the keep-alive electrode except for the provision of one or more narrow slots in the member at the cathode surface, such slots extending in a generally normal direction with respect to the cathode surface.

2. A discharge device comprising an anode and a pool-type cathode having a discharge space therebetween and means for facilitating the initiation of a discharge through the space upon the application of a favorable difference of potential between said anode and cathode, said means comprising a keep-alive electrode in operative relation to the cathode surface for maintaining a holding arc thereto, and a hollow shielding member extending from a point below the cathode surface to and around the keep-alive electrode, said member substantially separating the holding-arc from the main discharge space except for the provision of one or more openings through the member at the cathode surface, the portion of said shielding member which is in contact with the cathode surface being of materially smaller transverse dimensions than the upper portion of the member so as to confine the holding-arc cathode spot to a region which is closely adjacent to said openings.

3. A discharge device comprising means providing a principal discharge space, means including a pool-type cathode affording terminals for a discharge passing through said space, a keep-alive electrode in operative relation to the cathode surface for maintaining a holding-arc thereto, a shielding member extending from the cathode surface to and around the keep-alive electrode, said member substantially separating the discharge path of the holding-arc from the main discharge space except for the provision of one or more restricted openings between them at the cathode surface, and means including a body of a cathode-spot-anchoring material in contact with the cathode surface for anchoring the cathode spot of the holding arc in the vicinity of said openings during the use of the device.

4. A discharge device comprising means forming a principal discharge space, means including a pool-type cathode providing terminals for a principal discharge passing through such space, and means for facilitating the initiation of a discharge through the space upon application of a favorable potential difference between such terminals, said last-named means including an electrode cooperating with the cathode for maintaining a holding-arc and a hollow member extending from a point below the cathode surface to and around the keep-alive electrode, the portion of said hollow member more remote from the cathode comprising a refractory insulating material and the portion in contact with the cathode material comprising a refractory metal body provided with one or more restricted openings.

5. A discharge device comprising an anode and a liquid metal cathode having a discharge space therebetween and means for facilitating the initiation of a discharge through said space upon the application of a favorable difference of potential

between said anode and cathode, said means comprising a keep-alive electrode in operative relation to the cathode surface, and a hollow shielding member extending from adjacent to the cathode surface to and around the keep-alive electrode, said member substantially separating the keep-alive electrode from the main discharge space except for the provision of a narrow passage to said space between the lower edge of the shielding member and the cathode surface, and means for stabilizing the cathode surface to maintain the dimensions of said passage substantially constant during the use of the device.

6. A discharge device according to claim 5 in which the cathode surface stabilizing means includes a body of a wick-like substance capable of being wet by the cathode material and adapted to anchor the cathode spot.

7. A discharge device comprising means forming a principal discharge space, means including a pool-type cathode providing terminals for a discharge passing through said space, a keep-alive electrode cooperating with the cathode surface for maintaining a holding-arc adapted to facilitate initiation of a discharge between said terminals, and means for controlling the initiation of such a discharge, said last-named means including a hollow enclosure substantially segregating the discharge space of the holding-arc from the principal discharge space, and means including a plurality of successively arranged metallic members providing a tortuous passage between such spaces adjacent to the cathode surface.

8. A discharge device comprising an anode and a pool-type cathode spaced to provide a discharge space therebetween, and means for facilitating the initiation of a main discharge through said space upon the application of a favorable difference of potential between the anode and cathode, said means including one or more keep-alive electrodes effective to maintain a continuous holding-arc to the cathode surface throughout the normal operation of the device, and a hollow shielding member of constant potential extending from a point below the cathode surface to and around the keep-alive electrodes, said shielding member substantially completely enclosing the keep-alive electrodes except for the provision in the member of one or more restricted openings adjacent to the cathode surface, the openings being of such dimensions as to prevent the holding-arc cathode spot from escaping the shielded enclosure, while nevertheless permitting the ignition of the main discharge therefrom.

9. A discharge device comprising an anode and a pool-type cathode providing terminals for a main discharge, a keep-alive electrode cooperating with the cathode surface for maintaining a continuous holding-arc thereto throughout the normal operation of the device, a hollow shielding member extending from a point below the cathode surface up to and around the keep-alive electrode and completely enclosing the same except for the provision of a restricted passage through the member adjacent to the cathode surface, said passage being of such dimensions as to prevent the holding-arc cathode spot from escaping the shielded enclosure while nevertheless permitting the ignition of the main discharge therefrom, and an electrostatic control electrode arranged in operative relation to said passage for controlling initiation of the main discharge.

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