Sept. 24, 1946. J. H. FINDLAY ET AL 2,407,979

CONTROLLED ELECTRODE FOR FIELD EMISSION DISCHARGE DEVICES

Filed Sept. 26, 1942

Fig. 1.

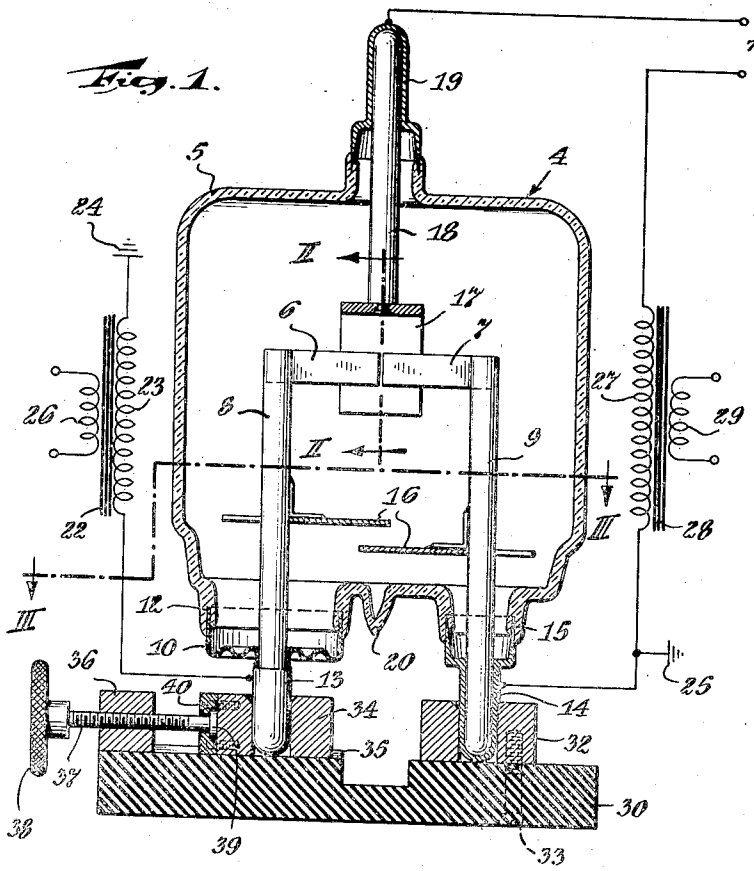


Fig. 2.

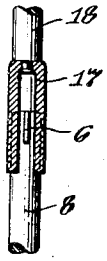
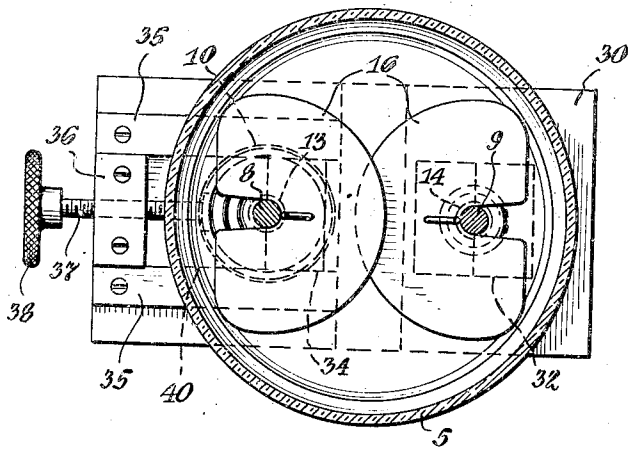


Fig. 3.



INVENTORS
J. H. FINDLAY
C. E. DAWLEY
A. PFEIFFER
BY
ATTORNEY

Patented Sept. 24, 1946 2,407,979

UNITED STATES PATENT OFFICE

2,407,979

CONTROLLED ELECTRODE FOR FIELD EMISSION DISCHARGE DEVICES

John H. Findlay, Upper Montclair, and Clarence E. Dawley and Andrew Pfeiffer, Bloomfield, N. J., assignors to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

Application September 26, 1942, Serial No. 459,776

7 Claims. (Cl. 250—27.5)

1

The present invention relates to discharge devices and more particularly to such devices wherein operation is initiated by a "field emission arc" as an electron source, and constitutes an improvement on the structure such as shown in the copending applications of Charles M. Slack et al., Ser. No. 412,566, filed Sept. 27, 1941, and Ser. No. 459,775, filed concurrently herewith, both of which are assigned to the same assignee as the present invention.

In the operation of devices of this character and as pointed out more in detail in the above noted application, Ser. No. 412,566, field emission of electrons occurs between a pair of "cold" electrodes due to the high potential gradient at the cathode. This electrostatic field pulls electrons from one of the electrodes, which causes a minute arc discharge to form between the starting electrode and the cathode, apparently due to evolved metallic particles, and the positive ion bombardment caused by ionization of the evolved metal vapor resulting from the arc forms a cathode spot which reduces the impedance of the device, and an electron discharge between the cathode and anode of the device almost instantaneously occurs following initiation of the arc discharge between the starting electrode and cathode.

In a device of this character it inherently follows that a certain amount of material will be lost from and transferred between the closely spaced electrodes between which the "field emission arc" is initiated. This is because operation of a "field emission arc" discharge device does not depend upon the ionization of volume gases or vapors within the device, but is dependent primarily on positive ions which are the result of the vaporized material from one of the electrodes interacting with the field emission electrons. The positive ions are necessary to relieve space charge and to increase the field concentration at the cathode spot which in turn produces more field and Schotky electrons. Inasmuch as a voltage of sufficient magnitude, depending upon the initial spacing of the starting electrode and cathode, is required to initiate the field emission arc discharge, there is a tendency for such voltage to increase as the electrodes wear away during operation of the device.

In the above noted copending application Ser. No. 459,775, filed concurrently herewith, a structure is shown and claimed for maintaining the electrode spacing constant during the life of such device which inherently maintains the voltage required to initiate the field emission arc discharge substantially constant, and whenever such voltage tends to vary such is an indication that the electrode spacing needs readjusting to maintain this constancy of spacing and initiating voltage. The structure as shown in such copending application depends primarily for its operation upon the flow of electrical current through a bimetallic element and therefore might be said to be electrically controlled.

2

It is the primary object of the present invention to provide a discharge device wherein operation is initiated by a "field emission arc" and the spacing between the electrodes which support such arc discharge is mechanically controlled so as to maintain the electrode spacing constant.

Another object of the present invention is the provision of a discharge device wherein operation is initiated by a "field emission arc" discharge and in which movement of the ignition electrodes is mechanically controlled exteriorly of the device at will by an operator to compensate for the inherent tendency for the electrode spacing to increase due to loss of material during operation.

A further object of the present invention is the provision of a discharge device wherein operation is initiated by a "field emission arc" discharge between a pair of ignition electrodes and in which the voltage required to initiate the "field emission arc" is maintained substantially constant despite an inherent tendency for the spacing between the electrodes to increase due to loss of electrode material by mechanically adjusting the electrode spacing exteriorly of the device at the will of an operator.

Still further objects of the present invention will become obvious to those skilled in the art by reference to the accompanying drawing wherein:

Fig. 1 is a sectional view in elevation of a device constructed in accordance with the present invention wherein operation is initiated by a "field emission arc" discharge showing a mechanical control of the spacing between the electrodes as well as a schematic diagram of an operating circuit.

Fig. 2 is a sectional view taken on the lines II—II of Fig. 1 and looking in the direction indicated by the arrows, and

Fig. 3 is a sectional view taken on the lines III—III of Fig. 1 and looking in the direction indicated by the arrows.

Referring now to the drawing in detail, the discharge device 4 as shown in Fig. 1 comprises an

envelope 5 of vitreous material provided with a pair of electrodes 6 and 7 which are of substantially rectangular configuration and of uniform cross section disposed parallel to each other and having their edges spaced apart a minute distance of less than approximately .010 inch, depending upon the voltage to be applied. These electrodes 6 and 7 are formed of suitable metal such as copper, gold, silver, uranium, or the like, and welded or otherwise secured to leading-in and supporting conductors 8 and 9. The leading-in and supporting conductor 8 is welded, soldered, or otherwise affixed to a flexible metallic diaphragm 10 of copper or the like, which latter at its peripheral edge 12 forms an hermetic seal with the vitreous envelope 5; and exteriorly of the device 4 such leading-in and supporting conductor is provided with a metallic terminal 13 of copper, tantalum, molybdenum, or the like, welded or otherwise rigidly affixed thereto which thus constitutes an integral part of the leading-in and supporting conductor 8. The leading-in and supporting conductor 9 is similarly secured to a metallic terminal 14 of copper, tantalum, molybdenum or the like, which thus forms an integral part thereof and, as shown, such terminal is provided with an enlarged diameter portion having a feather edge 15 also forming an hermetic seal with the vitreous envelope 5. Both of the leading-in and supporting conductors are provided with suitable baffles 16 for the purpose of preventing hot metallic particles from the electrodes 6 and 7 from falling in the vicinity of the seals and thus destroying the same.

An anode 17 of a refractory metal such as tungsten, molybdenum, or the like, and of substantially U-shape, is also supported by a leading-in conductor 18 so as to position the anode a short distance from the electrodes 6 and 7 and overlapping the gap between these latter electrodes. This leading-in and supporting conductor 18 is secured to a terminal 19 which is identical to and forms an hermetic seal with the envelope 5 in the same manner as previously mentioned with respect to the terminal 14. After assembly of the device it is exhausted to a high degree of evacuation through an exhaust tip 20 with the various metallic parts being thoroughly degasified, as is customary in the art, so that satisfactory operation is entirely independent of vapor or gas present in the device.

If desired, however, a metal vapor such as mercury may be introduced into the envelope 5 prior to "tipping off" at 20, which also results in satisfactory operation so long as its pressure is such that the spacing between the ignition electrodes is less (and preferably many times less) than the mean free path of electrons in the vapor so that ignition and operation of the device is entirely independent of the mercury vapor present.

In the embodiment as shown in Fig. 1 the electrode 6 constitutes the starting electrode, while the electrode 7 is the cathode. For the purpose of initiating a "field emission arc" between these two electrodes, a suitable source of energy is provided such, for example, as a high tension transformer 22, the secondary winding 23 of which has one end connected to the terminal 13 and hence to the starting electrode 6 through the leading-in conductor 8, while the remaining end is grounded at 24. Since the terminal 14 is also grounded at 25, a circuit from the secondary winding 20 to the cathode 7 is completed through the leading-in and supporting conductor 9. In order to energize the transformer 22, the primary winding 26 thereof is connected to a suitable source of supply such, for example, as shown more in detail in the above noted copending application, Ser. No. 459,775, so that when the primary winding 26 is periodically energized, an appropriate ignition voltage is impressed across the electrodes 6 and 7. However, since the circuit per se forms no part of the present invention, further detailed description is believed superfluous.

Although the discharge device 4 as shown can be employed for numerous purposes and circuits, it is illustrated as a control device for controlling the supply of energy to a load. As a typical purpose, it is shown in Fig. 1 as a control tube for a high voltage circuit and for such application one end of the secondary winding 27 of a high tension transformer 28 is grounded at 25; and since the cathode is also grounded at 25, as above mentioned, a connection is thus completed to the cathode 7 through the leading-in and supporting conductor 9. The remaining end of the secondary winding 27 connects "to load" as indicated by such legend, as does the anode 17 through the leading-in and supporting conductor 18 and terminal 19. The primary winding 29 of the transformer 28 may be connected to a suitable source of the customary domestic potential of 115–230 volts. When an impulse of electrical energy passes through the primary winding 26 of the transformer 22, a high voltage impulse is induced in the secondary winding 23 of this transformer 22 which voltage is impressed across the starting electrode 6 and cathode 7. Since these electrodes are closely spaced, as above noted, a high potential gradient results which initiates a "field emission arc" discharge therebetween. The space charge, and consequently the impedance of the device, is accordingly reduced and an electron discharge almost instantaneously occurs between the cathode 7 and the anode 17 as hereinbefore mentioned, which enables the "load" to be energized from the transformer 28.

As previously mentioned herein and as set forth in the concurrently filed copending application, Ser. No. 459,775, there is a gradual wearing away of the ignition electrodes and particularly the starting electrode 6. Moreover, the electrode spacing between the starting electrode 6 and cathode 7, even though it might not be measured directly, is nevertheless a function of the voltage required to initiate the "field emission arc" discharge. Consequently, this wearing away of the electrodes causes an increase in the voltage required to initiate the arc, as above mentioned, which not only affects the characteristics of the device, but considerably shortens its useful life. Yet by knowing the relationship of voltage and electrode spacing, which naturally varies with different materials and electrode configurations, and by holding the spacing constant, the voltage will likewise be maintained constant, for any tendency of voltage variation is an indication that an adjustment of the electrode spacing is required in order to maintain constancy of ignition voltage.

In accordance with the present invention, a constant voltage is obtained by a mechanical structure for effecting controlled movement or adjustment of the electrode spacing. Such structure, as illustrated in Fig. 1, comprises a base member 30 of suitable insulating material to which a block 32 is secured, such as by means of a screw 33. The block 32 is provided with a recess engageable by the metallic terminal 14 of the device. A further block 34 is arranged to

slide between a pair of guides 35 upon the upper surface of the base 30. For the purpose of moving the block 34, the base 30 is provided with a lug 36 threadedly engaged by an adjustment screw 37 having a knurled handle 38 and provided with a collar 39 fitting into a recess provided in a retainer plate 40. The block 34, similar to the block 32, is provided with a recess which is engaged by the metallic terminal 13 forming an integral part of the leading-in and supporting conductor 8.

During operation of the device as above noted, when the electrodes 6 and 7 wear away to the point where there is a tendency for the ignition voltage to vary, it is only necessary for an operator to rotate the knurled handle 38 of the adjusting screw 37 in a counter-clockwise direction, and since the adjusting screw threadedly engages the lug 36 and loosely engages the block 34, the latter will be slid along the base 30 to the left, as shown in Fig. 1. Inasmuch as the metallic terminal 13 forming an integral part of the leading-in and supporting conductor 8 fits into the block 34, the leading-in and supporting conductor 8, together with the starting electrode 6 supported thereby, will be moved due to the flexible metallic diaphragm 10 which accordingly prevents a strain being placed upon the hermetic seal where the leading-in and supporting conductor passes through the wall of the device. This movement of the adjusting screw 37 will accordingly cause the electrode 6 to be moved in closer proximity to the cathode 7, thus again setting such spacing to that desired and maintaining the spacing together with the ignition voltage substantially constant.

It should also be noted that although the leading-in and supporting conductor 8 has been shown as secured to the flexible diaphragm 10, such is not absolutely essential, but, on the other hand, the hermetic seal formed between the leading-in and supporting conductor 8 and the envelope 5 may be identical to that of the leading-in and supporting conductor 9. In other words, the leading-in and supporting conductor 8 may be provided with a terminal member 14 and movement of the leading-in and supporting conductor still obtained by regulation of the adjusting screw 37. This is because appreciable flexibility results even with the provision of a metallic terminal, such as shown at 14, allowing movement of the leading-in conductor without placing undue strain on the seal, particularly since the adjustment of the spacing between the electrodes 6 and 7 at any time is exceptionally minute, being of the order of .010 inch as above noted. However, in some instances it may be preferable to employ a flexible metallic diaphragm such as shown at 10 in Fig. 1.

From the foregoing description it thus becomes obvious to those skilled in the art that an electron discharge device wherein operation is initiated by a "field emission arc" discharge is herein provided in which the spacing between the electrodes, and hence the voltage required to initiate such discharge, is maintained substantially constant. Moreover, such constancy is obtained at the will of an operator by simple adjustment of a mechanical member disposed exteriorly of the device which upon operation causes controlled movement of the leading-in and supporting conductor for one of the electrodes, together with the electrode carried thereby, so that a fixed spacing is maintained between the ignition electrodes, thus compensating for their wearing away due to evolution of metallic particles caused by the "field emission arc" discharge.

Although one embodiment of the present invention has been shown and described, it is to be understood that other modifications may be made without departing from the spirit and scope of the appended claims.

We claim:

1. A discharge device wherein operation is initiated by field emission of electrons comprising a pair of oppositely disposed spaced electrodes between which a field emission arc discharge occurs upon the application of a potential thereto and subject to deterioration tending to increase the gap therebetween during operation, an anode in juxtaposition to said pair of electrodes for supporting an electron discharge with one of the electrodes of said pair immediately following the field emission arc discharge between said pair of electrodes, and means disposed exteriorly of said device and operable by an operator at will to cause relative movement between said pair of electrodes to maintain the spacing therebetween substantially constant during the useful life of said device.

2. A discharge device wherein operation is initiated by field emission of electrons comprising a pair of oppositely disposed spaced electrodes between which a field emission arc discharge occurs upon the application of a potential thereto and subject to deterioration tending to increase the gap therebetween and the voltage required to initiate the field emission arc discharge during operation of said device, an anode positioned adjacent said pair of electrodes for supporting an electron discharge with one of the electrodes of said pair immediately following the field emission arc discharge between said pair of electrodes, and means disposed exteriorly of said device and operable at will by an operator to maintain the voltage required to initiate the field emission arc discharge constant despite deterioration of said pair of electrodes during the useful life of said device.

3. A discharge device wherein operation is initiated by field emission of electrons comprising a pair of oppositely disposed spaced electrodes between which a field emission arc discharge occurs upon the application of a potential thereto and subject to deterioration tending to increase the gap therebetween during operation, an anode positioned adjacent said pair of electrodes for supporting an electron discharge with one of the electrodes of said pair immediately following the field emission arc discharge between said pair of electrodes, and a mechanical member disposed exteriorly of said device and operable at will by an operator to cause relative movement between said pair of electrodes to maintain the spacing therebetween substantially constant despite deterioration of said pair of electrodes during the useful life of said device.

4. A discharge device wherein operation is initiated by field emission of electrons comprising a sealed envelope, a pair of oppositely disposed spaced electrodes in said envelope between which a field emission arc discharge occurs upon the application of a potential thereto and subject to deterioration tending to increase the gap therebetween and the voltage required to initiate the field emission arc discharge during operation of said device, a leading-in and supporting conductor for each electrode of said pair and forming an hermetic seal with said envelope, an anode positioned adjacent said pair of electrodes for supporting an electron discharge with one of

the electrodes of said pair immediately following the field emission arc discharge between said pair of electrodes, and a member disposed exteriorly of said envelope and operable at will by an operator to cause movement of one of said leading-in and supporting conductors together with the electrode supported thereby for the purpose of maintaining the spacing between said pair of electrodes substantially constant despite deterioration of the latter during the useful life of said device.

5. A discharge device wherein operation is initiated by field emission of electrons comprising a sealed envelope, a pair of oppositely disposed spaced electrodes in said envelope between which a field emission arc discharge occurs upon the application of a potential thereto and subject to deterioration tending to increase the gap therebetween and the voltage required to initiate the field emission arc discharge during operation of said device, a leading-in and supporting conductor for each electrode of said pair and forming an hermetic seal with said envelope, an anode positioned adjacent said pair of electrodes for supporting an electron discharge with one of the electrodes of said pair immediately following the field emission arc discharge between said pair of electrodes, and a mechanical member engageable with the leading-in and supporting conductor for one of the electrodes of said pair exteriorly of said envelope and operable at will by an operator to apply a tension to said conductor to cause deflection thereof with attendant movement of the electrode supported thereby for the purpose of maintaining the spacing between said pair of electrodes substantially constant despite deterioration of the latter during the useful life of said device.

6. A discharge device wherein operation is initiated by field emission of electrons comprising a sealed envelope, a pair of oppositely disposed spaced electrodes in said envelope between which a field emission arc discharge occurs upon the application of a potential thereto and subject to deterioration tending to increase the gap therebetween and the voltage required to initiate the field emission arc discharge during operation of said device, a leading-in and supporting conductor for each electrode of said pair, a resilient

hermetic seal between one of said leading-in and supporting conductors and said envelope, an anode positioned adjacent said pair of electrodes for supporting an electron discharge with one of the electrodes of said pair immediately following the field emission arc discharge between said pair of electrodes, and a member disposed exteriorly of said envelope and engageable with the leading-in and supporting conductor for one electrode of said pair and operable at will by an operator to cause movement of said conductor at the resilient seal with said envelope accompanied by movement of the electrode supported thereby for the purpose of maintaining the spacing between said pair of electrodes substantially constant despite deterioration of the latter during the useful life of said device.

7. A discharge device wherein operation is initiated by field emission of electrons comprising a sealed envelope, a pair of oppositely disposed spaced electrodes in said envelope between which a field emission arc discharge occurs upon the application of a potential thereto and subject to deterioration tending to increase the gap therebetween and the voltage required to initiate the field emission arc discharge during operation of said device, a leading-in and supporting conductor for each electrode of said pair, a flexible metallic diaphragm secured to one of said leading-in and supporting conductors and forming an hermetic seal with said envelope, an anode positioned adjacent said pair of electrodes for supporting an electron discharge with one of the electrodes of said pair immediately following the field emission arc discharge between said pair of electrodes, and a member disposed exteriorly of said envelope and engageable with the leading-in and supporting conductor for one electrode of said pair and operable at will by an operator to cause flexing of said diaphragm and attendant movement of one of said leading-in conductors together with the electrode carried thereby for the purpose of maintaining the spacing between said pair of electrodes substantially constant despite deterioration of the latter during the useful life of said device.

JOHN H. FINDLAY.
CLARENCE E. DAWLEY.
ANDREW PFEIFFER.