Oct. 22, 1946. C. M. SLACK ET AL 2,409,716

HIGH VOLTAGE DISCHARGE DEVICE

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Fig. 1.

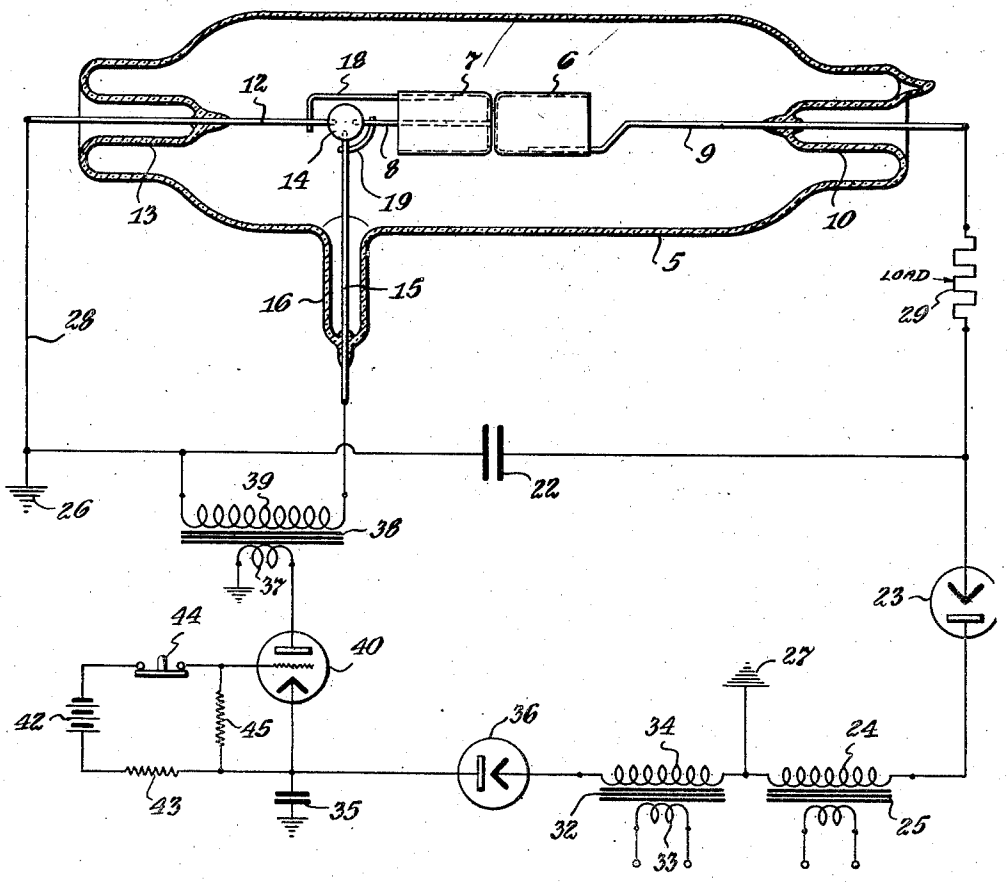


Fig. 2.

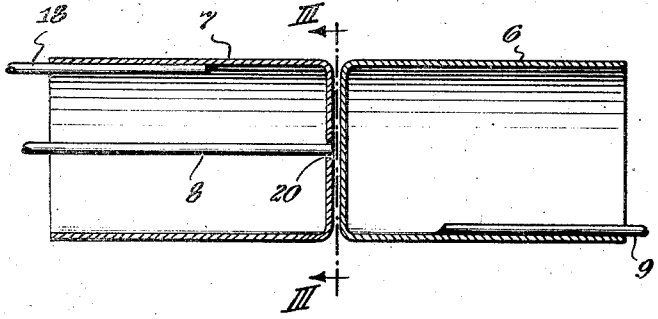
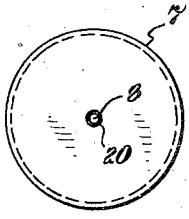


Fig. 3.



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Fig. 4.

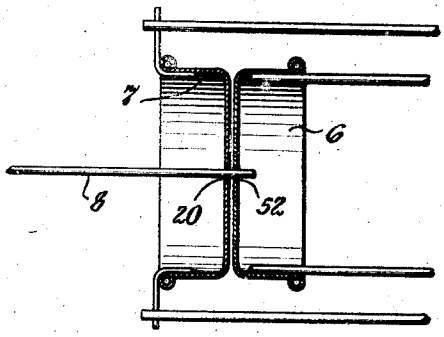


Fig. 5.

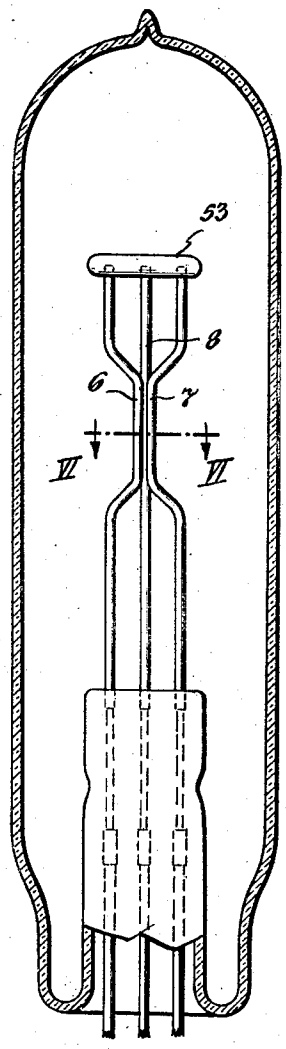


Fig. 6.

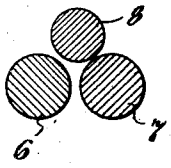


Fig. 7.

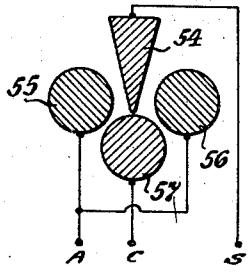


Fig. 8.

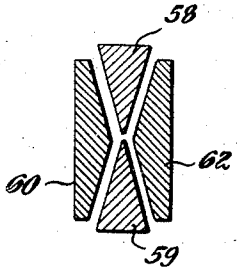


Fig. 9.

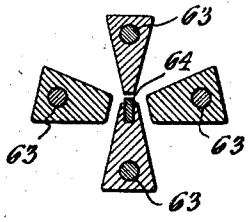


Fig. 10.

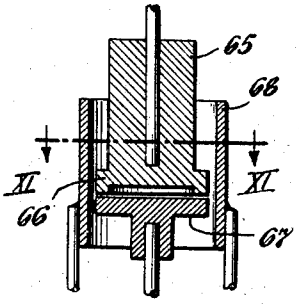


Fig. 12.

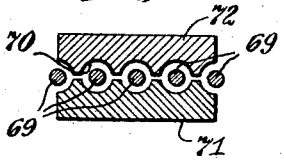


Fig. 11.

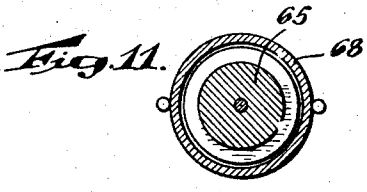
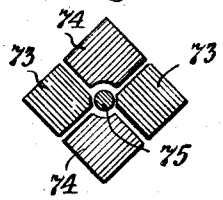


Fig. 13.



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Patented Oct. 22, 1946

2,409,716

UNITED STATES PATENT OFFICE

2,409,716

HIGH-VOLTAGE DISCHARGE DEVICE

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Application September 27, 1941, Serial No. 412,566

8 Claims. (Cl. 315—326)

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The present invention relates to discharge devices and more particularly to high vacuum devices capable of passing high currents and capable of withstanding comparatively high voltage.

Devices of a somewhat similar nature are known to the art but in most instances they depend for their operation on the continual presence of a metallic vapor or gaseous environment to carry current between the electrodes. This limits the amount of current which can be passed by the device without the occurrence of destructive discharges.

It is accordingly an object of the present invention to provide a discharge device capable of passing high currents of the magnitude of hundreds or even thousands of amperes.

Another object of the present invention is the provision of discharge devices capable of passing exceptionally high currents at comparatively high voltages wherein "cold electrodes" are employed between which the current flows during operation of the device.

Another object of the present invention is the provision of a discharge device which passes exceptionally high currents by using field emission from "cold electrodes" to initiate and sustain a discharge therebetween.

A further object of the present invention is the provision of a discharge device which passes exceptionally high currents by utilizing field emission from cold electrodes to initiate and sustain a discharge therebetween and wherein initiation of the discharge is controlled at will.

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

Fig. 1 is a side view of a high vacuum discharge device constructed in accordance with the present invention and showing schematically its connection to a load and a control circuit therefor.

Fig. 2 is a fragmentary sectional view on an enlarged scale of the electrode construction of the discharge device as shown in Fig. 1;

Fig. 3 is a sectional view taken on the line III—III of Fig. 2;

Fig. 4 shows a modification which the electrode structure for the discharge device of Fig. 1 may take;

Fig. 5 is a side view of a high vacuum discharge device showing a modification of the electrode structure;

Fig. 6 is a sectional view taken on the line VI—VI of Fig. 5;

Figs. 7, 8, and 9 are sectional views similar to

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Fig. 6, of additional modifications which the electrode structure may take;

Fig. 10 is a fragmentary view of a further modification which the electrode structure of the device as shown in Figs. 1 and 5 may take.

Fig. 11 is a sectional view taken on the line XI—XI of Fig. 10, and

Figs. 12 and 13 are each still further modifications which the electrode structure for the high vacuum discharge device as shown in Fig. 1 may take.

Referring now to the drawings in detail, a discharge device is shown in Fig. 1 which comprises a vitreous envelope 5 provided with a pair of electrodes constituting an anode 6 and two-part cathode 7 and 8 as will be hereinafter described. The anode 6 is supported by a leading-in conductor 9 sealed through a reentrant press 10 provided at one end of the envelope 5, and in a similar manner a leading-in conductor 12 is sealed through a reentrant press 13 in the opposite end of the envelope. The inner end of the leading-in conductor 12 is shown provided with a suitable insulator 14 to the latter of which is also secured a further leading-in conductor 15 hermetically sealed to a side-arm 16 of the envelope 5.

A conductor 18 is welded or otherwise affixed to the conductor 12 so as to constitute an extension of the latter to complete an electrical connection to the cathode member 7 and similarly a conductor 19 is secured to the leading-in conductor 15 and completes an electrical connection to the remaining cathode member 8. By reference now more particularly to Figs. 2 and 3, it will be noted that the anode 6 and main cathode member 7 are metallic cylinders, which may be of tantalum, molybdenum, or an alloy known under the trade name of "Kovar", closed at their closely spaced adjacent ends except that the cathode member 7 is provided with a small opening 20. The remaining metallic cathode member 8 being of rod-like configuration has its end projecting through this small opening 20, thus leaving a very small spacing between the metallic rod-like member 8 and the surrounding edge of the cylindrical cathode member 7 formed by the slightly larger diameter opening.

When a positive impulse of several thousand volts is applied to the cathode member 8, field emission of electrons occurs from the edges of the surrounding cathode member 7 due to the high potential gradient at the cathode. This field emission of electrons resulting from the high electrostatic field causes a minute arc to form at points around the edge of the cathode member

7 apparently due to evolved metal vapor from this cathode member much in the same manner that a cathode spot is formed on the surface of the mercury cathode of a vapor electric discharge device. The positive ion bombardment resulting from ionization of the evolved metal vapor caused by the arc, heats this cathode member 7 or the metallic arc becomes an electron source and the impedance of the device is so reduced that an electron discharge is almost instantaneously initiated or transferred between the closely spaced cathode and anode. An electron-emissive cathode of enormous current capacity is accordingly provided despite the fact that the cathode is what is known in the art as a "cold electrode."

In the fabrication of the discharge device of the present invention the electrodes and all metal parts are thoroughly degasified and the envelope preferably evacuated to a very high degree so that satisfactory operation of the device is entirely independent of vapor present in the tube. Satisfactory operation also results, however, with a metal vapor such as mercury present in the device so long as its pressure is such that the spacing between the cathode members is less (and preferably many times less) than the mean free path of electrons in the vapor so that firing or ignition of the device to form the metallic arc is entirely independent of the mercury vapor present. The same condition holds respecting the ensuing electron discharge between the cathode and anode, for again the spacing therebetween is less than the mean free path of electrons in the mercury vapor at the pressure employed, so that this electron discharge is also independent of the mercury vapor present and apparently supported entirely by the metal vapor ionization produced by the field emission arc. The presence of mercury vapor in the device performs the function of making the high current discharge more certain and increases the area of the anode impinged by the electrons from the cathode.

In order to obtain a discharge in the device particularly at will, it is desirable to keep the potential gradient at all electrodes as low as possible due to the high voltage between the anode 6 and cathode 7 to prevent the occurrence of spurious discharges. At the same time the potential gradient at the cathode 7 should be as high as possible due to the voltage between the cathode members 7 and 8. Due to the positioning of the cathode member 8 in closer proximity to the cathode member 7 than the spacing between the anode 6 and cathode 7—8 the potential gradient at all the electrodes is thus properly selected. Also, to have low energy dissipated within the tube, it is necessary that the arc spread as quickly as possible between the anode 6 and cathode 7—8 and hence this spacing should be kept as small as is consistent with the voltage therebetween which is to be controlled.

Naturally these spacings between the electrodes will vary depending upon the magnitude of the voltage to be controlled and existing between the electrodes 6 and 7, as well as the controlling voltage applied to the cathode member 8 to initiate the metallic arc discharge. However, as an example, with an applied voltage of 20,000 volts to be controlled between the anode 6 and cathode 7 and with spacing of .2 cm., a discharge is satisfactorily and rapidly initiated by applying a controlling voltage of 10,000 volts to the cathode member 8 with a spacing of .01 cm. between the latter and the adjacent cathode member 7.

From the above description it can thus be readily seen that the discharge device of the present invention can be controlled at will to supply enormous current to a load. A simple circuit for supplying such currents to a load and for controlling a discharge is shown in Fig. 1. In this figure a condenser 22 of about .04 mfd. capacity is charged to about 20,000 volts through a rectifying valve 23 from the secondary winding 24 of a high voltage transformer 25, one plate of the condenser 22 being grounded as at 26 and one end of the secondary winding 24 being also grounded at 27, thus completing the charging circuit for the condenser. The discharge circuit for the condenser 22 includes the high vacuum discharge device 5 having its cathode member 7 connected by a conductor 28 and leading-in conductor 12, 18 to one plate of the condenser, while the remaining plate of the condenser 22 is connected through a load 29 to the anode 6 of the discharge device by means of leading-in conductor 9.

A high potential is accordingly impressed across the electrodes 6 and 7, but since the electrodes are non-thermionic or "cold electrodes" no discharge occurs in the device and hence the load 29 receives no energy. When it is desired to energize the load 29, a high voltage is impressed across the cathode members 7 and 8 to cause the formation of an annular arc discharge at points around the edge of the cathode at the opening 20 and having an annular appearance which initiates almost instantaneously a thermionic discharge between the cathode 7 and anode 6, as before noted.

The control circuit as shown in Fig. 1 comprises a high tension transformer 32 having its primary winding 33 connected to a suitable source of supply of the customary domestic potential in the same manner as the primary winding of the transformer 25. The secondary winding 34 of the transformer 32 is arranged to form a charging circuit for a condenser 35 by having one of its ends connected to ground as at 27 with its other end connected to one plate of the condenser 35 through a rectifying valve 36, and the charging circuit being completed by grounding the remaining plate of the condenser 35.

The discharge circuit for this condenser 35 includes the primary winding 37 of a high tension transformer 38, the secondary winding 39 of which is connected to the cathode members 7 and 8 so as to impress a high voltage thereacross when it is desired to energize the load 29. In order to control discharging of the condenser 35 a control tube 40 of the usual three electrode type is interposed between the condenser 35 and primary winding 37. A voltage is impressed across the grid and cathode electrodes of this control tube 40 from a suitable source, such as a battery 42, and through a resistance 43 and normally closed switch 44, so that the polarity of the grid electrode is made highly negative with respect to the cathode, in the usual manner of controlling a discharge through tubes of this type.

When it is desired to energize the load 29, switches (not shown) are first closed which connect the primary windings of both transformers 25 and 33 to a source of the customary domestic potential. This accordingly causes the condensers 22 and 35 to accumulate a high voltage charge from their respective charging circuits as previously described. The switch 44 is then opened (either manually by an operator or automatically by a relay) which thus removes the negative charge supplied by the batteries 42 to the grid

of the control tube 40, allowing the charge to leak off through a resistance 45.

The condenser 35 will accordingly discharge through tube 40 and primary winding 37 of the high potential transformer 38, thus inducing a high voltage current in the secondary winding 39 which is impressed across the cathode members 7 and 8. This, as before noted, causes the formation of an arc at points around the edge of the opening 20 of the cathode member 7, making the latter a high emissive cathode which causes a discharge of enormous current from the condenser 22 across the cathode 7 and anode 6 to the load 29, the magnitude of which is dependent upon the voltage and load.

In addition to the embodiment of the electrode structure thus far described, many other designs of the cathode are possible. For example, substantially the same design may be resorted to as shown in Figs. 1 to 3, but the side arm for the starting electrode eliminated by resorting to an arrangement such as shown in Fig. 4 wherein the leading-in conductors for the anode 6 and cathode member 7 are brought in from one end of the tube while the cathode member 8 is supported from the opposite end of the envelope. Also, the cathode member 8 may extend through an opening 52 provided in the anode 6 of the same diameter as the opening 20 in the cathode member 7, which thus permits either the electrode 6 or 7 to operate as anode or cathode.

In addition, the electrodes may comprise a plurality of rods with their upper ends supported by an insulator 53, as shown in Figs. 5 and 6, or the cathode member made of triangular form as shown at 54 in Fig. 7 and positioned between two parallel connected rod-like anodes 55 and 56 with the apex of the cathode member 54 spaced closely to the remaining cathode member 57. A still further modification may comprise making the cathode member 58 and cathode member 59 of triangular shape and the two anodes 60 and 62 substantially of pyramidal shape as shown in Fig. 8. Again, however, the electrodes 54 and 57, as well as the electrodes 58 and 59 of each modification, may operate as starting electrode and cathode.

The modification as shown in Fig. 9 differs from those previously described in that, while all of the electrodes are of trapezoidal configuration, they are of a material such as carbon supported upon metallic leading-in conductors 63 with one cathode member being provided with a metallic insert 64 of tungsten, tantalum, molybdenum or the like, from which the aforementioned arc discharge is initiated by the remaining closely adjacent cathode member.

For the purpose of prolonging the useful life of the high power device of the present invention, a structure such as shown in Fig. 10 may be employed. In this particular modification the cathode electrode 65 is shown as formed of a solid metallic cylinder provided with an annular flange 66 about its end periphery which is closely positioned adjacent the closed end of the remaining disc-shaped metallic cathode member 67. This construction provides a much greater edge surface for the initiation of the arc discharge due to the concentration of the electrostatic field about the two sharp annular edges formed by the periphery of the flange 66, and following initiation of the arc discharge the main high current discharge occurs between the cathode 65 and the surrounding cylindrical anode 68.

This same feature of providing a plurality of

sharp edges about which the arc discharge is initiated so as to prolong the life of the device is shown in Figs. 12 and 13, wherein a plurality of rod-like anodes 69, all connected in electrical parallel, extend through separate openings 70 provided between the metallic cathode member 71 and remaining cathode member 72, as shown in Fig. 12. In Fig. 13 the cathode member 73 and anode 74 are each formed of two rectangular metallic blocks with each pair again connected in electrical parallel and so disposed that one corner of each block is positioned adjacent the remaining cathode member 75, thus again providing a plurality of sharp edges from which the starting arc discharge is initiated.

It will thus become obvious to those skilled in the art that a high voltage discharge device is herein provided in which enormous currents are passed by the tube by utilizing field emission of electrons from a "cold electrode" to initiate a discharge. Moreover, operation of the tube can be controlled at will and since the molecules necessary for ion formation are obtained from the "cold electrodes" themselves, a greatly reduced deionization time results, thus enabling the device to be used at much higher frequencies than is possible with gas or metallic vapor devices. Owing to the fact that the device of the present invention is not subject to electron emission limitations, it can not only be employed in applications where gas or vapor devices are now employed, but because of its advantages it can be used where these latter type devices cannot be used owing to their inherent emission limitations.

Although several embodiments of the present invention have been shown and described, it is to be understood that still further modifications thereof may be made without departing from the spirit and scope of the appended claims.

We claim:

1. A discharge device for passing high currents comprising an envelope, an anode and a cathode in said envelope and spaced in such close proximity to each other that electron flow from said cathode is under the influence of a strong electrostatic field, and said cathode comprising a pair of members spaced closer to each other than either member to said anode to cause field emission of electrons from one of said cathode members and the formation of a metallic arc discharge between said pair of cathode members with the evolution of a metal vapor from one of said members, to reduce the impedance of said device and initiate a field emission electron discharge between said cathode and anode accompanied by enormous current flow upon the application of a high potential between said cathode members.

2. A discharge device for passing high currents comprising an envelope, an anode and a solid metallic cathode in said envelope and spaced in such close proximity to each other that electron flow from said cathode is under the influence of a strong electrostatic field, and said cathode comprising a member provided with an edge of sharpened contour for concentrating the electrostatic field thereat, and a second cathode member spaced in closer proximity to the sharpened edge of said first-mentioned cathode member than is said anode to cause field emission of electrons from said first-mentioned cathode member and the formation of a metallic arc discharge between said cathode members with the evolution of a metallic vapor from one of said members,

for initiating a field emission electron discharge accompanied by enormous current flow between said cathode and anode upon the application of a high potential across said cathode members.

3. A discharge device for passing high currents comprising an envelope, an anode and a solid cathode in said envelope and spaced in such close proximity to each other that a high potential gradient is produced at said cathode and electron flow from said cathode is under the influence of a strong electrostatic field, said cathode comprising a member having a surface of small radii of curvature for concentrating the electrostatic field thereat, and a solid metallic member spaced in closer proximity to the sharp edge of said cathode member than is said anode to produce a high potential gradient at said cathode surface and the formation of a field emission arc discharge between said cathode members with the evolution of a metallic vapor from one of said members, for initiating a field emission electron discharge accompanied by enormous current flow between said cathode and anode upon the application of a high potential across said cathode members.

4. A discharge device for passing high currents comprising an envelope, an anode and a solid metallic cathode in said envelope and spaced in such close proximity to each other that a high potential gradient is produced at said cathode and electron flow from said cathode is under the influence of a strong electrostatic field, said cathode comprising a member provided with a plurality of sharp edges for concentrating the electrostatic field thereat and a second solid metallic member positioned adjacent the sharp edges of said first-mentioned cathode member in closer proximity thereto than is said anode to produce a high potential gradient at said cathode with field emission of electrons from the latter and the evolution of a metal vapor from one of said cathode members causing the formation of a metallic arc discharge between said cathode members, for initiating a field emission electron discharge accompanied by enormous current flow between said cathode and anode upon the application of a high potential across said cathode members.

5. A discharge device for passing high currents comprising an envelope, an anode and a cathode in said envelope and spaced in such close proximity to each other that a high potential gradient is produced at said cathode and electron flow from said cathode is under the influence of a strong electrostatic field, and said cathode comprising a pair of members spaced in closer proximity to each other than to said anode to produce a high potential gradient at said cathode with attendant field emission of electrons therefrom entirely independent of any gas continually present in the envelope, and the resulting electrostatic field causing the evolution of a metal vapor from one of said cathode members which forms a metallic arc discharge between said cathode members, for initiating a field emission electron discharge accompanied by enormous current flow between said cathode and anode upon the application of a high potential across said cathode members.

6. A field emission arc discharge device comprising an envelope, an anode in said envelope, and a cathode disposed adjacent said anode, said cathode comprising a pair of closely spaced elements for causing an arc discharge upon the application of a suitable potential across said elements, and said arc discharge forming an electron-emitting source for supporting a thermionic discharge between said cathode and anode substantially independent of any action due to residual gas or vapor in said device.

7. A field emission arc discharge device comprising an envelope, an anode in said envelope, and a cathode disposed adjacent said anode, said cathode comprising a pair of closely spaced elements at least one of said elements having a surface of small radii of curvature for causing the evolution of vaporized metallic particles from one of said elements and the formation of a metallic arc discharge upon the application of a suitable potential across said elements, and said arc discharge forming an electron-emitting source for supporting a thermionic discharge between said cathode and anode substantially independent of any action due to residual gas or vapor in said device.

8. A field emission arc discharge device comprising an envelope, an anode in said envelope, and a cathode disposed adjacent said anode, said cathode comprising a pair of closely spaced metallic elements for producing a high negative gradient at said cathode accompanied by field emission of electrons and attendant vaporization of metallic material with the formation of a metallic arc discharge upon the application of a suitable potential across said elements, and said metallic arc discharge forming an electron-emitting source for supporting a thermionic discharge between said cathode and anode substantially independent of any action due to residual gas or vapor in said device.

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