Dec. 27, 1938. L. F. PERROTT 2,141,933

CATHODE

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Fig. 1.

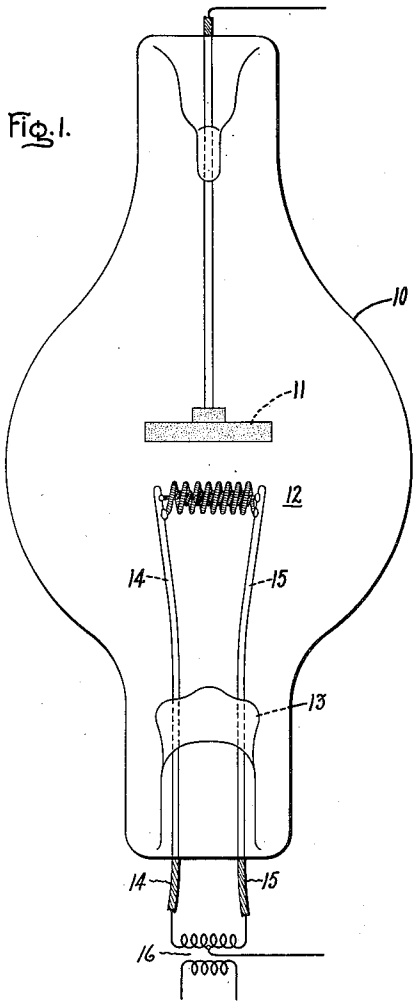

Fig. 5.

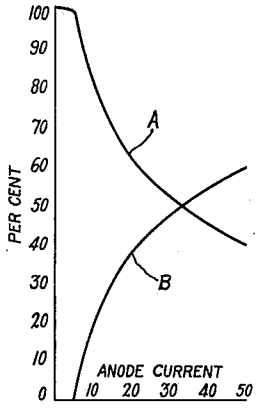

Fig. 4.

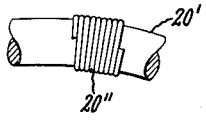

Fig. 3.

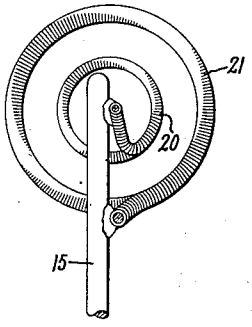

Fig. 2.

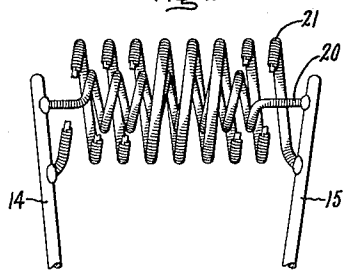

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Fig. 6.

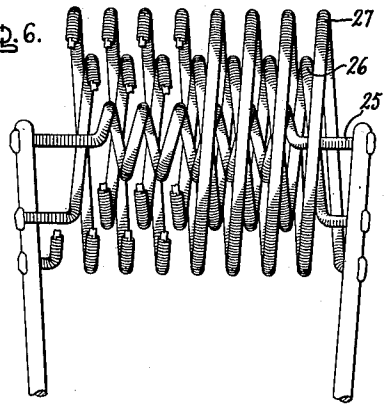


Fig. 7.

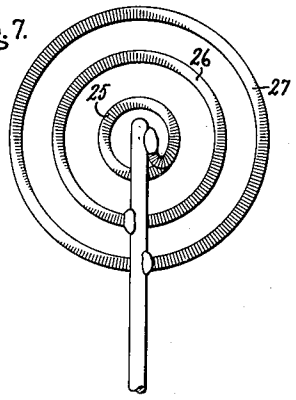


Fig. 8.

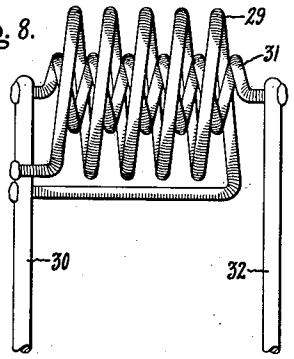


Fig. 9.

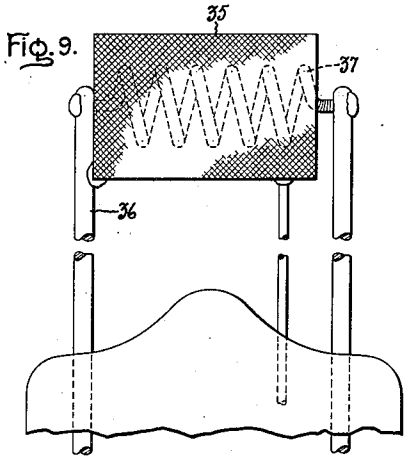


Fig. 10.

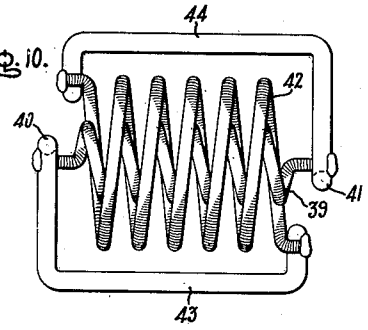
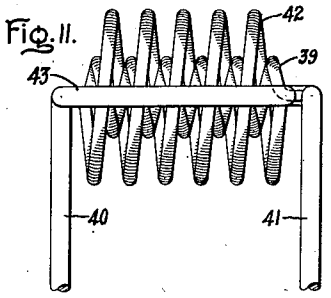


Fig. 11.



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Patented Dec. 27, 1938 2,141,933

UNITED STATES PATENT OFFICE

2,141,933

CATHODE

Laurence F. Perrott, Revere, Mass., assignor to General Electric Company, a corporation of New York

Application November 26, 1937, Serial No. 176,463

5 Claims. (Cl. 250—27.5)

The present invention relates to cathodes and more particularly to improvements in cathodes for use in discharge devices for power purposes.

It is a primary object of the invention to provide a cathode which is highly efficient in respect to the emission current developed for a given input of heating energy.

It is another object to provide a cathode which automatically adapts itself to changes in load current by supplying emission which varies in accordance with variations in the power losses in the discharge space.

It is a still further object to provide a cathode which inherently operates to maintain a substantially constant arc drop irrespective of changes in the load current.

In accordance with a preferred embodiment of the invention these objects are accomplished by the use of a cathode having at least two electron-emitting portions. One of these is adapted to be electron-emitting in response to a heating current provided therefor, while the emissivity of the other is controlled primarily by heat generated as a result of power losses in the discharge space.

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 by reference to the following description taken in connection with the drawings in which Fig. 1 represents a complete discharge device suitably embodying the invention; Fig. 2 represents an enlarged detail view of the cathode of Fig. 1; Fig. 3 is an end view (somewhat enlarged) of the cathode of Fig. 2; Fig. 4 is a fragmentary detail view of a portion of the cathode filament; Fig. 5 is a graphical representation useful in explaining the operation of the invention; Figs. 6 and 7 represent one modification of the invention; Figs. 8 and 9 respectively represent two additional modifications, and Figs. 10 and 11 conjointly illustrate a still further modification of which the invention is capable.

Referring particularly to Fig. 1 I have shown a discharge device especially adapted for power purposes, such as the rectification of alternating currents. The device comprises a sealed envelope 10, suitably of glass, an anode 11 and a cathode (designated as a whole by the numeral 12). The envelope 10 preferably encloses a readily ionizable medium such, for example, as mercury in combination with argon, helium or the like.

The cathode 12 is supported from a press 13 by means of rigid lead-in conductors 14 and 15 which are adapted for connection to an external source of potential. Such a source may comprise, for example, a transformer 16 for supplying heating current to that portion of the cathode which requires such current.

As appears more clearly in Figs. 2 and 3, the cathode assembly includes two electron-emitting portions numbered 20 and 21, respectively. Of these, the portion 20 comprises a helically coiled filamentary heater, this being preferably so arranged as to be transverse to the normal path of the discharge current. It may consist, for example of a refractory metal wire 20', (Fig. 4) which is spirally overwound with a finer wire 20'' and which is preferably coated or treated with a material of high electron emissivity, for example, thorium oxide or an alkaline earth material. It should be so proportioned as to be readily brought to a temperature of effective electron emission by supplying heating current thereto during the operation of the device. This portion of the cathode is intended to supply substantially the total electron current for light loads but only a fraction of the current when the device is operating at full load.

As the discharge current is increased toward its full load value, it is contemplated that an increasing proportion of the current shall be supplied by the second cathode portion 21. In order that this may take place automatically, the portion 21 is arranged so that its emissivity is controlled primarily by heat developed through power losses in the discharge space. To this end, this portion is preferably sufficiently spaced from the heater 20 so as not to be rendered appreciably electron emissive by heat radiated from the heater. It is, however, constructed and arranged to be traversed by at least the major portion of the discharge current which is derived from the heater so that it is exposed to heat developed in the path of such current.

This latter condition is fulfilled most effectively by disposing the portion 21 between the heated filament 20 and the anode 11. However, if so disposed, it should be of sufficiently open construction so as not to impede the passage of an arc discharge therethrough. Various structures may be employed for this purpose and in Figs. 2 and 3 I have shown one possible arrangement in which there is provided a second helically wound filament 21 surrounding the heater filament 20. Like the filament 20 the filament 21 may also comprise an overwound base member

consisting of a refractory metal (preferably tungsten) which is coated with a material of inherently high electron emissivity, for example, thorium oxide or an alkaline earth material.

The filament 21 is shown as being supported by and electrically connected at its ends to the lead-in conductors 14 and 15 from which it receives a certain amount of heating current. It should be understood, however, that it is not intended to be heated to a temperature of effective electron emission by current derived from said conductors. As previously stated, heating of the filament 21 to a temperature of effective electron emission is accomplished primarily by the power losses which occur in the discharge stream.

The characteristics of a cathode constructed in the manner described are shown in Fig. 5 in which the line A represents the percentage of the anode current taken by the inner filament 20 and the line B shows the percentage of anode current taken by the outer filament 21. These are plotted against the variations in anode current, the values being taken on a discharge device rated at 50 amperes. It will be noted that up to 5 amperes the inner filament takes approximately 100% of the anode current but that as the current increases above this value, the outer filament 21 begins to take a greater portion of the current. Thus at 33 amperes the current is divided equally between the inner and outer filaments and at 50 amperes the outer filament is carrying 60% of the current. The explanation for this operation lies in the fact that as the current density in the arc stream is increased the power loss in the discharge space increases proportionately. The heat thus developed raises the temperature of the outer filament (which lies in the path of the arc stream) and consequently increases the amount of emission from this filament. I have thus provided a form of cathode in which the total thermal electron emission varies automatically in accordance with the demands of the load current.

It is a further advantage of my improved cathode construction that after the discharge current has risen to a substantial value, say 30 to 50% of full load, the cathode operates to maintain a substantially constant arc drop in the discharge space irrespective of variations in the load current. This is due to the fact that an increase in the load current is automatically met by increased heating of the active portions of the cathode structure and by enhanced thermionic emission therefrom. As a result of this increase in emission due to thermionic causes, no increase in arc drop is required to supply the additional load demand. (It will be understood that in many cathodes of the prior art thermionic emission requires to be supplemented at higher loads by field emission, which in turn is attained only by an increase in the arc drop. This increase in arc drop is objectionable in that it decreases correspondingly the useful voltage applied to the load).

Furthermore, since my invention provides a way for utilizing the hitherto useless power dissipation in the discharge space, it makes possible a cathode efficiency higher than has been previously obtainable in open cathodes. For example, with a particular cathode I have obtained as much as 500 milliamperes of emission current per watt of heating power supplied to the cathode. Increased cathode efficiency also means that for a cathode of given capacity, less heating current needs to be transmitted through the lead-in conductors. Consequently, a greater useful load current can be transmitted through the device without increasing the size of the lead-in conductors. In view of the fact that the permissible cross-sectional area of such conductors is limited by the difficulty of forming satisfactory seals, it will be understood that this is a factor of considerable importance.

In Figs. 6 and 7 I have shown an alternative embodiment of the invention in which a central filament 25 is surrounded by two additional filaments 26 and 27, all of these filaments being so constructed as to be capable of effective electron emission. In accordance with the principles previously set forth, the inner filament 25 is so proportioned as to be electron emissive in response to a heating current supplied thereto. The filaments 26 and 27, on the other hand, are so arranged as to be electron emissive only in response to the heating effects of power losses in the discharge space.

In Fig. 8 I have shown a further embodiment which resembles the construction of Figs. 2 and 3 except in the respect that the outer filament 29 is connected at both ends to a single conductive support 30. The inner filamentary heater 31 on the other hand, is connected both to the conductor 30 and to a cooperating conductor 32 so as to permit heating current to be supplied thereto.

It should be understood that a filamentary construction is not essential for either of the operative cathode portions and in Fig. 9 I have shown a variant form of the invention in which the outer cathode portion takes the form of a discharge-permeable wire mesh or screen 35. This screen, which is illustrated as comprising an open-ended cylinder, is connected to and partially supported by a lead-in conductor 36 and is coated with a suitable electron emitting material. It is arranged to surround a helical filamentary heater 37 which is adapted to become electron emissive in response to the passage therethrough of a heating current supplied for that purpose. The screen 35, like the filamentary constructions previously described, has the characteristic of being electron emissive primarily in response to power losses in the discharge space. It need not be of a cylindrical form as shown, but may comprise almost any form of grid or even in some cases a solid member interposed between the heater 37 and the anode of the discharge device (not shown). Thus, I consider that the use of an open-ended imperforate cylinder in place of the perforate screen 35 is within the scope of my invention provided that the cylinder is so proportioned and spaced from the filament 37 as to be rendered electron-emissive in response to power losses in the discharge space rather than by heat radiated from the filament. The outer cathode portion should either be of sufficiently open construction so as to be readily traversed by the discharge current flowing from the filament 37 or should be of such small size as not to impede unduly such current or should have suitable openings through which the current may pass.

A still further modification embodying two concentric filaments is shown in Figs. 10 and 11. Referring to Fig. 10, the mode of connection of the inner filament (numbered 39) is such that its left end is connected to a conductor 40 and

its right end to a conductor 41. On the other hand, the outer filament (identified by the numeral 42) is so supported that its left end (Fig. 11) is connected to conductor 41 and its right end to conductor 40, this transposition being accomplished by means of jumpers 43 and 44 which run from end to end of the cathode assembly. This arrangement has the advantage of tending to produce a uniform distribution of the discharge current along the entire length of the cathode, due to the fact that the current in the filament 39 is in the opposite direction to the current flowing through the filament 42. The reverse connection of the filaments also eliminates magnetic effects, a factor which is of importance in some connections.

While I have exemplified my invention by reference to particular embodiments it will be understood that many modifications may be made by those skilled in the art without departure from the invention. I, therefore, aim in the appended claims to cover all such modifications as 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 cathode including a first portion comprising a heating element adapted to be rendered electron emissive in response to a heating current provided therefor and a second portion surrounding the first portion and adapted to be rendered electron emissive in response to heat generated by power losses in the discharge space, said second portion comprising a relatively open structure arranged to be traversed by that portion of the discharge current which is derived from the heating element and being so proportioned that its emission increases automatically with an increase in such discharge current.

2. In a device of the type which includes cooperating discharge electrodes and a readily ionizable discharge medium, a cathode comprising a first electron-emitting portion adapted to be rendered electron-emissive in response to a heating current provided therefor, and a second electron emitting portion interposed between said first portion and the cooperating discharge electrode, said second portion being of relatively open construction so as to be readily traversed by discharge current and being so proportioned that its emissivity increases with increasing discharge current.

3. A discharge device of the type which includes a readily ionizable discharge medium and an anode and cathode positioned in face-to-face relation, wherein the cathode comprises a filamentary heater constituted at least in part of an effective electron emitting material, a helically wound filament surrounding said heater and appreciably spaced therefrom, said filament also comprising an effective electron-emitting material, and connections for conducting heating current to the heater, both the filament and the heater being arranged so that their major axes are transverse to a line drawn between the anode and cathode.

4. A cathode comprising a heater portion adapted to be rendered electron emissive in response to a heating current provided therefor, a discharge-permeable metal screen appreciably spaced from said heater portion and having an effective electron emitting material applied thereto, said screen being arranged to be traversed by the portion of the discharge current which is derived from the heater portion.

5. A cathode assembly comprising a pair of spaced current conductors, a helically coiled filament connected between said conductors, said filament comprising an effective electron-emitting material and being adapted to be rendered electron emissive by the passage of heating current therethrough, a second helically coiled filament concentrically surrounding the first filament and appreciably spaced therefrom, said second filament also comprising an effective electron emitting material, and means connecting the ends of said second filament to said conductors in an order which is the reverse of the order of connection of the first filament.

LAURENCE F. PERROTT.