Dec. 13, 1955 H. J. DAILEY ET AL 2,727,178

THORIATED CATHODE

Filed March 25, 1952

Fig. 1.

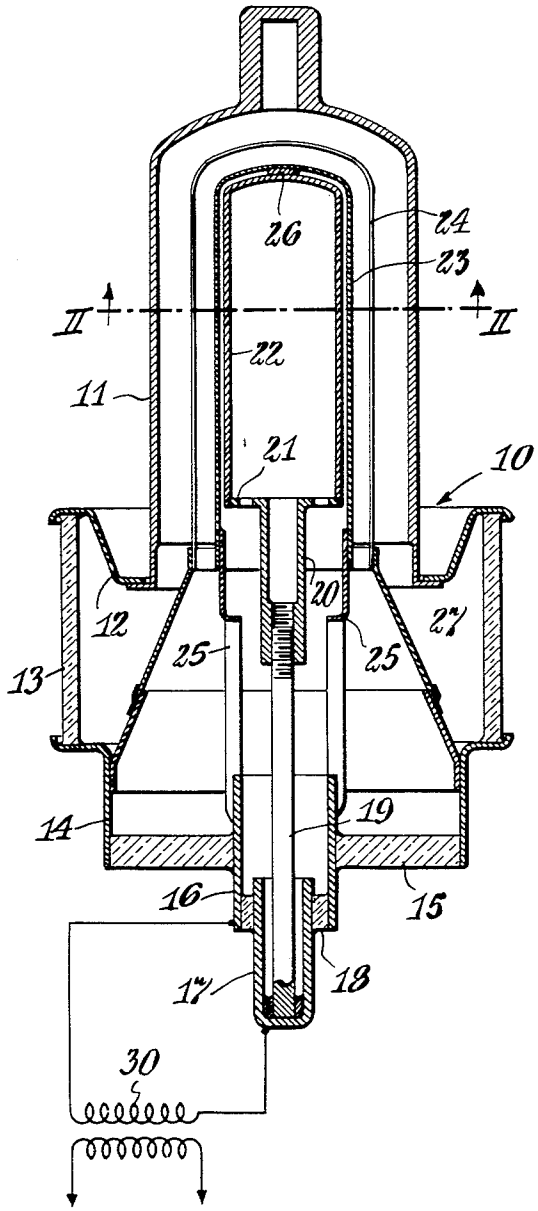


Fig. 2.

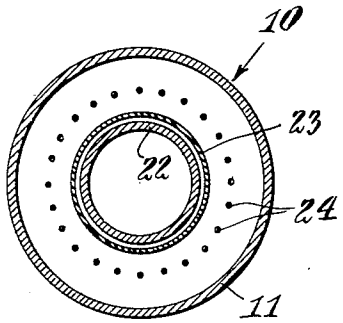
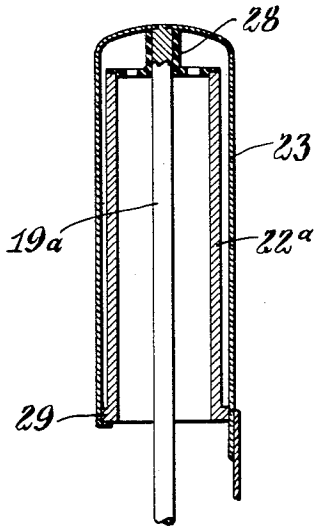


Fig. 3.



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THORIATED CATHODE

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This invention relates to thoriated cathodes, and particularly to a directly heated thoriated tungsten cathode for use with high voltage electron discharge devices.

Directly heated cathodes of the filament type have been used in electron tubes for many years, and are usually fabricated, either as wire or ribbon, from an intermixture of tungsten and thorium and usually with some carbon also added to the mixture. In fabrication, heating of the cathode changes a portion of the tungsten to tungsten carbide by virtue of the presence of the carbon. The percentage of the filament cross section which is carburized is usually no greater than 30% as greater proportion results in the filament becoming excessively brittle. These prior art thoriated tungsten filaments have been found to have a life span of electron emission which ends when the available carbon has disappeared. They are also limited in that it is difficult to get a uniform distribution of carbide throughout the filament.

Indirectly heated cathodes of cylindrical type with an internal heater have been employed and in general are fabricated in a manner similar to the filamentary cathodes as described above. This type of cathode also has the limitation of a relatively short life span limited by the using up of the available tungsten carbide. Likewise an even distribution of carbide is often difficult to attain.

According to the present invention we propose an even distribution of carbon from, for all practical purposes, an inexhaustible reservoir, to supply an adequate amount at all times to maintain the carbon content of the cathode.

A more specific but highly important objective we accomplish is to maintain an even distribution of the carbon to the cathode.

In relation to the prior constructions noted above, a distinct purpose of our invention is to avoid detrimental effects of differential of expansions caused by variations in temperature.

Other objects of the invention, which include simplicity of construction and operation, will become apparent to persons skilled in the art to which the invention appertains as the description progresses, both by direct recitation thereof and by implication from the context.

Referring to the accompanying drawing in which like numerals of reference indicate similar parts throughout the several views:

Fig. 1 is a longitudinal central section of an electron discharge device having our improved cathode therein and likewise shown in longitudinal central section.

Fig. 2 is a cross-section on line II—II of Fig. 1; and

Fig. 3 is a longitudinal central section of a modified construction of cathode.

In the specific embodiment of the invention illustrated in said drawing, and referring initially to Figures 1 and 2 thereof, the reference numeral **10** designates in general an evacuated envelope. The selected construction of envelope here shown includes a domed metallic anode **11** as part thereof, the open end of the anode having a vacuum-tight seal with a dished annular deck **12** thereabout. Vacuum-tight seal is made between the peripheral margin of said deck with an end edge of a glass cylindrical ring **13** coaxial to the anode and extending partly above and partly below the level of the open edge of said anode. The other or lower edge of said ring **13** is sealed to a flanged metallic body ring **14** coaxial thereto and having its other end sealed to a glass header **15**. A tubular metallic outer lead **16** is sealed through said header **15** at the middle thereof, and inside and protruding at the lower end of said outer lead is an inner lead **17** of cupped formation with the open end of the cup directed inwardly of the outer lead and with said inner lead sealed, as with glass bead **18**, to said outer lead. Thus a completely sealed envelope is obtained which may be evacuated as usual with this type of electron discharge device.

Rigidly secured in said cupped inner lead **17** is a metallic rod **19** which extends coaxially toward the open end of the anode, and has a connector **20** on its upper end extending into the anode where it is provided with a perforated flange **21** to the periphery of which is secured a hollow carbon domed cylinder **22** smaller than but having a contour proportionate to the shape of the anode. This carbon domed cylinder **22** is coaxial to the anode and spaced therefrom an appropriate distance to permit inclusion of a similarly dome-shaped cathode **23** and grid **24** coaxially between the carbon cylinder and anode. Said cathode is an imperforate hollow dome of thoriated tungsten whereas the grid is composed of a plurality of wires in bird-cage assembly. The lower margin of the cathode is supported by brackets **25** secured thereto and extending to and secured to the inwardly projecting end of the outer coaxial lead **16**, said brackets also affording electrical connection from the said lead to the cathode. At the peak of the carbon and cathode domes is interposed a conductive lug **26** by which longitudinal and coaxial spacing of the domes in general is maintained in addition to the electrical connection afforded at that particular area of the two domes.

The lower ends of the wires constituting the grid are secured to a collar **27** which flares outwardly downwardly and has both supporting and electrical connection with body ring **14**. Thus it will be seen that all external lead-in connections for the carbon cylinder, cathode, and grid are coaxial. It should be understood that whereas for convenience of description the term dome is herein employed, it is not to be construed as a restriction, it being contemplated that cylinders, each with a closed end of any configuration, may be employed and not necessarily one having a bulbous contour.

Heating current for the cathode of Fig. 1 is applied to the outer and inner coaxial leads **16** and **17** so the current flows in by way of one lead, for instance outer lead **16**, and out by way of the other lead, as **17**. Assuming this stated direction of current flow, the current passes up through the cathode cylinder to the lug **26** and then down through the carbon cylinder, heating both cylinders. However, if desired, only one cylinder may be directly heated by current flow therein, such modification being indicated in Fig. 3.

The structure shown in Fig. 3 comprises a domed cathode **23** as before. The carbon cylinder **22***a*, however, has a perforated insulator cap **28** at its end next the dome of the cathode, and that cap is also mounted on a coaxial rod **19***a* therein which in this instance extends to the cathode end or dome. Said rod in this instance, therefore, makes electrical connection to the upper end of the cathode but has no direct electrical connection with the carbon cylinder. The cap **28** maintains proper spacing of the carbon cylinder coaxially in the cathode at their upper ends. Lower end spacing is maintained by a basal flange **29** on the carbon cylinder making peripheral engagement with the inside of the cathode. Current flow

in this construction will be introduced into the device by the coaxial terminals as shown and described with Fig. 1, and then flows the length of the cathode for heating purposes. Current does not flow in the carbon cylinder of Fig. 2 and heating thereof is obtained by radiation thereto from the cathode.

In both modifications heating current may be supplied in any suitable manner, a transformer 30 for that purpose having been indicated in Figure 1 specifically and equally, applicable in Figure 3. Likewise, in both modifications the cathode is fabricated from appropriate mixture of tungsten and thorium and up to 30% carbon. It is believed the carbon, to extent available, forms tungsten carbide. In use, thorium is vaporized from the cathode surface and in order to free the thorium it is believed that the following reaction occurs

$$2W_2C+ThO_2=Th+4W+2CO$$

and that therefore two atoms of carbon are needed for each atom of thorium evaporated. But since the physical characteristics of tungsten with more than 30% of carbon are prohibitive, a reservoir of carbon is provided by the carbon cylinder to supply the added carbon necessary to replace that which is used up by the reaction described.

It has been found that at the following listed temperatures, atoms of thorium per second per square centimeter evaporate from the tungsten surface as listed opposite the several temperatures in the following tabulation:

T° K.	Th Atoms vaporized per sec. per cm.^{2}
1,800	5.15×10^{8}
1,900	1.03×10^{9}
2,000	1.53×10^{9}
2,100	1.75×10^{10}
2,200	1.61×10^{11}
2,300	1.22×10^{12}

From the above explanation, the figures given of the number of atoms of thorium listed as vaporized have to be doubled to give the number of atoms of carbon required to accomplish the chemical change to release the thorium. The prior art relies upon presence of tungsten carbide initially processed into the cathode with no provision for replacing the consumed carbon in the cathode. According to the present invention the carbon is supplied by vaporization from the carbon cylinder to the cathode. We have determined theoretically and practically that carbon can be thus supplied and furthermore can obtain the necessary vaporization of the carbon from the carbon cylinder with a heating of the carbon cylinder to a temperature no greater than the heating of the cathode in use. Thus, the presence of the carbon cylinder provides a means for replacing carbon consumed in operation of the thoriated tungsten cathode, extending the life of the cathode indefinitely. The vaporization of the carbon onto the cathode obtains a constant, active and evenly distributed supply of carbon which is continuously converted to tungsten carbide in the cathode. In the construction of Fig. 1, the carbon cylinder or reservoir is both enclosed within the heated cathode and is itself heated by current flowing through it against the inherent resistance of the carbon. In the construction of Fig. 2, the carbon cylinder or reservoir is heated by radiation from the enclosing cathode so that the temperature of the reservoir cylinder may substantially equal, but not exceed, the cathode temperature.

We wish to make it definitely clear that the structures shown will develop carbon vaporization from the reservoir at a rate, under the temperature conditions imposed, to furnish the carbon to the cathode at least as fast as required and at the rate which will form two molecules of carbide for each atom of thorium evaporated from the cathode.

First, from literature the rate of evaporation of carbon has been empirically expressed by the equation

$$\log W=9.08-\frac{39,500}{T} \quad (1)$$

where W is grams per square centimeter per second and T is degrees of temperature Kelvin.

Second, the number n of atoms in a given weight of material may be expressed by the known formula

$$n=\frac{W}{g}\times6.06\times10^{23} \quad (2)$$

where W is again the weight and g is gram-atomic weight. From chemical handbooks, the value of g for carbon is 12, and using that value and combining Formulas 1 and 2 above, we derive

$$\log n=31.75-\frac{39,500}{T} \quad (3)$$

Assuming the cathode employed is to run at 2000° K., it was shown hereinabove that 3.06×10^{9} carbon atoms will be required per second at this figure being substituted for n in Formula 3 enables a determination to be derived that the temperature T to which the carbon must be heated for the minimum requirement of carbon atoms in the filament, is 1772° K. A similar solution for a cathode at 2100° K. gives the temperature required for the carbon as 1860° K. Consequently the structures disclosed, wherein the carbon cylinder and the cathode are both heated to substantially the same temperature, a supply is obtained which is somewhat better than the minimum requirement of carbon atoms to replace carbon atoms lost from the cathode by the reaction permitting the release and evaporation of thorium atoms. As cathodes are generally operated at about 2050° K. the two solutions are satisfying for this intervening temperature. Solutions with respect to other cathode temperatures given hereinabove also show adequate supply of carbon atoms to maintain desired presence of carbon in the cathode operating at those temperatures, but the mathematics will not be further elaborated herein.

We claim:

1. A thoriated tungsten cathode with a carbon reservoir comprising a self-sustaining cylinder of carbon proximate to said thoriated tungsten cathode, said cylinder in operation being heated to a temperature high enough to vaporize carbon at a sufficient rate to replace the carbon used by and in addition replace the carbon vaporized from, the thoriated tungsten.

2. A thoriated tungsten cathode essentially enclosing a carbon section with a space separating the same throughout the major portions thereof.

3. A thoriated tungsten cathode essentially enclosing a carbon section with contact at one end only of the carbon section and said cathode for effecting heating of the cathode by passing current through the tungsten sections only.

4. A thoriated tungsten cathode essentially enclosing a carbon section with contact at one end only of the carbon section and said cathode for effecting heating of the cathode by passing current through the tungsten sections only and the carbon section heated only by absorption.

5. A thoriated tungsten cathode essentially enclosing a carbon section with said cathode and said section connected in series whereby heating is accomplished by passing current through the carbon and tungsten sections.

6. An electron emitter of the character described comprising a hollow cylindrical cathode of thoriated tungsten having a carbonized emissive surface, and a cylindrical carbon body in proximity to said cylinder at the side thereof opposite from said carbonized surface, said carbon body comprising a reservoir for carbon which in normal operation of the cathode is heated and sup-

plies vaporized carbon to the thoriated tungsten of the cathode to replace the carbon vaporized from said carbonized surface.

7. An electron emitter of the charactcer described comprising a hollow cylindrical cathode of thoriated tungsten having an exterior carbonized surface, and a carbon cylinder within said cathode in proximity to and of substantially equal length as said cylindrical cathode, said carbon cylinder comprising a reservoir for carbon which is normal operation of the cathode is heated and

supplies vaporized carbon to the thoriated tungsten of the cathode to replace the carbon vaporized from said carbonized surface.

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