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THERMIONIC ELECTRODE FOR DISCHARGE LAMPS

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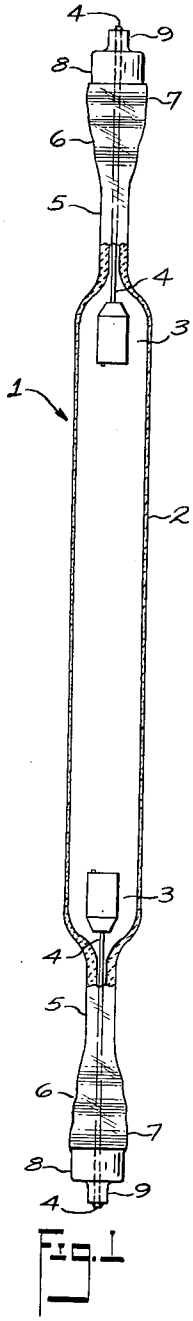


Fig. 1

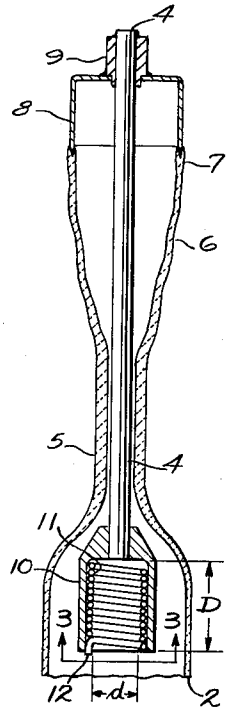


Fig. 2

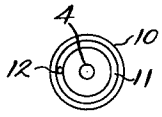


Fig. 3

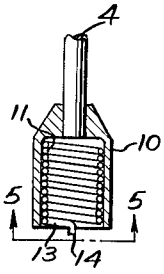


Fig. 4

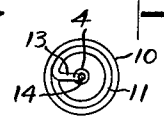


Fig. 5

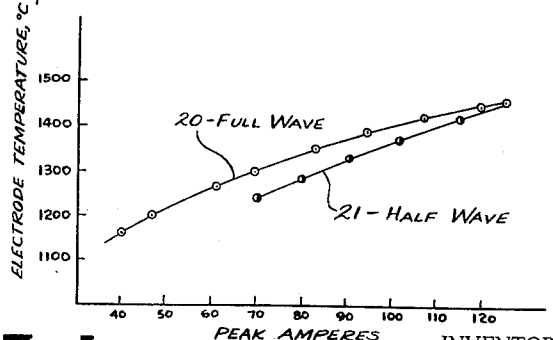


Fig. 6

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THERMIONIC ELECTRODE FOR DISCHARGE LAMPS

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This invention relates to high current electric discharge lamps and more particularly to a thermionic electrode for use in same.

There has recently been developed an intermediate pressure gas discharge lamp which operates with high pressure characteristics and wherein the discharge is wall stabilized. This lamp is described and claimed in Patent 2,924,733, Schirmer et al., issued February 9, 1960. The filling gas in this lamp ordinarily is xenon and the discharge therethrough fills substantially the entire cross section of the envelope. The gas temperature is only a little less than the electron temperature, as evidenced by a strong continuum in the spectrum. These results are achieved by operating the lamp at a very high current. For instance, in a lamp having a tubular envelope with an internal diameter of approximately 3 centimeters and designated XBL 16,000, the discharge current is approximately 75 amperes R.M.S. The thermionic electrodes of the present invention are designed to support discharge currents of this order of magnitude and are intended primarily for use in this type of lamp.

The thermionic electrodes or cathodes originally used in wall stablized high current lamps consist of hollow bullet-shaped bodies of thoriated tungsten. The rounded front end or nose of the tungsten body was provided with several narrow slits and within the body a pellet of thorium oxide was inserted. In operation, some thorium oxide is reduced by the tungsten of the electrode body and thorium metal diffuses through the narrow slits to the outer surface of the tungsten body. The work function of the tungsten body is thereby reduced to facilitate thermionic emission. However it has been observed that with such electrodes the lamps darken quite rapidly. At the rated load of 75 amperes R.M.S. the electrodes run very hot, for instance at approximately 2250° C. corresponding to a white heat. Calculations establish that at this temperature, the electrodes radiate approximately 700 watts each. Such a large electrode loss can hardly be explained on the basis of power delivered during the anode half-cycle, and must result from the presence of a substantial proportion of ion current during the cathode half-cycle. It thus appears that the current density available from the thorium-thoria film near the electrode slits under thermionic conditions of emission is insufficient to meet the circuit requirements. Therefore the proportion of current carried by positive ions goes up and the electrode is heated up by ion bombardment. Ion bombardment sputtering and thermal evaporation therefore appear to be the major factors which produce early bulb blackening in these lamps.

The object of the invention is to provide a new and improved self-heating thermionic cathode particularly suitable for operation at high currents in a gas or vapor discharge medium.

A more specific object of the invention is to provide a thermionic cathode capable of supplying the current requirements of a wall stablized gas discharge lamp operating with high pressure characteristics, and achieving substantially improved maintenance and reduced bulb blackening.

Still another object of the invention is to provide a thermionic cathode having the above-described characteristics and which supplies the current requirements on

the cathode half-cycle with a low ion component and at a substantially lower temperature in order to achieve higher efficiency and a relatively long-life lamp.

In accordance with the invention, a thermionic self-heating cathode achieving the above objects is composed of a hollow cup-like body of a refractory metal such as tungsten or molybdenum, open towards the front, that is in the direction of the arc; a coil of a refractory metal wire, again tungsten or molybdenum, is located within the body cavity in contact with the wall; emissive material consisting of an alkaline earth metal-containing compound is placed on the coil within the cavity and lodged in the interstices between the turns of the coil and the wall of the body. In a preferred embodiment, the body and coil both consist of tungsten and the emissive material consists of barium thorate. Strontium thorate is also suitable.

Preferably according to the invention, the ratio of depth to diameter of the electrode cavity is at least 1:1 or more. Surprisingly, despite the depth of the cavity, the arc does not hot spot on the first few turns but remains diffuse and extends all the way into the cavity to the last turns of the tungsten coil therein. The cathode operates at a much lower temperature and with a very low cathode drop and correspondingly low losses. For instance a fivefold reduction in cathode loss over that obtaining with the prior type of electrode has been achieved.

For further objects and advantages and for a better understanding of the invention, attention is now directed to the following description of a preferred embodiment of the invention and to the accompanying drawing illustrating same. The features of the invention believed to be novel will be more particularly pointed out in the appended claims.

In the drawing:

FIG. 1 illustrates a wall stabilized high current gas discharge lamp incorporating thermionic electrodes in accordance with the invention.

FIGS. 2 and 3 illustrate a cathode construction embodying the invention.

FIGS. 4 and 5 illustrate another cathode embodying the invention.

FIG. 6 illustrates graphically the temperature-current characteristics of the cathode of the invention under various conditions of operation.

Referring to the drawing and more particularly to FIG. 1, the illustrated lamp **1** is intended for A.C. operation. It comprises a tubular envelope **2** made of quartz, shown herein partly sectioned, and containing xenon as the filling gas. At the ends of the envelope are mounted the thermionic electrodes **3** supported on rod-like conductors **4** which extend through reduced tubular quartz extensions **5**. Beyond the tubular extensions **5**, graded seals **6** consisting of vitreous sections with intermediate coefficients of expansion terminate in glass sections **7** to which are sealed thin-walled metal thimbles **8**. The thimbles **8** are made of a suitable metal for sealing to the glass and the outer ends of the conductors **4** extend through and are welded or brazed to contact buttons or terminals **9** on the ends of the thimbles.

The construction of the electrodes **3** is best seen in FIGS. 2 and 3 illustrating a preferred embodiment. The electrode proper comprises a generally cylindrical cup-shaped body **10** of tungsten open towards the front, that is in the direction of the arc. Within the body a tightly wound coil **11** of tungsten wire lines the cylindrical walls of the cavity. Emissive material consisting of an alkaline earth metal compound is applied to the coil within the cavity and lodged in the interstices between the coil and the cylindrical cavity wall. Suitable emissive materials are the interoxide systems consisting of barium thorate

or barium zirconate. I have found barium thorate according to the formula $BaThO_3$ satisfactory and apply the material as a suspension in nitrocellulose. The material may be applied with a brush, then dried and fired to sinter it.

Preferably the forward end of the tungsten coil is turned axially outward as indicated at **12** in FIGS. 2 and 3 in order to project forwardly of the electrode body in the direction of the arc. The forwardly projecting tip **12** may be located immediately at the cylindrical cavity wall of the electrode body as best seen in FIG. 3. Alternatively, the end of the coil may be turned radially in towards the center line of the electrode body, as indicated at **13** in FIGS. 4 and 5, and the end of the extension turned forwardly at **14** so as to project along the axis of the electrode. The arrangement of FIGS. 2 and 3 is the simpler one and facilitates the application of the activation material to the coil while the arrangement of FIGS. 4 and 5 results in greater symmetry.

In actual tests of electrodes constructed as illustrated, certain highly advantageous features have been established. Firstly the use of a forwardly projecting coil tip projecting slightly beyond the electrode body permits ignition of the arc at a preferred location, that is directly on the electrode coil. Ignition at this point is preferred because when the arc is initially cold started, the emission is field emission rather than thermionic emission. It follows that the activating material at the ignition point will, at least in part, be sputtered off. However the electrode wire operates at a higher temperature than the electrode body so that, especially at the tip, there is but a trace of emissive material on it, of the order of a monolayer. As a result, the amount of emissive material sputtered off at starting is minimized. Since the electrode coil is thermally shielded by the electrode body, it can be heated up with much less energy than would be required to heat up the entire electrode body and thus a lower power starting circuit can be used. I have observed that at starting the electrode coil becomes incandescent much before the electrode body and therefore goes into the desirable thermionic mode of emission long before the body.

A feature of the present electrode is that emissive material located in the electrode cavity diffuses over its inner surface and over the surface of the electrode coil making the entire concave region thermionically emitting at a relatively moderate temperature. It is well-known that at temperatures sufficient for surface migration of emissive material such as barium metal, evaporation is imminent. In an electrode wherein the exterior surface is the electron emitting surface, vaporization of emissive material is relatively rapid.

For instance, in the bullet-shaped type of electrode originally used with wall stabilized high current gas discharge lamps, the emissive material diffusing out through the narrow slits in the electrode would migrate on the average only a short diffusion length before becoming evaporated and totally lost to the lamp wall. However with the present hollow electrode, much of the evaporation proceeds only to the other side of the cavity and the evaporated material is there recaptured and remains available for further aid in emission.

Certain electrical effects supplement the geometry of the instant concave electrodes in conserving the emissive material. In the half-cycle during which the electrode is operating as anode, electrophoretic transport by electrons reduces the migration of neutral atoms away from the anode. When the electrode is operating as cathode, such of the atoms as are ionized are returned to the cavity under the action of the electric field. This serves to reduce further the loss of emissive material and blackening of the envelope wall.

One of the surprising features of the present electrode is the fact that it operates in a diffused mode without the formation of any hot spot at any point. The arc extends even to the innermost turns of the electrode coil within the cavity and this fact has been verified experimentally using electrode probes. These probes were inserted right into the electrode cavity through small holes pierced through the electrode wall for that purpose. The cathode potential drop has been measured and has the extremely low value of 1.2 volts peak at 75 amperes R.M.S. This is surprisingly low, especially when compared with the 7.5 volt cathode drop of prior art cathodes as used in xenon discharges reported in the literature.

It is advantageous to make the depth D of the cathode cavity as great as possible provided the arc extends into it in a diffuse mode. Whether the arc will so extend is governed in part by the ratio of cavity depth to diameter D/d, where d is the diameter of the cavity measured within the electrode coil **11**. In one cathode which I have constructed and tested, the ratio D/d was approximately 1:1. This cathode supported a current of 75 amperes A.C. (R.M.S.) and operated at a temperature of approximately 1600° C., the loss per electrode being about 250 watts. In another cathode wherein the ratio D/d was approximately 2.7:1, a current of 75 amperes A.C. (R.M.S.) was supported with a cathode drop of 1.2 volts. The cathode operated at a temperature of 1430° C., corresponding to a loss of approximately 140 watts per electrode. In this latter cathode having the physical configuration illustrated in the drawing, cavity depth D was 0.713", outside diameter of electrode body was 0.491", and overall cavity diameter was 0.366". The electrode coil consisted of .050" diameter tungsten wire, the diameter d of the cavity defined by the electrode coil was 0.266". Thus the ratio D/d was approximately 2.7:1.

In general, a ratio of cavity depth to diameter D/d in the range of 1:1 to 4:1 is desirable in accordance with the invention for thermionic emission in the diffuse mode with minimum electrode losses and least vaporization or sputtering of emissive material. For use in a wall stabilized gas discharge lamp operating with high pressure characteristics, a ratio D/d in the range of 2:1 to 3:1 is preferred. The illustrated electrodes, wherein the ratio D/d is 2.7:1, were tested in a wall stabilized discharge lamp having a filling of xenon at a pressure of about 165 millimeters of mercury and having an operating pressure of about 1.4 atmospheres at a current intensity of 75 amperes A.C. (R.M.S.). A threefold reduction in the rate of envelope blackening was observed, and the electrode loss of 140 watts per electrode represented a fivefold reduction from that obtaining with prior electrodes.

A feature of the present electrode is that substantially no heating occurs on the cathode half-cycle of conduction. This is due to the fact that the cooling effect due to electron emission offsets the heating effect due to concurrent ion current. These results are shown by the curves of FIG. 3 wherein curve **20** shows the electrode temperature against current for normal A.C. operation wherein the electrode operates as cathode on one half cycle and as anode on the other half cycle. Curve **21** shows the temperature-current relationship for half-wave anode operation wherein the current is rectified by external circuit means and the electrode conducts on the anode half cycle only. It will be observed that the electrode temperatures in both cases are very close. Therefore on normal A.C. operation, the cooling effect due to electron emission on the cathode half cycle must approximately balance any heating effect due to ion current during that half cycle. Thus electron emission is seen to occur in a very efficient mode.

The preferred embodiment of the invention which has been described herein is intended as exemplary and not as limitative of the invention. Various modifications will readily occur to those skilled in the art. The appended claims are therefore intended to cover any such modifications coming within the true spirit and scope of the invention.

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

1. A high current thermionic self-heating electrode comprising a hollow cup-shaped refractory metal body open at one end, a coil of a refractory metal wire located within said body and lining the inside walls thereof, an electron emitting compound coated on said coil and on the interior walls of said body, said electrode defining a cavity having a ratio of depth to diameter at the open end of at least 1:1.

2. A high current thermionic self-heating electrode comprising a hollow cup-shaped refractory metal body open in the direction of the arc to be supported thereby, a coil of a refractory metal wire located within said body and lining the inside walls thereof, an electron emitting compound coated on said coil and on the interior walls of said body and filling the interstices between the turns of said coil and the walls of said body, said electrode defining a cavity having a ratio of depth to diameter at the open end of at least 1:1.

3. A high current thermionic self-heating electrode comprising a hollow cup-shaped refractory metal body open in the direction of the arc to be supported thereby, a coil of a refractory metal wire located within said body and lining the inside walls thereof, an electron emitting alkaline earth metal compound coated on said coil and on the interior walls of said body and filling the interstices between the turns of said coil and the walls of said body, said electrode defining a cavity having a ratio of depth to diameter at the open end in the range of 1:1 to 1:4.

4. A high current thermionic self-heating electrode comprising a hollow cup-shaped refractory metal body open in the direction of the arc to be supported thereby, a coil of a refractory metal wire located within said body and lining the inside walls thereof, an electron emitting alkaline earth metal compound coated on said coil and on the interior walls of said body and filling the interstices between the turns of said coil and the walls of said body, said electrode defining a cavity having a ratio of depth to diameter at the open end in the range of 1:1 to 4:1, said coil having a tip projecting forwardly of said body a slight distance in the direction of the arc.

5. A high current thermionic self-heating electrode comprising a hollow cup-shaped tungsten body open in the direction of the arc to be supported thereby, a coil of tungsten wire located within said body and lining the inside walls thereof, an electron emitting alkaline earth metal compound coated on said coil and on the interior walls of said body and filling the interstices between the turns of said coil and the walls of said body, said electrode defining a cavity having a ratio of depth to diameter at the open end in the range of 2:1 to 3:1, and said coil having a tip projecting out of said cavity and forwardly a slight distance in the direction of the arc.

6. A wall stabilized high current discharge lamp operating with high pressure characteristics comprising an envelope having a filling of inert gas and a pair of thermionic self-heating electrodes sealed into opposite ends, each electrode comprising a hollow cup-shaped refractory metal body open at one end, a coil of a refractory metal wire located within said body and lining the inside walls thereof, an electron emitting compound coated on said coil and on the interior walls of said body, said electrode defining a cavity having a ratio of depth to diameter at the open end of at least 1:1.

7. A wall stabilized high current discharge lamp operating with high pressure characteristics comprising an envelope containing a filling of xenon and having a pair of thermionic self-heating electrodes sealed into opposite ends, each electrode comprising a hollow cup-shaped relatively massive tungsten body open in the direction of the arc to be supported thereby, a coil of tungsten wire located within said body and lining the inside walls thereof, an electron emitting alkaline earth metal compound coated on said coil and on the interior walls of said body and filling the interstices between the turns of said coil and the walls of said body, said electrode defining a cavity having a ratio of depth to diameter at the mouth in the range of 1:1 to 4:1, the coil in each electrode having a tip projecting out of the electrode cavity in the direction of the other electrode.

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