Nov. 23, 1965 K. SCHMIDT 3,219,869

CESIUM VAPOR DISCHARGE LAMP

Filed July 1, 1963

Fig. 1.

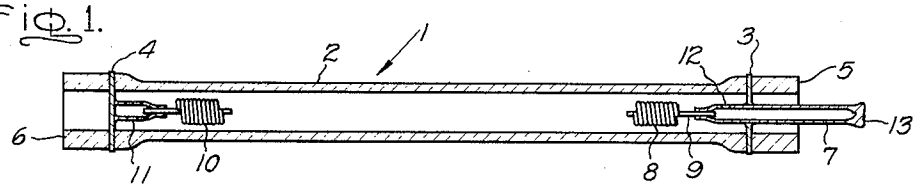
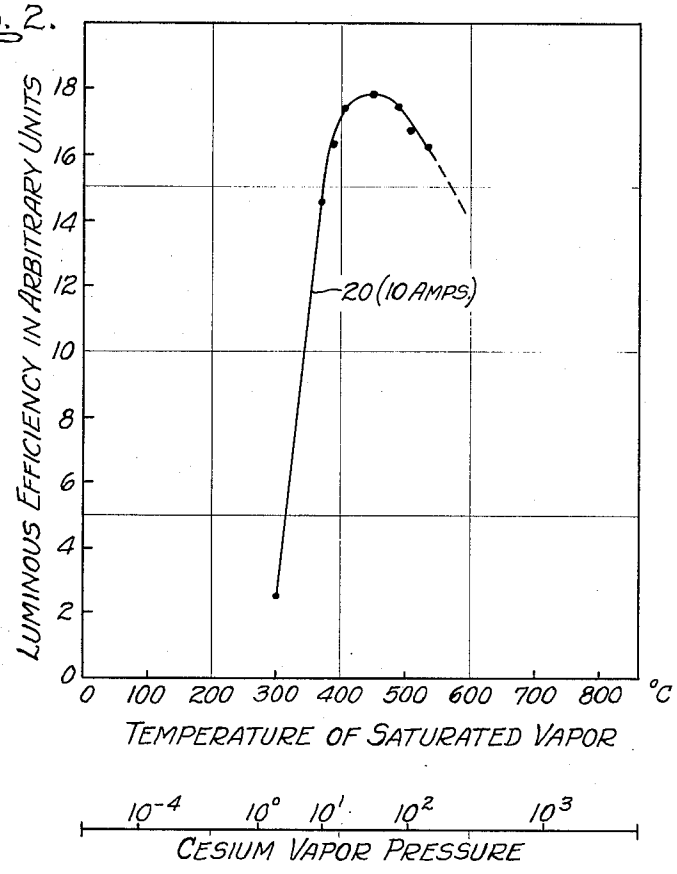


Fig. 2.



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CESIUM VAPOR DISCHARGE LAMP

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This invention relates to electric discharge lamps utilizing cesium vapor as the source of radiant emission. This application is a continuation-in-part of my copending application Serial No. 88,087, filed February 9, 1961, of like title and assignment, and now abandoned.

The spectrum of cesium, under suitable conditions of excitation, lies in the visible and infrared with a very strong continuum in the visible. It provides a white light of excellent quality or color rendition and entirely suitable for general illumination. However cesium attacks glass and quartz very strongly and at a temperature of a few hundred degrees centigrade causes a quartz envelope to blacken in a few minutes. This factor has until now retarded the development of cesium vapor lamps. In my copending application Serial No. 836,200, filed August 26, 1959, now Patent 2,971,110, entitled Metal Vapor Lamps and assigned like the present invention, I describe and claim various metal vapor lamps, including a cesium vapor lamp, utilizing an envelope of sintered transparent high density polycrystalline alumina which is capable of resisting the attack of cesium vapor at least up to temperatures as high as 1600° C. Other ceramic materials capable of withstanding the attack of cesium vapor may likewise be used for the envelopes of cesium vapor lamps.

The object of this invention is to provide an improvement in cesium vapor discharge lamps permitting operation at higher efficiencies than heretofore possible.

In accordance with the invention, I have found that by including mercury vapor in a cesium vapor lamp, the luminous efficiency can be increased 10% or more over that of a pure cesium vapor lamp. Cesium vapor lamps embodying the invention desirably have a partial pressure of cesium vapor in the range of 15 to 350 millimeters of mercury for maximum luminous efficiency, and in addition a partial pressure of mercury vapor which may lie in the range of .15 to 15 atmospheres. For best results, the partial pressure of mercury preferably lies in the range of 0.5 to 5 atmospheres. To facilitate starting, it is also desirable to provide an inert starting gas at a pressure of a few millimeters, for instance neon, argon, krypton or xenon, the latter being preferred for lowest heat losses.

In lamps embodying the invention, the envelopes are tubular, having an internal diameter from 3 to 15 millimeters, and consist of a material capable of withstanding the attack of cesium vapor at temperatures up to at least 900° C. and preferably higher. As the envelope diameter is reduced, the operating and starting voltages of the lamp rise and also the wall loading increases; these factors determine approximately 3 millimeters as the minimum practical envelope diameter. The lamps operate with wall stabilization. As the diameter is increased, the effectiveness of wall stabilization diminishes and instability of the arc by reason of convection currents gradually sets in. When the arc is unstable, it may bow up by convection; depending upon the envelope material used, this may cause softening of the wall or set up stresses due to local overheating resulting in cracks. With loss of wall stabilization, the efficiency also drops. In practice the requirement for wall stabilization imposes a maximum limit of approximately 15 millimeters on the internal envelope diameter. The lamps operate at current densities in the range of 20 to 100 amperes per square centimeter of discharge cross section, and volume loadings in

the range of 200 to 900 watts per cubic centimeter of discharge volume.

The envelope is hottest about the middle of the lamp, that is midway between the electrodes; under the operating conditions according to the invention, the minimum temperature is about 900° C. The envelope must therefore be made of a material which will transmit the desired radiation and withstand the attack of cesium vapor at least up to a temperature of 900° C. and preferably higher. High density polycrystalline alumina consisting essentially of aluminum oxide will withstand the attack of cesium vapor up to 1600° C. and is therefore an ideal material for the purpose; however other materials meeting the foregoing criteria may be used.

In lamps according to the invention wheerin the above-stated conditions are observed, the discharge remains essentially a cesium vapor discharge and does not become a mercury vapor discharge. Despite the high partial pressure of mercury vapor, the mercury atoms do not participate directly either in the conduction of current or in the production of radiation. The mercury atoms are not excited in the cesium discharge because the ionization potential of cesium at 3.9 electron volts is lower than the lowest excitation potential of mercury at about 4.9 volts. It appears that the mercury increases the efficiency of the cesium discharge by serving as a buffer gas and reducing the heat losses by conduction.

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 taken in conjunction with the accompanying drawing. The features of the invention believed to be novel will be more particularly pointed out in the appended claims.

In the drawing:

FIG. 1 is a sectional view of a cesium vapor discharge lamp embodying the invention.

FIG. 2 illustrates the variation in luminous efficiency with cesium vapor pressure or temperature of the saturated cesium vapor.

Referring to FIG. 1, the illustrated lamp **1** embodying the invention comprises an envelope **2** of ceramic tubing resistant to the attack of cesium vapor at high temperatures. As disclosed in my previously mentioned copending application, a suitable ceramic material consists of sintered transparent polycrystalline alumina. This particular material has a very high alumina content, suitable in excess of 99.5% Al_2O_3 and though translucent, rather than clear like glass, has exceedingly good light transmittance, in excess of 95%. Closure members, in this case metal caps **3**, **4** consisting of a nickel chromium iron alloy having a high melting point and a coefficient of expansion close to that of the alumina are brazed to the ends of the alumina tube, titanium being used to metallize the ends of the tube in order to bond the discs thereto. In order to equalize the strains set up between the caps **3**, **4** and the ceramic envelope **2** throughout the temperature range to which it is subjected in operation of the lamp, short sections or back-up rings of alumina tubing **5**, **6** are brazed to the outer faces of the caps **3**, **4**, again through the use of titanium. The brazing of the end caps is done in a vacuum or in a reducing or inert atmosphere at a suitably high temperature, for instance a temperature in the range of 900 to 1000° C.

A hollow metal tube **7**, suitably of stainless steel or of iron nickel chromium alloy passes through a central perforation in an outwardly projecting embossment in cap **2**. The tube is brazed to the cap to make a hermetic seal and supports on its inner end a cathode **8** consisting of a double wound tungsten wire coil with the interstices filled with activating material in the form of alkaline earth oxides including barium oxide. The tungsten coils forming the cathode are wound over a tungsten shank **9**

which is welded in the end of the metal tube **7**. Electrode **10** at the other end of the tube is supported from a short length of metal tube **11** welded to the inside face of end cap **4**. By virtue of the low work function of cesium (0.7–1.36 volts) a plain tungsten rod, preferably thoriated, may be used if desired instead of the illustrated electrode.

The tube **7** is used to evacuate the lamp and to introduce the ionizable medium therein including an inert starting gas, and the cesium and mercury. The side aperture **12** in tube **6** permits passage of gas or vapor into the alumina envelope after which the envelope is sealed by pinching or welding the tube shut as at **13**. The heavier inert gas, argon, krypton and xenon, in ascending order of atomic weight and preference, are desirable for the starting gas and result in higher efficiency by reducing heat losses. The cold filling pressures (measured at room temperature) are in the range of 5 to 50 millimeters of mercury.

The cesium discharge operates with maximum luminous efficiency in the pressure range from 15 to 350 millimeters of mercury pressure. In the case of a saturated vapor cesium lamp wherein the vapor exists in equilibrium with an excess of the cesium metal, the pressure range of 15 to 350 millimeters corresponds to a temperature range of about 370 to 600° C. for the coldest spot in the lamp structure which will of course determine the cesium vapor pressure. The curve in FIG. 2 illustrates the variations in luminous efficiency with variation in cesium vapor pressure in a typical lamp utilizing an envelope of polycrystalline alumina having an inside diameter of 6 millimeters and an interelectrode gap or distance between the ends of the electrode of about 60 millimeters. The current was 10 amperes, corresponding to a current density of approximately 35 amperes per square centimeter of discharge cross section. The cold spot temperature is also shown on the ordinate scale for the case of a lamp operating with an excess of cesium and saturated cesium vapor. In a saturated cesium vapor lamp, the projecting length of the pinched-off metal tube **6** may conveniently serve as a cesium vapor pressure control center and its length adjusted to attain in operation the desired cold spot temperature. It will be observed in FIG. 2 that a peak in the efficiency versus pressure curve occurs at about 48 millimeters of mercury pressure which is equivalent to a cold spot temperature of about 450° C.

As previously stated, an increase in luminous efficiency of 10% or more may be achieved in accordance with the invention by adding mercury to provide a partial pressure of mercury vapor in the range of .15 to 15 atmospheres. The preferred partial pressure range for the mercury addition is from .5 to 5 atmospheres; this may be achieved by utilizing a limited quantity of mercury in a lamp having an excess of cesium metal, and in such case, the cold spot temperature of the lamp is regulated to obtain the desired partial pressure of cesium vapor. However, if a partial pressure of the mercury additive in excess of 5 atmospheres is desired, then a cold spot temperature in excess of 450° C. is needed in order to produce the high mercury vapor pressure. Under these circumstances, an excess of cesium metal cannot be used because a cold spot temperature in excess of 450° C. would result in a partial pressure of cesium vapor higher than that needed for maximum efficiency, that is higher than 48 millimeters of mercury. Therefore, recourse must be had to a lamp operating with unsaturated cesium vapor wherein only a limited amount of cesium is put into the lamp, measured to provide the required partial pressure of cesium at that lamp temperature necessary to achieve the desired partial pressure of mercury.

According to another feature of the invention, I have found that by operating a cesium vapor lamp at relatively high pressures, in excess of 100 millimeters of mercury, although luminous efficiency begins to fall, radiant energy

in the near-infrared region continues to increase. With increasing cesium vapor pressure, more and more energy is radiated in the near-infrared region, particularly in the region extending from about 7500 A. to about 12,500 A. This is caused mainly by two factors: (1) the resonance lines which occur at 8521 A. and 8943 A. are broadened preferentially further into the infrared; and (2) continuous molecular radiation appears to contribute substantially to the radiation in the spectral region from 9000 to 13,000 A. I have made spectral emission comparisons of a cesium vapor lamp operating at 500 watts and at a cesium partial pressure of about 200 millimeters of mercury with an incandescent tungsten filament lamp operating at the same wattage. The tungsten filament lamp was of the kind using the iodine regenerative cycle to prevent envelope darkening. Measurements of total radiation with a thermopile indicate about equal output for the cesium and for the incandescent tungsten filament lamp, thus demonstrating the suitablility of the cesium discharge lamp as near-infrared radiator.

The foregoing specifically described example of the invention is intended as illustrative and not in order to limit the invention thereto except inasmuch as specific limitations may appear in the appended claims.

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

1. An electric discharge lamp comprising a tubular elongated envelope of material resistant to the attack of cesium vapor at least up to a temperature of approximately 900° C., a pair of electrodes sealed into opposite ends, and an ionizable medium within said envelope comprising cesium and mercury, said cesium exerting a partial pressure in the range of 15 to 350 millimeters of mercury and said mercury exerting a partial pressure in the range of .15 to 15 atmospheres in normal operation of said lamp at current densities in the range of 20 to 100 amperes per square centimeter of discharge cross section, the discharge through said medium being carried principally by the cesium, and the mercury serving as a buffer without appreciable participation in the production of radiation.

2. An electric discharge lamp comprising a tubular elongated envelope of material resistant to the attack of cesium vapor at least up to a temperature of approximately 900° C. and having an internal diameter in the range of 3 to 15 millimeters, a pair of electrodes sealed into opposite ends, and an ionizable medium within said envelope comprising cesium and mercury, said cesium exerting a partial pressure in the range of 15 to 350 millimeters of mercury and said mercury exerting a partial pressure in the range of .15 to 15 atmospheres in normal operation of said lamp at volume loadings in the range of 200 to 900 watts per cubic centimeter, the discharge through said medium being carried principally by the cesium, and the mercury serving as a buffer without appreciable participation in the production of radiation.

3. An electric discharge lamp comprising a tubular elongated envelope of material resistant to the attack of cesium vapor at least up to a temperature of approximately 900° C. and having an internal diameter in the range of 3 to 15 millimeters, a pair of electrodes sealed into opposite ends, and an ionizable medium within said envelope comprising cesium and mercury, said cesium exerting a partial pressure in the range of 15 to 350 millimeters of mercury and said mercury exerting a partial pressure in the range of .15 to 15 atmospheres in normal operation of said lamp at current densities in the range of 20 to 100 amperes per square centimeter of discharge cross section, the discharge through said medium being carried principally by the cesium, and the mercury serving as a buffer without appreciable participation in the production of radiation.

4. A cesium vapor electric discharge lamp comprising a tubular elongated envelope of material resistant to the

attack of cesium vapor at least up to a temperature of approximately 900° C. and having an internal diameter in the range of 3 to 15 millimeters, a pair of electrodes sealed into opposite ends, and an ionizable medium within said envelope comprising an inert starting gas, cesium, and mercury, the starting gas being from the group consisting of argon, krypton, xenon and mixtures thereof at a filling pressure of 5 to 50 millimeters of mercury, the quantity of cesium being such as to exert a partial pressure in the range of 15 to 350 millimeters of mercury and the quantity of mercury being such as to exert a partial pressure in the range of .15 to 15 atmospheres in normal operation of said lamp at current densities in the range of 20 to 100 amperes per square centimeter of discharge cross section, the discharge through said medium being carried principally by the cesium, and the mercury serving as a buffer without appreciable participation in the production of radiation.

5. A high luminous efficiency cesium vapor lamp comprising a tubular elongated envelope of material resistant to the attack of cesium vapor at least up to a temperature of approximately 900° C. and having an internal diameter in the range of 3 to 15 millimeters, a pair of electrodes sealed into opposite ends, an ionizable medium within said envelope comprising an inert starting gas, an excess

of cesium metal, and a limited quantity of mercury, said lamp operating with a current density in the range of 20 to 100 amperes per square centimeter of discharge cross section resulting in partial vaporization of said cesium and complete vaporization of said mercury and with the coldest spot in said envelope at a temperature in the range of 370 to 600° C. whereby to achieve a cesium vapor pressure in the range of 15 to 350 millimeters of mercury, the quantity of mercury in said envelope being limited to provide, when completely vaporized in normal operation of said lamp, a partial pressure in the range of .5 to 5 atmospheres, the discharge through said medium being carried principally by the cesium, and the mercury serving as a buffer without appreciable participation in the production of radiation.

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