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DISCHARGE LAMP

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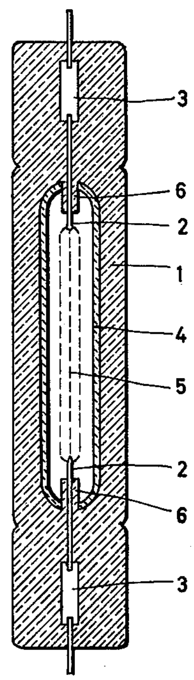
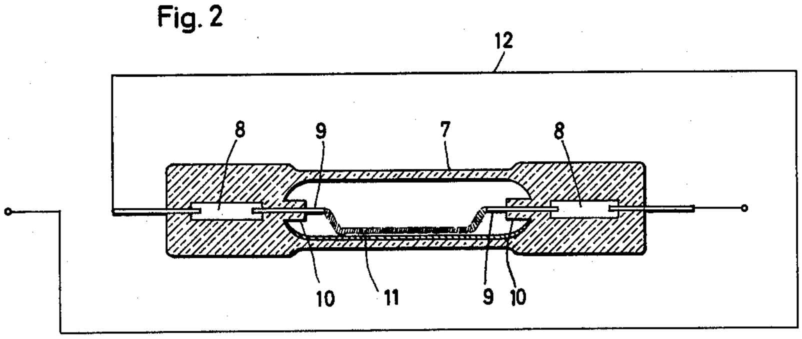


Fig. 1

Fig. 2



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DISCHARGE LAMP

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This invention relates to high-pressure discharge lamps and, more particularly, to high-pressure discharge lamps which have a high luminous output and a color which is quite similar to that of natural sunlight.

Various types of high-pressure discharge lamps are used, with high-pressure, mercury-vapor lamps being the most common. These mercury vapor lamps normally have an arc tube fabricated of quartz and the arc tube contains a starting gas and a measured quantity of mercury which vaporizes completely when the lamp is operated. When such lamps are operated, the vapor pressure within the arc tube is from 1 to 25 atmospheres. The color of the mercury-vapor arc is primarily a line spectrum and the resulting light not only differs considerably from natural light, but the color rendition of objects illuminated by the lamp leaves much to be desired. The color of such lamps may be improved through the use of selected luminescent materials which convert the ultraviolet radiations into long wave visible radiations, but even with this color correction, the overall spectral emission of such lamps is not completely satisfactory. The efficiency of mercury vapor lamps which incorporate a color-modifying phosphor can be quite high, such as 60 to 70 lumens per watt.

High-pressure, xenon discharge lamps are used for projection and other purposes because the color of the discharge is a continuous spectrum, similar to that of a combination of direct sunlight and diffused sky light. The efficiency of these lamps, however, is about 35 lumens per watt, which is below that of mercury-discharge lamps, although this efficiency is much higher than that of incandescent lamps.

It should be noted that it is also known to excite halides of selected elements of Groups VI, VII and VIII of the periodic chart in conjunction with vapor discharge devices.

It is the general object of the present invention to provide a high-pressure discharge lamp with a color similar to that of a high-pressure xenon lamp, or of natural light, but which lamp has an efficiency equal to or greater than high-pressure mercury lamps.

The aforesaid object of the invention is achieved by providing a high-pressure vapor-discharge lamp having an envelope formed of light-transmitting material which has a high melting point. In accordance with the present invention, a predetermined amount of rare earth halides, which when in melted state are light-transmitting and colorless, are included within the lamp envelope.

The plasmas of rare earth metals, and especially cerium and lanthanum, are a dense line spectrum, which lines principally are located within the visible spectral range. As a consequence, the overall color of such discharges is a pure white light which is generated with good efficiency. In order to produce a rare earth discharge with the desired properties of white light and good efficiency, it is necessary to achieve a vapor pressure for the rare earth metal of from at least 100 millimeters mercury up to 1 atmosphere and more. Elementary cerium and lanthanum, and the other rare earth metals, have a relatively low vapor pressure. As a result, the highest temperature which reasonably can be sustained within the lamp arc tube is not sufficient to generate a usable vapor pressure for the elemental rare earth metals, in order to make these lamps practical. It should be understood that the maximum vapor pressure

for the vaporizable material used with discharge lamps normally is controlled by the wall temperature of the envelope, and if all of the material is not vaporized, the vapor pressure of the filling material is determined by the temperature of the coolest portion of the envelope.

In cerium, lanthanum, and other rare earth discharge lamps, a sufficiently high vapor pressure for the rare earth material may be obtained by incorporating halides of these rare earth metals into the discharge tube. It has been found that lamps which incorporate the halides of one or several rare earth elements can be operated in such a manner that the halides are not completely vaporized. That part of the halide which does not vaporize when the lamp is operated is melted, and this melted material wets either a part or all of the envelope wall. Because of this factor, the halide which is used should be colorless and transparent when in the melted state.

In the usual discharge lamps, the maximum vapor pressure of the discharge-sustaining filling substance depends upon the wall temperature of the envelope. If the lamp is operated so that all of the filling substance is not vaporized, the vapor is in contact with a residue of unvaporized material, and the vapor pressure corresponds to the temperature of the coolest portion of the inner surface of the envelope. In the case of high-pressure lamps, the envelope is usually formed of quartz and the temperature of the quartz should not exceed 800° C. to 900° C. in the usual operation of the lamp. Even in the range of from 1000° C. up to the softening temperature of the quartz, the vapor pressure of rare earth halides is not always sufficient to cause these materials to operate with their best efficiency.

In accordance with the present invention, high-pressure lamps which incorporate non-volatile materials, such as rare earth halides, are so constructed that the filling materials have a higher pressure, during operation of the lamp, than would normally be expected from the temperature of the envelope wall. This is achieved by causing at least part of the inner wall of the discharge envelope to be coated, during operation, with a layer of the non-volatile material which sustains the discharge. The discharge arc is in contact with this material and this produces a local overheating of the unvaporized material, while still maintaining the temperature of the envelope within usable limits. The discharge-sustaining material which is vaporized goes directly into the plasma where it is excited to intense radiation. As a result, the envelope temperature is lower than would normally be required to produce the achieved vapor pressure of the discharge-sustaining material. The discharge-sustaining material thus continually redeposits on those sections of the envelope wall which are not touched by the arc, and the condensed, liquefied material then flows back to the continuously vaporizing halide which is contacted by the arc.

One means to cause the arc column to contact the non-volatile material on the envelope wall is to distort the normal path of the arc by means of an external magnetic field, or by means of the magnetic field produced by the lead-in conductors of the lamp itself. A non-uniform magnetic field of average intensity will serve this purpose. In another lamp embodiment, the discharge path which is defined by the lamp envelope has sufficiently small diameter so that the envelope wall is entirely coated with the melted filling material which is not vaporized, and because of the small envelope diameter, the arc is in contact with substantially all of the filling material which is coated onto the envelope wall.

For purposes of starting and initial heating, the lamp is desirably provided with a gas filling of one or a mixture of inert, ionizable starting gas or gases, such as the rare gases. When the discharge is first initiated, the rare gas sustains the discharge and causes the main filling, such as the cerium or lanthanum halides, to vaporize. After a few minutes, the main filling is sufficiently vaporized to sustain the discharge. When the designed operating temperature of the lamp is reached, the portion of the main filling which is not vaporized constitutes either a water-clear coating on the wall, or it forms a pool at the lower portion of the envelope. As an alternative embodiment, if the starting gas filling is not used, starting of the lamp may be facilitated by heating the lamp from an external source, and in order to initiate starting, a high-voltage pulse may be applied across the lamp electrodes.

In operation of the lamp, it may sometimes be necessary to cool the envelope externally, such as by blowing a current of air over it, or by flowing water over the envelope. In many cases, however, natural convection cooling of the surrounding air is sufficient.

In addition to the starting gas filling, it is desirable to add another heavy gas or vapor to the envelope in order to reduce the diffusion of the halide vapor within the envelope and also to promote heat conduction. Mercury is preferred for this latter purpose because it has the highest atomic weight of all gases and vapors which are available to provide this function. In addition, the mercury provides a contracted discharge arc, which facilitates vaporizing the halide filling.

If the lamp filling includes the inert, ionizable starting gas, and in some cases the heavy vapor or gas, the water-clear coating of the melted halide may become dark when the lamp is operated, thus impairing the light-transmissive quality of the envelope. This is attributed to the fact that some halogen in the lamp is absorbed and the stoichiometric equilibrium of the water-clear coating or pool of the halide is modified. As a result, elementary cerium or lanthanum, for example, is precipitated and blackens the envelope. This blackening can be prevented by also providing a small amount of halogen gas in addition to the specified halide, so that during operation of the lamp, there will result no deficiency of halogen which would permit halogen to be absorbed below the stoichiometric value required to maintain the lanthanum or cerium halide colorless when in the melted state.

For a better understanding of the invention, reference should be had to the accompanying drawings, wherein:

FIGURE 1 illustrates a high-pressure lamp designed for any position of burning; and

FIG. 2 illustrates a high-pressure lamp designed for horizontal burning.

The lamp as shown in FIG. 1 has a quartz envelope **1** having tungsten electrodes **2** operatively disposed therein and adapted to sustain a discharge therebetween. The electrodes **2** are sealed through the envelope by means of molybdenum foil seals **3**. The electrodes **2** may be formed of thoriated tungsten or of similar refractory conducting material. In the present lamp, alkaline-earth electron-emissive compounds are not recommended for use with the electrodes.

The envelope **1** is filled with argon at a pressure of 30 mm. mercury, for example, which serves as the inert, ionizable starting gas. As an example, the envelope also contains 25 $mm.^3$ of cerium bromide and bromine at a pressure of 2 mm. mercury. Because of this surplus of bromine, the well-known halogen cycle occurs in the lamp, in order to prevent blackening from the electrode material. As a result, the electrodes may, if desired, be highly loaded and need only have small dimensions, and the envelope will still not be blackened with the electrode material. After the lamp is started, the cerium bromide melts and forms a water-clear coating **4** over the entire inner surface of the envelope. As an example, the cerium bromide is present in sufficient amount to provide a uniform thickness of 0.1 mm. over the entire inner surface of the envelope **1**.

The quartz envelope **1** encloses what amounts to a discharge capillary tube which in effect is completely filled with the discharge arc **5** when the lamp is operated, so that the arc is what is known as wall-stabilized. The arc **5** is thus in contact with all portions of the melted bromide **4** which is not vaporized. As a result, the melted material is greatly overheated and develops a high vapor pressure. At the cooler portions of the envelope, more cerium bromide condenses than vaporizes, but the surface diffusion of the material transports the condensed material to the hotter wall zones, so that the actual vapor pressure in the arc is, in effect, governed by the hottest portion of the coating **4**. When the lamp is in non-operating condition, the molten coating **4** cools down and becomes solid. This forms on the inner wall of the envelope **1** a crystalline layer of cerium bromide. The electrodes **2** are provided with thin-walled quartz sleeves **6** which project into the discharge space and prevent any substantial contact of the tungsten electrodes with the cerium bromide.

As a specific example, the spacing between the electrodes **2** is 20 mm., the inner diameter of the quartz envelope **1** is 3 mm. and the thickness of the quartz envelope is 3 to 4 mm. If the lamp contains a filling of mercury, in addition to the bromide and starting gas, with the mercury present in sufficient amount to produce an operating pressure of approximately 50 atmospheres, the lamp can be operated with a potential of 200 volts, a current input of 1.5 amperes, and a power input of 300 watts. Under these operating conditions, the light output is 33,000 lumens and the lamp operates with an efficiency of 110 lumens per watt. In such an embodiment, the lamp is cooled by means of a slow draft of air applied to the envelope external surface. The addition of mercury reduces the heat conduction and diffusion of the cerium atoms within the discharge column, without altering the pure white light of the cerium discharge.

The lamp embodiment as shown in FIG. 2 is provided with a quartz envelope **7** and two electrodes **9** are operatively disposed within the lamp and are sealed through the envelope **7** by means of molybdenum foil seals **8**. Sleeves **10** protect the electrodes from contact with the specified halides. As a specific example, the inner diameter of the envelope is 8 mm., the wall thickness is 3 to 4 mm. The lamp is filled with the same materials as in the previous embodiment, except that 250 $mm.^3$ of cerium bromide is used. This lamp is designed to be operated in horizontal burning position. When the operating temperature is reached, the cerium bromide forms a water-clear pool **11** on the bottom portion of the envelope **7**. One of the current in-leads **12** is passed above the lamp and constitutes a magnetic field producing means. The resulting generated magnetic field serves to depress the arc toward the surface of the liquid pool **11** of cerium bromide. This depressed arc is much contracted, resulting in a local overheating in the region of contact between the arc and the pool **11** of melted cerium bromide. This lamp can be operated at a potential of 200 volts, a current input of 1.5 amperes, and a wattage input 300 watts, and sufficient cerium bromide will be vaporized because of the depressed arc to provide very efficient operation. The cerium bromide which is vaporized goes directly into the discharge, where the resulting vaporized material is excited to intense radiation. Since the envelope temperature is lower than would correspond to the resulting produced vapor pressure, the cerium bromide which is vaporized diffuses back to the envelope wall where it condenses, and thereafter flows back into the pool **11** along the bottom portion of the envelope wall. This cycle provides a very uniform wall temperature. Because of the depressed arc, overheating need be prevented only at the lower wall region next to the arc, and when the lamp is operated in accordance with the foregoing specific power input, any necessary cooling of the envelope is accomplished by natural convection currents which are relatively intense at the bottom portion of the envelope.

While the foregoing examples consider cerium bromide, equivalent amounts of the other rare earth halides can be substituted therefor.

The lamp envelope may also be formed of light-transmitting material which has a higher melting point than quartz glass, for example, polycrystalline, very pure, translucent, aluminum oxide, and this material is well known. With such a lamp construction, the power input can be increased and no fluid pool or coating of halide need be used, in order to achieve a sufficient vapor pressure for the halide. As a result, all of the halide which is placed into the lamp may be vaporized.

It will be recognized that the object of the invention has been achieved by providing a high-pressure discharge lamp with a color similar to that of a high-pressure Xenon lamp or that of natural light, and which lamp operates with a very high efficiency.

While best embodiments of the invention have been illustrated and described in detail, it is to be particularly understood that the invention is not limited thereto or thereby.

I claim as my invention:

1. A high-pressure vapor-discharge lamp adapted to be operated with a predetermined power input, said lamp comprising, a sealed elongated envelope of predetermined external and internal dimensions and formed of light-transmitting material having a high melting point, electrodes operatively disposed within said envelope and adapted to sustain an arc discharge therebetween, a predetermined amount of rare-earth halide enclosed by said envelope, said rare-earth halide when in melted state being light-transmitting and colorless, and the predetermined dimensions of said envelope and the predetermined amount of said halide enclosed by said envelope bearing such relationship to one another that during normal operation of said lamp, only a portion of said halide is vaporized and residual halide is melted and adheres to said envelope in colorless transparent form.

2. A high-pressure vapor-discharge adapted to be normally operated with a predetermined power input, said lamp comprising, a sealed elongated envelope of predetermined external and internal dimensions and formed of light-transmitting material having a high melting point, electrodes operatively disposed within said envelope and during lamp operation adapted to sustain an arc discharge therebetween, a predetermined amount of rare-earth halide enclosed by said envelope, said rare-earth halide when in melted state being light-transmitting and colorless, the predetermined dimensions of said envelope and

the predetermined amount of said halide enclosed by said envelope bearing such relationship to one another that during normal operation of said lamp, only a portion of said halide is vaporized and residual halide is melted and adheres to at least a portion of said envelope in colorless transparent form, and the arc discharge sustained between said lamp electrodes during lamp operation contacting melted halide adhering to said envelope to create a zone of local overheating between the arc and said melted halide, whereby during lamp operation the vapor pressure of said halide within said envelope is increased.

3. The lamp as specified in claim 2, wherein said rare-earth halide is at least one halide of the group consisting of cerium bromide and cerium iodide, said envelope encloses a predetermined amount of insert ionizable starting gas, and said envelope also encloses a predetermined amount of mercury.

4. The lamp as specified in claim 2, wherein said rare-earth halide is at least one halide of the group consisting of lanthanum bromide and lanthanum chloride, said envelope encloses a predetermined amount of inert ionizable starting gas, and said envelope also encloses a predetermined amount of mercury.

5. The lamp as specified in claim 2, wherein said lamp is adapted to be operated with said envelope in horizontal position, said melted halide collects during lamp operation as a pool in the bottom portion of said envelope, and a magnetic field producing means is positioned external to said lamp to depress the arc sustained between said electrodes during lamp operation to cause such arc to contact said pool of melted halide.

6. The lamp as specified in claim 2, wherein the predetermined interior dimensions of said envelope form a capillary discharge tube, said melted halide collects during lamp operation as a colorless transparent coating on the interior surface of said envelope, and the arc sustained between said electrodes during lamp operation contacts all portions of said melted halide coating.

7. The lamp as specified in claim 5, wherein external current in-leads supply electrical energy to said lamp, and one of said current in-leads passes above said lamp and constitutes said magnetic field producing means.

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