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Zollweg et al.

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[54] **DISCHARGE LAMP WHICH INCORPORATES DIVALENT CERIUM HALIDE AND CESIUM HALIDE AND A HIGH MERCURY LOADING**

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[52] **U.S. Cl.** **313/229,** 313/184, 313/225, 313/227

[51] **Int. Cl.** **H01j 61/20**

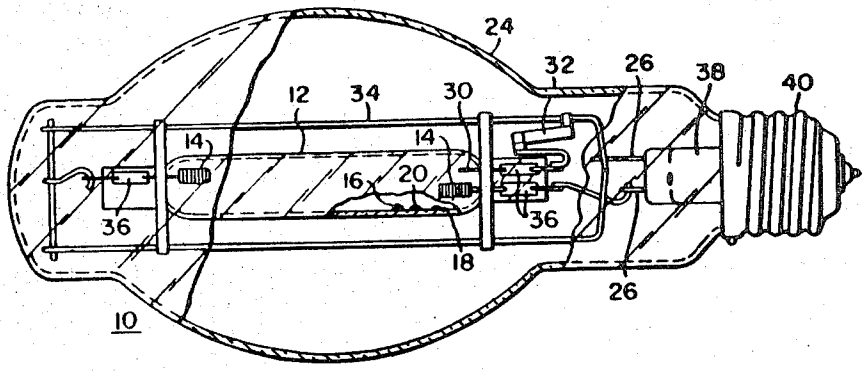
[58] **Field of Search** 313/184, 225, 227, 228, 229

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[57] **ABSTRACT**

Arc-discharge device wherein the discahrge-sustaining filling includes as essential elements predetermined amounts of at least one of praseodymium halide, neodymium halide and cerium halide plus cesium halide and sufficient mercury to provide an operating mercury-vapor pressure of from 3 to 15 atmospheres, in addition to the usual starting gas. The rare-earth metal halide provides a very efficient discharge and the cesium halide plus the high mercury loading permits a high efficiency to be obtained with a relatively low minimum envelope temperature. The ratio of total gram-atoms of halogen to total gram-atoms of metal in the praseodymium, neodymium or cerium halides is from about 1.8:1 to about 2.7:1, and this provides a very diffuse, stable discharge which improves the performance of the device. Other discharge-sustaining materials desirably are added to the foregoing essential constituents to modify the color of the discharge.

9 Claims, 2 Drawing Figures



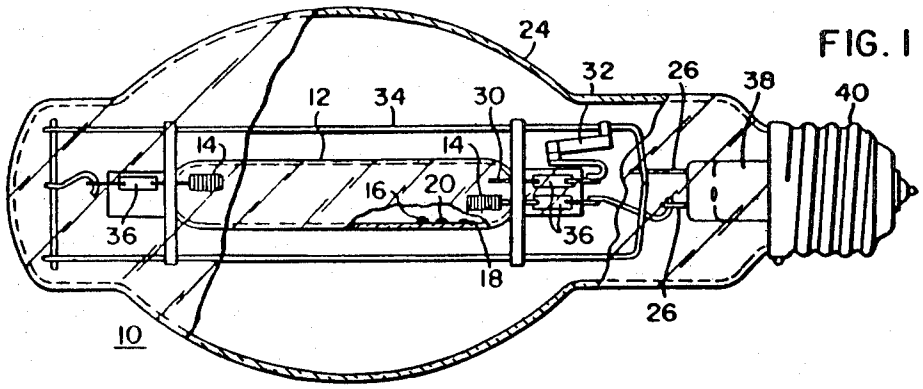

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10

FIG. 1

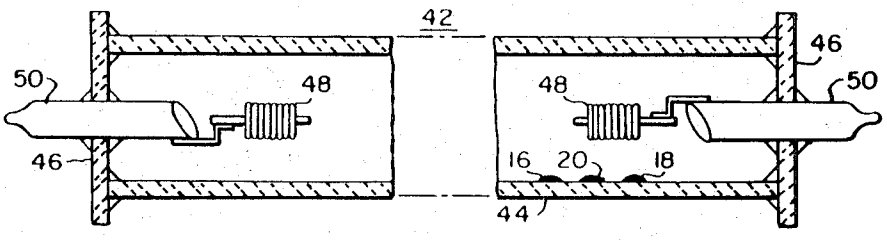

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18
44

FIG. 2

DISCHARGE LAMP WHICH INCORPORATES DIVALENT CERIUM HALIDE AND CESIUM HALIDE AND A HIGH MERCURY LOADING

CROSS-REFERENCE TO RELATED APPLICATION

The discharge device described in this application is an improvement over the discharge device described and claimed in copending application Ser. No. 243,711, filed Apr. 13, 1972, entitled "Discharge Lamp Which Incorporates Cerium and Cesium Halides and a High Mercury Loading", by the present inventors, and owned by the present assignee.

BACKGROUND OF THE INVENTION

This invention generally relates to discharge devices and, more particularly, to so-called metal halide discharge devices wherein predetermined amounts of selected discharge-sustaining materials are utilized in order to improve the performance of the device.

In U.S. Pat. No. 3,234,421 dated Feb. 8, 1966, is disclosed a so-called metal halide discharge lamp wherein selected metallic halides, particularly those of Group IA, IIA, IIB, and IIIA are incorporated into the device in order to modify the color of the discharge and the operating efficiency of same with respect to the generation of visible light.

In U.S. Pat. No. 3,334,261 dated Aug. 1, 1967, is disclosed a metal-halide discharge device which incorporates rare-earth metal halides in order to modify the discharge. In U.S. Pat. No. 3,407,327 dated Oct. 22, 1968, is disclosed a metal-halide discharge device which incorporates a filling of alkali metal halide and scandium halide. In U.S. Pat. No. 3,514,659, dated May 26, 1970, is disclosed a metal-halide lamp which incorporates a relatively small amount of cesium iodide in order to reduce the so-called reignition voltage, with the cesium halide being limited in amount so that it will not lower the arc temperature to a point where the emission lines of the primary light emitting metals are weakened. In U.S. Pat. No. 3,262,012 dated July 19, 1966 is disclosed a discharge device which utilizes cesium and sodium halides in addition to other rare-earth metal halides. The device is intended to operate on a conventional ballast and the mercury loading which is utilized is quite low.

In U.S. Pat. No. 3,398,312 dated Aug. 20, 1968, is disclosed a metal vapor lamp which includes sodium iodide and a small amount of free metal which reacts with any free iodine released during operation of the lamp.

SUMMARY OF THE INVENTION

An arc-discharge device comprises a sealed elongated light-transmitting envelope which encloses a predetermined volume. As is conventional, electrical lead-in conductors are sealed through the envelope and are electrically connected to electrodes which are operatively spaced apart a predetermined distance within the envelope. A discharge-sustaining filling is enclosed by the envelope and contains the following as essential constituents: a small charge of inert ionizable starting gas; mercury in predetermined amount as required, when fully vaporized, to produce an operating mercury vapor pressure of from 3 to 15 atmospheres; at least one of praseodymium halide, neodymium halide and cerium halide, excluding the fluoride, in total amount of from 2×10^{-7} to 2.5×10^{-4} gram mol/cm of spacing between the lamp electrodes, and preferably from 1.4×10^{-6} to 5.4×10^{-5} gram mol/cm of spacing between the lamp electrodes, with the ratio of total gram-atoms of halogen to total gram-atoms of metal in the praseodymium, neodymium and cerium halides being from about 1.8:1 to about 2.7:1; cesium halide excluding the fluoride, in amount of from 3.5×10^{-7} to 2.5×10^{-4} gram mol/cm of spacing between the lamp electrodes and preferably from 3.5×10^{-7} to 5.4×10^{-5} gram mol/cm of spacing between the lamp electrodes; and the molar ratio of total praseodymium halide, neodymium halide and cerium halide to cesium halide is from 4/1 to 1/2.5. Other additives desirably are included with the discharge sustaining filling, such as sodium halide, dysprosium halide and samarium halide, with these additional added halides present in predetermined amount.

BRIEF DESCRIPTION OF THE DRAWING

For a better understanding of the invention, reference may be had to the preferred embodiment, exemplary of the invention, shown in the accompanying drawings, in which:

FIG. **1** is a discharge lamp, shown partly in section, which incorporates a quartz inner envelope and a discharge-sustaining filling in accordance with the present invention; and

FIG. **2** is a modified form of discharge device showing only a sectional view of the inner arc tube which is formed of polycrystalline alumina or similar refractory envelope material and which incorporates a discharge-sustaining filling in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

With specific reference to the form of the invention illustrated in the drawing, the discharge device or lamp **10** is generally similar in construction to the usual high-pressure, mercury-vapor lamp and comprises a radiation-transmitting sealed inner envelope or arc tube **12** having electrodes **14** operatively disposed proximate either end thereof and operable to sustain a vapor discharge therebetween. A charge of mercury 16 and a small charge of inert ionizable starting gas such as 20 torrs of argon are contained within the inner envelope **12.** The charge of mercury **16** is present in predetermined amount as required, when fully vaporized as the sole discharge-sustaining constituent, to provide an operating mercury-vapor pressure of from 3 to 15 atmospheres as calculated on the basis of an average temperature for the vaporized mercury of 2000°K. This average temperature may vary somewhat depending upon the various discharge-sustaining constituents which are used and the lamp operating conditions, but this indicated figure is a representative average temperature for the vaporized mercury. Since the envelope volume is always known, the required amount of mercury to provide the proper operating conditions can readily be calculated. During operation of the device, the other discharge-sustaining materials may interact with the mercury to affect the actual operating pressure of the mercury and, in addition, the extreme temperature gradients from the actual arc to the envelope wall may have an effect on the actual pressure within the operating device. For this reason, it is more accurate to express the required amount of mercury as if that material, per

se, were the sole discharge-sustaining constituent, since the amounts of mercury placed into the arc tube are known and the resulting pressure as determined by the foregoing mercury vapor temperature, can readily be ascertained.

At least one of praseodymium halide, neodymium halide and cerium halide **18,** excluding the fluoride, is included within the arc tube **12** in total amount of from 2×10^{-7} to 2.5×10^{-4} and preferably from 1.4×10^{-6} to 5.4×10^{-5} gram mol/cm of spacing between the electrodes **14,** and as a specific example, the electrodes are spaced from each other by a distance of 7 centimeters and the arc tube **12** encloses a volume of 20 cubic centimeters. Also included within the arc tube is cesium halide **20,** excluding the fluoride, in amount of from 3.5×10^{-7} to 2.5×10^{-4} and preferably from 3.5×10^{-7} to 5.4×10^{-5} gram mol/cm of spacing between the electrodes **14.** The molar ratio of total praseodymium halide, neodymium halide and cerium halide to cesium halide is from 4/1 to 1/2.5. In accordance with the present invention, the ratio of total gram-atoms of halogen to total gram-atoms of metal in the praseodymium halide, the neodymium halide and the cerium halide is from about 1.8:1 to about 2.7:1. The normal stable valence state for these metals is a plus three, but in the case of the indicated halides, the metals also can exhibit a valence state of plus two. These metal halides can be dosed into the arc tube **12** either in the two-plus state or as a mixture of plus-two and plus-three states. Ratios of halogen to metal of less than 2:1 are obtained by dosing a small amount of the rare-earth metal with the indicated rare-earth metal halide. As a specific example, the atom ratio of halogen to rare-earth metal is 2.5:1.

A radiation-transmitting, sealed outer envelope **24** is spaced from and surrounds the arc tube and preferably the space between the arc tube **12** and the outer envelope **24** is evacuated. Electrical lead-in conductors **26** are sealed through both the inner arc tube **12** and the outer envelope **24** and serve to electrically connect the operating electrodes **14** to a conventional power source (not shown).

A starting electrode **30** is also included within the arc tube **12** and connects through a starting resistor **32** to one end of the electrical lead-in conductors **26.** The arc tube **12** is maintained in speced relationship from the outer envelope **24** by means of a conventional supporting frame **34.** Ribbon conductors **36** serve to facilitate hermetically sealing the lead-in conductors through the ends of the arc tube. The lead-in conductors are sealed through the outer envelope **24** by means of a conventional re-entrant stem press **38** and connect to a standard mogul base **40** to facilitate electrical connection to the power source. As a specific example, the lamp **10** as shown is designed to operate with the power input of 500 to 700 watts.

In the alternative embodiment **42,** as shown in FIG. **2,** the arc tube or envelope **44** is a high density sintered polycrystalline alumina body which has alumina end caps **46** sealed thereto. The electrodes **48** are operatively positioned proximate the envelope ends. At the ends of the arc tube **44** there are provided exhaust and fill tubulations **50** which also serve the function of supporting the electrodes **48.** In accordance with the present invention, the mercury **16,** at least one of praseodymium iodide, neodymium iodide and cerium iodide **18** and also cesium iodide **20** are included within the arc tube **44** in predetermined amount and halogen to rare-earth metal ratio as specified for the previous embodiment, along with the small charge of inert ionizable starting gas. To complete this embodiment as an operative device, the arc tube **44** would normally be included within an outer envelope as in the embodiment shown in FIG. **1,** and the general construction of such a device is well known.

As outlined hereinbefore, the essential constituents which comprise the discharge-sustaining filling are the small charge of inert ionizable starting gas, mercury as required to provide an operating vapor pressure of mercury per se of from 3 to 15 atmospheres, at least one of praseodymium halide, neodymium halide and cerium halide, excluding the fluoride, in predetermined amount and halogen to rare-earth metal ratio and cesium halide, excluding the fluoride, in predetermined amount, with a specified relative molar ratio of these rare-earth metal halides to cesium halide. The functioning of the mercury is to provide adequate voltage drop or loading between the electrodes and in conjunction with the cesium halide, the relatively high mercury vapor pressure and cesium halide function to lower the minimum envelope temperature or so-called "cold-spot" temperature at which optimum lamp operating efficiency is obtained. The specified rare-earth metal halides function to produce an extremely efficient discharge, and cerium halide is preferred. As a specific example, for an arc tube which encloses a volume of approximately 20 cubic centimeters and an electrode spacing of 7 centimeters, mercury included in amount of approximately 200 mg. will provide a mercury operating pressure of approximately 8 atmospheres. Along with the mercury filling are included cerium diiodide in amount of 10 milligrams mixed with cerium triiodide in amount of 10 milligrams, and cesium iodide (CsI) in amount of 10 milligrams. Alternatively, a similar mixture of praseodymium diiodide and triiodide in total amount of 20 milligrams or a similar mixture of neodymium diiodide and triiodide in total amount of 20 milligrams can be used to replace the cerium iodide in the foregoing example. These rare-earth metal iodides can be mixed, if desired.

In order to improve the color appearance and color rendering properties which are obtained from a discharge-sustaining filling as described hereinbefore, it is highly desirable to include one or more of the following halides, excluding the fluorides: sodium halide, dysprosium halide and/or samarium halide. The dysprosium halide and saramium halide are preferably dosed as the dihalide. The sodium halide provides radiations in the yellow-orange region of the visible spectrum, dysprosium halide provides a red and blue emission and samarium halide provides a bluish-white emission. The supplemental rare-earth halides may be regarded as a partial substitute for the praseodymium, neodymium and/or cerium halides, although these supplemental halides desirably are present in total amount of at least 7×10^{-7} and preferably at least 1.4×10^{-6} gram mol/cm of electrode spacing. The sodium halide may be regarded as a partial substitute for the cesium halide, although the cesium halide should always be present in amount of at least 3.5×10^{-7} gram mol/cm of electrode spacing. The sodium halide desirably is present in amount of at least 2.5×10^{-7} and preferably at least 3.5×10^{-7} gram mol/cm of electrode spacing. Preferably, the supplemental rare-earth halides, as outlined herein-

before, namely dysprosium halide and samarium halide, are present in gram mol amount which does not substantially differ from the gram mol amounts of the praseodymium, neodymium and/or cerium halides and the mol ratio of supplemental rare-earth halide to these required halides should not exceed 5/1. Preferably the sodium halide is present in gram mol amount which does not substantially differ from the gram mol amount of the cesium halide and the mol ratio of sodium halide to cesium halide should not be greater than 5/1.

As stated hereinbefore, in order to achieve a usable minimum envelope temperature, the pressure of the mercury vapor should be present in such an amount that if used alone as the discharge-sustaining filling, the mercury vapor pressure in an operating device would be from 3 to 15 atomospheres. For an arc tube having a volume of approximately 20 cc as described in the preferred embodiment, the mercury dosing or loading should be from 75 milligrams to 375 milligrams. Preferably, the mercury vapor pressure during operation of the device should be from 4 atmospheres to 10 atmospheres which will require a mercury dose of from 100 mgs. to 250 mgs. (5 mgs/cc to 12.5 mgs/cc) for the preferred embodiment as described hereinbefore.

As disclosed in copending application Ser. No. 243,711 filed Apr. 13, 1972, the rare-earth metal halide provides a very efficient discharge and the cesium halide plus the high mercury loading permit a high efficiency to be obtained with a relatively low minimum envelope temperature. This permits a practical lamp to be fabricated which operates with excellent efficiency and a good color appearance. The mechanism by which this is achieved is not completely understood, but it appears that the increased mercury pressure in combination with the cesium halide increases the amount of the desired radiating species in the arc, and provides a more diffuse discharge mode which has a lower, more nearly optimum arc temperature. The resulting broader arc has less tendency to bow during operation and even when it does, this broader arc is less destructive to the envelope becuase it has a lower temperature and is less concentrated.

Since the normal stable valence state for cerium reacted with halogen is plus three, it is assumed that the cerium iodide, as vaporized in the arc tube, is in the trivalent state. Nevertheless, when the atom ratio of halogen to metal in the dosed material is from about 1.8:1 to about 2.7:1, in accordance with the present invention, the resulting discharge is even more diffuse and more stable. As a specific example, if cerium is dosed as the triiodide in the foregoing example, the discharge occupies a cross-sectional area, at the midportion of the arc tube, of about 6.5 mm diameter, as viewed through a filter. When the cerium is dosed in such manner that the atom ratio of halogen to metal is from about 1.8:1 to about 2.7:1, the resulting discharge is even more diffuse and occupies a cross-sectional area of about 13 mm diameter, as viewed at the midportion of the arc tube. In addition, the resulting discharge, when stabilized exhibits a positive resistance characteristic and near unity power factor. This simplifies ballasting and can permit normal operation of the device without the usual inductive current-limiting ballast. An otherwise identical lamp, but dosed with the triiodide, will exhibit a negative resistance characteristic and a power factor of less than unity. While the foregoing results are reported for cerium halide, equivalent results are obtained when the arc tube **12** is dosed with neodymium halide or praseodymium halide or any mixtures thereof with the cerium halide.

Other additional supplemental discharge-sustaining fillings can be used, if desired, further to modify the discharge. Examples of such additional halides, excluding the fluoride of course, are holmium halide, scandium halide, gadolinium halide, and indium halide. Also europium dihalide or ytterbium dihalide can be used. The holmium provides red and blue supplemental radiations, the scandium provides strong blue and supplemental other radiations, the gadolinium provides a blue supplemental radiation and the indium provides blue supplemental radiation. If these additional additives are used, the molar ratio of the holmium, scandium, europium, ytterbium and the gadolinium halides with respect to the praseodymium, neodymium and/or cerium halide should be less than about 5/1 and the molar ratio of the indium halide to the indicated rare-earth metal halide should be less than about 1/1. As a matter of of practicability, any of these additives should be present in amount of at least about 2×10^{-7} and preferably about 1.4×10^{-6} gram mol/cm of spacing between the arc tube electrodes, although lesser amounts can be used if desired. Preferably, the supplemental additives are generally used in gram mol amounts not substantially different from the gram mol amounts of praseodymium, neodymium and/or cerium halides, except for the sodium halide supplemental additive which desirably is used in gram mol amount not substantially different from the gram mol amount of cesium halide.

While the foregoing examples have considered the iodides, it should be understood that the bromides or the chlorides in equivalent gram mol amount can be substituted therefor. Alternatively, any mixture of iodide, bromide and/or chloride can be utilized if desired.

A particularly attractive combination of discharge-sustaining fillings is a combination of cerium trihalide, cerium dihalide, sodium halide, samarium as the dihalide, and cesium halide. As a specific example, for an arc tube having an electrode spacing of 7 cm. and enclosing a volume of 20 cc., the arc tube is dosed with 200 mg. mercury, 4 mg. cerium diiodide, 4 mg. cerium triiodide, 5 mg. sodium iodide, 15 mg. samarium diiodide and 5 mg. cesium iodide. Argon starting gas is used at a pressure of 20 torrs. Such an embodiment operates with an efficiency of 140 lumens per watt when operated with a minimum envelope temperature of 560°C. The foregoing so-called dosing will provide a mercury vapor pressure of about 8 atmospheres, the cerium iodide and cesium iodide are present in amount of about 2 to 3×10^{-6} gram mol/cm of electrode spacing, and the samarium iodide and sodium iodide are present in amount of about 5×10^{-6} gram mol/cm of electrode spacing. The discharge is stable and diffuse and approximates a white color and the color rendition of illuminated objects is good.

The total amount of iodide dosing in the foregoing specific lamp combination is 33 mgs. It has been found that this total iodide dosing can be substantially reduced without materially affecting the performance of the lamp. As an example, for the foregoing specific lamp, the total amount of iodide dosing can be reduced to 10 mgs. or even less, while still maintaining the total mercury dosing at about 200 mgs. For best performance, however, the relative gram mol amounts of the iodide additives should be maintained at about the

same relative molar ratio. More specifically, the relative amounts of the indicated iodides are preferably maintained in about the following relative gram mol proportions: total cerium iodide, 2 to 3; cesium iodide, 2 to 3, samarium iodide, 4 to 6.

What we claim is:

1. An arc-discharge device comprising a sealed elongated light-transmitting envelope which encloses a predetermined volume, electrical lead-in conductors sealed through said envelope and electrically connected to electrodes which are operatively spaced apart a predetermined distance within said envelope, a discharge-sustaining filling enclosed by said envelope and having the following as essential constituents: a small charge of inert ionizable starting gas; mercury in predetermined amount as required, when fully vaporized as the sole discharge-sustaining constituent, to provide an operating mercury-vapor pressure of from 3 to 15 atmospheres as calculated on the basis of an average mercury vapor temperature of 2000°K, at least one of praseodymium halide, neodymium halide and cerium halide, excluding the fluoride, in total amount of from 2×10^{-7} to 2.5×10^{-4} gm mol/cm of spacing between said electrodes; cesium monohalide, excluding the fluoride, in amount of from 3.5×10^{-7} to 2.5×10^{-4} gm mol/cm of spacing between said electrodes; the molar ratio of said praseodymium halide, neodymium halide and cerium halide to said cesium halide being from 4/1 to 1/2.5; and the ratio of total gram-atoms of halogen to total gram-atoms of metal in said praseodymium halide, said neodymium halide and said cerium halide being from about 1.8:1 to about 2.7:1.

2. The arc-discharge device as specified in claim 1, wherein said praseodymium halide, neodymium halide and cerium halide are present in total amount of from 1.4×10^{-6} to 5.4×10^{-5} gm mol/cm of spacing between said electrodes; and said cesium halide is present in amount of from 3.5×10^{-7} to 5.4×10^{-5} gm mol/cm of spacing between said electrodes.

3. The arc-discharge device as specified in claim 2, wherein said mercury is present in predetermined amount as required when fully vaporized to produce an operating mercury vapor pressure of from about 4 to about 10 atmospheres.

4. The arc-discharge device as specified in claim 3, wherein said halides are the iodides.

5. The arc-discharge device as specified in claim 3, wherein said mercury is present in amount of from 5 to 12.5 mgs/cc of said predetermined volume of said envelope.

6. The arc-discharge device as specified in claim 1, wherein there is also included within said envelope as supplemental discharge-sustaining filling at least one halide, excluding the fluoride, of sodium halide, dysprosium dihalide, and samarium dihalide, the molar ratio of said dysprosium halide and said samarium halide to said praseodymium and neodymium and cerium halide being less than about 5/1, and the molar ratio of said sodium halide to said cesium halide being less than about 5/1.

7. The arc-discharge device as specified in claim 6, wherein said dysprosium halide and said samarium halide are present in amount of at least 7×10^{-7} gm mol/cm of spacing between said electrodes, and said sodium halide is present in amount of at least 2.5×10^{-7} gm mol/cm of spacing between said electrodes.

8. The arc-discharge device as specified in claim 6, wherein said halides are the iodides.

9. The arc-discharge device as specified in claim 8, wherein said mercury vapor pressure is about 8 atmospheres, and said cerium iodide, said cesium iodide, said samarium iodide and said sodium iodide are present in about the following proportions, as expressed in terms of relative gram mol amounts: cerium iodide, 2 to 3; cesium iodide, 2 to 3; samarium iodide, 4 to 6; and sodium iodide, 4 to 6.

9. The arc-discharge device as specified in claim 8, wherein said mercury vapor pressure is about 8 atmospheres, and said cerium iodide, said cesium iodide, said samarium iodide and said sodium iodide are present in about the following proportions, as expressed in terms of relative gram mol amounts: cerium iodide, 2 to 3; cesium iodide, 2 to 3; samarium iodide, 4 to 6; and sodium iodide, 4 to 6.

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