June 24, 1969 D. A. LARSON 3,452,238

METAL VAPOR DISCHARGE LAMP

Filed Dec. 5, 1966 Sheet 1 of 2

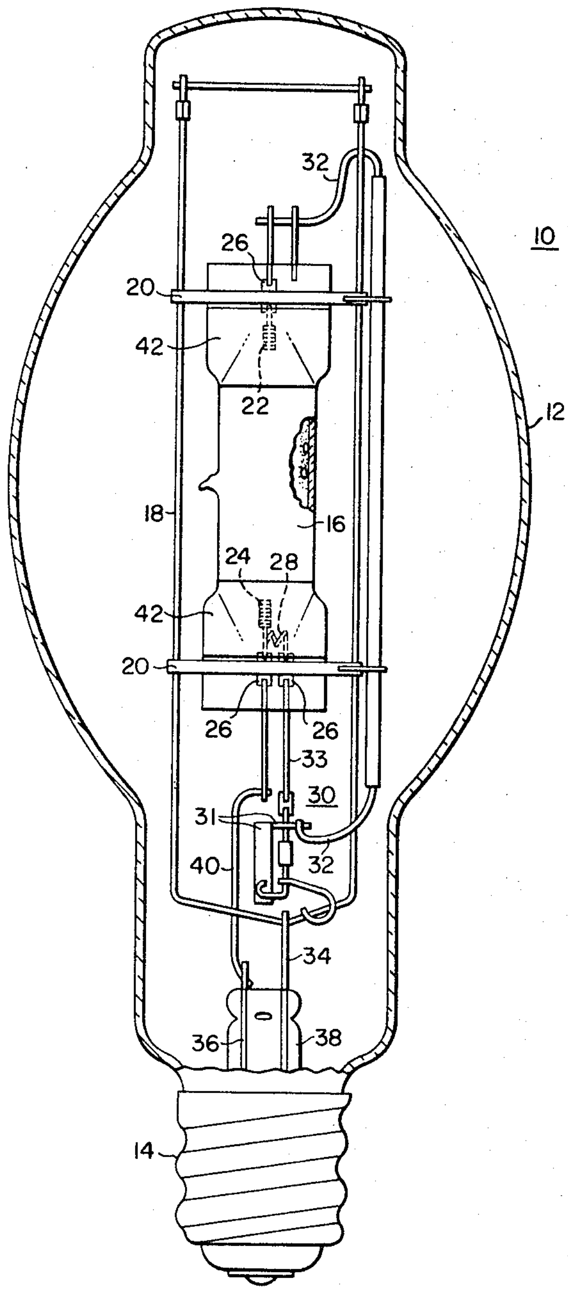

FIG. 1.

WITNESSES

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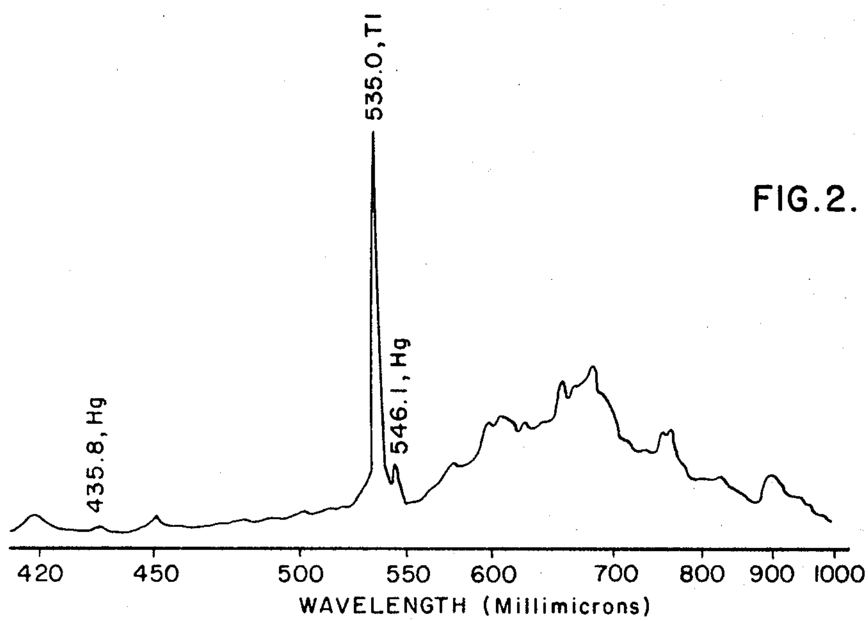
535.0, Tl
546.1, Hg
435.8, Hg
420
450
500
550
600
700
800
900
1000
WAVELENGTH (Millimicrons)

FIG. 2.

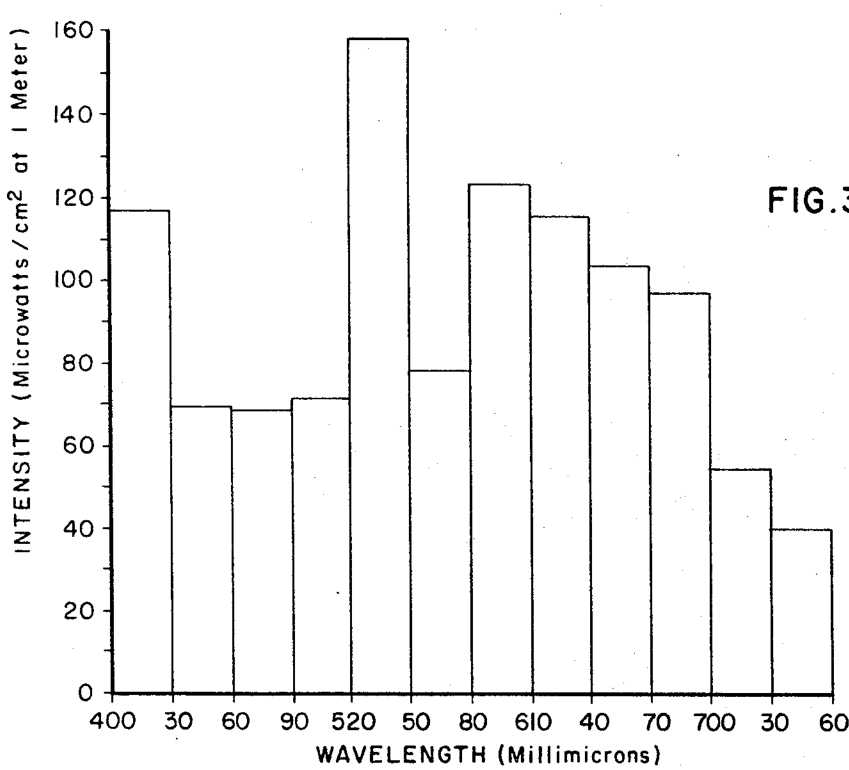
INTENSITY (Microwatts / cm2 at 1 Meter)
160
140
120
100
80
60
40
20
0
400
30
60
90
520
50
80
610
40
70
700
30
60
WAVELENGTH (Millimicrons)

FIG. 3.

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METAL VAPOR DISCHARGE LAMP

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U.S. Cl. 313—229 2 Claims

ABSTRACT OF THE DISCLOSURE

This high-pressure, mercury-vapor, discharge lamp employs a discharge sustaining filling of selected quantities of mercury, thallium, dysprosium and iodine along with a small quantity of insert starting gas to provide a lamp which exhibits good efficiency and excellent color rendition.

This invention relates to high-pressure mercury discharge lamps of the so-called "additive" type and more particularly to an additive type discharge lamp of significantly improved maintenance and superior color rendition particularly in the red spectral region.

The high-pressure mercury-vapor discharge lamp has become increasingly familiar as the highly efficient bluish-white light that brightens many of the highways and city streets across the nation. The mercury lamp has developed slowly but steadily into a highly efficient and reliable long-life lamp. One great disadvantage of the mercury lamp, however, is the characteristic blue-white light which it emits and its extremely poor color rendition. More recently the addition of metal halides to the mercury discharge singly or in combination to produce the spectral characteristics of the metals have permitted efficiency increases up to 100% to be obtained as well as radical improvements in color with increased lamp efficiencies of 50% and more. Many difficulties have been encountered with respect to metal additives which, from their spectral properties, would appear to be desirable additives, either because they chemically attack the quartz envelope or have vapor pressures which are too low at reasonable envelope temperatures. Most commercially successful additive lamps have included sodium generally in the form of iodide in the discharge sustaining filling because of the significant increase in efficiency provided by that additive. Of particular note is a lamp which includes sodium, indium and thallium iodides as additives, and has a comparatively white appearance and an efficiency of 80 to 85% lumens per watt.

The use of sodium iodide in a lamp is not without difficulties and has created three specific problems. The lamps having sodium iodide in the discharge tend to be more difficult to start. The sodium, during lamp-life, disappears from the discharge resulting in a color shift and a voltage rise during that life and, in addition, some of the discharge filling attacks some lamp parts to cause darkening. Furthermore, since the sodium is very active chemically, the normal oxide type emission material could not be used in the electrodes. Thus far only tungsten has proven satisfactory as an electrode material in a lamp containing sodium, and the elimination of the emission material from the electrode causes an increase in lamp starting voltage. Although it has been known that a thallium iodide addition to the discharge sustaining filling will, similarly to sodium iodide, improve efficiencies, the light emitted from such a lamp has generally had a greenish color due to the high green emission of the thallium.

The foregoing objections have now been overcome by the production of a lamp having fine color, excellent color rendition, particularly in the red region of the spectrum,

along with high efficiency. The lamp of the present invention provides an unexpected extension to the growth of the metal halide family from the early, almost monochromatic, green of thallium iodide and yellow-green of sodium-thallium iodide with improved color and the whiter source obtained by combining them with indium iodide. The new lamp eliminates the use of sodium iodide along with its characteristic detriments to lamp operation, maintains a relatively high level of efficiency over a long period of time and provides a color rendition that compares favorably with the cool-white fluorescent lamp commonly used for office and retail business illumination. This remarkably improved lamp has resulted from the addition of selected amounts of thallous iodide and a rare earth halide, namely dysprosium iodide, to the mercury discharge.

An object of this invention is to provide a high-pressure discharge lamp satisfactory for the illumination of commercial businesses, offices and shops in addition to the illumination of streets, highways and factories.

Another object of this invention is the production of a high-pressure mercury-vapor discharge lamp which exhibits a spectrum consisting of a large number of lines throughout the visible region and vastly improved color rendition.

A further object of the present invention is to provide a high-pressure mercury-vapor discharge lamp wherein the color coordinates of the lamp approximate that of the cool-white fluorescent lamp with an even better color rendering ability.

A still further object of the present invention is the provision of a high-pressure mercury-vapor discharge lamp in which the elements sustaining the discharge do not attack the quartz envelope and there is no significant color shift or operating or starting voltage rise during the life of the lamp.

The foregoing objects are accomplished in accordance with the present invention in a high-pressure mercury-vapor discharge lamp by employing a discharge sustaining filling therein which consists essentially of a quantity of mercury, which when fully vaporized during normal operation of the lamp will provide a predetermined mercury vapor pressure in said arc tube, plus selected quantities of thallium, dysprosium and iodine wherein, upon full vaporization of said mercury and substantial vaporization of said thallium, dysprosium and iodine the effect of a spectral continuum is produced in the visual range which includes a red component of at least 10% of the total output of said lamp.

The foregoing objects as well as many of the attendant advantages of the present invention will become more readily apparent and better understood as the following detailed description is considered in connection with the accompanying drawings, in which:

FIGURE 1 is a side elevation, with part of the outer envelope broken away, of a discharge lamp constructed in accordance with the present invention;

FIG. 2 is a reproduction of the spectrum produced by the radiations emitted from a lamp constructed in accordance with the present invention; and

FIG. 3 is a spectral energy distribution diagram illustrating the relative intensities of emission at the various wavelengths within the visual spectrum produced by a lamp constructed in accordance with the present invention.

Referring now in detail to the drawings, and more particularly to FIG. 1, there is shown the general arrangement of a high-pressure mercury vapor discharge lamp into which the additive materials of the present invention are placed.

The lamp, generally designated **10**, includes a radiation-transmitting, sealed outer envelope **12** which is sealed to a standard mogul base **14**. Mounted within the outer envelope **12** and spaced therefrom is an inner envelope or arc tube **16**. The arc tube **16** is mounted within outer envelope **12** by a conventional frame **18** and a pair of straps **20**. Sealed within the inner envelope or arc tube **16** and disposed at opposite ends thereof are a pair of tungsten operating electrodes **22** and **24**. The electrodes **22** and **24** are sealed through the opposite ends of the arc tube **16** by conventional ribbon seals **26**. A starting coil **28** is connected to electrode **24** through a starting switch mechanism **30** which also connects a lead-in conductor **32** to electrode **22**. The starting circuit **30** is specifically described in copending application Ser. No. 379,109, filed June 30, 1964 for "Discharge Lamp" by Hugh D. Frazer and Melvin C. Unglert and owned by the assignee of the present invention. Briefly, a pair of lead-in conductors **34** and **36** connect the lamp through a re-entrant stem **38** to standard mogul base **14**. Lead-in conductor **34** connects through the frame **18** to the starting switch mechanism **30** while lead-in conductor **36** connects directly through a lead **40** to electrode **24**. To maintain sufficiently high temperatures in the normally coldest areas of the arc tube (i.e. that portion behind each of the electrodes) a heat retaining coating **42** of, for example, a zirconium oxide-silicon dioxide coating, which is applied as a suspension with nitrocellulose, is adhered to that portion of each end of the arc tube surrounding an electrode. This end coating **42** maintains a cold spot temperature within the arc tube of not less than 750° C.

When the above-described lamp is operated the bi-metal switch mechanism, generally designated **30**, cuts out the heater coil **28** after 10 to 20 seconds and allows the arc to operate normally from the main electrodes. The lamp current passes through the bi-metal at all time, heating the bi-metal and thereby keeping the switch opened. The starting or heater coil **28** provides additional heat to warm the lamp under cold starting conditions and also acts as an emitter to help start the lamp while the bi-metal and link **31** is in contact with the lead **33** to heater coil **28**.

It has generally been found that the addition of sodium iodide plus thallium iodide to a lamp containing a rare earth increases the luminous efficiency considerably but that the contribution to the spectrum of the rare earth additive is reduced substantially, thus diminishing considerably the desired color rendering properties of the lamp.

It has further been found that when thallium iodide is employed in a discharge that the predominance of the green spectral emission generally produces a poor lamp with respect to color rendition, but high efficiency.

Quite unexpectedly, it has been found that when thallium in the form of thallious iodide is added to the mercury-dysprosium discharge that the expected significant reduction in red emission does not occur but, in fact, there is a distinct increase in the amount of red emission. Additionally, the considerable reduction in efficiency that would be expected in a mercury-dysprosium-thallium lamp as opposed to a simple mercury-thallium lamp does not materialize.

Mercury-vapor lamps of this type are generally operated at 400 watts and in the embodiment illustrated in FIG. 1 the arc tube generally encloses a volume of 14 cc. with an electrode spacing of approximately 5.2 centimeters. This conventional arc tube contains a starting gas, of, for example, argon at a pressure of about 20 to 25 torr and a quantity of mercury which in this lamp is about 32 to 40 mg. When operating at rated wattage and with a cold spot temperature of not less than 750° C. the mercury is completely vaporized and reaches a pressure of several atmospheres. At this pressure the lamp voltage and current are approximately 135 volts and 3.2 amperes respectively. To these basic components

about 1 to 15 mg. of thallium iodide (TlI), about 1 to 4 mg. of dysprosium metal and about 4 to 17 mg. of mercuric iodide are added to produce the lamp of the present invention.

It will be seen then that for arc tubes of other configurations the necessary constituents required to produce the lamp of the present invention are from about 5.8 to 8.0 mg. of mercury per centimeter of arc length, from about 0.2 to 0.8 mg. of dysprosium metal per centimeter of arc length, from about 0.2 to 3.0 mg. of thallium iodode per centimeter of arc length and from about 0.8 to 3.2 mg. of mercuric iodide per centimeter of arc length. Excessive but small amounts of thallium iodide or dysprosium metal, which do not vaporize, will not significantly affect the lamp output. However, it is preferable if the quantities do not exceed that amount which will vaporize to a great degree to preclude the possibility of buildup on the arc tube walls which could eventually obscure the emission. A lamp operated with these additives will have present in the discharge sustaining filling, when operating, thallium, dypsprosium and iodine in such gram-atom proportions of total thallium-dysprosium to total iodine that TlI and DyI_3 will be formed and a spectrum will be produced substantially as shown in FIG. 2 having a spectral energy distribution substantially as shown in FIG. 3. The spectrum shown in FIG. 2 is that recorded by employing an RCA 7102 photomultiplier and it will be seen that the radiation is fairly uniform throughout the visible region of the spectrum except for the peak at 535 millimicrons which is the radiation from the thallium spectrum and clusters of lines at 420 and 600 to 700 millimicrons from the dysprosium. This comparatively uniform visible spectral distribution is responsible for the excellent color rendition of all colors and especially the reds, blues and violets which were somewhat deficient in previous lamp designs. It will be further noted that for the first time a lamp having good source color and color rendition as well as reasonably high efficiency and which does not include sodium iodide as one of the constituents is provided. Previously, such mixtures as sodium-thallium, sodium-thallium-indium, sodium-thallium-thorium and sodium-scandium in halogen forms have been used in lamps. In each case, sodium iodide is required to add supplemental output or color. When sodium iodide is present in a lamp of this type, it brings with it the problems previously detailed. The present lamp uses only thallium and dysprosium iodides or thallium iodide and dysprosium metal and still yields an initial 100 hour efficiency of 80+ lumens per watt. The elimination of sodium iodide also permits wider latitude in the choice of arc tube size parameters since the loss of sodium to the quartz walls is no longer a problem. Other advantages of eliminating sodium include: more uniform color stability of these lamps during life, an increase in lamp-life, and greater uniformity and reliability of product through elimination of highly reactive sodium iodide from the arc tube envelope.

Of course, it is not necessary that the dysprosium be added to the mercury discharge as indicated in the above specific example. The dysprosium may be added in the form of dysprosium iodide rather than as dysprosium metal thus eliminating the requirement for mercuric iodide and accordingly necessitating an increase in the initial charge of mercury. A lamp of this type may be operated by providing a discharge sustaining filling which includes from 6.8 to 8.0 mg. of mercury per centimeter of arc length, from 0.67 to 2.68 mg. of dysprosium iodide per centimeter of arc length and from 0.2 to 3.0 mg. of thallium iodide per centimeter of arc length. The principal reason for initially charging the lamp with dysprosium in the form of a metal is the difficulty surrounding the handling of the highly hygroscopic dysprosium iodide. Although these difficulties are not insurmountable present practice requires that the dysprosium metal lamp be seasoned for approximately 24 hours to convert the dysprosium metal and mercuric iodide to dysprosium iodide and mercury in the discharge.

Additive lamps have been produced, as for example a lamp including mercuric iodide and thorium, which have a maximum spectral emission of about 5% in the red. The lamp of the present invention provides almost a perfect red rendition by displaying a spectrum as illustrated in FIGS. 2 and 3. In every test of a lamp constructed in accordance with the present invention the percentage of spectral emission in the red areas of the visible spectrum (i.e., in excess of 6100 angstroms) has been in excess of 10% with an average of close to 15% and in some instances a spectral emission in the red area of from 17% to 20%. As will be seen from the foregoing and with reference to FIGS. 2 and 3, the lamp of the present invention provides a substantial continuum in the visual range of the spectrum with a significant output in the red-orange above 6100 angstrom units. Such color characteristics should extend the use of additive lamps beyond the field of factory, street and floodlighting to the area of commercial lighting. This light source should be acceptable where color rendition and appearance are important, and perhaps even more acceptable than any other source in these areas, especially when a beautiful rendition of the red colors is important.

It should be understood that minor amounts of other metals and metal halides may be added to the discharge sustaining filling to produce desired minor changes in color appearance without departing from the scope of this invention.

Since numerous changes may be made in the above-described apparatus and different embodiments of the invention may be made without departing from the spirit thereof, it is intended that all matter contained in the foregoing description or shown in the accompanying drawings, shall be interpreted as illustrative and not in a limiting sense.

I claim as my invention:

1. An improved discharge lamp comprising:

(a) a radiation transmitting elongated arc tube enclosing a predetermined volume;

(b) arc supporting electrodes disposed within said arc tube proximate the ends thereof and defining a predetermined arc length;

(c) lead-in conductors connected to said electrodes and sealed through said arc tube; and

(d) a discharge sustaining filling within said arc tube which initially consists essentially of a quantity of mercury which when fully vaporized during normal operation of said lamp will provide a predetermined mercury vapor pressure in said arc tube plus selected quantities of thallium iodide, mercuric iodide, and dysprosium metal, wherein upon full vaporization of said mercury and substantial vaporization of said thallium iodide and dysprosium metal a spectral continuum is produced in the visual range which includes a red component of at least 10% of the total output of said lamp, said mercury being initially present in an amount of from about 5.8 to 8.0 mg. per centimeter of arc length, said thallium iodide being initially present in an amount of from about 0.2 to 3.0 mg. per centimeter of arc length, said mercuric iodide being initially present in an amount of from about 0.8 to 3.2 mg. per centimeter of arc length, and said dysprosium metal being initially present in an amount of from about 0.2 to 0.8 mg. per centimeter of arc length.

2. An improved discharge lamp comprising:

(a) a radiation transmitting arc tube enclosing a predetermined volume;

(b) arc supporting electrodes disposed in said arc tube proximate the ends thereof and defining a predetermined arc length of approximately 5.2 centimeters;

(c) lead-in conductors connected to said electrodes and sealed through said arc tube; and

(d) a discharge sustaining filling within said arc tube consisting essentially of from about 30 to 40 milligrams of mercury, from about 1 to 4 milligrams of dysprosium metal, from about 1 to 15 milligrams of thallium iodide, and from about 4 to 17 milligrams of mercuric iodide, wherein upon full vaporization of said mercury and substantial vaporization of said thallium and dysprosium a substantially white light is produced having a red component of at least 10% of the total visible output of said lamp.

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R. F. HOSSFELD, *Assistant Examiner.*

U.S. Cl. X.R.

313—184, 228