United States Patent [19]

Waymouth et al.

[11] **3,868,525**

[45] **Feb. 25, 1975**

[54] **METAL HALIDE DISCHARGE LAMP HAVING A PARTICULAR RATIO OF HALOGEN ATOMS TO MERCURY ATOMS**

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[22] Filed: **Mar. 26, 1969**

[21] Appl. No.: **810,490**

Related U.S. Application Data

[63] Continuation of Ser. No. 209,974, July 12, 1962, abandoned.

[52] **U.S. Cl.** **313/184,** 313/217, 313/225, 313/229

[51] **Int. Cl.** **H01j 61/18**

[58] **Field of Search** 313/184, 217, 218, 25, 313/225, 227, 229

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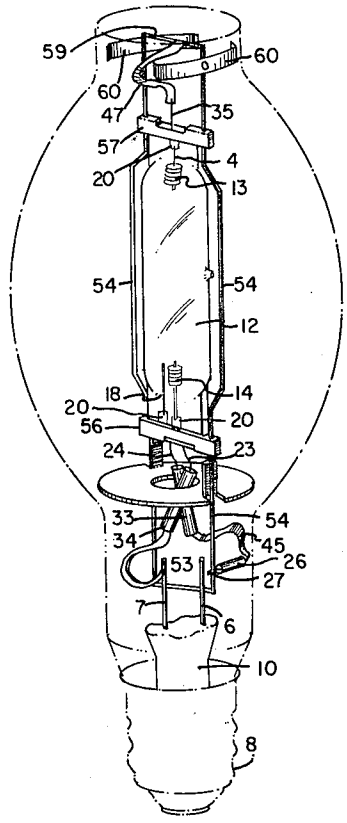
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[57] **ABSTRACT**

A high pressure electric discharge device having an arc tube containing halogen and mercury together with a light emitting metal. The ratio of atoms of these materials is maintained between 0.08 and 0.75 to attain an almost complete forest of spectral lines appearing generally less than about 5A apart.

12 Claims, 2 Drawing Figures



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SHEET 1 OF 2

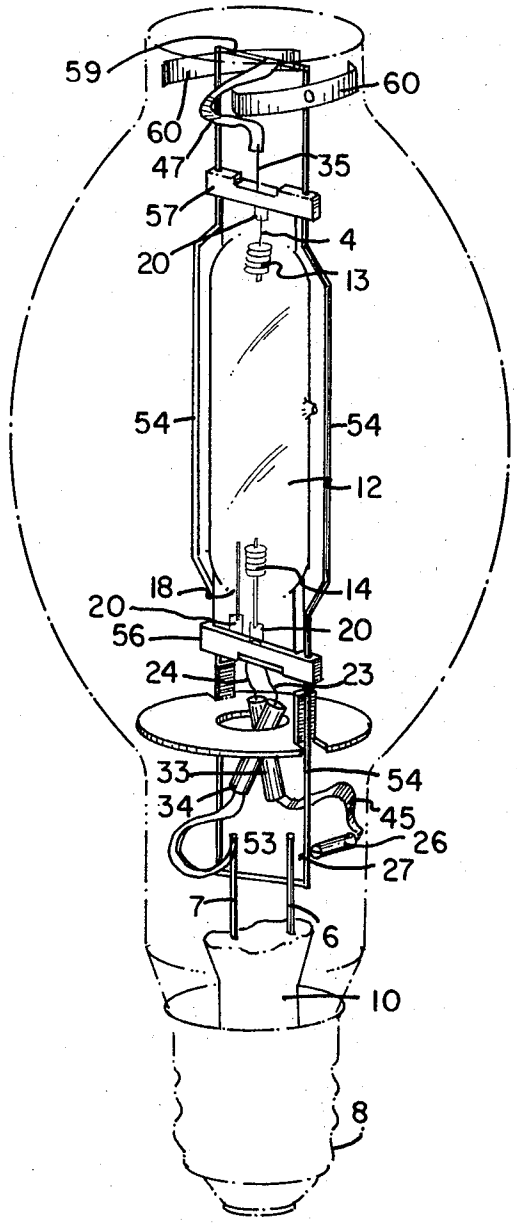


FIG. 1

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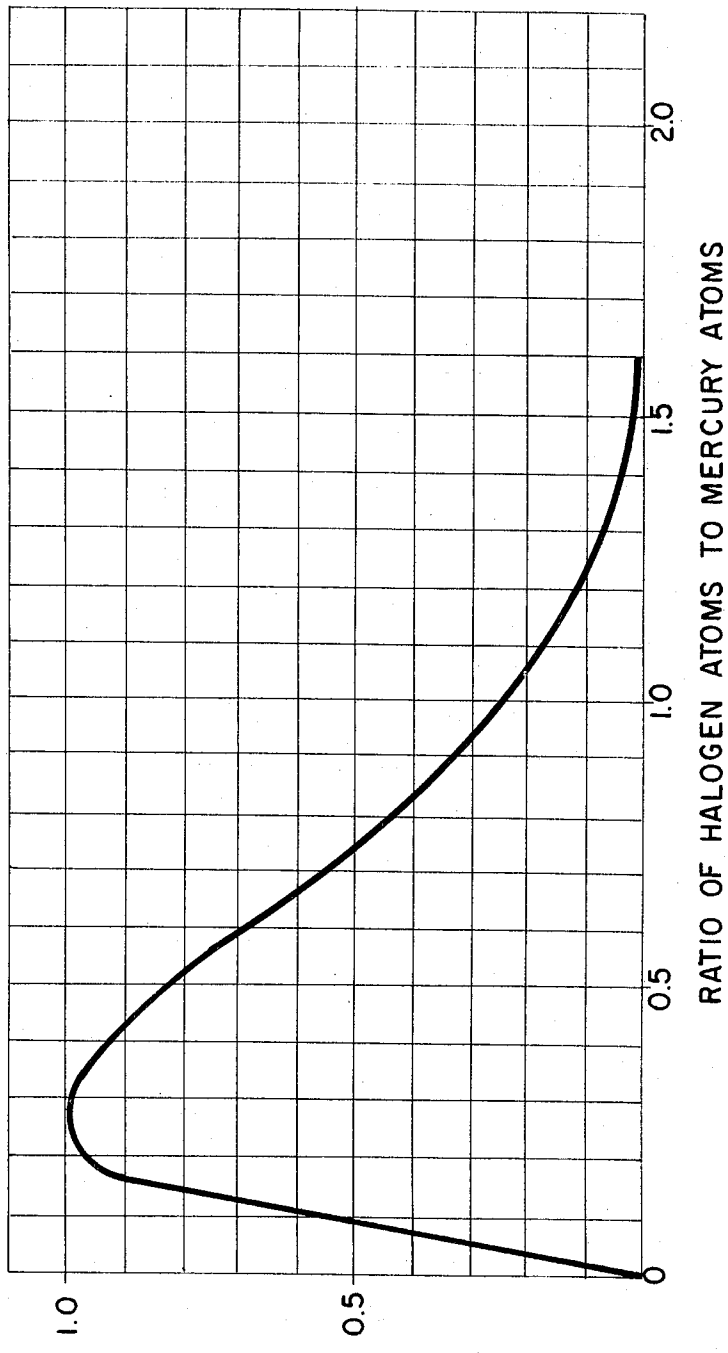


FIG. 2

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METAL HALIDE DISCHARGE LAMP HAVING A PARTICULAR RATIO OF HALOGEN ATOMS TO MERCURY ATOMS

This application is a continuation of our application, Ser. No. 209,974 filed July 12, 1962, and now abandoned.

This invention relates to high pressure electric discharge devices and particularly to the production of a white light from such devices.

High pressure electric discharge devices are well known to the art, however white light has never been obtained from practical commercial applications of such devices. Most commercially available high pressure electric discharge devices contain mercury vapor, and the discharge produced is only the typical mercury discharge consisting of a number of discrete, separate wavelengths, generally called lines. Almost all of the radiation is contained in the blue region together with a line in the green and a line in the yellow. Hence when a conventional high pressure mercury discharge device illuminates a red object, particularly one reflecting light only in the range of 6,000 to 6,800A, the object appears black.

Attempts have been made by the art to obviate this problem and among the suggested modifications have been the inclusion in the mercury arc stream of various metallic elements which emit radiation at wavelengths different than the mercury emission, so that lamps having such inclusions will produce radiations resulting from a combination of mercury lines together with lines of the metallic additions. Typical of the inclusions have been the addition of thallium, zinc, cadmium or sodium metals. Although such additions did add other lines to the spectrum and improve the color rendition still only a series of separate and discrete lines was generally present. A white light derived from a substantially continuous spectrum was yet to be obtained in such devices.

Another suggested modification was the color-improved mercury vapor lamps wherein the inner surface of the outer bulbous envelopes were coated with fluorescent phosphors which convert some of the invisible ultra-violet arc radiations into visible light of a red-orange color. The mixture of the red-orange together with the blue-green from the mercury discharge produced some improvement in color. However there was a loss of efficiency in the lamp because the phosphor absorbed some of the visible radiation from the arc. Furthermore, phosphor coatings failed to solve the real problem in the lack of a continuous spectrum in the lamp's radiation.

Although the art has known that a white light or continuous spectrum can be obtained from radiation in which all, or a majority of all visible wavelengths are present, such radiation has not been present in commercially available high-pressure electric discharge devices. Quite unexpectedly, we have discovered in the presence of a metal such as thorium, that the addition of certain mercury halides, that is mercurous or mercuric iodides, bromides or chlorides to a mercury arc produces a white light, fluorides of mercury however do not produce such radiation. Furthermore, it is possible to add the certain halides in elemental form together with metallic mercury. To achieve maximum white light emission, certain ratios in the number of iodine, bromine or chlorine atoms to mercury atoms must be maintained. By white light or continuous spectrum we

mean an almost complete forest of spectral lines in the emission spectrum, substantially a continuum, appearing generally less than about 5A apart and containing, superimposed upon the forest, the typical mercury lines at 4,048, 4,348, 5,461, 5,770 and 5,790A. The measurement of the spectrum was obtained by measuring the density of photographic records of the spectrum obtained at various exposure times from lamps of varying ratios of iodine to mercury. For Example, when the photographs of the spectra of lamps containing a given ratio of iodine to mercury was compared to lamps containing twice that ratio and exposed for one half the time, the density of lines on all photographs of the spectrum was substantially the same.

Accordingly, the primary object of this invention is the production of an almost continuous spectrum from a high pressure discharge device.

A feature of this invention is the incorporation of mercury metal together with controlled quantities of certain mercury halides in high pressure electric discharge devices.

Many other objects, features and advantages of the present invention will become manifest to those conversant with the art upon making reference to the detailed description which follows and the accompanying sheets of drawings in which preferred embodiments of an electric discharge device are shown and described which emits a white light and wherein the principles of the present invention are contained by way of illustrative examples. Of these drawings:

FIG. **1** is an elevational view of a high pressure electric discharge device illustrating the positioning of an electric discharge arc tube disposed within an outer bulbous envelope.

FIG. **2** is a graph illustrating the effect produced upon white light emission radiation by varying the ratio of the number of halogen atoms to the number of mercury atoms. The ordinate is plotted in relative units of white light, that is continuous spectrum and the abscissa is plotted in a ratio of the total number of halogen atoms to the total number of mercury atoms in the arc tube.

According to our invention we have discovered that certain elemental halogen or mercury halides, that is iodine or the iodides, bromine or the bromides and chlorine or the chlorides, can convert or shift up to 50% of the ultra-violet radiations normally emanating from a mercury lamp into the visible spectrum, not by conventional fluorescence, but rather by a reduction in the temperature of the arc whereby ultraviolet emission is reduced through the production of white light. Since ultra-violet can often be considered valueless for direct lighting purposes because the eye is not sensitive to such radiation, the shift is quite advantageous. The same effect or shift from the ultra-violet is evidenced by each of the above-named halogen or mercury halides, varying only in intensity, the iodide producing the greatest white light emission and the bromide and chloride producing less in that order. Furthermore, lamps containing such materials are very efficient and can have light output in the order of 80 lumens per watt.

Referring to FIG. **1**, an elevational view of a mercury vapor lamp is shown. For clarity of presentation, the outer bulbous envelope and the base of the lamp are shown in phantom lines surrounding the arc tube harness and the arc tube.

A high pressure electric discharge device, such as shown in the drawing comprises an outer vitreous envelope or jacket **2** of generally tubular form having a central bulbous portion **3.** The jacket is provided at its end with a re-entrant stem **10** having a press through which extends relatively stiff lead-in wires **6** and **7** connected at their outer ends to the electrical contacts of a usual screw-type base **8** and at their inner ends to the arc tube and the harness.

The arc tube **12** is generally made of quartz although other types of glass may be used such as alumina glass or Vycor, that is a glass of substantially pure silica. Sealed in the arc tube **12** at the opposite ends thereof are main discharge electrodes **13** and **14** which are supported on lead-in wires **4** and **5** respectively. Each main electrode comprises a core portion which may be a prolongation of the lead-in wires **4** and **5** and may be prepared of a suitable metal such as for example, molybdenum or tungsten. The prolongations of these lead-in wires **4** and **5** can be surrounded by molybdenum or tungsten wire helixes. A material of low work function, such as a small piece or sliver of thorium or similar metal (not shown) is inserted between the core and the helix to reduce cathode drop during operation and to react with the halogen derived either from the mercury halide or the elemental halogen addition. Although in this example, thorium or similar metal is disposed under the helix, the metal may, instead, or in addition, be coated on the electrode or merely laid in the arc tube **12.** Quite importantly, if the conventional oxide-type emissive coating is disposed upon the electrode, white light emission is markedly reduced. No such deleterious effects are noticed with the so-called thorium type electrodes. An auxiliary starting probe or electrode **18,** generally prepared of tantallum or tungsten is provided at the base end of the arc tube **12** adjacent the main electrode **14** and comprises an inwardly projecting end of another lead-in wire.

Each of the current lead-in wires described has its end welded to intermediate foil sections **20** of molybdenum which are hermetically sealed within the pinched sealed portions of the arc tube. The foil sections are very thin, for example, approximately 0.0008 inch thick and go into tension without rupturing or scaling off when the heated arc tube cools. Relatively short molybdenum wires **23, 24** and **35** are welded to the outer ends of the foil and serve to convey current to various electrodes inside the arc tube **12.**

Metal strips **45** and **46** are welded to the lead-in wires **23** and **24** respectively. A resistor **26** is welded to foil strip **45** which in turn is welded to the arc tube harness. The resistor may have a value of, for example, 40,000 ohms and serves to limit current to auxiliary electrode **18** during normal starting of the lamp. Metal foil strip **46** is welded directly to stiff lead-in wire **5.** Lead-in wire **35** is welded at one end to a piece of molybdenum foil sealed in the arc tube **12** which in turn is welded to main electrode **13.** Metal foil strip **47** is welded at one end to lead-in wire **35** and at the other end to the harness. The pinched or flattened end portions of the arc tube **12** form a seal which can be of any desired width and can be made by flattening or compressing the ends of the arc tube **12** while they are heated. The arc tube **12** is provided with a filling of mercury in a quantity such as to vaporize completely when pressure in the order of one half to several atmospheres is reached during lamp operation at temperatures of 450° to 700°C. Particularly, we have found that through the addition of certain mercury halides to the mercury fill, that the quantity of the latter can be reduced as low as about 0.5 mg. per centimeter of arc length and possibly lower; arc length being measured as the distance between opposing tips of the main electrodes **13** and **14.** Although the amount of mercury to be added can be varied rather widely as we have indicated, we prefer to add approximately 5 to 10 mg. of mercury per centimeter of arc length, however, maximum white light radiation can be obtained at filling pressures substantially less than the stated upper limit. Furthermore, the continuum appears to be independent of the quantity of mercury metal added and the mercury metal content can be reduced while white light is still attained. As is conventional in the art, a quantity of rare gas such as helium, argon, neon, krypton or xenon at a pressure of about 25 millimeters of mercury is added to facilitate starting. To these materials we have discovered that a mercury halide, preferably the iodide, or elemental halogens, except the fluoride must be added to the arc tube to obtain white light emission and in particular we have discovered that about 0.35 atoms of halide must be added for every atom of mercury irrespective of whether the mercury atoms are derived from the metal or from the mercury compound, although this ratio may be varied in reasonable tolerances between about 0.08 to 0.75 atoms of halide per atom of mercury. It is quite important to use anhydrous materials in the arc tube since the incorporation of water tends to make the discharge hard to start.

The U-shaped wire internal supporting assembly or arc tube harness serves to maintain the position of the arc tube **12** substantially coaxial within the envelope **2.** To support the arc tube **12** within the envelopes **2** stiff lead-in wire **6** is welded to the base **53** of the harness. Because stiff lead-in wires **6** and **7** are connected to opposite sides of a power line, they must be separated by insulators **33** and **34** from each other together with all members associated with each of them. Clamps **56** and **57** hold the arc tube **12** at the end portions and are fixedly attached to legs **54** of the harness. A rod **59** bridges the free ends of the U-shaped support wire **54** and is fixedly attached thereto, to impart stability to the structure. The free ends of the U-shaped wire **54** are also provided with a pair of metal leaf springs **60,** frictionally engaging the upper tubular portion of the lamp envelope **2.** A heat shield **61** is disposed beneath the arc tube **12** and above the resistor **26** so as to protect the resistor from excessive heat generated during lamp operation.

Having described the construction of a typical high pressure electric discharge device in which our invention can be used and also having described the addition of a halogen or a mercury halide to the arc tube, reference is now made to the graph in FIG. **2.**

The arc tube **12** contains an amount of mercury metal which is sufficient, when operating pressures are reached in the order of one-half to several atmospheres, to form and maintain the well known restricted arc between the main electrodes **13** and **14** upon the application of about 100 to 450 volts. Preferably the quantity of mercury metal is sufficiently small so that it is entirely vaporized when the above mentioned pressures are reached. Now as we have stated, the amount of white light developed is not dependent solely upon the amount of halogen or mercury halides

added but rather is dependent upon a ratio of the total number of halogen atoms to the total number of mercury atoms. At a point in FIG. 2 where no halogen atoms are present in the arc tube, as in a conventional high pressure electric discharge device, no white light is evidenced. Following the ascending curve, white light occurs upon the addition of small quantities of halogen atoms, however, the amount is so slight as to be substantially unnoticeable. However incorporation of greater quantities rapidly causes a substantial increase until a peak is reached. Further increase in the halogen-mercury ratio then actually results in a diminution of the white light. And when a ratio of 2.0 is reached, the white light is again substantially absent as was the case when no halogen atoms at all were added.

Thus for obtaining maximum white light emission, we have discovered that the ratio of halogen atoms to mercury atoms should be approximately 0.35. However as indicated above reasonable white light emission is still obtained when the ratio is slightly less or slightly greater then 0.35, but the radiation is reduced using such off-peak ratios. Since it is difficult, if not impossible, to produce lamps in production lines wherein the ratio of mercury to halogen is exactly 0.35, tolerances are allowed between about 0.08 to 0.75 and within such tolerances reasonable white light emission is still evidenced.

The fabrication of the envelope, sealing techniques and positioning of the electrodes in the high pressure electric discharge device according to our invention takes place in a manner well known and conventional in the art. Further, the mercury metal may be also added according to techniques well known in the art. To prepare the arc tube, we pump down the envelope having a thorium cathode through an exhaust tubulation extending from the surface of the envelope and disposed in communication with the interior thereof. The envelope is then heated with a torch and filled with argon to flush out residual entrapped impurities. This pump and fill procedure is repeated usually three times and then an arc is struck between the electrodes while there is a filling of argon gas. This operation of the arc removes residual impurities from the electrodes and these contaminants are withdrawn from the system when the argon filling is pumped out. We then add approximately 61.2 milligrams of mercury and 15.4 milligrams of mercurous iodide to an envelope having an arc length of approximately 7 centimeters. The arc tube is then filled to atmospheric pressure with argon gas which is slowly leaked out until a pressure of about 23 millimeters of mercury is obtained. Subsequently, the exhaust tubulation is tipped off and the envelope is sealed. Testing of the lamp indicates that the white light emission is substantially at the peak of the curve shown in FIG. 2.

It is apparent that modifications and changes may be made within the spirit and scope of the instant invention. For example, when stronger color lines are desired, it is possible to include additives in the form of metal or metal compounds which radiate in the desired lines such as cadmium for red, thallium for green or sodium for yellow. It is thus our intention to be limited only by the scope of the appended claims.

As our invention, we claim:

1. In a high pressure electric discharge device having an arc tube with electrodes sealed at each end thereof and having means to convey electrical energy to each of said electrodes and having atoms of mercury, atoms of a halogen selected from the group consisting of iodine, bromine and chlorine and atoms of a metal capable of reacting with halogen, the improvement which comprises: said halogen and mercury being contained in said arc tube in a ratio of halogen atoms to mercury atoms between about 0.08 to 0.75, the visible emission of said arc tube when an arc is formed therein being a substantially complete forest of spectral lines in the emission spectrum, appearing at spacings less than about 5A apart.

2. The device according to claim **1** wherein the forest of spectral lines produces a white light.

3. The device according to claim **1** wherein a rare gas is contained within said arc tube.

4. The device according to claim **1** wherein the source of said halogen atoms is at least one member selected from the group consisting of mercury iodide, mercury bromide, mercury chloride, elemental iodide, elemental chlorine and elemental bromine.

5. The device according to claim **1** wherein the amount of mercury within said arc tube is that which will be completely vaporized at normal operating temperatures of said device and when a pressure in excess of one half atmosphere is attained.

6. The device according to claim **1** wherein thorium metal is disposed upon at least one of the electrodes.

7. The device according to claim **5** wherein substantially anhydrous materials for said arc tube are used.

8. The device according to claim **5** wherein the halogen is iodine.

9. A high pressure electric discharge device having an arc tube with electrodes sealed at each end thereof and having means to convey electrical energy to each of said electrodes and having atoms of mercury, atoms of a halogen selected from the group consisting of iodine, bromine and chlorine and atoms of a metal capable of reacting with halogen, the improvement which comprises: said halogen and mercury being contained in said arc tube in a ratio of halogen atoms to mercury atoms between about 0.08 to 0.75, the amount of mercury within said arc tube being such as to be completely vaporized at temperatures attained within said arc tube between 450° and 700°C when a pressure in excess of one half atmosphere is attained, the visible emission of said arc tube when an arc is formed therein being a substantially complete forest of spectral lines in the emission spectrum, appearing at spacings less than about 5A apart.

10. The device according to claim **9** wherein thorium metal is disposed upon at least one of the electrodes.

11. The device according to claim **10** wherein substantially anhydrous materials for said arc tube are used.

12. The device according to claim **11** wherein a rare gas is contained within said arc tube.

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