

[54] ELECTRIC DISCHARGE DEVICE CONTAINING THORIUM, MERCURY AND IODINE

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313/229, 218, 311, 346

[56]

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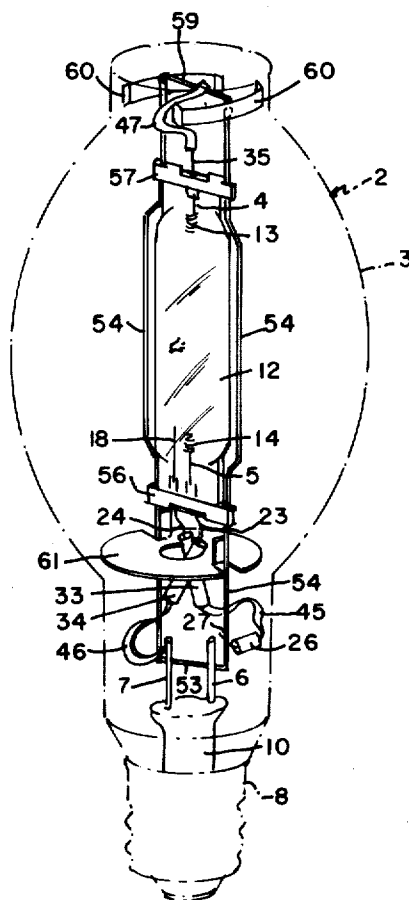
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ABSTRACT

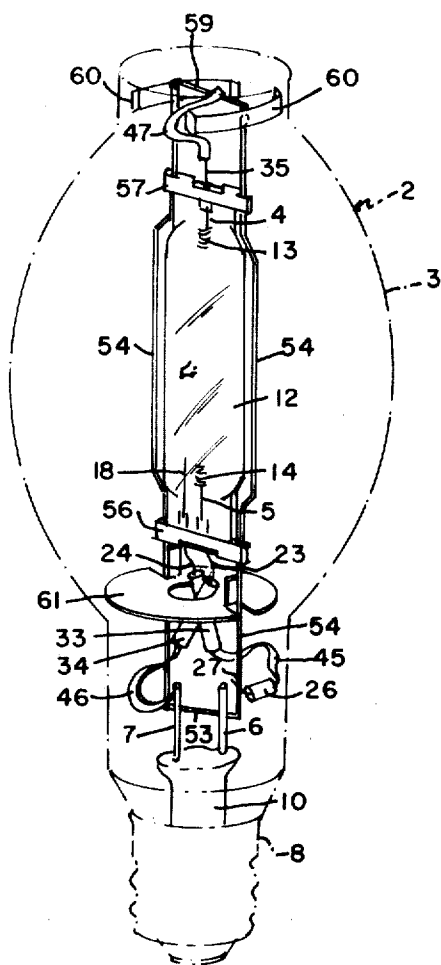
A high pressure electric discharge device for the emission of white light has an electrode-containing arc tube which contains a fill of iodine, mercury and thorium. The ratio of iodine to mercury is between 0.10 and 0.85. Thorium is present in quantities of 2.6×10^{-7} to 2.6×10^{-6} gram atoms per centimeter of arc length.

10 Claims, 1 Drawing Figure



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ELECTRIC DISCHARGE DEVICE CONTAINING THORIUM, MERCURY AND IODINE

This application is a division of application Ser. No. 230,944, filed Oct. 16, 1962, which is a continuation-in-part of application Ser. No. 209,974, filed July 13, 1962, 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 their practical commercial applications. Most commercially available high pressure electric discharge devices contain mercury vapor and the discharge produced is only the typical mercury discharge consisting 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 6,800 Å, 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 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 not add other lines to the spectrum and improve the color rendition, still only a series of separate and discrete lines were generally present. A white light derived from a substantially continuous spectrum was yet to be obtained from such devices.

Another suggested modification was the color-improved mercury vapor lamps wherein the outer surface of the outer bulbous envelopes were coated with fluorescent phosphors which converted some of the invisible ultraviolet arc radiation into visible light of a red-orange color. Although the mixture of the red-orange together with the blue-green of the mercury produced some change in color, there was a loss of efficiency in the lamp because the phosphor absorbed some of the visible radiation from the arc. Furthermore, phosphor coatings fail to solve the real problem which is the lack of a continuous spectrum in the radiation of the discharge itself.

A white light or a substantially continuous spectrum can be obtained from radiation having a large number of lines very close together and extending throughout the whole spectrum, but such radiation has not been present in commercially available high pressure electric discharge devices, which spectrum consisted instead of a very few widely separated lines. Quite unexpectedly, we have discovered that a continuum is formed when thorium is used in a high pressure mercury arc; a spectrum is emitted whose lines are so closely spaced as to be almost a continuum, and for convenience we should call such a spectrum a continuum. In addition, mercury, either as a metal or as an iodide, must be included in the filling of the tube, the quantity of mercury being such as to allow complete vaporization at normal operating temperatures of the arc tube and to form a restricted arc therein. To achieve maxi-

mum white light emission, certain ratios in the number of iodine atoms to mercury atoms must be maintained and although we prefer a ratio of about 0.45, it is possible to use a ratio between 0.10 to 0.85. By a white light or continuous spectrum we mean, as previously noted, almost a complete forest of spectral lines in the emission spectrum, substantially a continuum, appearing generally less than 5 Å apart and containing superimposed upon this forest, the typical mercury lines at 4,048, 4,348, 5,461, 5,770 and 5,790 Angstrom units. 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 mercury to iodine 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 production of a white light from a high pressure discharge device.

A feature of this invention is the incorporation of mercury either as the metal or as the halide together with controlled quantities of thorium either alone or in addition to the thorium sliver normally contained in the electrodes.

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 sheet of drawing in which preferred embodiments of an electric discharge device which emits white light are shown and described and wherein the principles of the present invention are contained by illustrative examples. Of these drawings:

The FIGURE 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.

According to our invention we have discovered that an arc tube having a filling of a combination of certain materials can produce a continuum without the necessity of correctional phosphor, the lamp having an efficiency of 70 to 90 lumens per watt. In particular, we have discovered that when mercury and iodine, added either as the individual elements or as the compound, in very specific atomic ratios of iodine to mercury are included in the arc tube together with specific quantities of thorium in place of, or in addition to the thorium normally contained in the electrodes, that white light can be obtained. Additionally, it is advantageous to add 5.25×10^{-7} to 6.8×10^{-5} gram atoms per centimeter of arc tube length of a material having a low vapor pressure iodide such as sodium, to stabilize the arc and insure at room temperature that there is no iodine in the vapor state thereby lessening starting voltages.

The lamps according to our invention have an efficiency which is considerably higher than conventional mercury lamps; 70 to 90 lumens per watt and even higher being attainable. The reason for the large increase is that approximately 50 percent of the total energy of the thorium spectrum is concentrated in the visible range whereas with conventional mercury lamps only 23 percent is in the visible. In addition, the use of mercury, iodine and thorium in the arc tube fill enables the inclusion of other metals in the system so as to

allow for modification of the arc's color. Such inclusions can be easily used to modify the emission color of the lamp, for example cadmium may be added for increased red or thallium for increased green. However, with the case of cadmium, the inclusion adds to the cadmium spectrum, suppressing the mercury slightly but not effecting the general configuration of the thorium spectrum. On the other hand, the inclusion of thallium improves the efficiency because of the strong green line of thallium. Efficiencies of over 80 lumens per watt have been achieved with thallium additions, however, the light emitted has a greenish color.

Referring to the FIGURE, an elevational view of a high pressure electric discharge device 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. The 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 having a press through which extends relatively stiff lead-in wires 6 and 7 connected at their outer ends to the electrical contacts of the usual screw type base 8 and at their inner ends to the arc tube and the harness.

The arc tube is generally made of quartz although either types of glass may be used such as alumina glass or Vycor, the latter being 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 helices.

The design of the thorium-tungsten electrodes utilized to operate the lamps according to our invention is quite important. At low temperatures, the ThI_4 which is formed by reaction of thorium and iodine in the arc tube is quite stable and hence can form and evaporate and the pressure of the thorium is the vapor pressure of the ThI_4 . This can continue only up to that temperature at which the rate of formation of ThI_4 is greater than the rate of evaporation, assuming that every molecule of ThI_4 which evaporates gets into a high temperature arc and dissociates. Redeposition of thorium on the electrode is as thorium metal condensing from the arc stream. The rate of formation of ThI_4 is limited by the rate of arrival of iodine atoms at the surface of the thorium metal. The absolute maximum rate is when every iodine atom which strikes a thorium atom is captured and added to a growing thorium-iodine molecule. When four iodine atoms have hit, the molecule is ThI_4 which evaporates. The rate of evaporation of ThI_4 is then one quarter of the arrival rate of iodine and hence during operation of a discharge device the maximum pressure would be one quarter that of iodine. However at electrode temperatures normally associated with operation of the lamp, the evaporation rate of the ThI_4 and hence, the partial pressure of the ThI_4 is substantially less than the above, due to the fact that ThI_4 is no longer stable. At ever higher temperatures the evaporation of the thorium metal atoms takes place at an increasing rate. There is therefore, a temperature of minimum thorium pressure for Th-W electrodes in iodine

vapor, said temperature being that at which the evaporation rate of ThI_4 has become small because ThI_4 is unstable but the evaporation rate of the metal has not yet become large.

The effect of electrode design on thorium pressure appears to be quite substantial. The point of minimum pressure on a standard cathode appears to occur upon the coil part of the electrode. Thus, eventually all of the thorium in the lamp will deposit upon this portion of the coil and if the fraction of electrode area at this temperature is large enough, all of the thorium will be trapped thereon thereby reducing lamp efficiency and depressing the red rendition to very low values. The electrode should thus be designed to keep the total area which stays at this temperature sufficiently small that it cannot accommodate the thorium without forming a large drop which would flow out all over the whole electrode to portions where the pressure of ThI_4 or Th is substantially higher than the minimum.

An auxiliary starting probe or electrode 18, generally prepared of tantalum 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 have their ends welded to intermediate foil sections 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 inches 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 in the outer ends of the foil and serve to convey current to the various electrodes inside the arc tube 12.

Metal strips 45 and 46 are welded onto 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 7. 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 and 14. Metal foil strip 47 is welded to one end of lead-in 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 a pressure in the order of one half to several atmospheres is reached during normal lamp operation at temperatures of 450° to 700° C. Particularly we have found that through the addition of certain mercury iodides to the mercury fill, that the quantity of the latter can be reduced to as low as 1×10^{-5} gram atoms 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 added can be varied widely as we have indicated, we prefer to add approximately 2.5×10^{-5} to 4.1×10^{-5} gram atoms of mercury per centimeter of arc length. However, maximum white light radiation can be obtained at filling pressures substantially less than the above stated limits. Furthermore, the continuum or white light emission appears to be substantially inde-

pendent of the amount of mercury metal added and hence the quantity of the latter can be reduced while 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. In addition to these materials we have discovered that a mercury iodide, or combination of elemental mercury and elemental iodine, must be added to the arc tube to attain white light emission and particularly we have discovered that about 0.45 atoms of iodide 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 0.10 to 0.85 atoms of iodide per atom of mercury. It is quite important to use anhydrous material in the arc tube since the incorporation of water tends to make the discharge hard to start.

The U-shaped internal wire 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 envelope 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 insulated 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 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 for imparting stability to the structure. The free ends of the U-shaped wire 54 are also provided with a pair of metal leaf springs 60, frictional 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 to protect the resistor from excessive heat generated during lamp operation.

When attempting to attain maximum white light emission a ratio of iodine atoms to mercury atoms should be maintained at approximately 0.45. However, white light emission will still be obtained when the ratio is greater or less than 0.45 (within definite limits) but the emission 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 iodine is exactly 0.45, tolerances are allowed between 0.10 to 0.85 and within such tolerances, reasonably white light emission is still evidenced. However the white light which we have referred to necessitates the inclusion of thorium as a continuum-emitting material. As noted above, the arc may be operated either with or without the conventional 5 mg thorium sliver disposed inside each electrode. When using thorium slivers, 2.6×10^{-7} to 2.6×10^{-6} gram atoms of thorium per centimeter of arc length (excluding the slivers) must be included and when no thorium slivers are used 5.2×10^{-7} to 5.2×10^{-6} gm. atoms of thorium per centimeter of arc length must be added. In the latter case it is preferable to use 5.2×10^{-8} gram atoms of thorium per centimeter of arc length and in the former case it is preferable to add 1.6×10^{-6} gram atoms of thorium per centimeter of arc length. The thorium may be added either as the metal per se, or as the anhydrous iodide. Above this range the thorium metal tends to deposit upon the walls of the arc tube while below the range no continuous spectrum is evidenced. Additionally, it is often de-

sirable to add 5.25×10^{-7} to 8.6×10^{-5} gram atoms of sodium per centimeter of arc length. Without the sodium the voltage drop is often too high to operate the lamp on constant watt ballasts. But when more than the stated upper limit is used, the quartz envelope is adversely effected. The sodium may be added either as the metal or the corresponding iodide.

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 quite similar to that known to the art with conventional mercury lamps. And further, the mercury metal may be added to the arc tube by techniques well known to the art. To prepare the arc tube, we pump down an envelope having a pair of electrodes disposed at either end thereof, 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 impurities. It is quite important to eliminate or substantially eliminate the presence of hydrogen from the arc tube. Hydrogen is known to effect the starting of mercury lamps adversely but its effect appears to be greater in the lamps prepared according to our invention. The difficulty with hydrogen appears to be due to the formation of hydrogen iodide which has a much higher vapor pressure than any other iodide present. We believe that for every atom of hydrogen, that there is an extra atom of iodine in the vapor state. Presence of the iodine in the vapor state increases the voltage which must be applied to the lamps for starting. Hence, not only must hydrogen be substantially eliminated from the gases in the filling of the tube but each and every part going into making up the arc tube must be free of residual hydrogen impurities. For example, the electrodes can be vacuum baked at 600° to 800° C for a few hours before their use to eliminate hydrogen which might occur due to processing. Furthermore, care should be exercised when sealing the electrodes into the arc tube to prevent hydrogen-containing, combustion gases from seeping in or becoming absorbed upon the surface.

The pump and fill procedure above described is usually repeated three to four times and then an arc is struck between the electrodes while there is a filling of argon gas. This operation of the arc removes any residual impurities from the electrodes and these contaminants can then be easily drawn from the system when the argon filling is pumped out. We then add approximately 34 milligrams of mercury, 13 milligrams of mercuric iodide and 5.0 milligrams of thorium to an envelope having an arc length of approximately 8.3 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 a white light emission is evidenced, which emission is in the order of 75 lumens per watt.

It is apparent that modifications and changes may be made within the scope of the instant invention. It is our intention however to be limited only by the scope of the appended claims. This application is a continuation in part of our application Ser. No. 209,974, filed July 13, 1962.

As our invention we claim:

1. A high pressure discharge device for the emission of white light comprising: an arc tube having electrodes containing a thorium sliver sealed at either end thereof and a vaporizable fill of iodine, mercury and thorium atoms, said iodine and mercury respectively being present therein at a ratio of 0.10 to 0.85 and said mercury being present in sufficient quantities to be completely vaporized at normal operating temperatures of said arc tube and to form a restricted arc therein, said thorium being present in quantities of 2.6×10^{-7} to 2.6×10^{-6} gram atoms per centimeter of arc length and characterized in that said white light constitutes substantially a continuum of radiation in the visible spectrum in contrast to a balancing of line spectral emission that has the appearance of white or near-white light.

2. A high pressure discharge device for the emission of white light comprising: an arc tube having electrodes sealed at either end thereof and a vaporizable fill of iodine, mercury, thorium and sodium atoms, said iodine and mercury respectively being present therein at a ratio of 0.10 to 0.85 and said mercury being present in sufficient quantities to be completely vaporized at normal operating temperatures of said arc tube to form a restricted arc therein, said thorium being present in quantities of 2.6×10^{-7} to 2.6×10^{-6} gram atoms per centimeter of arc length and said sodium being present in sufficient quantities to stabilize said arc and characterized in that said white light constitutes substantially a continuum of radiation in the visible spectrum in contrast to a balancing of line spectral emission that has the appearance of white or near-white light.

3. The discharge device according to claim 2 wherein thorium slivers are present in the electrodes.

4. The high pressure discharge device according to claim 3 wherein said sodium is present as sodium iodide when the device is cold.

5. The high pressure discharge device according to claim 3 wherein at least a part of said mercury is present as mercuric iodide when the device is cold.

6. A high pressure discharge device for the emission of white light comprising: an arc tube having electrodes containing thorium slivers sealed at either end thereof and vaporizable filling of atoms of iodine, mercury, thorium and sodium said iodine and mercury respectively being present therein at a ratio of 0.10 to 0.85 and said mercury being present in sufficient quantities to be completely vaporized at normal operating temperatures of said arc tube and to form a restricted arc

therein, said thorium being present in quantities of 2.6×10^{-7} to 2.6×10^{-6} gram atoms per centimeter of arc length, said sodium being present in quantities of 5.25×10^{-7} to 6.8×10^{-3} gram atoms per centimeter of arc length and characterized in that said white light constitutes substantially a continuum of radiation in the visible spectrum in contrast to a balancing of line spectral emission that has the appearance of white or near-white light.

7. The high pressure discharge device according to claim 6 wherein said sodium is present as sodium iodide when the device is cold.

8. The high pressure discharge device according to claim 6 wherein at least a part of said mercury is present as mercuric iodide when the device is cold.

9. A high pressure discharge device for the emission of white light comprising: an arc tube having electrodes sealed at either end thereof and a vaporizable fill of iodine, mercury and thorium atoms said iodine and mercury respectively being present therein at a ratio of 0.10 to 0.85 and said mercury being present in sufficient quantities to be completely vaporized at normal operating temperatures of said arc tube and to form a restricted arc therein, said thorium being present in quantities of 5.2×10^{-7} to 5.2×10^{-6} gram atoms per centimeter of arc length and characterized in that said white light constitutes substantially a continuum of radiation in the visible spectrum in contrast to a balancing of line spectral emission that has the appearance of white or near-white light.

10. A high pressure discharge device for the emission of white light comprising: an arc tube having electrodes sealed at either end thereof and a vaporizable filling of atoms of iodine, mercury, thorium and sodium, said iodine and mercury respectively being present therein at a ratio of 0.10 to 0.85 and said mercury being present in sufficient quantities to be completely vaporized at normal operating temperatures of said arc tube and to form a restricted arc therein, said thorium being present in quantities of 5.2×10^{-7} to 5.2×10^{-6} gram atoms per centimeter of arc length, said sodium being present in quantities of 5.25×10^{-7} to 6.8×10^{-6} gram atoms per centimeter of arc length and characterized in that said white light constitutes substantially a continuum of radiation in the visible spectrum in contrast to a balancing of line spectral emission that has the appearance of white or near-white light.

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