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MERCURY METAL HALIDE DISCHARGE LAMP HAVING IODINE PRESENT IN STOICHIOMETRIC PROPORTIONS WITH RESPECT TO THE REACTIVE METALS

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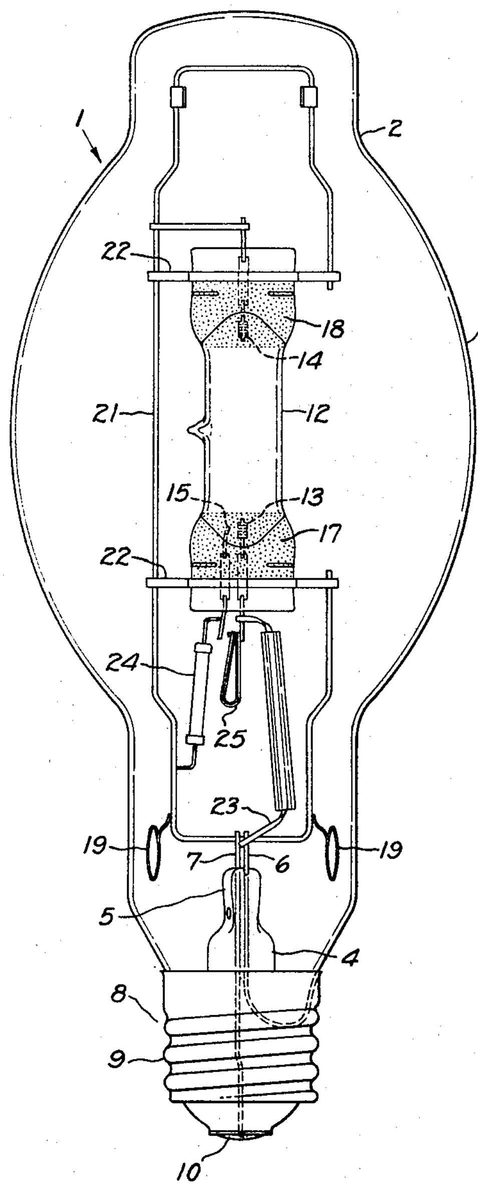

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MERCURY METAL HALIDE DISCHARGE LAMP HAVING IODINE PRESENT IN STOICHIOMETRIC PROPORTIONS WITH RESPECT TO THE REACTIVE METALS

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ABSTRACT OF THE DISCLOSURE

A high pressure mercury metal halide (sodium iodide) discharge lamp having thorium oxide activated electrodes. Improved maintenance and low starting voltage throughout life results from having the iodine present in stoichiometric proportions with respect to the reactive metals present in the discharge medium considered in their lowest valency state, but excluding mercury.

This invention relates to metallic vapor lamps using an arc discharge in mercury and metal halide vapors to produce visible light, and is more particularly concerned with an optimum combination of constituents for the filling to be used with a specific type of electrode.

The mercury arc lamp has a long life and reasonably good efficiency but relatively poor color rendition due to the bluish-green quality of its light. A radical improvement in both color rendition and efficiency may be achieved by adding to the mercury one or more vaporizable metal halides under proper control of loading, temperature and pressure. A preferred filling comprises mercury, sodium iodide, thallium iodide and indium iodide and this combination raises the efficiency from the 50 to 60 lumens per watt range into the 70 to 90 lumens per watt range for lamps of white to near white color, and into the 90 to 110 lumens per watt range for greenish-yellow lamps. Such improved lamps are described and claimed in copending application Ser. No. 84,068 of Gilbert H. Reiling, filed Jan. 23, 1961, entitled, "Gaseous Electric Discharge Lamps," and assigned to the same assignee as the present invention, now Patent 3,234,421.

In its general construction and appearance, the mercury metal halide lamp resembles the conventional high pressure mercury vapor lamp. It comprises a quartz arc tube mounted within a glass outer jacket having a screw base at one end. The arc tube contains a quantity of mercury and metal halides along with an inert gas such as argon for starting purposes. Thermionic main electrodes are provided at the ends of the arc tube. An auxiliary starting electrode is located adjacent one of the main electrodes to facilitate starting, and is connected through a current limiting resistor to the other main electrode. In the mercury metal halide lamp, the space between the arc tube and the outer jacket is evacuated in order to reduce loss of heat from the arc tube and achieve the desired arc tube wall temperature. The ends of the arc tube may be provided with a heat reflecting coating in order to assure the desired temperature at the ends.

The design of cathodes which will achieve long life and avoid premature envelope darkening or failure for other causes is much more critical in the mercury metal halide lamp than in the simple mercury lamp, and it is unavoidably related to the choice of constituents for the filling. With mercury vapor lamps, the thorium insert type electrode was at one time very common, but it has now been largely replaced by the oxide type cathode comprising a tungsten coil coated with a mixture of an alkaline earth oxide and a refractory oxide such as barium oxide and thorium oxide. Neither type is entirely satisfactory for use in mercury metal halide lamps such as the mercury sodium iodide lamp. With the thorium insert type, dark spots appear at the ends of the tube early in life which may develop devitrification and result eventually in a leak. With the emissive oxide type, in addition to chemical attack and devitrification a major problem has been that the lamps become hard starters early in life and require excessively high voltages to start them.

The object of the invention is to provide a combination of ingredients for the filling in conjunction with an electrode construction which will result in a high efficiency lamp of good color rendition having a long life and not subject to premature end darkening or other undesirable effects such as hard starting.

In accordance with the invention, we have found that in a high pressure mercury vapor lamp containing metal iodides for improved color and efficiency and equipped with thorium oxide-activated electrodes, optimum results from the point of view of maintenance and long life together with low starting voltage are obtained when the iodine is present in stoichiometric proportions with respect to the reactive metals present in the discharge medium considered in their lowest valency state, but excluding mercury. Generally the metals to be considered will be sodium and one or more additional metals such as thallium, or thallium and indium, or thallium and gallium in lieu of indium. Such stoichiometric proportioning at the lowest valency state appears to be an essential condition for achieving long life with thorium oxide-activated electrodes.

A feature of the invention is the selection for the filling of the monoiodide of thallium and indium or gallium in addition to mercury and sodium iodide. With this choice, exact stoichiometry at the lowest valency state is achieved as required by the invention, and without any need for precise measurement of minute quantities of chemical elements. This is a very significant advantage in manufacture.

For further objects and advantages and for a better appreciation of the invention, attention is now directed to the following detailed description of a preferred embodiment. The features of the invention believed to be novel will be more particularly pointed out in the appended claims.

The single figure of the drawing shows in side view a mercury sodium iodide arc lamp in which the invention is embodied.

Referring to the drawing, the illustrated mercury sodium iodide vapor lamp **1** comprises an outer vitreous envelope or jacket **2** of generally tubular form modified by a central bulbous portion **3**. The outer jacket is closed by a re-entrant stem **4** having a press **5** through which extend relatively stiff inlead wires **6**, **7** connected at their outer ends to the contacts of the usual screw type base **8**, namely the threaded shell **9** and the insulated center contact **10**.

The inner arc tube **12** is made of quartz or fused silica and has sealed therein at opposite ends a pair of main arcing electrodes, **13** at the base end and **14** at the outer end, plus an auxiliary starting electrode **15** at the base end adjacent main electrode **13**. The electrode inleads include intermediate thin molybdenum foil sections which are hermetically sealed through full diameter pinch seals **17, 18** at the ends of the arc tube. The main electrodes **13, 14** each comprise a double layer tungsten wire helix wrapped around a tungsten core wire. In the inner layer of the helix, the turns are spaced apart leaving gaps or interstices between them which are covered over by the closely spaced turns of the outer layer. The main electrodes are activated by thorium oxide which may be applied as an alcohol slurry without binder, coating the turns of the helix and filling the interstices between turns. The electrodes are dipped into the slurry and rough vacuum applied to eliminate any trapped air and insure that the voids or interstices are filled with the material. After air drying, the electrodes are fired in forming gas (N_2 with 5% H_2) at about 2000° C. for a few minutes. By way of typical example, in an electrode for a 400 watt lamp, wherein the shank diameter is 1.2 millimeters and the size of wire in the helix is 0.6 millimeter in diameter, the quantity of thorium oxide applied may be between 3 and 6 milligrams.

The coolest regions in the arc tube during operation are the ends. To insure that they do not drop below 500° C. in temperature, a heat reflective coating may be applied to the ends and to the adjacent portions of the pinch seals, as indicated by the speckling in the drawing. Also as a heat conservation measure the interenvelope space is evacuated; getter material provided in the channelled rings **19** may be flashed after sealing the jacket to assure high vacuum. A rare gas such as argon is provided at a low pressure, for instance at 25 millimeters of mercury, within the arc tube to facilitate starting and warm up.

The arc tube is supported within the outer jacket by a frame or harp **21** and metal straps **22**. The frame also serves as a conductor between electrode **14** and base shell **9** and a conductor **23** connects the other electrode **13** to center contact **10**. Starting electrode **15** is connected to main electrode **14** at the opposite end of the arc tube by current limiting resistor **24** which is spot welded to the inlead of the auxiliary electrode at one end and to frame member **21** at the other. Since only a relatively low current is needed to ionize the lamp at starting, the current limiting resistor may have a high value, for instance 40,000 ohms.

In the illustrated embodiment, a thermal switch **25** consisting of a strip of dissimilar metals bent to a U-shape is welded at one end to the inlead of main electrode **13**. As the lamp warms up, the U-shaped piece opens out and its free end engages the inlead of starting electrode **15**. The auxiliary electrode is thereby connected to the adjacent main electrode after starting and during operation of the lamp, and electrolysis of halide salts while yet in liquid form prior to vaporization is avoided. This feature is described and claimed in copending application Ser. No. 306,476, filed Sept. 4, 1963, by Alwin C. Green, entitled "High Pressure Metal Vapor Discharge Lamp" and assigned to the same assignee as the present invention, now Patent 3,226,597.

The arc tube contains a quantity of mercury which is entirely vaporized during operation of the lamp and which at such time exerts a pressure in the range of 1 to 15 atmospheres. A quantity of sodium iodide is provided in excess of that vaporized at the operating temperature of the arc tube which is not less than 500° C. at any place. The sodium contributes strong yellow-orange lines which may be broadened into the red.

The color and efficiency of the lamp depend not only on the choice of metal iodide but also on the relative proportions of the various iodides used. For example, changing the ratio of TlI to InI in a lamp containing Hg and NaI produces a range of colors varying from greenish-yellow through white to pinkish-violet, and efficiencies ranging from 110 to 60 lumens per watt. However for white or nearly white light as is desired for general lighting applications, we have found that the quantity of thallium monoiodide should be from 1 to 8% of the entire filling. Thallium produces an intense spectral line in the yellow-green at 5350 A. which complements the mercury spectrum and improves greatly the quality of the light. In addition indium monoiodide which may be replaced in whole or in part by gallium monoiodide may be provided to the extent of 0.10% to 2% by weight of the total filling. Indium generates intense spectral lines in the blue at 4102 and 4511 A. which offset the intense green line of thallium to produce a more balanced color rendition suitable for general illumination.

The sizes or ratings of mercury lamps in general use range from about 100 watts to 1000 watts, the commonest sizes being 175, 400 and 1000 watts. In the improved lamps of this invention containing metal iodides in addition to mercury, typical arc tube volumes are approximately as follows:

Watts—	Cc.
175	4
400	20
1000	50

In these lamps, the mercury is all vaporized during operation and the quantity is adjusted to achieve the desired voltage drop at the rated operating current. I have found that in such lamps desirable proportions for the constituents fall within relatively narrow ranges as follows:

	Mg./cc.
Hg	2.0–10
NaI	0.1–3.0
TlI	0.1–0.5
InI or GaI	0.01–0.15

By way of illustrative example, in a 400-watt mercury sodium iodide lamp operating with 135 volt arc drop, and an envelope of about 20 cubic centimeters volume, the composition of the filling is as follows:

	Milligrams
Hg	85
NaI	40
TlI	4
InI	0.75

The stoichiometric proportioning of iodine relative to the reactive metals present, as earlier defined, and achieved through the use of the monoiodide rather than the triiodide of thallium and indium, is important for obtaining a low starting voltage. For instance in a typical lamp, the use of InI as against InI_3 may reduce starting voltage by as much as 40 volts at room temperature, from 290 volts to 250 volts. The lower starting voltage appears due to the absence of free iodine or iodide salts having a high vapor pressure and a high degree of dissociation.

It may be noted that the substitution of InI for InI_3 in lamps using thorium metal rather than thorium oxide for electrode activation as called for by this invention, and containing mercury, sodium iodide and thallium monoiodide, also reduces starting voltage. However reaction takes place between the thorium metal, sodium iodide and the silica of the quartz envelope which is harmful to the lamp. Therefore the combination proposed in accordance with our invention utilizing thorium oxide activated electrodes is much preferable.

The explanation for the improvements in life and maintenance realized by the invention appears to be as follows. Sodium forms a single stable compound with iodine, sodium iodide (NaI), wherein the proportions are equimolar. If iodine in excess of such equimolar proportions is present, the sodium will be ineffectual to tie it up and high starting voltage will result. If there is a deficiency of iodine, free sodium may react with other components of the lamp, for instance it may attack the quartz envelope. Therefore both excess and deficiency of iodine must be avoided.

Mercury will also react with iodine, producing several compounds of different atomic proportions but these compounds are relatively unstable and easily decomposed within the lamp and so are not effectual in tying up the iodide. Indium and thallium form stable compounds of varying proportions with iodine: both can form the monoiodide and triiodide compounds. The triiodide can change into the monoiodide plus a quantity of "free"iodine which will affect lamp characteristics. By using only the monoiodide, this undesirable effect is avoided.

An advantage deriving from the use of indium monoiodide rather than triiodide is related to the nonhygroscopic nature of the former as against the hygroscopic or water vapor absorbing characteristics of the latter. Any water vapor absorbed in the materials used for the lamp filling is deleterious to maintenance or is harmful to achieving low voltage starting. By using indium monoiodide in accordance with the invention, the possibility of introducing water into the lamp as an impurity along with the filling is eliminated.

An additional advantage found with the selection of the monoiodides of thallium and indium (or gallium) is the ease of handling of these materials. These iodides can be mixed in the desired proportions and the mixture pressed into pellets of the desired size and weight for introduction into the lamp body. This eliminates the problem of measuring out and handling precise quantities of gaseous or liquid materials and greatly facilitates manufacture.

The preferred embodiment of the invention which has been illustrated and described is intended by way of example and not in order to limit the invention thereto, and the scope of the invention is to be determined by the appended claims.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. A high pressure metal vapor electric discharge lamp comprising a quartz envelope having a pair of thermionic electrodes sealed into opposite ends, each electrode comprising a tungsten conductor activated by thorium oxide, said envelope containing a filling comprising a quantity of mercury which is completely vaporized during normal operation at a minimum envelope temperature of 500° C., said quantity of mercury being sufficient to develop a vapor pressure in the range of 1 to 15 atmospheres, sodium iodide in excess of the quantity vaporized at said envelope temperature, and thallium monoiodide to the extent of 1 to 8 percent by weight of said filling, but no other iodine.

2. A high pressure metal vapor electric discharge lamp comprising a quartz envelope having a pair of thermionic electrodes sealed into opposite ends, each electrode comprising a tungsten conductor activated by thorium oxide, said envelope containing a filling comprising a quantity of mercury which is completely vaporized during normal operation at a minimum envelope temperature of 500° C., said quantity of mercury being sufficient to develop a vapor pressure in the range of 1 to 15 atmospheres, sodium iodide in excess of the quantity vaporized at said envelope temperature, thallium monoiodide to the extent of 1 to 8 percent by weight of said filling, and indium and gallium monoiodide to the extent together of 0.10 to 2 percent by weight of said filling, but no other iodine.

3. A high pressure metal vapor electric discharge lamp comprising a quartz envelope having a pair of thermionic electrodes sealed into opposite ends, each electrode comprising a tungsten shank having wound thereon a tungsten

wire coil and having a coating of thorium oxide on said coil and filling the interstices between turns thereof, said envelope containing a filling comprising an inert starting gas, a quantity of mercury which is completely vaporized during normal operation at a minimum envelope temperature of 500° C. and is sufficient to exert at such time a vapor pressure in the range of 1 to 15 atmospheres, sodium iodide in excess of the quantity vaporized at said envelope temperature, a quantity of thallium monoiodide between 1% and 8% by weight of the total filling, and a quantity of indium monoiodide between 0.10% and 2% by weight of the total filling, but no other iodine.

4. A high pressure metal vapor electric discharge lamp comprising a quartz envelope having a pair of thermionic electrodes sealed into opposite ends, each electrode comprising a tungsten conductor coated with thorium oxide, said envelope containing a filling of an inert gas at a low pressure, mercury between 2 and 10 milligrams per cubic centimeter of envelope volume, sodium iodide between 0.1 and 3.0 milligrams per cubic centimeter, and thallium monoiodide between 0.1 and 0.5 milligram per cubic centimeter, but no other iodine.

5. A high pressure metal vapor electric discharge lamp comprising a quartz envelope having a pair of thermionic electrodes sealed into opposite ends, each electrode comprising a tungsten conductor coated with thorium oxide, said envelope containing a filling of an inert starting gas at a low pressure, mercury between 2 and 10 milligrams per cubic centimeter of envelope volume, sodium iodide between 0.1 and 3.0 milligrams per cubic centimeter, thallium monoiodide between 0.1 and 0.5 milligram per cubic centimeter, and indium monoiodide between 0.01 and 0.15 milligram per cubic centimeter, but no other iodine.

6. A high pressure metal vapor electric discharge lamp comprising a quartz envelope having a pair of thermionic electrodes sealed into opposite ends, each electrode comprising a tungsten conductor coated with thorium oxide, said envelope containing a filling of an inert starting gas at a low pressure, mercury between 2 and 10 milligrams per cubic centimeter of envelope volume, sodium iodide between 0.1 and 3.0 milligrams per cubic centimeter, thallium monoiodide between 0.1 and 0.5 milligram per cubic centimeter, and indium monoiodide and gallium monoiodide together between 0.01 and 0.15 milligram per cubic centimeter, but no other iodine.

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