

PATENT SPECIFICATION (11)

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(54) HIGH PRESSURE MERCURY VAPOUR DISCHARGE LAMPS

(71) We, WESTINGHOUSE ELECTRIC CORPORATION of Westinghouse Building, Gateway Center, Pittsburgh, Pennsylvania, United States of America, a company organised and existing under the laws of the Commonwealth of Pennsylvania, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to high-pressure mercury vapour discharge lamps, and more particularly to discharge lamps having a color similar to that of an incandescent lamp and having good color rendition and high efficiency.

Since the advent of the use of high-pressure mercury vapour discharge lamps for general lighting purposes, it has been apparent that an improvement in quantity of light was gained, but, where the color of objects viewed under the light source was of importance, the quality of the light emitted from such lamps had shortcomings. This was primarily due to the lack of radiation in the red portion of the visible spectrum. As a result, the use of the high-pressure mercury discharge lamp was primarily limited to applications where lamp efficiency was of prime consideration and source color or color rendition from the source were of minor importance, for example, in highway, street and parking lot lighting.

The incandescent lamp, which has abundant emissions in the red portion of the visible spectrum has been in use for a long time and users have become "accustomed to" its radiation. When the high-pressure mercury discharge lamp came into use, users compared it with the incandescent lamp, and it became evident that unless the emission spectrum of the high-pressure mercury lamp was changed, it would never replace incandescent lamps where aesthetics were involved. One method of modifying the spectrum of the high-pressure mercury discharge lamp is to coat the inner surface of the outer envelope with a phosphor. Such

color corrected high-pressure mercury discharge lamps are well known in the art.

U.S. Patent No. 2,748,303 disclosed the use of magnesium fluorogermanate phosphor (Activated with manganese with a valence of 4 plus). Lamps of this type have been widely used and typically provide a correlated color temperature of about 4100°K with a color rendition index of about 43. U.S. Patent No. 2,615,848 disclosed a high-pressure mercury lamp using a magnesium arsenate phosphor (also activated with manganese with a valence of 4 plus). The magnesium arsenate lamps provide light of a quality similar to that of the magnesium fluorogermanate coated lamps. U.S. Patent No. 3,569,762 discloses a high-pressure mercury discharge lamp with an yttrium vanadate phosphor (activated with europium with a valence of 3 plus). Such lamps typically have a correlated color temperature of about 3600°K and a color rendering index of about 47. U.S. Patent No. 3,661,791 discloses a method for preparing yttrium phosphate-vanadate phosphor (activated with trivalent europium) to be used with a high-pressure mercury discharge lamp. Lamps using such a phosphor have emissions similar to that of lamps using yttrium vanadate.

The internationally accepted method for standardizing and measuring the color rendering properties of light sources is set forth in the publication of the International Commission on Illumination, identified as publication C.I.E. No. 13 (E-1.3.2) 1965.

The radiation from an incandescent filament is well known. The emission is dependent upon the temperature at which the filament is operated and the locus of emissions for different temperatures as plotted on an ICI color diagram is commonly referred to as "the black body line." In order to maintain a reasonable life of an incandescent bulb, such are generally run at less than 3100°K and typically at about 2900°K.

The ICI color system is described in detail in the "Handbook of Colorimetry," by Arthur C. Hardy, The Technology Press, Massachusetts Institute of Technology (1936).

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Not only were color corrected mercury discharge lamps of the prior art of two high a correlated color temperature (too blue), but the emission of such lamps was also away from the black body line (the magnesium fluorogermanate lamp, for example, was too green) and therefore inherently provided relatively poor color rendition.

One method which has been used to lower the correlated color temperature is to use a very thick coating of phosphor. Using such a thick coating of yttrium vanadate phosphor, for example, has reduced the correlated color temperature from approximately 3600 to approximately 3440°K. Unfortunately, this not only reduces the color rendering index slightly but also dramatically reduces the efficiency.

Silica layers have been used in high-pressure mercury vapor lamps. In U.S. Patent 2,838,705, a silica layer is used between the phosphor and a silverized reflector to prevent chemical reactions between the phosphor and the reflector. Silica has also been mixed with phosphors. In U.S. Patent 2,806,968 silica is mixed with the phosphor, such that less phosphor is required and the cost of the lamp reduced (silica being less expensive than the phosphor).

Apparently none of the lamps of the prior art succeeded in reducing the color temperature to the range of 2800—3100°K while simultaneously holding chromaticity to the black body line and thus none of the lamps achieved an emission of a color similar to that of an incandescent lamp.

The invention consists in a high pressure mercury vapor discharge lamp comprising an elongated light-transmitting arc tube containing a predetermined amount of mercury which when fully vaporized during normal operation of said lamp will provide a predetermined pressure of mercury vapor in the arc tube, outer light-transmitting envelope having spaced from and enclosing said arc tube an interior surface with a non-luminescent oxide coating of principally sub-micron particles of at least one of silica, magnesia, titania, and alumina disposed directly thereon and a phosphor mixture disposed on said non-luminescent oxide coating, said phosphor mixture consisting essentially of 70—90% by weight of at least one of yttrium phosphate-vanadate activated by europium and yttrium vanadate activated by europium and 10—30% by weight of at least one of magnesium fluorogermanate activated with manganese and magnesium arsenate activated with manganese.

It has been discovered that a color corrected high-pressure mercury vapour discharge lamp with an emission having a color very similar to that of an incandescent lamp, but with the efficiency and long life of a discharge lamp, can be obtained using the

non-luminescent oxide coating on the interior surface of the outer envelope with one of certain phosphor mixtures coated over the non-luminescent oxide coating. Best results have been obtained with a phosphor mixture consisting essentially of approximately 83% by weight of europium-activated phosphor and approximately 17% by weight of manganese-activated phosphor. The combination achieves a correlated color temperature of about 3000°K with a color rendering index of about 60.

In particular, it has been discovered that principally submicron particles of the above mentioned non-luminescent oxides provide a color shift which could be obtained by varying the percentages in the phosphor blend and this color shift, together with certain phosphor blends, makes possible and incandescent-color high pressure mercury discharge lamp.

In order that the invention can be more clearly understood, a convenient embodiment thereof will now be described, by way of example, with reference to the accompanying drawings in which:

Figure 1 is a side elevational view of a high pressure mercury vapour discharge lamp constructed in accordance with the present invention, with part of the outer envelope and arc tube broken away, a circuit diagram of a power supply also being shown;

Figure 2 illustrates the x, y-chromaticity diagram of the ICI system showing the x, y coordinance of the emission of various lamps; and

Figure 3 shows the emission spectrum of the lamp of the present invention, with relative energy plotted against wavelength in nanometers.

In Figure 1 there is shown the general arrangement of a high-pressure mercury discharge lamp within which the non-luminescent oxide coating and the phosphor mixture coating of the present invention are utilized. The lamp, generally designated 10, includes an outer light-transmitting envelope 12 which is sealed to a standard mogul base 14. Mounted within the outer envelope 12 and spaced therefrom is an arc tube 16. The arc tube 16 is mounted within the outer envelope 12 by conventional frame 18 and a pair of straps 20. Sealed within the arc tube 16 disposed at opposite ends thereof is a pair of tungsten operating electrodes 22 and 24. The electrodes 22 and 24 are sealed to opposite ends of the arc tube 16 by a conventional ribbon seal 26. A starting electrode 28 is also sealed to the arc tube adjacent to electrode 24 by means of ribbon seal 26.

The frame 18 is carried by one of a pair of conventional lead-in conductors 30 which extend through a conventional reentrance

stem press 32 connected to mogul base 14, which in turn is connected to a conventional power source 34 in the well-known manner. The electrodes 22, 24 and 28 are electrically

5 connected to one or the other of the lead-in conductors 30. A starting resistor 36 is connected between one of the lead-in conductors 30 and the starting electrode 28 to the frame 18.

10 A charge of mercury 38 is contained within the arc tube 16 and this predetermined amount of mercury will, when fully vaporized during normal operation of the lamp provide a predetermined pressure therein.

15 The arc tube also contains a small charge of an inert ionizable starting gas.

The non-luminescent oxide coating 40 is disposed directly on the interior surface of the outer envelope 12. The phosphor mixture 42 is coated over the non-luminescent oxide coating 40 and thus the two layers are provided with the phosphor-mixture layer 42 being on the inside closer to the arc tube and the non-luminescent oxide layer being

25 on the outside and directly on the interior surface of the outer envelope.

The lamp configuration, (other than the non-luminescent oxide and particular phosphor coatings) is essentially conventional and a more detailed description of its operation may be found in the aforementioned U.S. Patent No. 2,748,303.

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Generally, the non-luminescent oxide coating 40 will be from about 0.2 to 2 milligrams (mg) per square centimeter (and typically about 0.5—0.9 mg per square centimeter). Generally, the coating of the phosphor mixture 42 will be from about 1—8 mg of phosphor per square centimeter of coated area (and preferably about 2.4—2.8 mg per square centimeter).

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The particle size of the non-luminescent oxide coating 42 must be principally of sub-micron size (it must be principally comprised of particles having an average diameter of less than one micron). It has been found, for example, that silica particles having a 0.025 micron average size (such as Pittsburgh Plate Glass's "HiSil") provide a satisfactory coating. It has been found that the particle size is critical and experiments with, for example, titania of a particle size generally greater than 2 microns showed that the desired color shift was not obtained.

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Figure 2 shows the relative emissions of various lamps and also the black body line. Point A represents the emission of a clear (without any phosphor coating) high-pressure mercury lamp. Point B represents the emission of a magnesium fluorogermanate lamp with a normal thickness of phosphor coating. Point C represents the emission of a yttrium phosphate-vanadate lamp. Point

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the present invention and Point E represents the emission of a typical incandescent lamp. The line FG is the black body line. The filament temperatures for various points along the black body line are as indicated. As noted previously, the emission of the magnesium arsenate lamp is similar to that of the magnesium fluorogermanate lamp and the emission of the yttrium vanadate is similar to that of the yttrium phosphate-vanadate lamp.

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Emissions along the line AC can be obtained by using thinner layers of yttrium vanadate phosphor, and emissions along the line AB can be obtained by using thinner coatings of a vanadate phosphor. Emissions along the line BC can be obtained by a normal coating thickness with a mixture of vanadate and fluorogermanate phosphors. Similarly, points in the triangle ABC can be achieved by thinner layers of mixtures of these phosphors. Points beyond B along the extension of line AB could be obtained by a thicker coating of vanadate phosphor, but such thick coatings severely reduce luminous efficiency and, because of the cost of the phosphors, significantly raise the cost of the lamp. Surprisingly, an approximately normal thickness of an appropriate mixture of phosphor produces an emission, not inside triangle ABC, but at point D when the appropriate layer of non-luminescent oxide is included.

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The relatively inexpensive layer of non-luminescent oxide such as silica deposited on the interior surface of the outer envelope (between the phosphor mixture and the outer envelope) provides a significant shift in the color of the emission. An emission with a color temperature of about 3000°K in close proximity to the black body line can be obtained using normal phosphor thicknesses. When a proper blend (about 70—90% by weight of either yttrium phosphate-vanadate or yttrium vanadate or mixtures of the two is blended with about 10—30% by weight of either magnesium fluorogermanate or magnesium arsenate or mixtures of these two) is placed over a layer of appropriate non-luminescent oxide previously deposited on the inside surface of the light-transmitting outer envelope of a 400 watt high-pressure mercury discharge lamp, the result is a lamp emitting approximately 19,500—20,000 lumens after 100 hours of burning with a source chromaticity of an incandescent lamp. It was found that mixing the non-luminescent oxide with the phosphors into a single layer coating did not produce the desired color shift but that the deposition of the non-luminescent oxide and phosphors in separate layers provided a color shift (for all light leaving the lamp) and the desired color shift was obtained.

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A coating of silica can be done, for ex-

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ample, by mixing approximately 39 grams of submicron size silica, together with 170 milliliters of nitrocellulose lacquer and 85 milliliters of butylacetate solvent. This slurry is milled for about 3½ hours and then coated on the bulb. The bulb is then lehrd to remove the lacquer binder. After lehring of the silica coating, the phosphor mixture is applied. A first slurry is prepared by mixing 1200 grams of yttrium phosphate-vanadate of yttrium vanadate phosphor (preferably yttrium phosphate-vanadate) with 775 milliliters of butylacetate solvent and 825 milliliters of nitrocellulose lacquer. A second slurry is prepared by mixing 1200 grams of magnesium fluorogermanate or magnesium arsenate (preferably magnesium fluorogermanate) with 1475 milliliters of nitrocellulose lacquer and 600 milliliters of butylacetate solvent. After milling, two slurries can be mixed together by a ratio of 1 part by volume of magnesium-fluorogermanate to 4 parts of yttrium phosphate-vanadate and coated on the bulb. The coated bulb is then lehrd again to remove the binder. The phosphor mixture which results from this coating process is the preferred mixture and consists essentially of about 17% by weight yttrium phosphate-vanadate and about 83% by weight of magnesium fluorogermanate.

Magnesia, titania and alumina or mixtures thereof can be substituted in whole or in part for the silica in the preceding examples in approximately the same proportions. Alumina is especially convenient as it does not readily absorb moisture (as compared to magnesia or silica) and is readily obtained in submicron size particles (as compared to titania which is generally available only in particle sizes too large for this application).

Figure 3 illustrates the emission spectrum of a lamp of the present invention. Such a lamp has enough emission in the 600–700 nanometer region to provide enough red to give an incandescent color, but has very little emission in the infrared region (above approximately 700 nanometers). Conversely, the incandescent lamp emits most of its

energy in the infrared region, and this energy is generally wasted and any attempt to get more of the energy in the visible region by raising the filament temperature will, of course, result in further shortening the already relatively short life of the incandescent lamp). Thus, the lamp of the instant invention provides the color of the incandescent lamp, without the low efficiency and short life of the incandescent lamp.

WHAT WE CLAIM IS:—

1. A high pressure mercury vapour discharge lamp comprising an elongated light-transmitting arc tube containing a predetermined amount of mercury which when fully vaporized during normal operation of said lamp will provide a predetermined pressure of mercury vapor in the arc tube, an outer light-transmitting envelope having spaced from and enclosing said arc tube an interior surface with a non-luminescent oxide coating of principally submicron particles of at least one of silica, magnesia, titania, and alumina disposed directly thereon, and a phosphor mixture disposed on said non-luminescent oxide coating, said phosphor mixture consisting essentially of 70–90% by weight of at least one of yttrium phosphate-vanadate activated by europium and yttrium vanadate activated by europium and 10–30% by weight of at least one of magnesium fluorogermanate activated with manganese and magnesium arsenate activated with manganese.

2. A lamp according to claim 1, wherein the phosphor mixture consists essentially of approximately 83% by weight yttrium phosphate-vanadate activated by europium and approximately 17% by weight of magnesium fluorogermanate activated with manganese.

3. High pressure mercury vapour discharge lamps as claimed in claim 1 and substantially as described herein with particular reference to the accompanying drawings.

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