Nov. 7, 1967 A. BAUER 3,351,798

SCANDIUM HALIDE DISCHARGE LAMP

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Fig. 1.

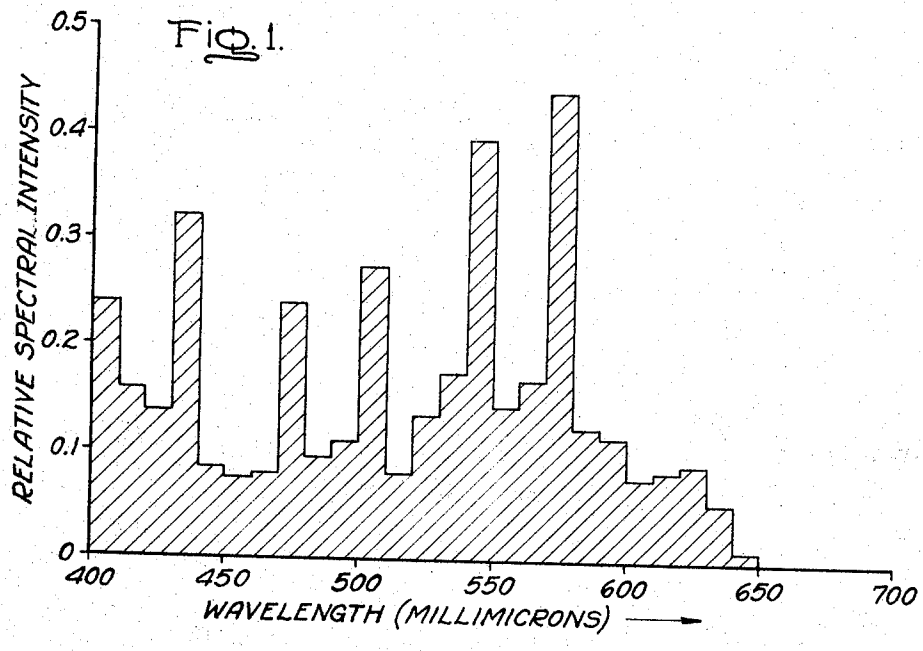
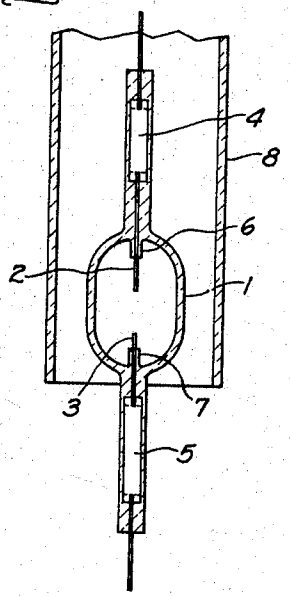


Fig. 2.



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SCANDIUM HALIDE DISCHARGE LAMP

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The present invention relates to high pressure discharge lamps having solid hot electrodes and containing a filling which includes a compound of a metal excited in the high pressure discharge.

Amongst high-pressure lamps, the one most generally used is the high pressure mercury vapor lamp. It comprises an envelope consisting generally of quartz glass which contains a starting gas and a small quantity of mercury which is completely vaporized in operation of the lamp. The arc maintained at a vapor pressure of 1 to 25 atmospheres emits, besides a relatively weak continuum, primarily a line spectrum consisting of a few very strong lines. As a result, the light output of these lamps differs very much from natural light and also from the light emitted by an incandescent solid body, and color rendition is quite unsatisfactory. In order to improve the color rendition, it is already well known to add to the mercury other metals, as zinc or cadmium, for the purpose of increasing the percentage of red light emitted from the discharge. Such additions, however, cause a substantial decrease in light output which offsets the advantage gained in respect of color rendition.

In mercury vapor lamps of former construction provided with liquid mercury electrodes, the addition of salts, e.g. of halides, by means of which the mercury arc should get a definite coloration, was also known.

It has recently been proposed to provide in high-pressure mercury vapor discharge lamps with solid electrodes, in addition to the mercury filling, halide compounds of other metals which are excited to emission simultaneously with the mercury. Mercury vapor discharge lamps manufactured according to this proposal contain in most cases an addition of sodium iodide, potassium iodide, lithium iodide or thallium iodide. They show a satisfactory filling up of the deficiency in red of the mercury arc without the decrease in light output occurring in prior mercury vapor lamps upon addition of zinc or cadmium. Since however none of the excited metals emits many more lines than mercury, the visible spectrum consists notwithstanding of a few lines only and is not equivalent to daylight in respect of color quality.

There may be obtained an excellent color rendition with a high-pressure discharge lamp in which rare earths are excited because their spectra have a close sequence of lines. However rare earths have the disadvantage of a very low vapor pressure, so that in order to obtain high light output the discharge envelope must have temperatures of more 1000° C. Thus by way of example, lanthanum iodide has a boiling point of 1400° C.

Within the scope of experiments with rare earth additions, it has been surprising to find that scandium compounds hold an exceptional position as against all other metals or metal compounds hitherto used for the filling.

If scandium is excited to radiant emission with definite intensity then it emits in the visible range just as close a light spectrum as the rare earths but without any large energy losses in the ultraviolet and infrared ranges. Besides, the vapor pressure of some scandium compounds, especially that of scandium iodide ScI_3, suffices for a high pressure arc. Thus, high-pressure lamps containing Sc-compounds have two decisive characteristic features which

have hitherto, not been found simultaneously in any high-pressure lamp:

(1) The addition renders a light color which is extremely similar to natural daylight, in the same fashion as the light of a high-pressure xenon discharge lamp. This may be seen from FIG. 1 which shows the spectral energy distribution of a high-pressure lamp with an addition of ScI_3.

(2) While additions of metal halides proposed hitherto have no bad influence on light output but do not greatly increase it, now however the efficiency is raised to 105 lumens per watt (lm./w.) by addition of a Sc-compound.

For lamps with high output concentration and resulting high wall temperature, the envelope of which consists of quartz glass or fine-crystalline, transparent aluminum oxide and in which the scandium halide vapor pressure exceeds 1 atm., a filling of ScI_3, by way of example, is sufficient. For the purpose of better starting, an additional rare gas filling at 10 to 100 mm. of mercury cold pressure is desirable.

In case of wall temperatures below 900° C. as are usual for instance in ordinary high-pressure mercury lamps, the vapor pressure of ScI_3 is below 1 atm. Thus for instance at 800° C., it amounts to 0.1 atm. Therefore, it is desirable to fill-in additionally with a heavier buffer gas at higher pressure in order to reduce losses due to heat conduction and diffusion. The exciting voltages of Sc are low, generally below 4 volts. Therefore, a suitable buffer gas is a heavy gas having exciting voltages lying above this limit. The heavier rare gases for instance meet this requirement. Generally, an addition of mercury vaporizing completely in operation will be most suitable which ensures a partial pressure of more than 1 atm., e.g. of 5 to 25 atm. The average exciting voltage of mercury lies at about 7.8 volts and that of scandium below 4 volts, and an equal number of atoms of both elements are excited with a partial pressure ratio $p_{Hg}/p_{Sc} \approx 10^2$. Provided the above-mentioned ratio $p_{Hg}/p_{Sc}=25/0.1=250$ or less, scandium radiation predominates.

In an electric high-pressure vapor discharge lamp with solid hot electrodes comprising an envelope consisting of refractory or high-melting, light transmissive material and containing a filling including a metallic compound, according to the present invention scandium is chosen as the added compound to be excited. The scandium compound may consist of ScI_3, $ScBr_3$, $ScCl_3$ or of yet other scandium compounds with sufficient vapor pressure such as Sc_2S_3. In a lamp with tungsten electrodes, the preferred compound is ScI_3 because the iodine cycle then prevents vaporized tungsten from depositing on the bulb wall. The loading of the electrodes is desirably high enough that the tips or environments of the arc appendage thereon are molten in operation of the lamp.

The present invention provides a high-pressure lamp with excellent light output exceeding even that of a high-pressure mercury arc, and which has a very good color rendition comparable with that of a high-pressure xenon arc. Because of the relatively high vapor pressure of scandium halides, the lamp may be rated for an operating temperature as high as is usual for the well-known high-pressure mercury lamps. These lamps may, therefore, in advantageous manner be produced according to well developed methods of manufacture.

Beside scandium halide and, if desired, a quantity of mercury which is completely vaporized in operation, the lamp contains for the purpose of better starting a rare gas filling at some 100 mm. of mercury cold pressure. A small excess of halogen over the stoichiometric ratio corresponding to the scandium halide is desirable and may be introduced into the lamp for instance in the form of mercury halide.

Owing to the fact that a discharge is scandium contracts more than a discharge in mercury, the manufacture of a wall-stabilized lamp not artificially cooled is quite difficult. A lamp according to the invention of high wall loading which is cooled artificially can be made as a capillary lamp. The diameter of the discharge space amounts to a few millimeters at most; the length of the arc, up to some centimeters.

For cases in which artificial cooling is not desired, electrode-stabilized lamps have been made. Wall loading in these amounts of 20 to 60 w./cm.^{2}, preferably 40 w./cm.^{2}. The interelectrode distance or gap for projection lamps may amount to some millimeters. The lamp bulb is spherical or oval like that of well known extra high-pressure mercury lamps. If the operating mercury vapor pressure therein is higher and amounts for instance to 25 atmospheres, then with an electrode distance of 6 mm., an operating voltage of 90 to 100 volts results. In lamps not having such high efficiency, the operating pressure of the mercury vapor need not be so high. Thus an operating voltage of 150 to 250 volts is obtained with a vapor pressure of 5–10 atmospheres and an interelectrode distance of 1 to 2 cm.

FIG. 1 shows the spectral energy distribution of a high-pressure lamp with an addition of ScI_3.

FIG. 2 shows by way of example a lamp embodying the invention.

As illustrated in FIG. 2, the discharge envelope **1** consists of quartz glass and encloses a volume of 27 cm.^{3}. The inner diameter of the tubular envelope which is closed spherically at both ends amounts to about 30 mm. The pin electrodes **2** and **3** consist of refractory metal, preferably of tungsten wire 1.2 mm. in diameter and have the usual foil inleads **4** and **5**. The electrodes may be provided with tightly fitting quartz sleeves **6** and **7** passing integrally over into the quartz envelope **1** in order to suppress the iodine cycle at cooler places on the electrodes where tungsten sputtering may occur. Any electrode activation beyond the usual thorium addition should be avoided. The rare gas filling in order to facilitate starting amounts to 15 mm. Hg of argon. The mercury filling vaporizing completely in operation and amounting to 304 milligrams results in a vapor pressure of about 10 atms. A filling of 30 mg. ScI_3 does not vaporize completely in operation. An addition of 3 mg. HgI_2 brings about better behavior during life of the lamp.

The electrical and lighting data of the lamp are:

Wattage	watts	2430
Current intensity	amperes	13.3
Voltage	volts	240
Electrode distance	cm	1.5
Wall load	w./cm.^{2}	40
Luminous flux	lumen	254,000
Efficiency	lm./w.	105

An increase in output may easily be obtained with this lamp type by enlarging the lamp envelope and/or by means of forced cooling. Wall loading may be increased in simple manner up to 50% to 70% by putting the lamp into a glass tube **8** arranged vertically and open at both ends. The tube may be elongated upwardly for instance a length of 40 cm. and produces a cooling air flow by chimney effect. With this arrangement, there may for instance be converted an electric energy of 10 kw. in a quartz burner having a length of 9 cm. and a diameter of 5.8 cm.

Beside the type with short arc distance there was developed another type with greater arc distance which is operated with proportionately high voltage of for instance 400 to 600 volts. It has been found that such lamps require magnetic field stabilization.

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

1. A high pressure electric discharge lamp comprising an envelope of refractory light-transmitting material having a pair of slender solid tungsten electrodes sealed therein and containing a filling of mercury providing a vapor pressure in excess of 1 atmosphere when fully vaporized in normal operation, a quantity of scandium iodide in excess of that vaporizing during operation, and a rare gas at a cold filling pressure between 10 and 100 millimeters of mercury.

2. A high pressure electric discharge lamp as defined in claim **1** wherein the partial pressure of mercury is in the range of 5 to 25 atmospheres and the ratio of partial pressure of mercury to partial pressure of scandium during operation does not exceed 250 in order to have scandium radiation predominating.

3. A lamp as defined in claim **1** wherein the filling contains additional iodine over the stoichiometric proportion corresponding to the scandium iodide present.

4. A high pressure electric discharge device comprising an arc tube having electrodes sealed at either end thereof and a vaporizable fill of iodine, mercury and atoms of scandium; said iodine and mercury respectively being present in an atomic ratio of about 0.14 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, the atoms of said scandium being present in sufficient quantities to produce white light.

5. A high pressure electric discharge lamp comprising an envelope of refractory light-transmitting material having a pair of tungsten electrodes sealed therein and containing a filling of mercury providing a vapor pressure in excess of one atmosphere when fully vaporized in normal operation, a quantity of a scandium compound in excess of that vaporizing during operation, and a rare gas at a cold filling pressure between 10 and 100 millimeters of mercury.

6. A high pressure electric discharge lamp comprising an envelope of refractory light-transmitting material having a pair of tungsten electrodes sealed therein and containing a filling of mercury providing a vapor pressure in excess of 1 atmosphere when fully vaporized in normal operation, a quantity of a scandium halide in excess of that vaporizing during operation, and a rare gas at a cold filling pressure between 10 and 100 millimeters of mercury.

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