March 20, 1951 G. G. ISAACS ET AL 2,545,884

HIGH-PRESSURE MERCURY VAPOR ELECTRIC DISCHARGE LAMP

Filed Nov. 25, 1947 3 Sheets-Sheet 1

Fig. 1

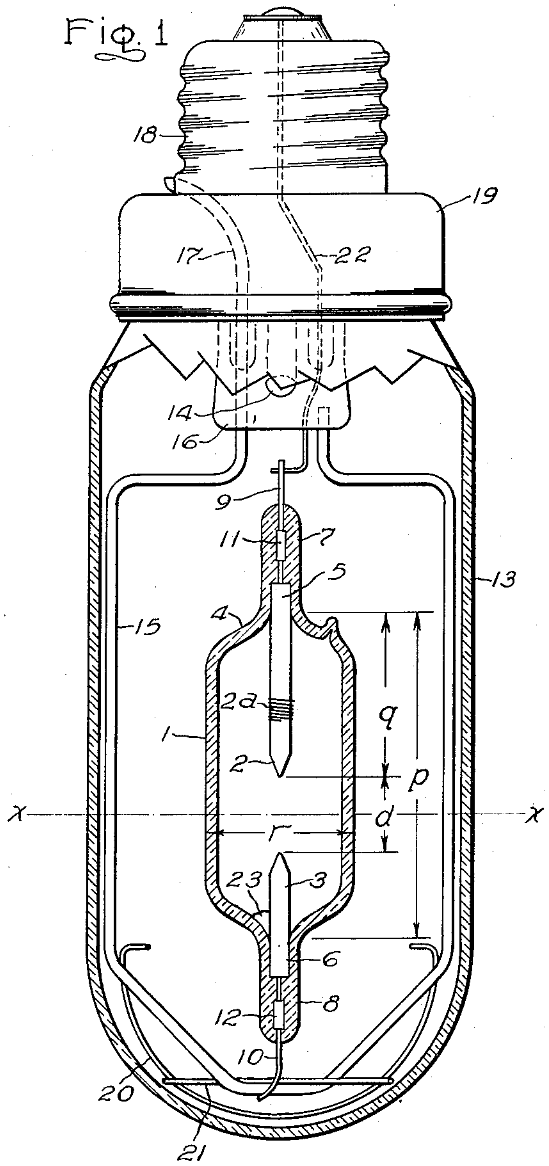
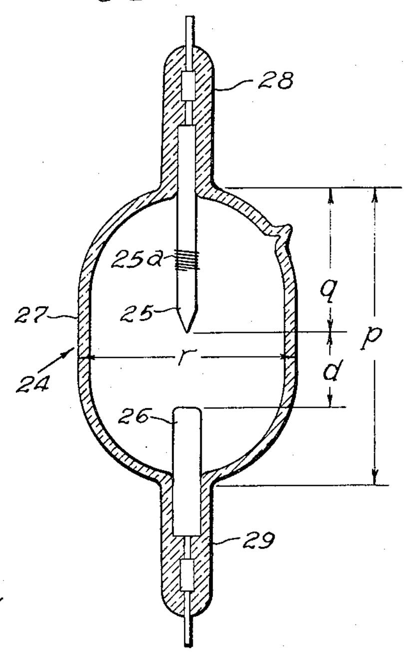


Fig. 2



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Filed Nov. 25, 1947 3 Sheets-Sheet 2

Fig. 3

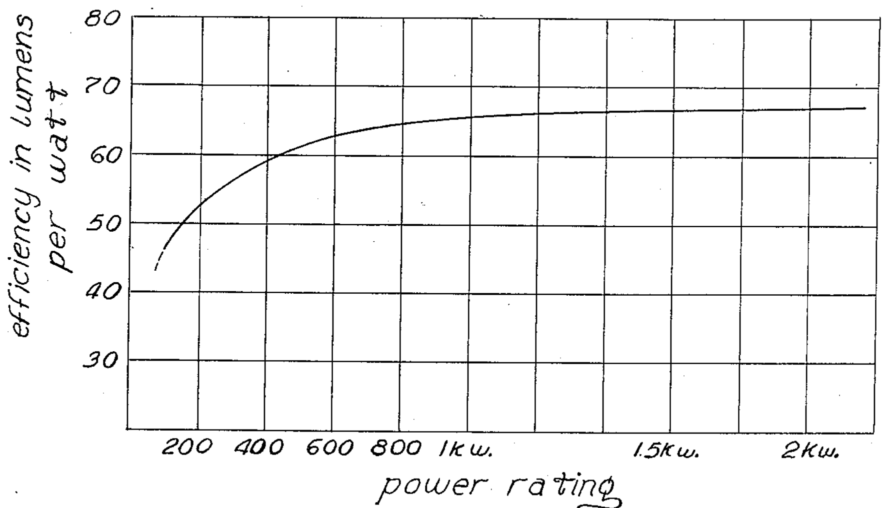

Fig. 4

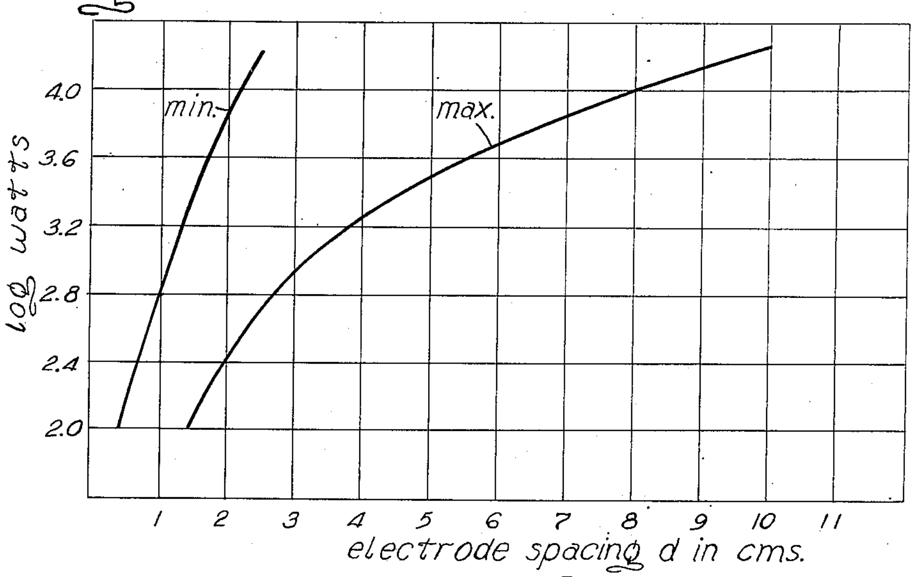

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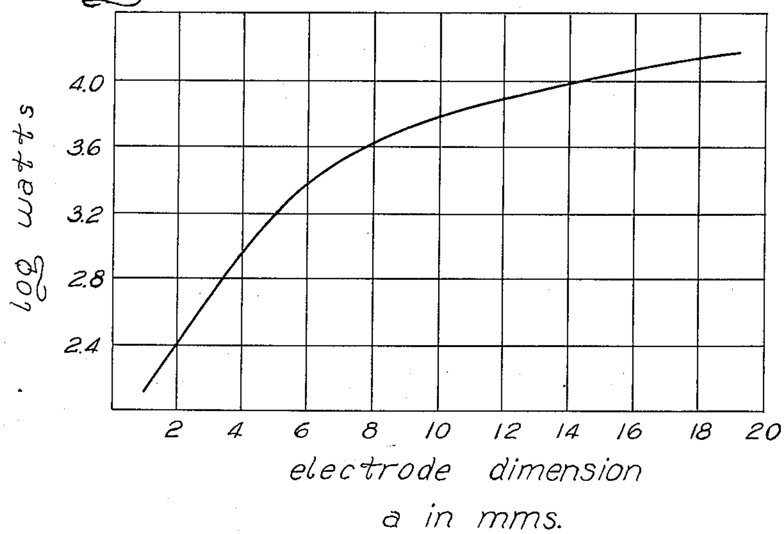
Fig. 5



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UNITED STATES PATENT OFFICE

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HIGH-PRESSURE MERCURY VAPOR ELECTRIC DISCHARGE LAMP

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Application November 25, 1947, Serial No. 787,982
In Great Britain January 18, 1946

2 Claims. (Cl. 176—122)

1

Our invention relates to high pressure electric discharge devices and more particularly to high pressure mercury vapor electric discharge lamps.

This application is a continuation-in-part of our copending patent application Serial No. 717,028, filed December 18, 1946, now abandoned, and which is assigned to the assignee of the present application.

As a general matter, electric discharge lamps may be roughly classified into: glow discharge lamps, low pressure positive column discharge lamps, and high pressure discharge lamps. Our invention is concerned particularly with lamps coming within the last category and more specifically to high pressure electric discharge lamps of the short-gap type. Although certain aspects of our invention described hereinafter are applicable to high pressure discharge lamps generally, we are particularly concerned with high pressure lamps of the short-gap type wherein the configuration or diameter of the arc discharge is controlled primarily by the pressure of the ionizable medium employed, or in which an inside transverse dimension or diameter of the enclosing envelope is substantially greater than the length of the arc discharge path, as contrasted with high pressure discharge lamps of the capillary type wherein the inside diameter of the enclosing envelope, or its bore, is substantially smaller than that of the arc gap length.

The most efficient form of high pressure mercury lamp known hitherto has been the water-cooled type in which the discharge takes place through a narrow tube, for example of about two millimeters diameter, and with such lamps efficiencies as high or higher than 60 lumens per watt have been obtained; the water-cooling required is, however, usually inconvenient and, moreover, gives rise to considerable obscuration of the light; the lamps also usually require operation at about 300 to 400 volts per cm. of arc length which with arc lengths of several cms. necessitates the use of inconveniently high operating voltages.

It is an object of our invention to provide new and improved high pressure electric discharge lamps.

It is another object of our invention to provide new and improved methods of operating electric discharge lamps.

It is a further object of our invention to provide new and improved constructions for high pressure mercury vapor discharge lamps capable of sustained operation at high power ratings.

It is a still further object of our invention to

2

provide a lamp structure of the short-gap type in which efficiencies higher than 60 lumens per watt can be obtained, except possibly in those lamps adapted to dissipate less than 500 watts. It may be stated here that high efficiency is more difficult to attain with lamps adapted to dissipate relatively low wattages.

Generally speaking, in accordance with our invention we have found that in order to obtain substantial improvements in efficiency over and above that obtainable in prior art discharge lamps, without sacrificing the desired long life, the discharge lamps of this type should be constructed in accordance with definite relationships between: the power transmitted to the lamp per unit of arc length established by the electrode spacing, the voltage per unit of arc length as established by the same spacing, and the arc length or electrode spacing determined in accordance with predetermined ranges of maximum and minimum values correlated to the power supplied to the lamp terminals. A decrease in volts per cm. generally leads to a decrease in efficiency, but the effect is however small as long as the volts per cm. are sufficiently high. A further feature involves the utilization of electrodes of predetermined size commensurate with, or a function of, the power supplied to the lamp.

In accordance with our invention a high pressure mercury vapor lamp adapted to operate without water cooling and to dissipate in normal operation a wattage lying between 100 watts and 15,000 watts is constructed so that the arc length *d* lies within or between predetermined minimum and maximum values for particular wattages as stated hereinafter, and the volts per cm. of arc length when the lamp is operated at a specified wattage, is not less than 20 for wattages greater than 2000, and not less than 30 for wattages less than 2000. That is, the voltage per cm. of arc length should not be less than 20.

Referring now particularly to Fig. 1, we have illustrated our invention as applied to a high pressure mercury vapor lamp 1 comprising a pair of spaced electrodes 2 and 3 constructed of a refractory metal, such as tungsten, establishing between the terminals or arc supporting surfaces thereof an arc gap of length *d*. The electrodes 2 and 3 may be tapered at the ends thereof in the manner illustrated, and these arc supporting surfaces may be activated with a refractory material such as thoria. Other activating material, such as barium or strontium oxides, may be provided away from the terminal surfaces, in well known manners, to assist in the starting operation of the lamp. One such arrangement for activating the electrode or cathode may be a tungsten helic 2a tightly wound about the cathode spaced from the arc supporting surface thereof.

For a better understanding of our invention reference may be had to the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims. Fig. 1 illustrates one modification of our invention wherein a high pressure electric discharge lamp of the short-gap type is positioned in and supported by an external lamp structure comprising an outer enclosing envelope. Fig. 1a is a modification of the lamp shown in Fig. 1 intended for operation on direct current. Figs. 2–5, inclusive, are curves representing the optimum lamp characteristics to be employed in constructing lamps in accordance with our invention. Fig. 3 is representative as to the efficiencies which are obtainable by employing our invention in the construction of high pressure lamps. Fig. 4 is a curve showing the relationship between lamp power rating and the range of electrode spacings, wherein the ordinates represent the logarithms of the wattage to the base 10, and the abscissae represent the maximum and minimum values for the electrode spacing. In Fig. 5, the curve represents the relationship between the logarithm to the base 10 of the lamp wattage and the electrode size or diameter.

Electrodes 2 and 3 are positioned in and supported by a quartz envelope construction 4. Electrodes 2 and 3 are preferably of cylindrical form having substantial outer end parts 5 and 6 extending appreciable distances into the seal constructions 7 and 8 at each end of the envelope. If desired the electrodes 2 and 3, or more particularly the ends 5 and 6 may be connected to externally accessible terminals constituted by conductors 9 and 10 which are electrically connected to electrodes 2 and 3 through strip seal constructions comprising metallic members 11 and 12 which are embedded in the quartz and sealed thereto.

By the term "discharge lamp of the short-gap type" we mean an electric discharge lamp in which an inside dimension of the arc chamber defined by envelope 4 is larger than the arc-gap length d. Referring to Fig. 1, which is an example of one shape of envelope which may be employed, the inside transverse dimension or diameter of the envelope 4 in a plane $x—x$ intermediate the arc-supporting surfaces of electrodes 2 and 3 is substantially larger than the arc-gap length d. It will be apparent that a great variety of envelope shapes may be employed in carrying out our invention.

We have found that precautions should be taken to prevent instability of operation from arising due to the convection flare of the arc discharge atmosphere during operation. To this end the diameter of the envelope 4 should be as small as possible consistent with a desirable limitation in the heating of the quartz employed in the envelope. Where the lamp is intended to be operated in a vertical position the uppermost part of the envelope 4 should be as near as possible to the discharge path without causing overheating of the quartz. Alternatively, or in addition to the above consideration, a shield (not shown) may be provided around the upper electrode 2 intermediate its arc supporting surface and the uppermost part of the envelope 2 and preferably an appreciable distance therebelow, in order to counteract and control the above-mentioned convection flare when the lamp is intended for operation in a vertical position. Such a shield may be of a refractory metal, and in some instances even of quartz, since devitrification of a quartz shield is not a limiting factor and inasmuch as such a shield would not be subjected to a net gas pressure. The shield may take the form of a dish arranged with its concave surface downward.

The lamp 1 may be enclosed within an outer protecting envelope 13. This envelope may be coated with a fluorescent material and furthermore may be constructed of a vitreous composition having desired light transmitting characteristics. The outer envelope 13 may define an evacuated space between it and the lamp 1 which serves to equalize the temperature distribution of the lamp 1. As a means for supporting the lamp 1, we may employ a suitable structure wherein the outer glass envelope 13 is provided with a stem tube 14 and exhaust tube through which the envelope 13 may be exhausted. The supporting structure for the lamp which comprises a conductive support 15 bent into a substantially U or rectangular shape frame having its upper end sealed into a stem press 16. One end of the wire support 15 is attached to an outer lead wire 17 which in turn is attached to the screw-threaded shell 18 having a skirted base 19. The other end of the support wire 15 terminates in the stem press 16. The lower end of the frame 15 is braced by a substantially semi-circular and preferably resilient wire 20 located at the bottom of the envelope 13. Wire 20 is attached to the lower end of the frame 15 by a wire 21 which is welded at its middle to conductor 10 constituting the lower external terminal of the lamp 1. In this manner, electrical connection to the electrode 3 is established through support 15 and lead wire 17. Electrical connection to electrode 2 and mechanical support for the upper part of lamp 1 is obtained by connecting conductor 9 to a lead-in wire 22.

Considering now more specifically the characteristics of the lamp 1, we preferably employ an ionizable medium such as mercury, indicated at the bottom of the envelope 2 as a globule 23. The amount of mercury employed may be in excess of that evaporated or vaporized during the normal operation of the lamp. The term mercury does not exclude the possibility of the presence of small or other substances which may contribute to the light from the discharge.

In carrying out our invention we have provided high pressure vapor lamps of the short-gap type which afford efficiencies substantially greater than that of lamps developed heretofore and which are capable of sustained operation at high power ratings. For example, improvements in efficiencies of 60 lumens per watt, or more, are obtained by constructing the lamps in accordance with the factors described hereinafter. In constructing lamps according to our invention we have found that it is necessary that the arc length should be neither too long nor too short. If the arc length, that is the spacing between the arc supporting surfaces of the electrodes 2 and 3, is too short the electrode losses form too large a part of the total voltage, and moreover a larger fraction of the light is obscured by the electrodes. If the arc length is too long for a given overall power supplied to the lamp, the intrinsic watts per cm. of arc length is too low to provide the desired high efficiencies. The following factors or features have been found to be important in providing lamps having efficiencies greater than 60 lumens per watt, that value of efficiency being obtainable in lamps known heretofore.

The range of electrode spacings, or arc length *d*, as a function of lamp wattage rating is shown in Fig. 4, where maximum and minimum values of arc length *d* are correlated to the lamp wattage, or more strictly, to the logarithm to the base 10 of the lamp wattage.

The relationship between lamp wattage and maximum and minimum values of arc length *d*, may be tabulated as follows:

Wattage	*d* (max.)	*d* (min.)
100	1.5	0.4
250	2.0	0.6
500	2.5	0.8
1,500	3.7	1.3
4,000	5.5	1.7
10,000	8.0	2.2

A still further factor, shown in form of a curve in Fig. 5, and which may be employed in constructing lamps in accordance with our invention, is the electrode diameter *a* in mm. which is correlated to the power input W in watts to the lamp in the following manner:

W	*a* (in mm.)
100	about 0.5
250	2.0
500	2.9
1,500	4.7
4,000	7.6
10,000	14.0

These values of electrode diameters in mm. have been found optimum for operation on alternating current. For operation on direct current, the cathode is preferably smaller and the anode larger than the above stated values. When the electrodes are not of circular cross-section, the term "diameter" is to be understood to indicate an area having the same value as that corresponding to a circle of diameter *a*. For operation on alternating current the electrodes may be tapered, for example at an angle of about 20° with respect to sides of the electrodes and provided with terminal surfaces of small radii. For operation upon direct current the cathode may be shaped as described and the anode may have a flat end for an arc supporting surface and be provided with chamfered edges.

Observed improvements in efficiency of lamps constructed in accordance with our invention greater than or equal to that defined by a curve passing through 60 lumens per watt at 450 watts, and 50 lumens per watt at 125 watts have been obtained. This curve tends toward zero lumens at zero watts, and remains at or above 60 lumens per watt above 450 watts. The above values refer to a photometric standard by which the efficiency of the well known 400 watt street-lighting lamp is given as 45 lumens per watt, the arc length being 16 cm. and the voltage across the lamp 120 to 160 volts. The overall efficiency set forth is obtainable when the lamp is operated on direct current, or in an inductive circuit on alternating current of substantially sinusoidal wave form of commercial frequency.

The intrinsic efficiency of the lamps with which our invention is concerned depends in a primary manner upon the correlation of the watts per cm. and the arc length. It has been found that the efficiency depends to some extent upon the volts per cm. of arc length, a decrease in volts per cm. generally leading to a decrease in efficiency. This latter effect is considered to be secondary to the relationship involving watts per cm. of arc length and the arc length.

A lamp constructed in accordance with our invention and similar in general arrangement to that shown in Fig. 1, except that it is designed for direct current operation, and having its axis vertical is designed to dissipate 700 watts in normal operation. The envelope 4 is made of quartz having walls about 2.5 mms. thick. An anode and cathode such as that shown in Fig. 2 are employed, both of which are formed of tungsten rods, four mms. in diameter, set into suitable seals, such as strip seals.

The cathode is preferably tapered, as explained above, at an angle of about 20° for the last five mms. and is rounded off at the end to form a tip of small radius. The anode has a flat end provided with chamfered edges. Around the cathode, spaced away from its end, is arranged a tightly-fitting helix 2*a* of tungsten wire, coated with electron emissive material, which forms a starting electrode.

The distance *d* between the anode and the cathode, i. e. the arc length, is about 1.5 cms., and the dimensions *p*, *q* and *r* are approximately 60 mms., 30 mms., and 30 mms., respectively.

Mercury and a starting gas such as argon are used, the quantity of mercury being such that about 700 watts are dissipated, the voltage between the electrodes during operation being about 250 volts. The efficiency is about 70 lumens per watt.

In Fig. 2 we have there illustrated a modification of our invention as applied to a high pressure mercury vapor lamp 24 particularly suitable for operation on direct current. A cathode 25 and an anode 26 are enclosed within a quartz envelope 27. These electrodes may be cylindrical shaped members of refractory metal, such as tungsten, sealed to the envelope 27 and extending through seal constructions 28 and 29 to provide external connections directly thereto, thereby reducing electrode and connection losses. An activating helix 25*a*, similar to 2*a*, may be employed.

Where a lamp is intended for operation on direct current, the area of the cross-section of the cathode 25 is preferably smaller than that stated above and shown in Fig. 5, and the area of the anode 26 is larger than the optimum values stated above.

The lamp shown in Fig. 2 is constructed to dissipate 1750 watts. The envelope wall thickness is about 2.5 mms., but the width of the envelope, i. e. the dimension *r* is now about 45 mms. The dimensions *p* and *q* are 60 mms., and 30 mms. The arc length is 1.5 cms., and the mercury filling is such that the lamp dissipates 1750 watts; the lamp operating voltage is about 225 volts, and the efficiency is about 70 lumens per watt.

As stated above, the terminal surface of each of the electrodes for operation on alternating current may be activated with a refractory material such as thoria. One preferred embodiment of an activated electrode is that disclosed and claimed in U. S. patent application of Victor J. Francis, filed February 25, 1947, Serial No. 730,805, now Patent 2,460,738, and which is assigned to the assignee of this application. An alternative cathode or electrode construction may be used corresponding to that disclosed and claimed in U. S. patent application Serial No. 730,806 of Victor J. Francis, filed November 19, 1946, now Patent 2,460,739, and which is assigned to the assignee of this application.

Certain species of the invention not claimed herein are claimed in our application Serial No. 177,252, filed August 2, 1950, which is a division of the present application.

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

1. In a high pressure mercury vapor electric discharge lamp of the short-gap type for operation at a power input of 4000 watts, the combination comprising an enclosing envelope, a pair of electrodes defining therebetween an arc gap of a length lying within the range from 1.7 to 5.5 cm., inclusive, and operable at a voltage of not less than 20 volts per centimeter of arc length at a luminous efficiency of 60 lumens per watt or greater.

2. In a high pressure mercury vapor electric discharge lamp of the short-gap type for operation at a power input of 4000 watts, the combination comprising an enclosing envelope, and a pair of tungsten electrodes defining therebetween an arc gap having a length lying within the range from 1.7 to 5.5 cm., inclusive, the diameters of said electrodes being greater than about 7 mm., and operable at a voltage of not

less than 20 volts per centimeter of arc length at a luminous efficiency of 60 lumens per watt or greater.

GEORGE GLYNN ISAACS.
EVAN HERBERT NELSON.

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