Dec. 9, 1941. W. ELENBAAS ET AL 2,265,362

REFLECTOR FOR DISCHARGE LAMPS

Filed Feb. 26, 1941

Fig. 1.

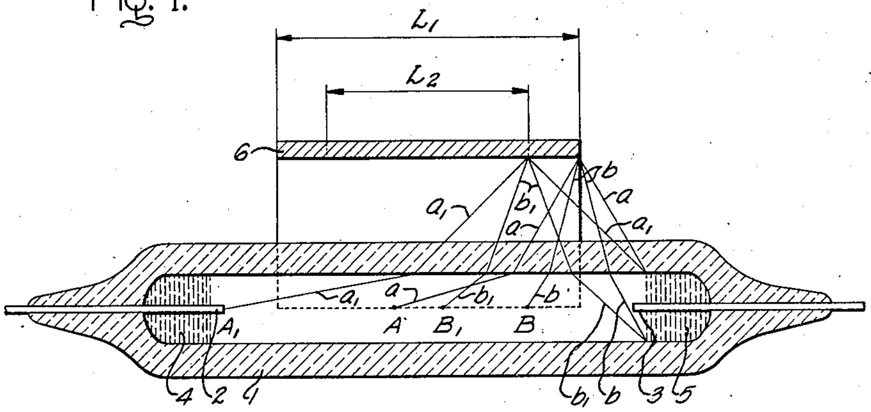
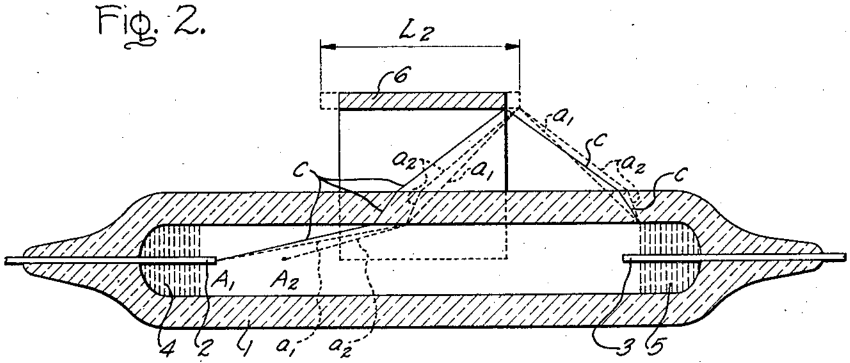


Fig. 2.



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Patented Dec. 9, 1941 2,265,362

UNITED STATES PATENT OFFICE

2,265,362

REFLECTOR FOR DISCHARGE LAMPS

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Application February 26, 1941, Serial No. 380,716
In the Netherlands October 30, 1939

5 Claims. (Cl. 176—122)

The present invention relates to lighting apparatus comprising a high pressure, metal vapor, electric discharge lamp and a reflector for said lamp. More particularly the invention relates to such apparatus comprising a liquid cooled discharge lamp comprising an elongated tubular envelope of small bore having solid electrodes sealed therein at the ends thereof and a quantity of vaporizable metal, such as mercury, held in place by capillary attraction about each of said electrodes. The electrodes project a slight distance from the mercury and into the space defined by the envelope.

Discharge lamps of the above type are disclosed in the United States Patent No. 2,094,694, issued October 5, 1937, assigned to the assignee of the present application. The operating voltage of high pressure discharge devices is determined by the pressure of the metal vapor and this is determined by the lowest temperature part of the surface defining the space inside the envelope. In the type of lamp described above the vapor pressure is determined by the temperature of the exposed surface of the metal around the electrodes. One of the factors determining the temperature of said metal surface is the distance between said surface and the discharge sustaining, projecting end of the solid electrode. The operating voltage of the lamp can thus be determined by adjusting this distance during the manufacture of the lamp and this is the present practice.

It has been proposed to increase the surface brightness or intrinsic brilliancy of such lamps by mounting a reflector in light receiving relation thereto. These reflectors have been coextensive with or longer than the discharge path between the electrodes and in certain instances have been of such shape, cylindrical, for example, that substantially all of the light rays striking it are directed thereby back to the lamp.

We have observed that such reflectors are ineffective for the purpose of increasing the surface brightness or intrinsic brilliancy of such discharge lamps. We have discovered that the failure of the reflector to produce the desired result is due to the fact that part of the light rays are redirected by the reflector onto the vaporizable metal surrounding the electrode. These light rays give up their radiant energy to said metal to increase its temperature. The increased vaporization of the metal resulting from the increased temperature thereof causes an increase in vapor pressure and in the operating voltage of the lamp. If the electrical characteristics of the current supply for the lamp are not changed the electrical energy consumed by the lamp and the light output thereof is decreased by the increase in operating voltage. The surface brightness of the part of the luminous discharge column seen by the observer stays substantially the same. Thus the intended purpose of the reflector is not attained.

The object of the present invention is to provide an apparatus comprising a reflector and a high pressure lamp in which the reflector is effective for increasing the surface brightness of the lamp. Still further objects and advantages of the invention will be apparent to those skilled in the art from the following particular description and from the appended claims.

Having discovered the cause of the difficulty the cure thereof is accomplished by reducing or eliminating the light rays directed to the vaporizable metal by the reflector. This is achieved by making the reflector shorter in length than the distance between the electrodes to reduce the input of radiant energy into the vaporizable metal. The shorter the reflector the lower this input and the object of the invention is attained when the length of the reflector is such that (*a*) one-half the difference between the distance between the electrodes and the length of the reflector with respect to (*b*) the distance between the reflector and the inside surface of the tubular envelope is at least equal to the ratio of 1 to 2.

The light rays which strike the reflector and which contribute to the heating of the vaporizable metal can be divided into two parts. One part of these rays strikes the surface of the vaporizable metal contiguous with the inner surface of the envelope. This metal surface will be designated as the "side surface" hereinafter. Another part of the rays strikes the surface of the vaporizable metal facing the discharge path. This surface will be designated as the "free surface" hereinafter. Preferably the length of the reflector is such that a light ray which originates at the end of one electrode and which is reflected by the end of the reflector nearest the opposite electrode strikes the inside of the envelope wall at the intersection of the plane of the free surface with the envelope wall. Thus the above mentioned first part of the light rays is practically eliminated while the free surface of the metal is struck only by reflected rays which are refracted twice in passing through the envelope wall and have lost a great deal of their radiant energy through the reflection which is concurrent with the refraction. The angle of incidence of these rays on the free surface is relatively large which entails a large reflection coefficient (i. e., the ratio of the total luminous flux reflected by the surface to the total luminous flux incident upon it). Thus the intensity of the reflected light rays which strike the free surface of the metal is weak. Such rays add no heat to the metal surrounding the electrode or only an inappreciable amount of heat.

In water-cooled high pressure, metal vapor discharge lamps having an envelope of quartz, this practice necessitates a reflector so restricted in length that the difference between the distance between the electrode ends and the length of the reflector equals or exceeds twice the distance between the inside wall of the discharge tube and the reflector. This is of critical importance when the reflector is mounted on the outside surface of the envelope.

In the drawing accompanying and forming part of this specification two embodiments of the invention are shown schematically in which—

Fig. 1 is a side elevational, partly sectional view of one embodiment of the invention and

Fig. 2 is a similar view of another embodiment of the invention.

Like numbers denote like parts in both the figures.

Referring to the drawing the new apparatus comprises a high pressure mercury vapor discharge lamp having a sealed envelope 1 of quartz containing a starting gas, such as argon, a pair of cooperating electrodes 2 and 3, such as tungsten electrodes, and two bodies 4 and 5 of mercury about each of the electrodes 2 and 3, respectively. The electrodes 2 and 3 project a few millimeters beyond the mercury bodies 4 and 5. During the operation of the lamp the mercury vapor pressure is so high, ten atmospheres and higher, for example, that the luminous, positive column, arc discharge is constricted, that is, it has the appearance of a luminous thread or cord extending along the longitudinal axis of the envelope 1. In the following discussion on the path of the light rays this discharge is considered as being approximately of the nature of a line.

The discharge lamp is cooled by a liquid, for instance water (the cooling system is not shown in order to simplify the drawing). It is assumed that this cooling liquid has the same index of refraction as quartz. A reflector 6, which is mounted in the cooling liquid and which has a cylindrical reflecting surface, is coaxial with the envelope 1. The length of the reflector 6 is considerably smaller than the distance between the ends of the electrodes 2 and 3.

First the case where the length of the reflector equals L_1, as shown in Fig. 1, is described.

In Fig. 1, a represents the ray of light, which, originating on a point A of the discharge, is reflected, after refraction on the inside surface of the envelope 1, by the right hand side of the reflector 6 and just hits the inside of the tube wall where the plane of the free surface of the mercury 5 intersects the inner surface of envelope 1. The light rays, which, after reflection by the reflector 6, hit the side-surface of the metal 5, all come from the part of the luminous discharge between the point A and the end of electrode 2, designated by A_1. The rays from the part of the discharge between A and electrode 3 are thus eliminated through the shortening of the reflector as far as the heating of the considered surface of the metal 5 by reflected rays is concerned. Furthermore, the rays from the discharge part A—A_1, which after reflection on the reflector 6 reach the cylindrically shaped side-surface of the metal 5, hit the inside surface of the envelope at a large angle of incidence, which is accompanied by a large reflection coefficient, such that these rays lose a lot of energy through reflection on the inner surface of the envelope wall. Thus the additional heating of side surface of the metal 5 by rays reflected from the reflector 6 is relatively small.

As the length of the reflector 6 is made smaller the point A shifts more to the left, which entails a continuously decreasing heating of the side surface of the metal 5. If the length of the reflector equals L_2 (see Fig. 1), then points A and A_1 coincide and the light beam a becomes identical to the beam a_1. No light rays emitted by the discharge and redirected by the reflector 6 hit the side surface of the metal 5 when the length of the reflector equals L_2. Further shortening of the reflector thus would not serve to decrease the heating of this side surface by rays impinging on the reflector.

In Fig. 1, b represents a light ray originating at a point B of the discharge, refracted by the inside surface of the envelope, striking the right hand end of the reflector 6, refracted again by the inside surface of the envelope and hitting the free surface of the metal 5 at the intersection between this surface and the envelope. The only reflected rays from reflector 6 which can strike the free surface of the metal 5 are those rays which originate from the part of the discharge situated between B and A_1. The additional heating of the free surface of the metal 5 by rays reflected from the reflector 6 and originating at the part of the discharge between B and electrode 3 is eliminated by the shortening of the reflector 6. Further, the rays originating on the part B—A_1 of the discharge, which after reflection on the reflector 6 reach the free surface of the metal 5, are refracted twice on the inner surface of the envelope 1. As a result of the concurrent reflection on this inner surface, the intensity of these rays is relatively small when they hit the free surface of the metal 5.

The shortening of the reflector thus also causes a reduction of the heating of the free surface of the metal 5 by the reflected rays. This reduction increases as the reflector is shortened. At the length L_2, considered above, the point B is shifted to B_1, so that only reflected rays originating from the discharge part B_1—A_1 can reach the free surface of the metal 5 after reflection on reflector 6.

If, between the wall of the envelope and the reflector, there is present a cooling medium with a smaller index of refraction than the envelope it is necessary, in order to obtain the same effect, to make the reflector shorter than in the case where both indices are equal. This is easily seen from Fig. 2, in which a lamp similar that shown in Fig. 1 is illustrated and in which the same numbers represent the same parts. The index of refraction of the cooling medium surrounding the envelope 1 is assumed to be smaller than that of the envelope. In this way, at a length L_2 of the reflector, the ray a_1 of Fig. 1, that is, the ray which is reflected at the right hand side of the reflector and which hits the inner surface of the envelope 1 at the intersection of the free surface of the metal 5, would be changed into the ray a_2 of Fig. 2. This means that at this length L_2 of the reflector 6, the side surface of the metal 5 would be heated by reflected rays originating between the points A_1 and A_2. It is clear that the reflector will have to be made shorter than L_2 in order to make a light ray c, which originates from the end of electrode 2 and is reflected from the right hand surface of the reflector, just reach the inside surface of the envelope 1 at the intersection of the free surface of the metal 5 with the envelope 1. As the refraction index of the medium between the envelope 1 and the reflector 6 is smaller than that of the envelope 1, the reflector must be shorter. On the other hand, when the refraction index of the cooling medium is larger than that of the envelope 1, the reflector can be longer.

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

1. A lighting apparatus comprising a reflector and a high pressure, electric discharge lamp comprising a tubular envelope having solid electrodes sealed therein at the ends thereof and a body of vaporizable metal contiguous with each of said electrodes and the inner surface of the envelope, said electrodes projecting beyond said vaporizable metal and into the space defined by said envelope, said reflector being shorter than the distance between said electrodes and directing the radiations produced by the luminous discharge in the vapor of said vaporizable metal back to the discharge path between said electrodes to increase the intrinsic brilliancy of said lamp without changing the electrical characteristics thereof.

2. A lighting apparatus comprising a reflector and a high pressure, electric discharge lamp comprising a tubular envelope having solid electrodes sealed therein at the ends thereof and a body of vaporizable metal contiguous with each of said electrodes and the inner surface of the envelope, said electrodes projecting beyond said vaporizable metal and into the space defined by said envelope, said reflector being shorter than the distance between said electrodes and directing the radiations produced by the luminous discharge in the vapor of said vaporizable metal back to the discharge path between said electrodes to increase the intrinsic brilliancy of said lamp without changing the electrical characteristics thereof, the length of the reflector with respect to the distance between the reflector and the inner surface of the envelope being such that one half the difference between the length of the reflector and the distance between the electrodes with respect to the distance between the reflector and the inside surface of the envelope is at least in the ratio of 1 to 2.

3. A lighting apparatus comprising a reflector and a high pressure, electric discharge lamp comprising a tubular envelope having solid electrodes sealed therein at the ends thereof and a body of vaporizable metal contiguous with each of said electrodes and the inner surface of the envelope, said electrodes projecting beyond said vaporizable metal and into the space defined by said envelope, said reflector being shorter than the distance between said electrodes and directing the radiations produced by the luminous discharge in the vapor of said vaporizable metal back to the discharge path between said electrodes to increase the intrinsic brilliancy of said lamp without changing the electrical characteristics thereof, said reflector not exceeding a length such that a light ray originating at the end of one of the electrodes and reflected by the end of the reflector nearest the opposite electrode strikes the inner surface of the envelope at the intersection of the vaporizable metal in contact with the latter electrode.

4. A lighting apparatus comprising a reflector and a high pressure, electric discharge lamp comprising a tubular quartz envelope having solid electrodes sealed therein at the ends thereof and a body of vaporizable metal contiguous with each of said electrodes and the inner surface of the envelope, said electrodes projecting beyond said vaporizable metal and into the space defined by said envelope, said reflector being shorter than the distance between said electrodes and directing the radiations produced by the luminous discharge in the vapor of said vaporizable metal back to the discharge path between said electrodes to increase the intrinsic brilliancy of said lamp without changing the electrical characteristics thereof, the length of the reflector being such that the difference between the length of the reflector and the distance between the electrodes is twice the distance between the reflector and the inner surface of the envelope.

5. A lighting apparatus comprising a reflector and a high pressure, electric discharge lamp comprising a tubular envelope having solid electrodes sealed therein at the ends thereof and a body of vaporizable metal contiguous with each of said electrodes and the inner surface of the envelope, said electrodes projecting beyond said vaporizable metal and into the space defined by said envelope, said reflector being shorter than the distance between said electrodes and directing the radiations produced by the luminous discharge in the vapor of said vaporizable metal back to the discharge path between said electrodes to increase the intrinsic brilliancy of said lamp without changing the electrical characteristics thereof, said reflector not exceeding a length such that a light ray originating at the end of one of the electrodes and reflected by the end of the reflector nearest the opposite electrode strikes the inner surface of the envelope at the intersection of the vaporizable metal in contact with the latter electrode, said reflector being mounted on the outer surface of said envelope.

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