PATENT SPECIFICATION

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Complete Specification Accepted: April 27, 1938.

PROVISIONAL SPECIFICATION

Improvements in or relating to High-pressure Metal-vapour Electric Discharge Lamps

We, THE GENERAL ELECTRIC COMPANY LIMITED, of Magnet House, Kingsway, London, W.C.2, a British company, and HENRY GRAINGER JENKINS, JOHN WALTER RYDE, and GEORGE HULBERT WILSON, all of Research Laboratories of The General Electric Company Limited, Wembley, Middlesex, all British subjects, do hereby declare the nature of this invention to be as follows:—

This invention relates to electric discharge lamps of the type comprising a device through which a high-pressure metal-vapour discharge is adapted to pass and material (hereinafter called luminescent material) adapted to be excited to luminescence by that discharge. The function of the luminescent material is usually to correct the colour of the discharge, that is to say, to supply visible radiation of wave-lengths in which the radiation of the discharge is deficient; thus it may be of the kind described and claimed in Patent Specification No. 401,846.

Luminescent material adapted to fulfil this function generally loses its efficiency, either immediately and reversibly or slowly and irreversibly, when its temperature rises above some value, for example, 180° C. The surface of the high-pressure discharge device, even if it is that of an outer jacket, is usually above this temperature; accordingly it is preferable to place the material on a transparent or translucent support surrounding the device, not necessarily completely. Further the support has to be arranged so that, possibly with the aid of diffusing screens, the light from the discharge and the luminescent light are adequately mixed. The object of the invention is to provide a support of suitable shape. Since the problem arises in virtue of the sensitivity of the material to heat and not in virtue of the nature of the luminescent light that it emits, the invention is applicable whenever the material is sensitive to heat and the primary and secondary lights have to be adequately mixed, even if the function of the material is not mainly or wholly colour correction, but is, for example, increase in total luminous output.

It is generally desirable that the support should be as small as possible. Consider a support of any shape surrounding the hot discharge device. If any point on it is below the critical temperature, then this point could be brought nearer the hot device and the size of the support decreased. Accordingly it appears that the smallest possible support would be one so shaped that the temperature is the same all over its surface, so that the surface is isothermal, and is equal to the highest permissible temperature. It may not be possible to shape the surface so that it is truly isothermal; then it would still appear that the smallest possible support would be that which is most nearly isothermal, that is to say, the support which is such that the departure of the temperature of any point on it from the highest permissible temperature averaged over the whole surface, is as small as possible. It is not certain that this proposition is always true, but it is generally true.

The discovery on which the invention rests is that it is often possible to make a support whose surface is approximately the most nearly isothermal, which is at the same time well suited in other ways for carrying the luminescent material. Thus if the surface of the discharge device is tubular with its axis vertical, a pear-shaped support in still air, with the end of less diameter downward, can be made to approach closely the most nearly isothermal condition.

According to the invention in an electric discharge device of the type specified the said luminescent material is carried on a support whose surface is approximately the most nearly isothermal as hereinbefore defined.

The invention will now be further explained with reference to the accompanying drawing which shows by way of example one embodiment of it.

In the drawing 1 is the glass outer jacket of a 400 watt high-pressure mercury-vapour discharge lamp of a known commercial type. It hangs vertically, as usual, from the screw cap 2.

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From this cap hangs also the pear-shaped glass vessel 3, which is the support according to the invention, coated internally with luminescent material which deteriorates when its temperature exceeds 180° C. The parts are drawn to scale, the dimensions marked A, B, C being respectively 340, 165, 52 mm. The space between the jacket 1 and the vessel 3 is filled with dry oxygen at 10 mm. pressure. The vessel 3 is surrounded by still air, so that the temperature is substantially constant along any circle on its surface in a horizontal plane.

The chart alongside the figure shows in a manner obvious to those skilled in the art how this temperature varies over the surface. The temperature is given only for the region between the horizontal planes X and Y, for the temperature above and below these planes is of little consequence. The parts of the support above and below these planes occupy a solid angle which is but a small part of 4π; moreover, since the lamp emits but little light in directions near its axis, the light emerging within this solid angle is much less than that emerging within an equal solid angle elsewhere. Accordingly it matters little whether the luminescent material does or does not retain its efficiency in this region. For the rest the temperature never varies more than 50° C. and over a considerable central region is constant to within 10° C.

This example indicates the meaning that is to be attributed to the term approximately in the foregoing statement of invention. In interpreting it, parts of the support can be neglected, on which only a small part of the light falls, in virtue of the inequality of the distribution of the light round the source. In respect of the remainder, since the purpose of the invention is to provide a small support, the ultimate test of the approximation must be the degree in which the area of the surface of the support exceeds the area of the surface of that support which is most nearly isothermal in similar surroundings. But the application of this test would often require tedious experiments to discover what is the most nearly isothermal support. It appears that, subject always to this ultimate test, a support will never depart greatly from the most nearly isothermal form if there is a considerable part of its surface over which the temperature is constant within 10° C. and if no part of its surface (other than that discarded as immaterial) differs from this part by more than 50° C.

It is to be observed that one of the variables that can be adjusted to make a support approximately the most nearly isothermal is the filling of the space between the support and the discharge device. This space may be evacuated or may be filled with any gas at any pressure which has no deleterious effect on the luminescent material or on the lamp at the temperature of the support.

It is to be observed that the use of an isothermal support will not necessarily produce a perfect mixture of the primary and secondary light; that is to say, the ratio of the quantity of secondary to the quantity of primary light received by an observer at a distance may vary with the position of the observer. Any imperfection of mixture, if it is important, can be removed, in known manner, by the use of diffusing fittings. Sometimes it is not important; thus in street lighting it is generally permissible that the light emitted at large angles to the vertical should be less perfectly corrected for colour than light emitted near the vertical; such a difference is likely to be secured by the use of a support according to the invention.

On the other hand the use of an isothermal support has subsidiary advantages. The pear-shape is very easy to coat internally with a uniform layer of the luminescent material. Moreover the luminescent material will usually act to some extent as a diffusing screen; the distribution of the diffused light produced by the pear-shape is very suitable for some problems of street-lighting.

Dated the 11th day of November, 1936.

For the Applicants,
NORMAN R. CAMPBELL.

COMPLETE SPECIFICATION

Improvements in or relating to High-pressure Metal-vapour Electric Discharge Lamps

We, THE GENERAL ELECTRIC COMPANY LIMITED, of Magnet House, Kingsway, London, W.C.2, a British company, and HENRY GRAINGER JENKINS, JOHN WALTER RYDE, and GEORGE HULBERT WILSON, all of Research Laboratories of The General Electric Company Limited, Wembley, Middlesex, all British subjects, do hereby declare the nature of this invention and in what manner the same is to be per-

formed, to be particularly described and ascertained in and by the following statement:—

This invention relates to electric discharge lamps of the type comprising an envelope through which a high-pressure metal-vapour (HPMV) discharge is adapted to pass in the form of a substantially straight vertical column and material (hereinafter called luminescent material) outside the envelop adapted to be excited to luminescence by radiation from that discharge. The function of the luminescent material is usually to correct the colour of the discharge, that is to say, to supply visible radiation of wavelengths in which the radiation of the discharge is deficient; thus the lamp may be of the kind described and claimed in Patent Specification No. 401,846. On the other hand the function of the luminescent material may be to increase the total luminous output without regard to colour. In either case the envelope must, of course, transmit radiation capable of exciting the luminescent material. But this does not mean that the envelope must be of quartz, at any rate if the purpose of the luminescent material is colour correction. For, as indicated in the said specification, zinc-cadmium sulphide activated by copper, which is excited by radiation to which glass is transparent, is a suitable material for supplying red light to supplement the deficiency of the mercury spectrum in that colour.

The most convenient place for the luminescent material is on the inside of the usual outer jacket. But the temperature of this jacket, though below that of the inner envelope, is often much above normal atmospheric temperature. Figure 1 of the accompanying drawings shows the temperature distribution over the outer jacket of a 400 watt HPMV lamp of a well-known commercial type, much used for street-lighting and like purposes, when the lamp is operated with the discharge column vertical. Here line 1 is a half-section of the inner envelope, 34 mm. in diameter, containing the electrodes 4 and 5, 160 mm. apart, line 2 is a half-section of the outer jacket, 50 mm. in diameter. Line 3 referred to axes X, T, gives the temperature T at points on the outer jacket distant X from one end of the outer jacket. It will be seen that the temperature is above 300° C. over a considerable central portion.

Now few luminescent materials operate satisfactorily at such a temperature. Their efficiency usually decreases notably even at a temperature as low as 180° C. The decrease is partly reversible and is restored when the temperature is reduced; but it is also partly permanent if the high temperature, combined with strong illumination, is maintained for many hours. The reversible change is mainly or entirely determined by the nature of the material itself; the permanent change depends largely on the gases to which the material is subjected and the binder (if any) by which it is held. But it is unnecessary to distinguish between permanent and reversible changes, since the temperatures at which they have to be taken into account are not very widely different; for either of them, in circumstances with which this invention is concerned, the critical temperature that must not be exceeded (which of course depends on the efficiency and on the permanence required) usually, if not always, lies between 130° C. and 300° C.

One method of avoiding loss of efficiency due to high temperature is to put the luminescent material, not in the lamp itself, but on some part of a fitting associated with the lamp, but sufficiently far from it to be at substantially atmospheric temperature. But then it is not always easy to secure that the primary light from the discharge and the secondary light from the luminescent material are adequately mixed, as is often required. It would be more convenient if the material could still be placed on the outer jacket, which must then be so large that it is below the critical temperature.

If the energy dissipated in the lamp is sufficiently small, for example 125 watts or less, and more particularly if the length of the discharge column is small, for example less than 20 mm. (these conditions are fulfilled in known lamps operating at vapour pressures much exceeding one atmosphere), the size of a spherical, or possibly cylindrical, outer jacket whose temperature is nowhere above 130° C. is not seriously inconvenient. But when the length of the discharge exceeds 100 mm. and the watts dissipated exceed 250, the size of a spherical or cylindrical jacket fulfilling this condition becomes inconvenient. The object of this invention is to avoid this inconvenience and to provide jackets fulfilling this condition that are not inconveniently large.

When the maximum temperature T_m of the jacket is given, the smallest possible jacket, if it were possible, would probably be an isothermal jacket, having the temperature T_m all over its surface. But it is not possible. If the envelope were suspended in free air, there would, of course, be isothermal surfaces around it; one of these would have any given temperature T_m. But there would be convection currents in the air, and the introduction

of a solid jacket on which luminescent material could be placed would distort these currents; it appears improbable that any jacket cooled by convection could have a uniform temperature all over its surface.

In these circumstances, the smallest jacket will probably be the most nearly isothermal, that is to say, that which, for a given T_m, has the highest mean temperature. It is probable further that there is only one such surface (other conditions being constant, such as the material and the thickness of the jacket and the medium between it and the discharge envelope) or at most only a few such surfaces. The question therefore arises whether such a most nearly isothermal jacket will be practicable on other grounds, for example whether it will be sufficiently small and of a shape that can easily be made and coated with luminescent materials and that will lead to an adequate mixing of the primary and secondary light. The question can be answered only by experiment.

The discovery on which this invention is based is that the answer is affirmative, so long as the power dissipated in the lamp does not exceed some 550 watts. Then a jacket of a simple pear-shape, with the narrow end downwards, approximates closely to the most nearly isothermal surface, is not unduly bulky, and is otherwise suitable. On the other hand when the voltage much exceeds 550, even the most nearly isothermal jacket is unduly bulky; accordingly the invention does not include such lamps.

In applying this discovery, it must be remembered that, if the discharge column is vertical and the space between the inner envelope and outer jacket is filled with gas at a pressure so low that convection in it transfers little heat to the jacket, the coolest parts of the jacket will always be at the upper and lower ends, towards which little radiation is emitted. In order to bring these ends up to nearly the maximum temperature in the central portion of the jacket, the ends would probably have to be re-entrant. This would be a disadvantage, not an advantage; accordingly in estimating whether a shape approximates closely to the most nearly isothermal surface, so as to obtain the object of the invention, the ends through which not more than 10% of the total radiation issues may be neglected; a shape is not to be regarded as not approximately the most nearly isothermal, merely because, by a re-shaping of these ends, it could be made more nearly isothermal. The true criterion of approach to the most nearly isothermal surface is the uniformity of temperature over that part of the surface through which the greater part of the radiation issues.

To determine how far any given shape approximates to the most nearly isothermal, considerable experimenting is required. Accordingly we propose to define our invention, not in terms of the most nearly isothermal surface, but in terms of the temperature distribution over the jackets that our experiments have shown to approach as nearly as possible (subject to the foregoing considerations) to that surface. These experiments show that it is possible to obtain jackets in which, over the whole of a surface on which 75% of the total radiation falls, the temperature does not vary by as much as 15° C., and in which over the whole of a surface on which 90% of the total radiation falls the temperature does not vary more than 50° C.

According to the invention in a lamp of the type specified, wherein the discharge is adapted to consume more than 250 watts, but not more than 550 watts and the discharge column is more than 100 mm. long, the luminescent material is carried on the interior surface of a sealed outer jacket surrounding the discharge envelope, the space between the said jacket and envelope being evacuated or occupied by a gas at a pressure greatly below atmospheric, and the said jacket is so shaped that, when exposed in free air at a temperature of 20° C. in full operation, the temperature over a part of the surface of the said jacket on which 75% of the radiation falls does not vary by as much as 15° C., and the mean temperature of this part of the surface lies between 130° C. and 300° C. Greatly below atmospheric pressure means that convection in the gas does not materially affect the distribution of temperature over the jacket.

One embodiment of the invention will now be described with reference to the drawing accompanying the provisional specification, which shows an axial section through a lamp and a curve indicating the distribution of temperature over it.

In the drawing, 1 is the glass inner envelope of a 400 watt high-pressure mercury-vapour discharge lamp of a known commercial type. It hangs vertically as usual, from the screw cap 2. From this cap hangs also the sealed pear-shaped outer jacket 3, which is of glass about 1 mm. thick, coated internally with zinc-cadmium sulphide activated by copper. The parts are drawn to scale, the dimensions marked A, B, C being respectively 340, 165, 52 mm.; the distance between the electrodes, represented by

thick short vertical lines is 150 mm. The space between the jacket 1 and the vessel 3 is filled with dry oxygen at 10 mm. pressure. The jacket 3 is surrounded by free air at about 18° C., so that the temperature is substantially constant along any circle on its surface in a horizontal plane.

The chart alongside the figure shows in a manner obvious to those skilled in the art how this temperature varies over the surface. The temperature is given only for the region between the horizontal planes X and Y. The proportion of the radiation falling on the jacket outside these planes is considerably less than 10%; the planes could be moved towards each other so that each passed through the adjacent points at a temperature of 130° C. and the proportion of the radiation falling outside them would still be less than 10%. Accordingly in this embodiment the temperature over a part of the surface on which 90% of the radiation falls does not vary by more than 40° C. The central part of the surface over which the temperatures does not vary by 15° C. receives at least 75% of the radiation and the mean temperature of this part is between 150 and 160° C.

In order to ascertain how far these measurements could be repeated, two other lamps intended to be similar were made and the temperatures over their surfaces measured. The results are shown in Figure 2 of the accompanying drawing in a manner similar to that adopted in the drawing accompanying the provisional specification. The temperature measurements extend from the bottom of the jacket (X = 0) to a point on the neck of the jacket 250 mm. distant. The points indicated by crosses refer to tests on one of these lamps, those indicated by circles refer to the other; the dotted line from the drawing accompanying the provisional specification is reproduced for comparison.

It is to be observed that there are minor discrepancies which are, in part at least, due to experimental errors. If the average error for a large number of lamps was drawn, apparent irregularities would be smoothed out and the said limit of 15° C. could certainly be reduced, probably to 10° C.

It is not necessary that the whole of the interior of the jacket should be coated with the luminescent material; but no advantage is known from leaving any considerable part of it uncovered, except possibly if it is desired to obtain lights of different colour in different directions. The luminescent material on the jacket will act to some extent as a diffusing surface, promoting the mixture of primary and secondary light. But the surface of the globe, either that which bears the luminescent material or that which does not, or the glass of which it is composed, may be rendered diffusing in known manner so as to promote mixture further. Again the lamp may be associated with diffusing surfaces outside the globe, so long as they form part of a fitting in which the lamp is placed and not an integral part of it, so as to increase its bulk. But it is not always necessary to produce a perfect mixture of the primary and secondary light; that is to say, the ratio of the quantity of secondary to the quantity of primary light received by an observer at a distance may vary with the position of the observer. Thus in street lighting it is generally permissible that the light emitted at large angles to the vertical should be less perfectly corrected for colour than light emitted near the vertical; such a difference is likely to be secured by the use of a jacket according to the invention, without subsidiary diffusing means.

Finally something must be said about the application of the invention to lamps other than that described by way of example.

The main factor determining the shape of the sealed outer jacket is the length of the discharge column; the shape of the envelope enclosing the discharge column is of minor importance. On the other hand the main factor determining the size of the outer jacket for which the approximately uniform temperature has a given value is the watts dissipated in the discharge; in accordance with well-known principles, for the same surface temperature, the area of the surface of the jacket should be approximately proportional to the watts dissipated within it.

All known 400 watt HPMV lamps for vertical operation with straight discharge columns more than 100 mm. long have columns so nearly equal in length that the instructions given for one of these lamps will serve for any other without any modifications that cannot be deduced from a few simple trials.

If the wattage is varied, the aforegoing considerations indicate that, if the same temperature distribution over the envelope is to be reproduced, the length of the discharge column should be varied as the square root of the wattage. This relation may not always be perfectly fulfilled; but since the whole range of wattage within the scope of the invention is small (250-550), accurate fulfilment of it is ~~necessary~~ unnecessary. It will be found in practice that if the linear dimensions of

the jacket are varied as the square root of the wattage, the temperature distribution over its surface will remain so nearly the same that any modifications required will be deducible from a few simple trials.

Again, in view of the limitations of the luminescent materials that are suitable at all for use in lamps of the type specified, it is unlikely that the uniform temperature over the main part of the envelope will be required to depart greatly from the value given by way of example, namely 155° C. But it is obvious that slightly higher temperatures can be obtained by diminishing, and slightly lower temperatures by increasing, the size of the jacket; and that, if the shape is preserved during such slight changes, the distribution of the temperature will not be changed greatly.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. An electric discharge lamp of the type specified wherein the discharge is adapted to consume more than 250 watts but not more than 550 watts and the discharge column is more than 100 mm. long, wherein the luminescent material is carried on the interior surface of a sealed outer jacket surrounding the discharge envelope, the space between the said jacket and envelope being evacuated or occupied by a gas at a pressure greatly below atmospheric, and wherein the said jacket is so shaped that, when it is exposed in free air at 20° C. in full operation, the temperature over a part of its surface on which 75% of the radiation falls does not vary by as much as 15° C., and the mean temperature of this part of the surface lies between 130° C. and 300° C.

2. An electric discharge lamp according to Claim 1, wherein, when the said jacket is exposed in free air at 20° C. in full operation, the temperature over a part of its surface on which 90% of the radiation falls does not vary by more than 50° C.

3. An electric discharge lamp according to Claim 1 wherein the said luminescent material is zinc-cadmium sulphide activated by copper and the said mean temperature lies not higher than 180° C.

4. An electric discharge lamp of the type specified substantially as hereinbefore described with reference to the drawing accompanying the provisional specification.

Dated the 13th day of October, 1937.

For the Applicants,
NORMAN R. CAMPBELL.

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2. An electric discharge lamp according to Claim 1, wherein, when the said jacket is exposed in free air at 20° C. in full operation, the temperature over a part of its surface on which 90% of the radiation falls does not vary by more than 50° C.

3. An electric discharge lamp according to Claim 1 wherein the said luminescent material is zinc-cadmium sulphide activated by copper and the said mean temperature lies not higher than 180° C.

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