Nov. 22, 1960 J. F. WAYMOUTH ET AL 2,961,566

FLUORESCENT LAMP

Filed June 18, 1958

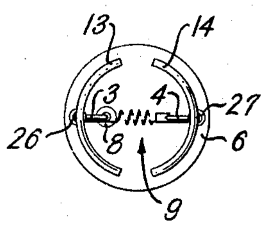

Fig. 2

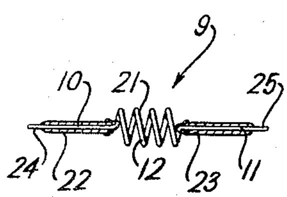

Fig. 3

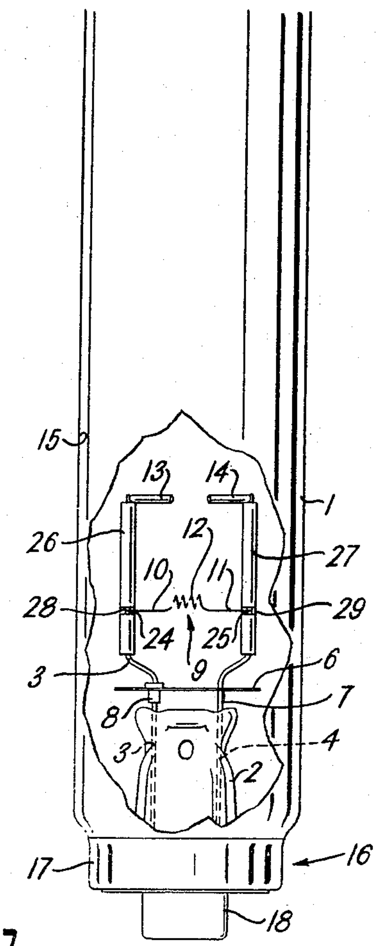

Fig. 1

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FLUORESCENT LAMP

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This invention relates to electric discharge lamps, especially those of high power input, and is particularly useful in low-pressure fluorescent lamps of that type.

In order to obtain good efficiency in low-pressure fluorescent lamps with high power loading, a gas filling containing neon or even helium is used, instead of the substantially pure argon generally used with lamps of lower input. Despite the presence of mercury, the use of neon or helium has a far more deleterious effect on the cathodes of such lamps than does argon, and the cathode drop has a tendency to be higher. In fact, it has been stated by R. N. Thayer in "Illuminating Engineering," the official journal of the Illuminating Engineering Society, May 1957, page 269, that with neon, "lamp life is short, end-coloration severe and lumen maintenance sub-normal."

Since this result was presumed to follow from the light weight and high ionization potential of the neon atom, it would apply with even greater force to the use of helium.

We have discovered, however, that the life can be increased, the end-discoloration reduced, and the lumen maintenance improved, by spacing the lead-in wires to the cathode sufficiently far apart to be outside the region of the ionization layer around the effective part of the cathode. The ionization layer is the region in which substantially all of the ions present, about 97% of them, are produced by primary electrons from the cathode, and the effective portion of the cathode is the portion which carries the usual alkaline earth oxide coating. We have discovered that this coating should be confined to the middle portion of the electrode structure and that the ends of the electrode, that is the portions extending from the middle of the cathode to the lead-in wire, should be coated with a refractory insulating material, for example, aluminum oxide. The coated end portions should be of as small diameter as possible, to prevent interference with the ion stream to the cathode.

The primary electrons emitted from the cathode are accelerated in passing through the cathode sheath, which is a very thin region of high voltage gradient around the cathode, and each electron retains the energy so gained until it makes an inelastic collision with some other particle or object. Sub stantially all of the positive ions that reach the cathode are produced by primary electrons, and are consequently produced near the cathode in the space in which the primary electrons have inelastic collisions with atoms of gas.

The density of primary electrons near the cathode can be shown to vary as

$$e^{-(\sqrt{3P_cP_i})d}$$

where d is the distance from the cathode surface in centimeters, P_c the probability per centimeter of elastic collisions by a primary electron, P_i the probability per centimeter of inelastic collisions by a primary electron, and e is the base of natural logarithms, that is about 2.7186.

We have found that the ionization layer can be considered for practical purposes as the region in which 97% of the primary electrons make inelastic collisions, and accordingly extends for a distance d such that the above expression is equal to 0.03, which means that

$$(\sqrt{3P_iP_c})d=3.5$$

and, approximately

$$d=\frac{2.01}{\sqrt{P_iP_c}}$$

For a mixture of 80% neon and 20% argon at a pressure of about 1.5 mm. of mercury, d is about one centimeter.

We have discovered that the distance between the opposed surfaces of the lead-in wires to the cathode, or between the opposed surfaces of the insulation over the lead-in wires, if such insulation is used, should be at least about twice the thickness d of the ionization layer. The distance between the effective middle portion of the cathode and the nearest lead-in wire should be about one-half as great as d, that is, about 6 mm. under the conditions given.

The electrode structure preferable includes a doubly or triply coiled wire with straight legs, that is a structure in which a coil of small diameter is itself wound into a coil of larger diameter at its middle portion, while the ends or legs extending outward from said coil are coiled one less time and are thus of smaller diameter. For example, if the middle portion is triply-coiled, the extending legs would be just doubly-coiled.

The middle or large-diameter portion of the coil carries an electron-emitting coating, for example a coating of the usual oxides of barium, strontium and calcium, preferably with a small percentage of zirconium dioxide, and the extending legs are coated with a refractory insulating material such as aluminum oxide.

When such a material is used, it can be applied cataphoretically and then sintered to give a firmly-adherent coating. The aluminum oxide coating can be applied to the ends of the cathode, and the alkaline earth oxide coating then applied to the middle portion.

The lead-in wires can be protected by an insulating covering, such as ceramic tubes, although they can be coated instead with aluminum oxide if made of a metal which permits proper sintering. The outside diameter of the insulation should be as small as possible, and to permit this the wire diameter should be made small. The smaller the diameter, the smaller the amount of recombination of ions and electrons on the insulating tube.

The aluminum oxide coating confines the active or effective portion of the cathode to the middle of the coil, and allows the lead-in wires to be spaced outside the cathode ionization layer. The aluminum oxide acts as an effective insulating material to prevent ion bombardment of the non-effective portion of the cathode. With long legs extending outwardly from the effective portion of the cathode, the greater distance from the latter to the lead-in wires reduces heat conduction losses therefrom and keeps it a more uniform temperature throughout its length.

If, on alternating current, auxiliary electrodes are used to take part of the current during that portion of the cycle when the electrode is positive, they are preferably placed in the Faraday Dark Space of the discharge, and the lead-in wires to them insulated, as shown in co-pending application Serial No. 656,356, filed May 1, 1957 by John F. Waymouth et al.

A small amount of argon, krypton or xenon is prefer ably used with the neon or helium to reduce the cathode fall further, as shown in the previously-mentioned application, and the cathode can be heated by the application of a voltage between the lead-in wires supporting it, in the so-called "rapid-start" manner. The gaseous atmosphere can be, for example, about 80% neon and 20% argon, at about 1 mm. of mercury total pressure, in which case the cathode ionization layer will occupy a cylinder of about one centimeter radius around the outside surface of the cathode. The lead-in wires should be spaced from the end of the cathode a distance equal to the distance of the ionization layer from the surface of the cathode.

The ions in the ionization layer will then be drawn to the cathode, aiding in heating it to a proper emission temperature, and not drawn to the lead-in wires. This type of operation gives a lower cathode drop and hence lowers the velocity with which the ions strike the cathode. This result is unexpected, since it was not previously clear that the way to protect the cathode from positive ion disintegration was to increase the number of positive ions striking it.

Other objects, advantages and features of the invention will be apparent from the following specification, in which:

Fig. 1 is a view partly cut away, of a lamp according to an embodiment of the invention.

Fig. 2 is a top view of the mount structure of said lamp.

Fig. 3 is an enlarged view of the cathode in said lamp.

In Figure 1 the lamp envelope 1 is a glass tube having a flared stem 2, of the usual type, sealed to its end to close the same. The lead-in wires 3, 4, are sealed through the press 5 of said stem and extend into communication with the interior of said envelope 1. Just above the press 5, a flat metal disc 6, which can be of aluminum, is welded to the lead-in wire 4 by the tab 7, extending from said disc. The ceramic bushing 8 extends through the disc 5 to insulate lead-in wire 3 therefrom. Bent outwardly above the disc 6, the lead-in wires then extend forwardly into the envelope 1 in a direction parallel to the longitudinal axis of said tube.

The filamentary coil 9 comprises the doubly coiled legs 10, 11, of small outside diameter and the trebly-coiled middle portion 12 of larger outside diameter. The otherwise free ends of the legs 10 are welded to the lead-in wires, the end of leg 10 being welded to lead-in wire 3 and the end of leg 11 to lead-in wire 4. Said wires extend upwardly from the cathode 9 in order to support the curved auxiliary anodes 13, 14, each of which is welded to a lead-in wire 3, 4, and spaced from each other.

The sealed envelope 1 is filled with an inert gas or gases, preferably a mixture of 80% neon and 20% argon, at a pressure of about 1 mm. of mercury, and contains a small quantity of mercury. The latter should be sufficient to allow an operating mercury pressure of about 10 microns.

The inside of the lamp envelope 1 is preferably coated with a fluorescent material 15 in the manner customary in the art. A base 16, cemented to the end of envelope 1, can be of a type shown in United States Patent 2,771,589, issued November 20, 1956, to R. B. Thomas. The metal shell 17 of the base 16 carries an outwardly extending hollow insulating portion 18 and the metal contacts which are connected to the lead-in wires 3, 4. Other types of bases can be used.

The mount structure of Figure 1 is shown also in Figure 2, in a view looking down on the auxiliary anodes 13, 14.

The filamentary structure of cathode 9 is shown in more detail in Figure 3. A fine tungsten wire is coiled loosely around a tungsten mandrel, the coil and mandrel being then coiled together to form a second coil, that second coil being then coiled into a third coil of larger diameter in the middle portion 12 of the filamentary structure 9. The middle portion 12 carries an electron emitting filling 21 of the usual alkaline earth oxides within the turns of the first and second coils but not within the turns of the third coil. This alkaline earth filling 21 is carried only by the middle portion of the coil. The outwardly extending doubly-coiled legs 10 and 11 are covered with a coating of aluminum oxide 22, 23, except for the end portions 24, 25, which are left uncoated so that they may be welded to the lead-in wires 3, 4. The alkaline earth filling extends for a slight distance over the aluminum oxide coating to insure that there will be no gap between them.

The lead-in wires 3, 4, are covered along their straight portions by the insulating ceramic tubes 26, 27, which have the small cut-away portions 28, 29, which expose the lead-in wires at the points to which the ends 24, 25, of the cathode 12 are welded.

For clarity, only one end of the envelope 1 is shown in the figure, but the other end would be the same.

In operation, a voltage is applied across the lead-in wires 3, 4, to heat the cathode 12, and a larger voltage is applied between one of the lead-in wires, say wire 3, at one end of the envelope, and one of the lead-in wires at the other end, in series with the usual ballast impedance. A glow discharge is established through the gas between the electrodes, until the cathode 12 becomes sufficiently heated, whereupon the discharge changes to an arc. When the voltage is positive at the end shown, much of the current will go to the auxiliary anodes 13, 14, but when the end shown is negative the discharge will emanate from the cathode 12. The anodes 13, 14, are placed so that they will then be in the Faraday Dark Space of the discharge, to avoid excessive disintegration by ion bombardment.

The lead-in wires 3, 4, have to go through regions where greater disintegration could occur and are protected by insulating tubes.

The voltage drop at the cathode is kept to a minimum by confining the effective or active portion of the cathode to its middle portion, spacing the lead-in wires so far apart that they are outside the cathode ionization layer and collect a smaller number of ions from that layer, and connecting the middle portion of the cathode to the lead-in wires through coiled legs of small diameter extending outwardly from the cathode and coated with a firmly-adherent insulating material, for example, cataphoretically-deposited aluminum oxide. The extending legs also serve to reduce heat conduction from the middle portion of the cathode, and to thereby keep the effective portion at a more uniform temperature.

The small diameter of the connection between the middle portion of the cathode and the lead-in wires keeps at a minimum the number of ions which recombine there. That effect could also be achieved by extending a solid, small-diameter, lead-in wire to the middle portion of the cathode, instead of the coiled legs, but that would not be as effective in reducing losses by heat conduction.

In one embodiment of the invention, the lead-in wires 3, 4, were of nickel, 50 mils diameter and 22 mm. apart, between centers. The shield was of 5-mil nickel, about 26 mm. diameter, and was about 44 mm. from the flare, the lead-in wires 3, 4, were bent inward to a spacing of 12 mm. between centers. The distance from the center line of the auxiliary anodes 13, 14, to the center line of the transverse portion of the lead-in wires was about 33 mm., the ends of legs 10, 11 of cathode 12 being welded to the lead-in wires 3, 4, about 15 mm. from the plane of shield 6. The main longitudinal portions of the lead-in wires 3, 4, were covered by a ceramic insulating tube 26, 27, which have an inside diameter of 55 mils and an outside diameter of ⅛ inch, and a small cut out portion on one side about 45 mils wide and about 40 mils deep from the outside circumference, to make room for the welded connection between filament legs and lead-in wires.

Figure 3 gives an outside view of the coated filament. The filament itself is a tungsten wire about 0.0122 mil diameter coiled to an approximate ellipse of about 10.4 mils minor diameter. One mandrel is of molybdenum and is removed after the coiling, but the other mandrel of tungsten remains in place. This coil is then wound around a 12.0 mil diameter mandrel to form a second coil, and that mandrel removed in the usual manner. This double coil is used as the legs **10**, **11**, of the filamentary coil **9**. For middle portion **12**, the double-coil is itself coiled again around a 55.0 steel pin, which is then removed, to form a four-turn triple-coil.

A tungsten insert of 0.008 mm. diameter and 8 mm. length is inserted in each end of the coil to facilitate welding to the lead-in wires **3**, **4**. The insert goes into the second coiling.

An aluminum oxide coating is applied cataphoretically to the completed coil for a distance extending from the end of the coil to a point about 4 mm. from the end. The uncoated distance can be just large enough to permit welding to the lead-in wires **3**, **4**. The aluminum oxide not only coats the wire on the outside, but also fills the coils of the first and second coiling, except for the space occupied by the mandrel and the insert. The aluminum coating bridges all turns of the part it coats and fills.

After the aluminum coating is applied, the cathode is welded to the lead-in wires and a coating of the usual alkaline earth oxides applied in the usual manner by dipping.

The outside envelope **1** was about 48 inches from end to end, the anodes **13**, **14**, at one end being about 38½ inches from the corresponding anodes at the other end. The envelope was of so-called T12 tubing, about 1½ inches outside diameter, and about 30 and 36 mils in thickness. The envelope was filled with an atmosphere of 80% neon and 20% argon at a pressure of about 1 mm. of mercury, and with at least enough mercury to give a pressure of about 10 microns when vaporized.

The lamp can be operated for lighting purposes from a so-called "rapid start" circuit, for example, by a transformer supplying about 3.6 volts to the filaments and about 300 volts for application, through the usual series reactance, between the filament at one end of the tube and the filament at the other. The operating conditions should be about 89 volts and 1.4 amperes.

Although the invention is described above with respect to a particular gas filling it is not limited to that filling, but can be used with others, for example, helium and argon, say 15% helium and 85% argon. The latter filling will give increased life over the neon-argon filling, with the mount structure described herein or with others, but will give a small reduction in light output.

A cataphoretic method of coating the filament legs has been mentioned above, but a spray coating can be used, if adjusted to give the same kind of coating and filling with refractory insulating material. Aluminum oxide and other insulating materials can be used, for example, titania. With the latter a low sintering can be used, about 1100° C.; with aluminum oxide a temperature of about 1700° C. is best.

The part of the coil which is to remain uncoated can be shielded from the spray, or if cataphoretic coating is used, can be dipped in wax before coating, and the wax removed afterward.

Other modifications can be made without departing from the spirit and scope of the invention.

What we claim is:

1. An electric discharge lamp comprising a sealed envelope, a gaseous filling therein at low pressure, an electron-emissive cathode therein, having an ionization layer region therearound, lead-in wires outside said ionization layer, and an insulated metallic connection from said lead-in wires to said cathode.

2. An electric discharge lamp comprising a sealed envelope, a gaseous filling therein at low pressure, an electron-emissive cathode therein having an ionization layer, lead-in wires outside said ionization layer and spaced apart a distance substantially equal to twice the distance the ionization layer extends away from the outside of the cathode in the direction of the discharge.

3. An electric gaseous discharge lamp comprising a sealed envelope, a gaseous filling therein at low pressure, an electron-emissive cathode therein having an ionization layer, lead-in wires outside said ionization layer and spaced from the ends of said cathode a distance at least equal to half the thickness of the ionization layer around the cathode, and insulated electrical connections from said cathode to said lead-in wires.

4. An electric gaseous discharge lamp comprising: a sealed tubular envelope; a gaseous filling therein of about 80% neon and 20% argon therein at a pressure of about one millimeter of mercury; a quantity of mercury in said envelope; a tungsten filament cathode in said envelope, said cathode having doubly-coiled legs extending transversely outward from a triply-coiled middle portion; a cataphoretic coating of aluminum oxide over said doubly-coated legs; a coating of electron-emissive material over said triply-coiled portion of said filament and extending to said coating of aluminum oxide; and lead-in wires outside said ionization layer and connected to the ends of said filament.

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