April 12, 1966 J. F. WAYMOUTH 3,246,189

VAPOR PRESSURE CONTROL IN ELECTRON DISCHARGE DEVICES

Filed Dec. 31, 1962

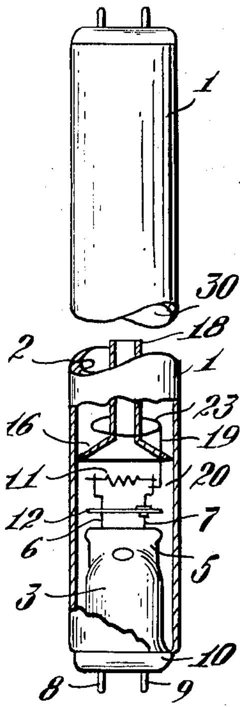

Fig. 1

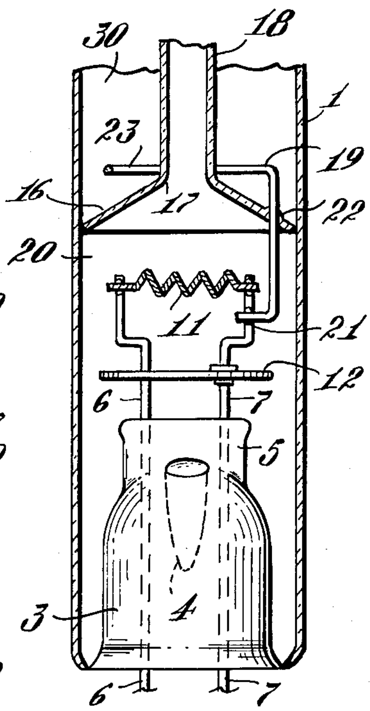

Fig. 2

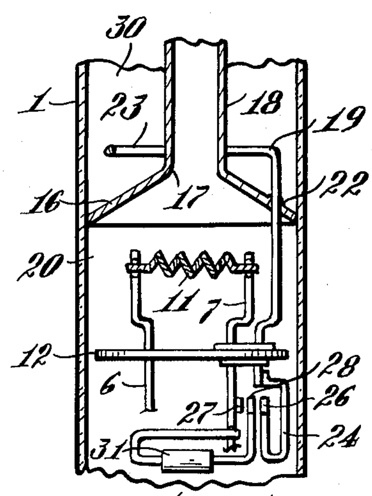

Fig. 4

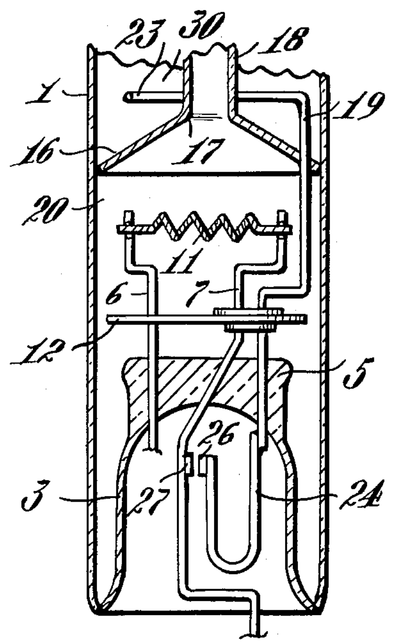

Fig. 3

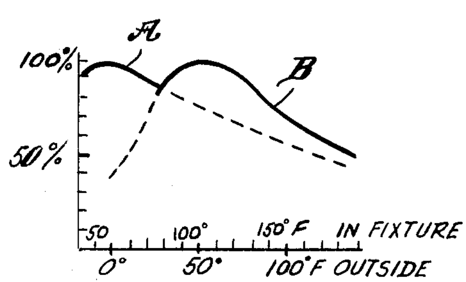

Fig. 5

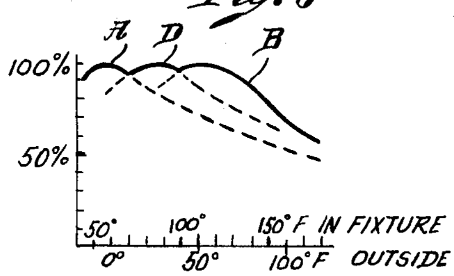

Fig. 6

INVENTOR.

John F. Waymouth

BY

Roberts, Cushman & Grover

ATT'YS

United States Patent Office

3,246,189
Patented Apr. 12, 1966

3,246,189
VAPOR PRESSURE CONTROL IN ELECTRON DISCHARGE DEVICES

John F. Waymouth, Marblehead, Mass., assignor to Sylvania Electric Products Inc., Wilmington, Del., a corporation of Delaware

Filed Dec. 31, 1962, Ser. No. 248,629
11 Claims. (Cl. 313—13)

This invention relates to electron discharge devices such as fluorescent lamps and particularly to the control of the vapor pressure of ionizable material, such as mercury, in such devices.

A very high output (VHO) fluorescent lamp, for example, comprises a sealed glass envelope, phosphor coated on its inner wall, containing a rare gas such as neon or argon at a low pressure in the order of a few millimeters of mercury, and a small supply of mercury. An electron discharge between emissive electrodes at each end of the envelope vaporizes and ionizes the mercury, and excites it to ultraviolet radiation which, in turn, causes the phosphor to radiate visible light by fluorescence.

It is well known that the light output of fluorescent lamps is dependent on ambient temperature. This dependence arises from the fact that mercury vapor pressure inside the lamp depends on the temperature of the coolest part of the bulb, which in turn depends on the temperature of the air in which the lamp is operating. The light output depends on mercury vapor pressure in two ways. First, the efficiency of conversion of electrical energy into ultraviolet energy is a maximum at a mercury vapor pressure of about six microns; and second, the power consumed by the lamp on a ballast circuit decreases with increasing mercury vapor pressure. Because of these two effects, lamps operating on commercial ballasts typically have maximum light output at a vapor pressure of about 3 microns, corresponding to a coolest spot temperature of 35° C., which is usually obtained in still air at about 70° F. Similarly, they reach maximum efficiency (lumens/watt) at a somewhat higher cool spot temperature 40° C., usually obtained at a still-air temperature of 77° F.

Operation of fluorescent lamps in ambient temperatures differing appreciably from the optimum values results both in lower efficiency and lower light output. At high temperatures, particularly, the drop off in light output may be quite severe, since not only has efficiency decreased but power consumption has decreased also. Light output is therefore substantially decreased. For instance, at an ambient temperature of 100° F., light output may be as much as 15% below the maximum, while at 120° F., a loss of 30% is typical.

Ambient temperatures in this range are frequently found in indoor fixtures, in fact, it might be said that they are the rule, rather than the exception. In the first place, fixtures are near the ceiling, where the temperature is already higher. Moreover, the heat from the lamps themselves increases the air temperature in the fixture, especially in fully-enclosed fixtures.

VHO fluorescent lamps, despite their use of end chambers to provide cool spots, suffer from the same limitation. The end chambers are designed so that at normal loading, they operate about 40° C. in an ambient of 77° F. In fact, the problem is more severe with VHO lamps than other types because the power input per fixture is greater and the temperature rise of the air inside the fixture is therefore greater.

The object of the invention is to provide an electron discharge device, such as a fluorescent lamp, which controls the vapor pressure of its ionizable material despite increases in temperature of the vapor. Such control is useful in mercury rectifier tubes, and in discharge tubes which contain sodium or other positively ionizable materials or mixtures of ionizable materials.

According to the invention an electron discharge device comprises an envelope containing a vaporizable, positively ionizable material, spaced electrodes adapted to provide an electron discharge between the electrodes and an ion counterflow of said material in said envelope, at least one of said electrodes being substantially electron emissive, and a wall between said electrodes forming a chamber for said one electrode, said wall forming a passage for electron discharge from said one electrode to the other electrode, said wall being adapted to inhibit ion flow from said chamber thereby tending to raise the vapor pressure of said material in said chamber and control the vapor pressure in said envelope outside said chamber.

Further according to the invention an auxiliary electrode is connected to said one emissive electrode and is located between the aforesaid wall and the other of said spaced electrodes whereby an excess of electrons are discharged from said one electrode and an excess of ions tends to flow to said one electrode through the opening in said wall, thereby to reduce the vapor pressure of said ionizable material between said wall and the other electrode.

For the purpose of illustration typical embodiments of the invention are shown in the accompanying drawing in which:

FIG. 1 is a side view of one form of fluorescent lamp according to the invention, partly broken away;

FIG. 2 is an enlarged section of the form of FIG. 1;

FIGS. 3 and 4 are views like FIG. 2 showing other forms of the invention; and

FIGS. 5 and 6 are characteristic curves showing the performance of the forms of FIGS. 3 and 4 respectively in terms of percent of optimum light output versus ambient temperature in degrees Fahrenheit.

As shown in FIGS. 1 and 2 a fluorescent lamp comprises an elongate glass tube or envelope **1** with an interior phosphor coating **2**. Each end of the envelope is sealed by a glass stem **3** which includes an exhaust tube **4** opening into the interior of the envelope and a steam press **5** through which lead wires **6** and **7** enter the envelope. Outside the envelope the lead wires **6** and **7** are connected to contact pins **8** and **9** extending from a base **10**. The base **10** covers the end of the tube **1** and insulates the contact pins **8** and **9**.

At one end of the envelope the lead wires **6** and **7** support a filamentary electrode **11**, preferably of coiled-coil or triple-coiled tungsten wire, carrying any of various well known electron emitting materials. An electrode assembly, similar as so far described, is located at the other end of the tube. The tube is filled with an inert gas such as neon, or a mixture of inert gases such as neon and a small amount of argon, and with a small amount of mercury. The two electrodes are resistively heated to emissive temperature whereupon electron discharge occurs between them, one acting as a cathode and the other as an anode during alternate half cycles of the voltage applied across the tube.

A disk shaped reflecting shield **12** is supported by a feed through insulating thimble on one lead wire **7** and by the other lead wire **6**. The shield **12** is somewhat less in diameter than the wall of the envelope **1** and somewhat wider than the stem press, and serves to maintain a cool zone at the end of the lamp by reflecting radiation from the discharge of the emissive electrode.

According to the invention a wall member of glass or other insulation **16** with a passage or aperture **17** spans the envelope **1** between the electrodes **11** and adjacent one of them. Preferably the wall forms a funnel with its mouth adjacent and tapering away from the adjacent electrode and the passage is formed by a tube **18** extending axially of the envelope along the electron discharge path from the electrode. The wall **16** makes a glass-to-glass seal with the envelope **1** thereby enclosing the electrode **11** in an end chamber **20** and separating the end chamber **20** from the main chamber **30** of the envelope.

Further an auxiliary electrode, connected by a weld **21** to one lead wire **7**, extends through a glass-to-metal seal **22** beyond the wall **16**. Preferably the auxiliary electrode terminates in a ring **23** encircling the glass tube **18**. The auxiliary electrode **19** may be tungsten or other refractory metal wire of the same diameter as the lead wires **6** and **7**, i.e., in the order of 40 mils. The auxiliary electrode carries no electron emissive material compared to the coated electrode **11** which is substantially more emissive. The auxiliary electrode may however, act as an anode, collecting electron discharge from the emissive electrode at the other end of the tube.

On alternate half cycles of the alternating current through the envelope the coated electrode **11** discharges electrons on a path through the pasage in the wall **16**, and the auxiliary electrode collects electrons from the other electrode. Since the alternating electron flowin the envelope is accompanied by a counterflow of ionized mercury atoms, there is an excess of ion flow to the coated electrode **11** over ion flow from the coated electrode. Therefor there is a gradient of mercury pressure through the tube **18** due to electrophoretic pumping of mercury through the tube into the end chamber **20**, and an increase of mercury vapor pressure in the end chamber **20** accompanied by a decrease of the mercury vapor pressure in the main chamber **30**. At a given operating temperature the pressure differential will reach an equilibrium dependent on the surface area of the auxiliary electrode **19** and the length and diameter of the tube **18**. In a typical 48-inch, 110-watt VHO fluorescent lamp with a tube two to three inches long and 10 mm. in outside diameter, pressure drops of 10 to 15 microns per mm. of pressure of rare gas can be obtained. Such a lamp would obtain maximum efficiency at an end chamber temperature of 58° C., corresponding to a temperature in the lamp fixture of about 110° F., as compared with a conventional VHO lamp with maximum efficiency at 35° C. in the end chamber, 77° F. in the fixture. A lamp according to the invention would therefore operate at up to about 30% more light output than conventional VHO lamps at temperatures above 100° F. Since such temperatures frequently exist in fixtures, the present invention makes possible a substantially higher output than has hitherto been possible, particularly in indoor installations.

Further, according to forms of the invention shown in FIGS. 3 and 4, the temperature range at which high efficiency is maintained can be extended to accommodate outdoor fluorecent lamp installations.

As shown in FIG. 3 the connection from the auxiliary electrode **19** to the lead wire **7** which supplies the coated electrode **11** extends through the stem press **5** to the interior of the stem **3** where it is interrupted by a thermostatic switch including a bimetallic element **24** carrying a contact **26** which closes with a contact **27** on the lead wire **7**. The bimetallic element is set to close the contacts at a temperature above the normal VHO operating range, for example, at a temperature of approximately 88° F. in the fixture, which would be the operating temperature with an outside ambient temperature of about 27° F. The lamp operates with its normal characteristic up to the closing temperature. Then with the switch connecting the auxiliary electrode, electrophoretic pumping reduces the vapor pressure and causes operation with a controlled characteristic.

FIG. 5 shows two characteristic operating curves in which relative light output in percentage of optimum output is plotted against the immediate ambient air temperature within the fixture and the outside ambient air temperature. From sub zero to about 28° F. outside temperature (88° F. inside the fixture) the lamp operates on a normal characteristic curve A at 85% or higher light output with a maximum between 60° to 70° F. within the fixture. With the switch contacts **26** and **27** closed, the lamp operates on a new characteristic curve B at 85% or higher output from 88° F. to about 140° F. within the fixture. In this elevated temperature range the light output is up to 30% more than normal. Thus the automatic switching to electrophoretic pumping provides light output in excess of 85% of optimum over an outside ambient temperature range from −20° F. to 80° F.

A somewhat improved performance is afforded by a two step switch shown in FIG. 4. Between the previously described thermostat contact **26** and the contact **27** on the electrode lead wire **7** there is interposed a contact **28** carried on the flexible lead of a ½ ohm, ½ watt resistor **31** which is connected to the lead wire **7** at the end of and within the envelope **1**. The bimetallic element is set to close contacts **26** and **28** at a fixture air temperature of 68° F. thereby connecting the auxiliary electrode to the coated electrode through the resistor **31**, and then also to close contacts **27** and **28** at a fixture air temperature of about 98° F.

With all contacts open the lamp operates with a light output on the normal curve A of FIG. 6. When contacts **26** and **28** connect the resistor **31** in series with the auxiliary electrode **19** the auxiliary electrode current heats the resistor **31** raising the end temperature within the cool zone of the envelope to about 55° C. It has been vertified that resistances up to 50 ohms do not interfere with electrophoretic pumping by affecting the preference of electrons to be collected upon the auxiliary electrode. However, anode current through the resistor is partly dissipated as heat in the end chamber **20** thereby raising the mercury vapor pressure and partly offsetting the electrophoretic pumping reduction of vapor pressure in the main chamber **30**. With only contacts **26** and **28** closed, the lamp operates with a characteristic shown by curve D of FIG. 6 between about 70° F. and 100° F. fixture air temperature. Above 100° F. fixture air temperature further movement of the bimetallic element **24** connects contact **26** to contact **27** through contact **28**, thereby shorting out the resistor **31** and eliminating its heating effect. The full electrophoretic effect then causes the lamp to operate with the characteristic of curve B of FIG. 6.

From FIG. 6 it can be seen that the lamp of FIG. 4 yields a light output in excess of 95% of optimum over an ambient temperature range outside the fixture from −10° F. to 70° F., the entire normal range of nighttime temperatures. A lamp with such performance is substantially independent of ambient temperature and constitutes what is believed to be the first truly universal fluorescent lamp.

To a lesser degree this universal performance is attributable to lamps embodying the structure of FIG. 3.

Street lighting installation particularly are based on the requirement of a minimum footcandle level between poles under the worst anticipated conditions of ambient temperature and age of lamp. The use of this invention, which permits 15–30% higher light output to be achieved at high ambients would permit spacing of poles further apart, while still maintianing the minimum footcandle level. Since such installations cost many hundreds of dollars a pole, the elimination of even one pole out of ten or twenty would more than pay for a substantial increase in lamp cost.

Attention is also called to the fact that, although the end chamber adapted for mercury pumping is longer than the end chamber presently in use, it need be installed on only one end of the lamp. The electrode and stem structure on the other end can be substantially shortened, so that no reduction in lighted length of the lamp need be incurred as a result of this construction.

It should be understood that the foregoing description is for the purpose of illustration and that the invention includes all modifications falling within the scope of the appended claims.

I claim:

1. An alternating current electron discharge device comprising an envelope containing a vaporizable, positively ionizable material, first and second spaced substantially electron emissive electrodes adapted to provide an alternating electron discharge and an alternating ion counterflow of said material in said envelope, a wall in the discharge path from said second electrode, said wall having a passage on the electron path from said first electrode, and an auxiliary electrode between said wall and the second electrode, said auxiliary electrode being connected to said first electrode so as to collect electron discharge from the second electrode, said first electrode being substantially more electron emissive than said auxiliary electrodes, whereby positive ions of said material are electrophoretically pumped through said opening toward said first electrode, thereby to control the vapor pressure between said wall and said second electrode.

2. A device according to claim **1** wherein said wall opening comprises a tube and said wall and tube form a funnel spanning the envelope transversely with the funnel mouth adjacent said first electrode, the funnel tapering away from said first electrode, and wherein said auxiliary electrode is located intermediate the ends of said tube.

3. A device according to claim **1** wherein the connection and support for said auxiliary electrode extend through said wall.

4. An alternating current electron discharge device comprising a sealed envelope containing a vaporizable, positively ionizable material, first and second spaced substantially electron emissive electrodes having leads extending outside the envelope and adapted to provide an alternating electron discharge and an alternating ion counterflow of said material in said envelope, a wall in the discharge path from said second electrode, said wall having an opening on the electron path from said first electrode, an auxiliary electrode between said wall and the second electrode, said auxiliary electrode being connected to a lead to said first electrode so as to collect electron discharge from the second electrode, said first electrode being substantially more electron emissive than said auxiliary electrode, whereby positive ions of said material are electrophoretically pumped through said opening toward said first electrode, thereby to control the vapor pressure between said wall and said second electrode at higher than normal operating temperatures, the connection between said first electrode lead and auxiliary electrode including a thermostatic switch adapted to open at normal temperatures to allow the device to operate without the pumping effect caused by said auxiliary electrode.

5. A device according to claim **4** wherein said thermostatic switch is disposed inside said envelope.

6. A device according to claim **4** wherein said switch is disposed outside the seal of said envelope but near said first electrode.

7. A device according to claim **1** in combination with a heating element connected to a lead to said first electrode, said thermostatic switch being arranged to connect said heating element between said first electrode lead and the auxiliary electrode at intermediate temperatures above normal operating temperatures so that electron current collected by said auxiliary electrode flows through said heating element, thereby partly to offset the pumping effect of said auxiliary electrode by heating the vapor at one end of said envelope.

8. A device according to claim **7** wherein said thermostatic element is further arranged to make a connection to said electrode lead at a temperature higher than said intermediate temperatures thereby to short out said heating element.

9. An alternating current electron discharge device comprising an envelope containing a vaporizable, positively ionizable material, first and second spaced substantially electron emissive electrodes having leads extending outside said envelope and adapted to provide an alternating electron discharge and an ion counterflow of said material in said envelope, a wall in the discharge path from said second electrode, said wall having an opening on the electron path from said first electrode, and an auxiliary electrode between said wall and the second electrode, said auxiliary electrode being connected to a lead to said first electrode so as to collect electron discharge from the second electrode, said first electrode being substantially more electron emissive than said auxiliary electrode, whereby positive ions of said material are electrophoretically pumped through said opening toward said first electrode, thereby to control the vapor pressure between said wall and said second electrode at temperatures higher than normal operating temperatures, the connection between said first electrode lead and said auxiliary electrode including a heating element and a thermostatic switch adapted to close at said higher temperatures thereby to modify the control of vapor pressure by electrophoretic pumping.

10. A fluorescent lamp comprising an elongate, tubular glass envelope having an internal phosphor coating and containing a vaporizable, positively ionizable material, electron emissively coated electrodes at each end of said envelope, said electrodes being adapted to provide an alternating electron discharge and an alternating ion counterflow of said material exciting said phosphor to fluoresence, a wall of insulating material adjacent one electrode spanning said tube transversely so as to impede electron flow from the other electrode to said one electrode, said wall having a passage facilitating electron flow from said one electrode to the other, and an auxiliary electrode connected to said one electrode and located between said wall and the other electrode for collecting electron flow from the other electrode, whereby an excess of electrons are discharged from and an excess of ions tends to flow to said one electrode through the wall passage, thereby to reduce the vapor pressure of said material between said wall and the other electrode and permit high light output operation at higher than normal temperatures.

11. An alternating current electron discharge device comprising an envelope containing a vaporizable, positively ionizable material, first and second spaced substantially electron emissive electrodes adapted to provide an alternating electron discharge and an ion counterflow of said material in said envelope, a wall in the discharge path from said second electrode, said wall having an opening on the electron path from said first electrode, an auxiliary electrode between said wall and the second electrode, said auxiliary electrode being connected to a lead to said first electrode so as to collect electron discharge from the second electrode, said first electrode being substantially more electron emissive than said auxiliary electrode, whereby positive ions of said material are electrophoretically pumped through said

opening toward said first electrode, thereby to reduce the vapor pressure between said wall and said second electrode, and switching means for modifying the resistance of the connection between said first and auxiliary electrodes thereby to vary the electrophoretic pumping control of vapor pressure.

References Cited by the Examiner

UNITED STATES PATENTS

2,182,751	12/1939	Reitherman	313—204 X
2,201,819	5/1940	Smith	313—227 X
2,217,436	10/1940	Evans	313—227 X
2,318,082	5/1943	Kober et al.	315—56
2,662,159	12/1953	Bilofsky et al.	315—73 X
2,932,753	4/1960	Arnott et al.	313—109 X
3,117,248	1/1964	Lake	313—204 X

GEORGE N. WESTBY, *Primary Examiner.*

R. J. JUDD, *Assistant Examiner.*