March 12, 1968 G. S. EVANS 3,373,303

AMALGAM-CONTAINING FLUORESCENT LAMP WITH INTEGRAL STARTING AID

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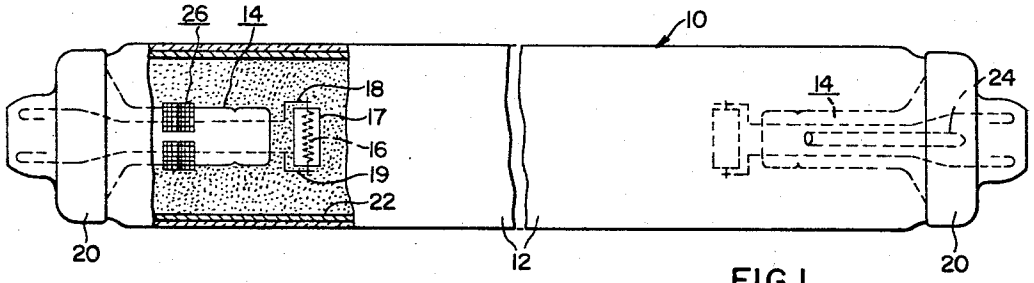


FIG. 1.

FIG. 2.

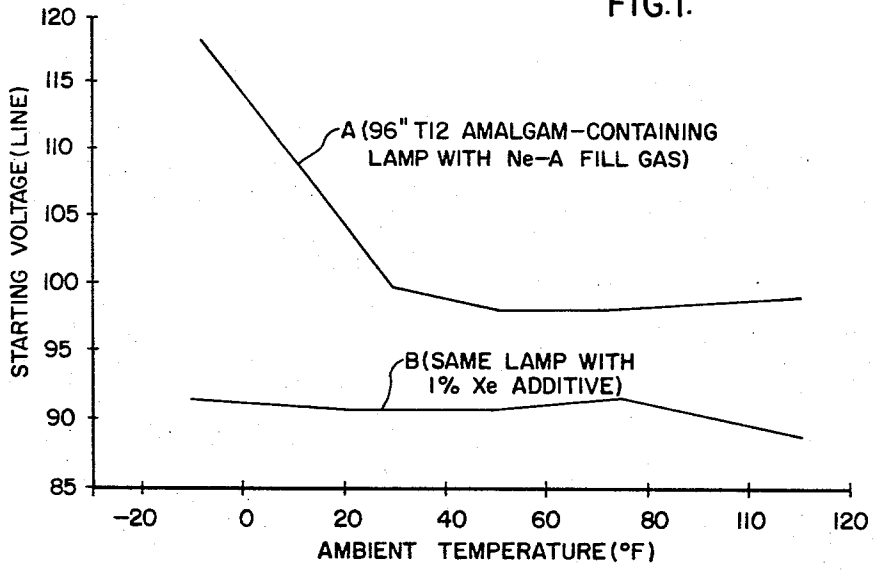
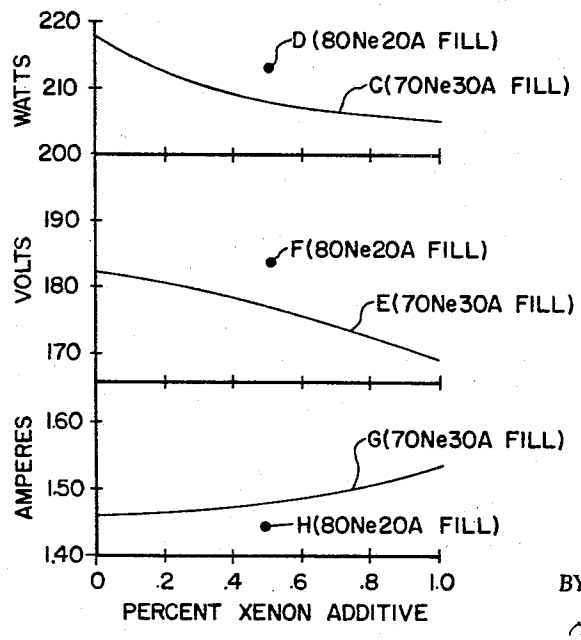


FIG. 3.



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AMALGAM-CONTAINING FLUORESCENT LAMP WITH INTEGRAL STARTING AID

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ABSTRACT OF THE DISCLOSURE

A small amount of xenon, preferably from 0.1% to 2% by volume, is added to the fill gas of an amalgam-containing fluorescent lamp to compensate for the initial deficiency of mercury vapor when the lamp and amalgam are at ambient temperature and reduce the starting voltage to a value such that the lamp can be operated in fixtures and on ballasts designed for conventional fluorescent lamps. The xenon additive also permits the electrical characteristics of the lamp to be adjusted and correlated with the design parameters of the ballast.

This invention relates to electric discharge lamps and has particular reference to an improved fluorescent lamp that contains an amalgam of mercury and another metal which controls the mercury vapor pressure within the lamp during operation.

As is well known, the light output and efficiency of a fluorescent lamp are dependent upon the concentration of mercury vapor, or the mercury vapor pressure, which exists in the lamp when it is operated. The mercury vapor pressure, in turn, varies with lamp temperature so that some means must be provided for controlling the mercury vapor pressure within the lamp and maintain it at the value required for optimum lamp performance. This is particularly true in the case of highly-loaded fluorescent lamps where the power input is such that the lamps operate at a considerably higher temperature than conventionally loaded lamps.

In accordance with one prior art solution to the mercury-vapor pressure control problem an amalgam of mercury with another metal is used as the source of mercury vapor rather than the usual pool of condensed pure mercury. Since the mercury vapor pressure produced by such an amalgam is lower than that generated by pure mercury under the same conditions, the amalgam keeps the mercury vapor pressure within the required limits despite the elevated operating temperatures which prevail within highly-loaded fluorescent lamps, or standard lamps which are used in enclosed lighting fixtures. Such an amalgam-containing fluorescent lamp is disclosed in U.S. Patent No. 3,007,071, entitled "Low-Pressure Mercury Vapor Discharge Lamp," issued Oct. 31, 1961, to A. Lompe et al. As stated in this patent, various metals can be combined with the mercury to form an amalgam having the desired characteristics. The amalgam-forming metal can consists of a single metal such as thallium, cadmium, indium, gallium or the like, or it may consist of two metals such as cadmium and gold.

An improved fluorescent lamp containing an indium-mercury amalgam of carefully controlled composition and characteristics is disclosed and claimed in copending applcation Ser. No. 381,503, entitled "Mercury Vapor Discharge Lamp And Pressure Regulating Means Therefor," filed July 9, 1964, by G. S. Evans and assigned to the assignee of the present invention.

While amalgam-containing fluorescent lamps perform satisfactorily under normal operating conditons, it has been found that they are difficult to start at low temperatures on ballasts designed and used for lamps of the same

size and wattage loading. Specifically, comparative tests have shown that at ambient temperatures below about 50° F., ballasts which reliably start 96 inch T12 highly-loaded fluorescent lamps having cool end chambers and pure mercury would not reliably start lamps of the same size and wattage rating which contained a mercury amalgam and the same mixed fill gas of neon and argon. The amalgam-containing lamps were thus not interchangeable with conventional highly-loaded lamps presently in use, particularly in those applications where abnormally low ambient temperatures would be encountered. This lack of interchangeability presents a serious obstacle to the commercial acceptance of amalgam-containing fluorescent lamps insofar as it necessitates the use of specially-designed ballasts and the conversion of existing lighting fixtures having ballasts designed for the various standard highly-loaded lamps now being marketed.

It is accordingly the general object of the present invention to overcome the foregoing and other problems associated with the use of amalgam-containing low-pressure mercury-vapor electric discharge lamps by providing a lamp of this type that is interchangeable with lamps of the same size and loading now in commercial use.

A more specific object is the provision of a highly-loaded fluorescent lamp that contains an amalgam of mercury and another metal and which can be reliably started at temperatures below 50° F. in existing fixtures having ballasts designed for fluorescent lamps that utilize a different mode of mercury-vapor pressure control.

Still another object is the provision of means for decreasing the voltage required to reliably start highly-loaded fluorescent lamps which utilize an amalgam to control the mercury vapor pressure during operation.

The foregoing objects, and other advantages which will become apparent to those skilled in the art as the description proceeds, are achieved in accordance with the present invention by adding a predetermined amount of xenon to the fill gas. Specifically, it has been discovered that a marked reduction in the voltage required to start amalgam-containing fluorescent lamps at low ambient temperatures is achieved by adding very small amounts (less than 5% by volume) of xenon to the fill gas introduced into the lamp during manufacture. By carefully controlling the amount of the xenon additive relative to the other component (or components) of the fill gas, the desired reduction in starting voltage is effected with substantially no adverse effect on the efficiency or other performance parameters of the lamp.

A better undestanding of the invention will be obtained by referring to the accompanying drawing, wherein:

FIGURE 1 is a front elevational view of an amalgam-containing fluorescent lamp embodying the present invention, portions of the bulb being removed for convenience of illustration;

FIG. 2 is a graph illustrating the typical reduction in starting voltage at various ambient temperatures achieved by the use of a xenon additive in accordance with this invention; and,

FIG. 3 is a graph illustrating the effect of various amounts of xenon additive on the electrical characteristics of a 96 inch T12 amalgam-containing fluoroescent lamp having a neo-argon fill gas.

While the present invention can be used with advantage in various types of electric discharge lamps which are difficult to start, it is especially adapted for use in conjunction with highly-loaded amalgam-containing fluorescent lamps and has accordingly been so illustrated and will be so described. The term "highly-loaded" as used in this description denotes a power loading in excess of about 20 watts per foot of lamp length.

With specific reference now to the drawing, in FIG. 1

there is shown a highly-loaded fluorescent lamp **10** having a tubular light-transmitting vitreous envelope **12** which has the usual re-entrant mounts **14** sealed into each of its ends. Each of the mounts carries a thermionic electrode, such as paired cathodes **16** and enlarged anodes **17**, that are connected by means of lead wires **18** and **19** to recessed contacts housed within a suitable base member **20** attached to each end of the envelope **12**. The inner surface of the envelope is coated with a layer **22** of a suitable ultraviolet-responsive phosphor and one of the mounts **14** is provided with a tubulation **24** that is tipped off in the usual manner after the lamp has been evacuated, mercury dosed, and charged with a suitable inert ionizable fill gas.

One of the lamp mounts **14** is also provided with a laminated collar **26** of wire mesh or the like that includes a layer of a metal that amalgamates with mercury and thus serves as a mercury-vapor pressure control assembly or center. The collar is secured to the mount and it may be fabricated in the manner described in the aforementioned copending Evans application Ser. No. 381,503. The amalgam can consist of a predetermined amount of mercury and at least 80 atomic percent indium, as disclosed in the above-cited Evans application. However, any suitable amalgam-forming metal such as cadmium, gallium, thallium, etc. can be used in accordance with the teachings of the Lompe et al. Patent No. 3,007,071. The amalgam can also be placed at other locations within the lamp remote from the electrodes, as for example, on the inner surface of the envelope **12** in accordance with the disclosure of the aforementioned Lompe et al. patent.

Comparative lamp starting tests have shown that lamps utilizing an amalgam as the mercury-vapor control means require higher starting voltages than lamps of the same wattage and type having end chambers and a condensed pool of pure mercury. Specifically, it was found that the amalgam-containing lamps did not meet the industry standards established for reliable starting at ambient temperatures below about 50° F. While this problem could be overcome by redesigning the ballast, this would not be a practical solution insofar as the ballasts in existing lamp fixtures would have to be replaced before amalgam-containing fluorescent lamps could be used. The resulting expense and supply problems would, obviously, deter the commercial acceptance of fluorescent lamps utilizing an amalgam as the mercury-vapor control means.

The aforesaid starting problem is overcome in accordance with the present invention by adding a small preselected amount of xenon to the fill gas introduced into the lamp during manufacture. Comparative tests have shown that a marked decrease in the starting voltage, particularly at ambient temperatures below 50° F., can very readily be achieved by adding up to 5% xenon, and preferably from about 0.1% to about 2% xenon, to the fill gas normally used in the lamp. While this phenomenon is not completely understood at the present time, it is believed that the xenon compensates for the deficiency of mercury molecules that exists within the lamp during starting while the amalgam is at ambient temperature and the mercury vapor pressure is thus very low. The lamp is thus initially in a "mercury-starved" condition due to the use of the amalgam, and this condition becomes worse as the ambient temperature decreases. At extremely low temperatures the lamp becomes so deficient in mercury molecules that the discharge, when initiated, remains in a relatively low-current high-gradient condition or glow discharge state.

While two lamps operating in series in the aforesaid low-current glow discharge condition can be forced into an arc discharge condition by the application of a sufficiently high voltage and power input, excessively high primary input voltages would be required in conventional commercially available ballasts to effect this transition. Apparently, the small amount of xenon added to the fill gas provides the low voltage current carriers which are normally supplied by the mercury molecules and required to effect the glow-to-arc transition. The xenon thus compensates for the dearth of mercury molecules when the lamp is at ambient temperature and in a mercury-starved condition. Since xenon has an ionization voltage of 12.08 volts compared to 10.38 volts for mercury, it behaves in substantially the same manner as mercury in the gas discharge. In contrast, the ionization voltages for neon and argon (the fill gas components customarily employed in highly-loaded lamps) are 21.47 volts and 15.69 volts, respectively.

The marked reduction in the voltage required to start an amalgam-containing fluorescent lamp achieved through the use of a xenon additive is illustrated in FIG. 2 of the drawing. The graph is based on comparative test data obtained on highly-loaded (1500 ma.) 96 inch T12 fluorescent lamps containing an amalgam of indium and mercury and a mixed fill gas comprising 70% neon and 30% argon at a pressure of 2.4 millimeters of mercury. The lamps were identical in every respect except that one group contained a fill gas that included 1% xenon. That is, the fill gas comprises 1% xenon (by volume) and 99% by volume of the aforesaid 70 neon-30 argon mixture. The lamps were operated at the indicated ambient temperatures on a typical commercial two-lamp series-sequence ballast used for the various types of 96 inch 1500 ma. fluorescent lamps now being marketed. The starting voltage indicated in the graph was the line voltage applied to the primary winding of the ballast.

As will be noted in FIG. 2, the amalgam-containing lamp with the straight neon-argon fill gas (curve A) required a starting voltage of slightly less than 100 volts over the ambient temperature range of from 70 to 50° F. As the temperature dropped below 50° F. the voltage required increased at a rate such that 100 volts was needed to achieve reliable starting at an ambient temperature of about 30° F. The starting voltage then increased sharply at temperatures below 30° F. at a rate such that approximately 118 volts was required to start the lamp at a temperature of −8° F.

In contrast, the lamps containing the 1% xenon additive (curve B) required a starting voltage of only approximately 92 volts at an ambient temperature of approximately 70° F., and the voltage remained substantially constant over the entire temperature range down to −8° F. The starting voltage decreased at ambient temperatures above 70° F. and fell to a value less than 90 volts at temperatures above 100° F. Thus, the addition of 1% xenon to the fill gas drastically reduced the required starting voltage, particularly at ambient temperatures below 50° F. Hence, amalgam-containing fluorescent lamps embodying the present invention have an "integral starting aid," so to speak, which enables them to be used in existing fixtures and operated on commercially available ballasts without encountering any starting problems.

The aforesaid marked difference between the required starting voltages for conventional amalgam-containing fluorescent lamps and those having a 1% xenon additive was confirmed in another test wherein the lamps were started on a laboratory assembled two-lamp series lead circuit. The lamp group with the 1% xenon additive started at approximately 15% lower arc-over voltage than did the group having the straight mixed-fill gas without xenon.

According to the standards adopted by the industry for reliable starting, a lamp must start on a line voltage (applied to the ballast) equivalent to 90% of the rated line voltage at ambient temperatures down to −20° F. Thus, in the case of a lamp ballast having a nominal rating of 120 volts, the lamp must start reliably at low ambient temperatures on a line voltage no greater than 108 volts. Curve B of FIG. 2 clearly shows that lamps having a 1% xenon additive are well within this limit.

Since the ionization voltage of xenon is slightly higher

than that of mercury, the presence of xenon in the fill gas raises the ionization voltage of the lamp (that is, the voltage required to produce a glow discharge between the electrodes as distinguished from an arc discharge). This does not constitute any problem, however, since commercial ballasts are so designed that they inherently provide sufficient voltage for ionization.

The xenon also affects the electrical characteristics of the lamp, as is shown in FIG. 3. As indicated by curve C, the wattage of a 96 inch T12 amalgam-containing lamp having a nominal current rating of 1500 ma. and a mixed fill gas of 70% neon-30% argon gradually decreased from a value of 218 watts to approximately 205 watts as the amount of the xenon additive was varied from zero to 1%. As indicated by curve E, the lamp voltage also dropped off gradually as the quantity of xenon added to the fill gas increased. In contrast, the lamp current (curve G) increased slightly as the xenon content increased. Thus, the electrical characteristics of the lamp can be readily controlled by suitably adjusting the amount of the xenon additive. While the percent xenon in this particular case was preferably kept within the range of about 0.1% to 1% by volume, the optimum amount will vary depending upon its effect on the lamp wattage and efficiency, lamp life, ionization voltage requirements, fill gas costs, and other factors that must be considered for the specific lamp type or design involved. Up to 5% xenon can be used in the fill gas, if desired.

As an example of the flexibility in lamp design afforded by varying the amount of xenon added to the fill gas, curve C of FIG. 3 indicates that a 96 inch 1500 ma. amalgam-containing lamp having a mixed fill gas of 70% neon-30% argon at 2.4 millimeters pressure without any xenon additive operates at 218 watts. Compared to the ASA value of 212 watts, this wattage is on the high side and may not be acceptable to all ballast manufactures in spite of the lower lamp current of 1.46 amperes (ASA value is 1.50 amperes). With 1% xenon additive, the wattage falls to 205 watts, approximately 6%. Since the light output would be reduced by a proportionate amount, this represents a considerable light loss.

In contrast, the use of 0.5% xenon in an amalgam-containing fluorescent lamp of the same size and rating having a fill gas consisting of 80% neon-20% argon at 2.4 millimeters pressure reduces the wattage from 218 to 214 watts (as indicated by point D in FIG. 3). While the lamp voltage increased somewhat with this combination of basic mixed-fill gas and xenon additive (point F in FIG. 3), the lamp current decreased(point H), which is desirable. Thus, the use of 0.5% xenon in a fill gas consisting of 80% neon-20% argon reduces the lamp wattage to a lower and safer value and provides satisfactory starting at low ambient temperatures without excessive penalty in light output. This specific fill gas composition thus offers more favorable electrical characteristics and is preferred for this particular type of highly-loaded lamp.

It will be apparent from the foregoing that the objects of the invention have been achieved in that an improved amalgam-containing fluorescent lamp has been provided which, by virtue of a small amount of xenon added to the fill gas, will reliably start at low ambient temperatures on commercial ballasts and is thus interchangeable with conventional lamps now in use.

While several embodiments have been described, it will be understood that various changes in both the construction and fill gas parameters of the lamp can be made without departing from the spirit and scope of the invention. For example, while a mixed fill gas of neon and argon has been used in the lamps described above, the invention is not limited to lamps having such a fill gas but encompasses lamps having a filling of straight argon or other suitable inert gas, or a triple-component fill gas, such as a predetermined mixture of argon, neon and krypton.

In addition, the pressure of the fill gas is not limited to 2.4 mm. of mercury but may vary from 0.5 to 5 mm. of mercury, depending upon the type of lamp involved and the life, efficiency etc. which is desired. In the case of the Ne-A fill lamps referred to above, the pressure is preferably maintained within the range of about 1.5 to 3 mm. of mercury.

I claim as my invention:

1. A low-pressure mercury-vapor electric discharge lamp comprising,
a sealed vitreous envelope containing a pair of spaced electrodes,
a source of mercury vapor within said envelope comprising an amalgam of mercury and another metal, and
an inert ionizable fill gas in said envelope that contains from about 0.1% to about 1% by volume of xenon which initiates and maintains an arc discharge between said electrodes when the lamp is energized and thus reduces its starting voltage despite the abnormally low mercury-vapor pressure which initially prevails within the lamp when the amalgam is at ambient temperature, the pressure of said ionizable fill gas being within the range of from about 0.5 to 5 mm. of mercury.

2. The low-pressure mercury-vapor electric discharge lamp set forth in claim 1 wherein said fill gas comprises said xenon and a mixture of neon and argon at a total pressure of from about 1.5 to 3.0 mm. of mercury.

3. A highly-loaded fluorescent lamp comprising,
an elongated phophsor-coated vitreous envelope having an electrode sealed in each end,
means for providing a regulated amount of mercury vapor within said lamp during operation comprising an amalgam of mercury and another metal that is so located within the envelope that the lamp atmosphere is in a mercury-starved condition when the lamp is deenergized and at a temperature below its normal operating temperature, and
an ionizable fill gas within said envelope comprising a mixture of argon, neon and xenon wherein xenon constitutes from about 0.1% to about 1% by volume of the fill gas.

4. In a fluorescent lamp, the combination of
an amalgam of mercury and another metal which serves as a temperature-dependent source of mercury vapor within the lamp,
a contained fill gas comprising a mixture of from 70 to 80% neon and from 20 to 30% argon at a pressure below about 5 millimeters of mercury, and
an additive in said fill gas comprising xenon which constitutes from 0.1% to 2% by volume of the fill gas.

5. In a fluorescent lamp, the combination of
an amalgam of mercury and another metal which serves as a temperature-dependent source of mercury vapor within the lamp,
a contained fill gas comprising a mixture of 70% neon and 30% argon at a pressure below about 5 millimeters of mercury, and,
an additive in said fill gas comprising xenon which constitutes about 1% by volume of the fill gas.

6. In a fluorescent lamp, the combination of
an amalgam of mercury and another metal which serves as a temperature-dependent source of mercury vapor within the lamp,
a contained fill gas comprising 80% neon and 20% argon at a pressure below about 5 millimeters of mercury, and
an additive in said fill gas comprising xenon which constitutes about 0.5% by volume of the fill gas.

7. A fluorescent lamp adapted for operation at a loading in excess of approximately 20 watts per foot of lamp length comprising,
a tubular phosphor-coated vitreous envelope having an

outer diameter of about 1½ inches and an electrode sealed in each end,

an amalgam of mercury and another metal disposed within said envelope at a location such that said amalgam maintains the mercury vapor pressure within predetermined limits during lamp operation but produces a mercury-starved condition within the lamp when the latter is deenergized and the amalgam is at a temperature below its normal operating temperature,

an ionizable fill gas within said envelope comprising a mixture of 80% neon and 20% argon at a pressure of 1.5 to 3 millimeters of mercury, and

an additive in said fill gas comprising xenon which constitutes from 0.1 to 1% by volume of the fill gas mixture.

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