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3,237,041

CATHODIC GLOW GASEOUS DISCHARGE DEVICE

Filed May 31, 1962

FIG. 1.

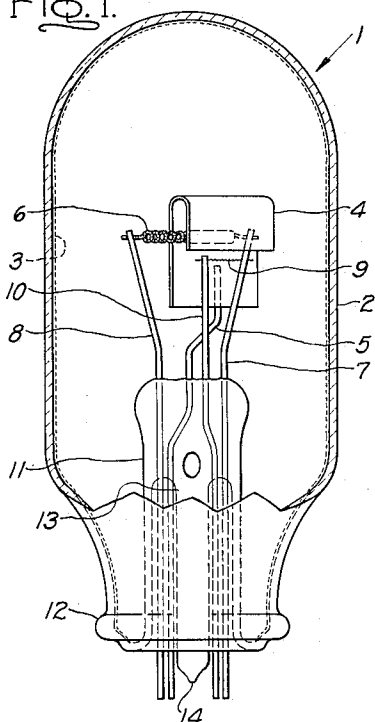


FIG. 2.

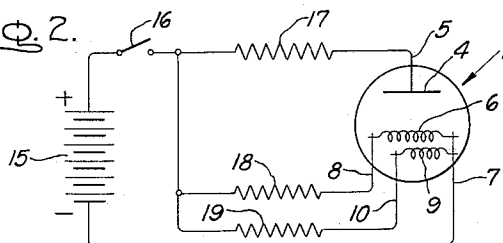


FIG. 3.

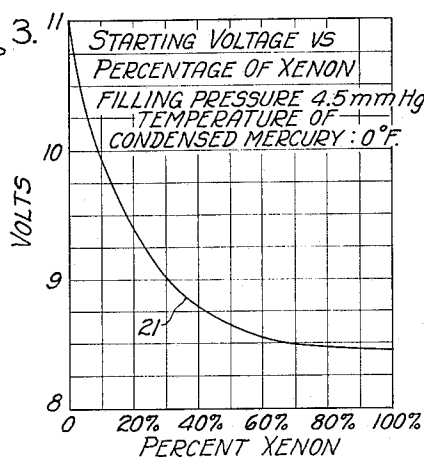


FIG. 5.

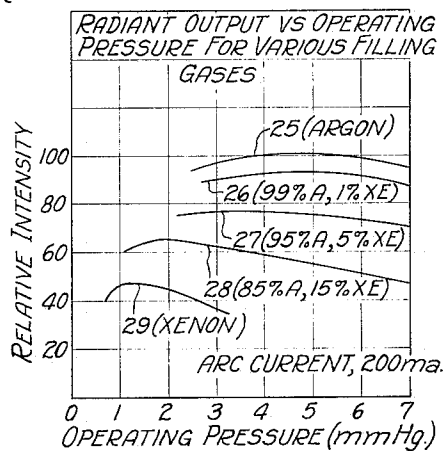
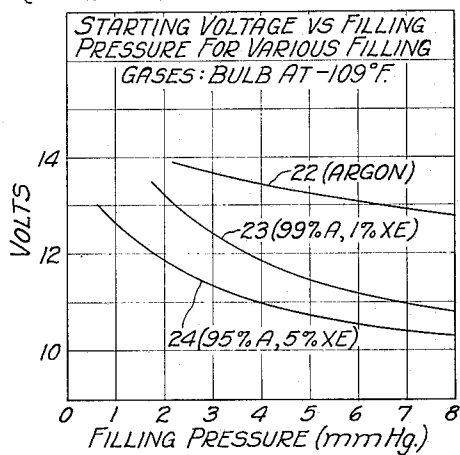


FIG. 4.



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CATHODIC GLOW GASEOUS DISCHARGE DEVICE
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This invention relates generally to gaseous electric discharge devices, and more particularly to the starting or buffer gas filling in low voltage thermionic arc discharge lamps of the cathodic glow type. Such lamps operate at low voltages, generally less than the ionizing potential of mercury at 10.4 volts and not much higher than the minimum voltage required to achieve ionization in the discharge medium.

Examples of the type of discharge lamp with which my invention is particularly useful are the lamps designated commercially RP-12 and 2W-T6. These lamps are miniature single-ended fluorescent lamps utilizing a thermionic arc in mercury vapor to produce 2537 Å radiation which excites a longer wavelength ultraviolet emitting phosphor coated on the envelope walls. One of their fields of application is in aircraft or vehicle instrument panel lighting wherein the instrument dials or indicia are coated with a fluorescent material which produces visible light upon irradiation by the long wave ultraviolet or so called black light from the lamp.

In order to make such lamps practical and economically attractive for dashboard and instrument lighting in automobiles or vehicles using the now common 12 volt battery system, it is necessary that the lamp start reliably at a voltage at least as low as 11.5 volts. Starting must be achieved without the use of special circuits such as inductive kick devices whose cost would make the system unattractive. In addition the system must start and operate reliably under the most adverse climatic conditions likely to be encountered, in practice down to temperatures of zero degrees Fahrenheit. Desirably the lamp should start upon mere application of the source or battery voltage through the circuit which limits or regulates the discharge current through the lamp.

The general object of the invention is to provide improvements for lowering the starting voltage of low voltage thermionic arc discharge devices.

More specific objects of the invention are to provide thermionic arc discharge lamps of the cathodic glow type which will start reliably upon mere application of the voltage from a storage battery of nominal 12 volts rating under adverse conditions of battery charge and temperature.

It was known heretofore that in low voltage discharge lamps utilizing as a source of radiation the cathodic glow of a thermionic arc in low pressure mercury vapor, the lower operating voltage resulting from the use of xenon instead of argon as the starting or buffer gas would be accompanied by lower radiant output. With a xenon gas filling at the usual pressure, the radiant output is reduced by 50% or more compared to argon. On account of this result, together with the relatively high cost of xenon, there has never been any interest in using xenon as the buffer gas for a cathodic glow mercury vapor lamp. Probably this explains why the effects of xenon in respect of starting behavior and ignition voltage in this application have never been adequately investigated prior to my studies which led to the present invention.

In accordance with my invention, I have determined that addition of xenon to argon for the buffer gas is very effective in reducing starting voltage. Furthermore, I have discovered that the initial increments in percentage of xenon relative to argon are much more effective in causing such reduction than later increments. In fact

over 50% of the entire reduction in ignition voltage possible by addition of xenon occurs with addition of only 15% xenon relative to argon. If the voltage reduction is plotted as a function of the percentage of xenon relative to argon used in the buffer gas, an exponential type of curve is obtained which tends asymptotically to the voltage reduction corresponding to 100% xenon. The curve is initially very steep; this means that the major part of the voltage reduction can be obtained by adding only a few percent of xenon with the result that the cost of the xenon addition is severalfold less than what it would be if a pure xenon filling were used. Thus the combination becomes economically feasible.

In addition, I have discovered that in the pressure range from about 0.5 to 10 millimeters of mercury when using a buffer gas consisting of argon plus a small percentage of xenon, the curve of ignition voltage against pressure drops appreciably with increasing pressure, whereas the curve of radiant output may show a broad maximum but is relatively flat. Therefore the selection of higher fill pressures permits appreciable reduction in ignition voltage, either at maximum possible efficiency or at just slightly less than maximum efficiency.

For further objects and advantages and for a better understanding of the invention, attention is now directed to the following description and accompanying drawing illustrating a preferred embodiment of the invention. The features believed to be novel will be more particularly pointed out in the appended claims.

In the drawings:

FIG. 1 is a side elevation view, partly sectioned, of a miniature single-ended fluorescent lamp embodying the invention.

FIG. 2 is a schematic diagram of an operating circuit for the lamp.

FIG. 3 presents a curve plotting ignition voltage versus percentage of xenon in the buffer gas mixture.

FIG. 4 presents curves of ignition voltage versus filling pressure for various buffer gases.

FIG. 5 presents curves of radiant output versus operating pressure for various buffer gases.

Referring to FIG. 1, the illustrated lamp 1, corresponds to the type designated commercially 2W-T6 having a nominal rating of two watts at an operating voltage of 11.5 volts. The envelope 2 of the lamp is generally tubular with a rounded end; typically it has a sealing length of 1½ inches and a diameter of ¾ inch. The lamp contains an ionizable medium consisting of a buffer gas of a composition and at a filling pressure which will be particularly described hereinafter, and a small quantity of mercury providing a pressure of mercury vapor determined by the operating temperature of the lamp but generally less than 100 microns. The envelope is coated internally with a phosphor 3 which fluoresces in the long wave ultraviolet region, for instance a cerium activated calcium phosphate or an aluminum silicate. Alternatively if a source of short wave ultraviolet radiation is desired, the phosphor coating is omitted and a vitreous material which transmits the desired ultraviolet is used for the envelope.

The lamp is provided with an anode 4 mounted on an inlead 5, a main cathode 6 supported across inleads 7, 8 and an auxiliary cathode 9 supported across inlead 7 which is common to the main cathode, and another inlead 10. The inleads extend through a conventional stem 11 sealed peripherally at 12 to the bulb and including an exhaust tube 13 which is tipped off at 14 after evacuation and filling of the lamp. The anode 4 is a strip of titanium metal bent to a U-shape, inverted, and surrounding the main cathode 6 with one leg extended downwardly, but other shapes may be used. The main

cathode is a triple-coiled tungsten filament or double-coiled with overwind coated with electron emissive material of low work function such as alkaline earth oxide, for instance a triple mixture of barium, strontium and calcium oxides. Typically, the main cathode operates at a dull red heat and supports a discharge current of approximately 200 milliamperes. The auxiliary cathode 9 may consist of a coil of bare tungsten wire or alternatively it may be a length of straight tungsten wire. Following the teachings of copending application Serial No. 173,407 filed February 15, 1962, of John E. White, entitled Electric Discharge Device, and assigned to the same assignee as the present invention, the auxiliary cathode is unactivated and operates at white heat (circa 2750° K.) to supply a small proportion of high potential energy electrons for reducing the ignition voltage. The anode becomes coated with a layer of barium during operation resulting in a contact potential difference in a direction to reduce the starting voltage.

In a typical lamp, the U-shaped portion of the anode may be bent around a diameter of 3 to 4 millimeters, the main cathode core may have a diameter of 1 millimeter, and the auxiliary cathode may be a straight length of tungsten wire 1.3 mils or less in diameter and about 5 millimeters long, located about 1.5 millimeters below and parallel to the main cathode coil.

A suitable circuit for energizing lamp 1 from a low voltage D.-C. supply is illustrated schematically in FIG. 2. The battery 15, a storage battery of 12 volts nominal rating, has its negative pole connected to inlead 7 which forms the common junction of main cathode 6 and auxiliary cathode 9. By closing switch 16, the positive pole of the battery is connected through a current limiting resistor 17 to the anode 4; at the same time, a circuit is completed to the positive side of the battery through resistor 18 for main cathode 6, and through resistor 19 for auxiliary cathode 9. Resistors 18 and 19 limit the current through the cathodes and, being interposed between the positive side of the source and the cathodes, do not diminish the voltage effective between the anode and the most negative points in the cathode to start and maintain the arc discharge. For testing for relative radiant output and for arc ignition voltage, the lamp may be connected in a circuit similar to that illustrated in FIG. 2 but including provision for varying the supply voltage, and for regulating the discharge current. Generally, for the lamps discussed herein, the pressure of the fill gas under room temperature operating conditions is about 25% greater than the filling pressure at which the lamp was tipped off in manufacture; in other words, filling pressure is normally 80% of operating temperature under average ambient conditions.

FIG. 3 is a plot of the results of ignition or starting voltage tests on the lamp of FIG. 1 previously described and using for the buffer gas an argon-xenon mixture at a filling pressure of 4.5 millimeters of mercury. Throughout the tests, the temperature of the condensed mercury within the envelope was maintained at zero degrees F. by immersing a portion of the envelope in a bath maintained at that temperature. The curve 21 shows the reduction in ignition voltage as the percentage of xenon in the mixture is increased from zero to 100%, other conditions being maintained constant. The curve is of an exponential type which tends asymptotically to the ignition voltage corresponding to 100% xenon. The curve is initially quite steep and 50% of the available voltage reduction (corresponding to an ignition voltage of 9.7) occurs with merely 13% xenon. This is indeed fortunate because it means that a substantial part of the voltage reduction obtainable by means of xenon can be achieved with only a small proportion of this expensive gas. As will be described hereafter, a high proportion of xenon is also undesirable for reasons of efficiency because in the pressure range of interest, namely from .5 to 10 millimeters of pressure, the output of 2537 A.

radiation decreases as the percentage of xenon is increased.

The variation in ignition voltage with filling pressure of the buffer gas for the case of argon is shown in FIG. 4 by curve 22; for 99% argon-1% xenon; by curve 23; and for 95% argon-5% xenon, by curve 24. The data for these curves were obtained with the condensed mercury at a temperature of -109° F. (or -78° C.) obtained by surrounding the bulb with carbon dioxide snow. Substantially identical results are obtainable with the bulb at zero degrees F., since the ionization of xenon far exceeds that of mercury atoms even at the higher temperature. There is a relatively rapid reduction in starting voltage as the small proportion of xenon in the filling gas mixture is increased, as indicated by the fairly wide separation of the curves in FIG. 4. Also the ignition voltage drops with increasing filling pressure in the range from .5 to 10 millimeters of mercury.

As appears from curve 21 of FIG. 3, if ease of starting were the only consideration, one would use 100% xenon and preferably at a fairly high filling pressure. However, such a lamp would not only be costly due to the use of expensive xenon but it would also have a relatively low ultraviolet output. This is indicated by the curves of FIG. 5 showing the relative intensity of 2537 A. output versus operating pressure for various gas compositions: curve 25 for argon; curve 26 for 99% argon-1% xenon; curve 27 for 95% argon-5% xenon; curve 28 for 85% argon-15% xenon; and curve 29 for pure xenon. The data for these measurements were obtained by use of a lamp made with a bulb transmissive of the 2537 A. radiation, the bulb utilizing a glass known in the trade as 9741 glass. The lamp was operated at ambient room temperature and the pressures indicated are those actually measured in operation. The corresponding filling pressures would be about 80% of the indicated operating pressures.

Referring to FIG. 5, it will be observed that with 100% xenon (curve 29), the maximum relative intensity, occurring at a pressure of about 1.5 millimeters, is less than 50%; thus pure xenon is undesirable as the filling gas at any pressure. By using relatively small proportions of xenon with argon, the relative intensity of 2537 A. radiation is maintained at appreciably higher levels. Thus with 1% xenon-99% argon, the relative intensity peaks at 93%; with 5% xenon-95% argon, the relative intensity peaks at 75%; with 15% xenon-85% argon, the relative intensity peaks at 65%. Reductions in intensity within these ranges are acceptable for the intended use. An interesting aspect of the curves of FIG. 5 where the proportion of xenon is less than 15% is their relative flatness over the pressure range of interest. This means that the filling pressure may be selected on the basis of the curves of FIG. 4 to provide the minimum ignition voltage with little effect on the relative intensity of 2537 A. output. Thus to meet the specification given earlier of starting at 11.5 volts at a temperature of zero degrees F., one may use 1% xenon-99% argon at a filling pressure of 5 millimeters or more and the relative 2537 A. output will be approximately 92%. Alternatively, one may use a mixture of 5% xenon-95% argon at a filling pressure of 4 millimeters; this would give a starting voltage of 11 volts, thus allowing a margin of 0.5 volt for variability of the product. The relative 2537 A. output in this case would be 75%. By increasing the filling pressure to 5 millimeters for the 5% xenon-95% argon mixture, the ignition voltage drops to about 10.6 volts, thus providing a 0.9 volt margin for variability of the product, and the relative output hardly decreases at all, being a shade under 74%.

By making use of the data provided by the curves of FIGS. 3 to 5, a choice of buffer gas composition to obtain reliable starting with a battery voltage of 11.5 volts or less at a temperature of zero degrees F. may readily be made. In general, the proportion of xenon relative to

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argon will be from 1 to 15% and the filling pressure will be in the range of .5 to 10 millimeters of mercury, preferably 4 to 7 millimeters of mercury. The specific choice will of course depend upon the relative weight attached to maximizing the 2537 A. output as against the need for a margin of safety below 11.5 volts in ignition voltage in view of product variability. A preferred choice for a lamp intended for automotive instrument panel lighting by means of long wave ultraviolet is a mixture of approximately 5% xenon-95% argon at a filling pressure of approximately 5 millimeters of mercury. This provides a mean starting voltage of 10.4 volts at zero degrees F. and a radiant output which is 75% of that achieved with 100% argon filling.

While a certain specific embodiment of the invention has been illustrated and described, it is intended as illustrative and not as limitative of the invention. The scope of the invention is to be determined by the appended claims.

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

1. A thermionic arc electric discharge lamp of the cathodic glow type having an operating voltage less than the ionizing potential of mercury comprising an envelope having sealed therein a pair of relatively closely spaced electrodes including an anode and a thermionic activated cathode, said envelope containing a buffer gas mixture at a low pressure and a small quantity of mercury, said buffer gas mixture consisting of argon with 1 to 15% xenon at a pressure in the range of .5 to 10 millimeters of mercury.

2. A thermionic arc electric discharge lamp of the cathodic glow type having an operating voltage less than the ionizing potential of mercury comprising an envelope having sealed therein a pair of relatively closely spaced electrodes including an anode and a thermionic activated cathode, said envelope containing a buffer gas mixture at a low pressure and a small quantity of mercury, said buffer gas mixture consisting of argon with 1 to 15% xenon at a pressure in the range of 4 to 7 millimeters of mercury.

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3. A thermionic arc electric discharge lamp of the cathodic glow type having an operating voltage less than the ionizing potential of mercury comprising an envelope having sealed therein a pair of relatively closely spaced electrodes including an anode and a thermionic activated cathode, said envelope containing a buffer gas mixture at a low pressure and a small quantity of mercury, said buffer gas mixture consisting of approximately 95% argon-5% xenon at a pressure of approximately 5 millimeters of mercury.

4. A thermionic arc electric discharge lamp of the cathodic glow type having an operating voltage less than the ionizing potential of mercury and having an ignition voltage less than 11.5 volts at 0° F. comprising an envelope filled with an ionizable medium comprising a buffer gas mixture at a low pressure and a small quantity of mercury and having sealed therein at relatively close spacing an anode, a main thermionic filamentary cathode of tungsten wire activated with alkaline earth oxide to have a relatively low work function, and an auxiliary thermionic filamentary cathode of unactivated finer tungsten wire having a relatively high work function and separate inleads for operation at the most negative potential in said lamp, said buffer gas mixture consisting of argon with 1 to 15% xenon at a pressure in the range of .5 to 10 millimeters of mercury.

5. A lamp as in claim 4 wherein the buffer gas mixture consists of argon with 1 to 15% xenon at a pressure in the range of 4 to 7 millimeters of mercury.

6. A lamp as in claim 4 wherein the buffer gas mixture consists of 95% argon-5% xenon at a pressure of approximately 5 millimeters of mercury.

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