Aug. 2, 1955 G. MEISTER ET AL 2,714,685

LOW PRESSURE FLUORESCENT AND DISCHARGE LAMPS

Filed Aug. 25, 1951

Fig. 1.

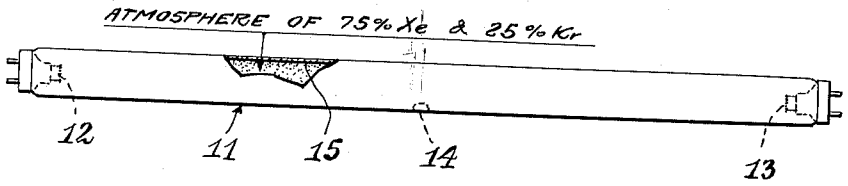


Fig. 3.

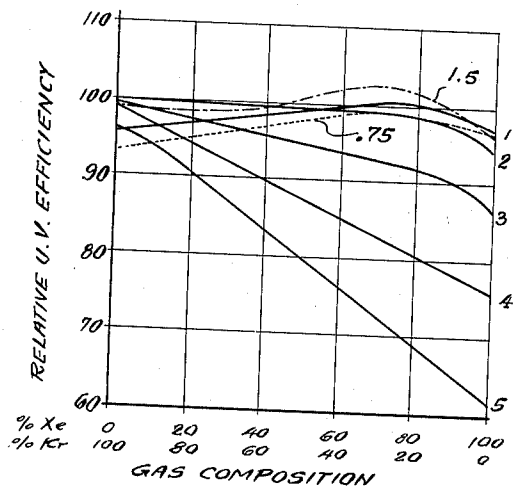
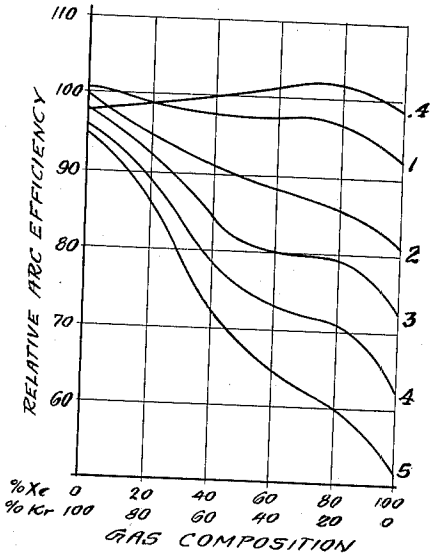


Fig. 2.



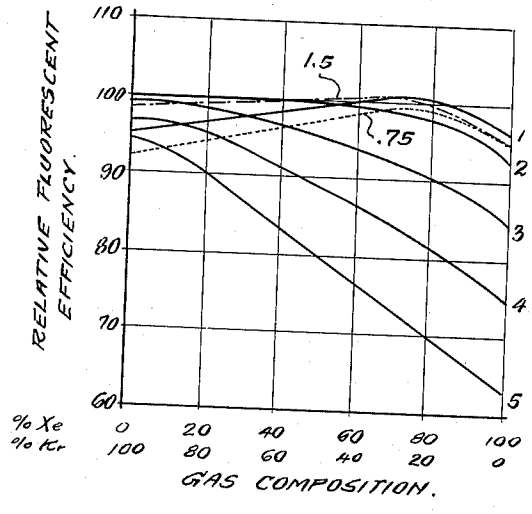


Fig. 4.

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United States Patent Office 2,714,685 Patented Aug. 2, 1955

2,714,685

LOW PRESSURE FLUORESCENT AND DISCHARGE LAMPS

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Application August 25, 1951, Serial No. 243,612

4 Claims. (Cl. 313—185)

This invention relates to low pressure discharge lamps and, more particularly, to such employing only mixtures of rare gases and mercury as the filling material.

The principal object of our invention generally considered, is to produce low pressure fluorescent and discharge lamps having a filling of a mixture of mercury and rare gases of such a composition that fluorescence is efficiently excited in the phosphor.

Another object of our invention is to produce a low pressure fluorescent or discharge lamp comprising a mixture of rare gases in which xenon is mixed with krypton and mercury in the proportion to get good efficiency at practical pressures.

A further object of our invention is to produce a fluorescent or discharge lamp which has characteristics such as above outlined, whereby it is better than a lamp having only one rare gas admixed with mercury vapor because it has a higher ultra-violet and corresponding luminous efficiency.

Other objects and advantages of the invention will become apparent as the description proceeds.

Referring to the drawing:

Figure 1 is an elevational view, with parts in longitudinal section of a lamp embodying our invention.

Figure 2 is a graph showing the variation in arc or visible light output as the composition of the contained gas is changed, each curve having applied thereto a numeral indicating pressure in millimeters of the enclosed gas.

Figure 3 is a graph showing the variations in ultra-violet output as the composition of the contained gas is changed, each curve having applied thereto a numeral indicating pressure in millimeters of the enclosed gas.

Figure 4 is a graph showing the variations in fluorescent light output as the composition of the contained gas is changed, each curve having applied thereto a numeral indicating pressure in millimeters of the enclosed gas.

As is well known, mercury vapor admixed with an inert or rare gas, such as argon at low pressure is commercially employed for the generation of ultra-violet radiations which may excite phosphors to give off visible radiations in fluorescent discharge lamps.

The electrical characteristics of such low pressure mercury discharges are known. It has been shown that, at a given lamp temperature, pressure and current, as the atomic weight of the inert gas increases, the voltage gradient in the mercury discharge and the voltage drop at the electrodes decrease.

The efficiency of such a low pressure mercury discharge fluorescent lamp depends upon the mercury pressure and the wattage in the discharge. It has been shown that at a constant bulb temperature and a given current, the inert gas with the greater atomic weight and lower ionization potential has a higher efficiency than an inert gas of lower atomic weight and higher ionization potential. Thus, of the gases tried, krypton was better than argon or neon.

The early data was mainly taken on the individual inert gases mixed with mercury. We have investigated the use of mixtures of inert gases with mercury for discharge lamps, as a continuation of the subject matter described and claimed in our application Serial No. 102,016, filed June 29, 1949, and owned by the assignee of the present application.

In order to obtain as much information as possible on one experimental lamp, a special tube was designed in which the central portion consisted of a 5 inch section of glass identified by the Corning trademark "Vycor" (as further identified in the Rentschler Patent No. 2,469,410, dated May 10, 1949) and of 1.5 inches inside diameter which was sealed to a 1.5 inch diameter glass tube, identified by the Corning trademark "Pyrex," at each end. The "Pyrex" sections could be coated with phosphors. Independently heated oxide coated cathodes were used and spaced about 24 inches apart, producing a so-called "positive column" lamp. In addition, a water-jacket three inches in diameter was designed to fit around the lamp in which the central portion again was a 5 inch "Vycor" section sealed with white wax to a "Pyrex" section at each end. With this construction it was possible to measure the light output of the phosphors, the ultra-violet output of the arc discharge, and the light output of the arc, at different gas pressures and controlled temperatures with corresponding voltages and power input.

The assembled tube with coated phosphor sections was sealed onto an exhaust system which had a cooling trap, surrounded by Dry Ice throughout the experiment. A liter reservoir for allowing proper diffusion of gas mixtures was provided into which could be introduced the spectroscopically pure inert or noble gases which were employed. The system also was equipped with a McLeod gauge to read pressures.

The lamp was exhausted and baked at 475° C. for about one hour. The cathodes were processed until no more gas was liberated. The water-jacket was put into place so that the "Vycor" sections of the jacket and lamp "Vycor" sections coincided and was firmly fastened to keep it in a fixed position. The annular space between the lamp and jacket could be flushed with water at any desired temperature, which was read on a thermometer placed in the water surrounding the lamp. A voltage stabilizer was used to control the voltage input on the filament transformers, the discharge transformer, and the ultra-violet meter.

The ultra-violet meter containing a tantalum cell to read the 2537 A. U. radiation was set in position opposite the "Vycor" section. The photovoltaic cells were placed in position opposite the "Vycor" section and the phosphor sections. They were checked before and after a set of readings with a standard incandescent lamp, also using a voltage stabilizer in the circuit. All stands were securely fastened so as to keep all positions fixed during a run.

The lamp was seasoned for several days before any readings were taken. This seasoning was done in mercury vapor alone, continuously exhausting during the entire period. During operation of the lamp, water was flushed up and down the tube until the water temperature was 45° C. All the data were subsequently taken at this temperature. The temperature was checked before and after each current reading. As each current setting was made, the ultra-violet output of the arc, the voltage, the visible light output of the arc, and the light output of the phosphor were read in that order. These zero gas pressure data were again obtained as a reference check after each change of inert gas or inert gas mixtures. After all the preliminary data were obtained, then this lamp was operated at different inert gas pressures and mixtures of inert gases. The inert gases investigated were xenon, krypton, and mixtures

of xenon and krypton. These gas mixtures were varied so as to obtain sufficient data to show any difference in characteristics and each one was diffused at least 16 hours to insure uniform mixing.

The following mixtures were used:

Krypton	Xenon
Percent	*Percent*
100	0
75	25
50	50
25	75
0	100

All data illustrated in the accompanying composition curves are for a constant lamp current of 500 milliamperes and for a constant temperature of 45° C. for different pressure parameters ranging from below 1 to 5 mm. Krypton at 2 mm. gas pressure is taken as the 100% reference point.

VOLTAGE CHARACTERISTICS

Curves plotted to compare the voltage with the corresponding composition at constant current and temperature for krypton-xenon mixtures show that the lowest voltage is obtained with 2 mm. gas pressure throughout the entire range of composition from 100% krypton to 100% xenon. These curves, therefore, generally agree with previous data obtained with the krypton-argon and krypton-neon mixtures. However, in the neon-rich krypton-neon mixtures, the lowest voltage was obtained with 1 mm. gas pressure. The reason for this difference is that with these inert gases there is a pronounced voltage minimum at about 2 mm. with krypton and xenon, but for the lower atomic number gases, higher ionization potentials, this voltage minimum vanishes and instead a plateau develops, especially with neon at about 2 mm. gas pressure with a subsequent decrease in voltage below this pressure.

The voltage-composition curves, furthermore, are vastly different from those of the krypton-argon and krypton-neon series. When the xenon concentration is increased, they do not proceed in any regular progressive manner but show a sharp inflection at about 20% xenon especially with 2, 4 and 5 mm. gas pressure. Up to this xenon concentration, the voltage at each pressure is practically constant. While this inflection is not pronounced with 1 and 3 mm. gas pressure, it is most pronounced with 5 mm. gas pressure.

The voltage for pure xenon is practically independent of the gas pressure for 1, 3, 4 and 5 mm. and amounts to approximately 95% of the voltage of pure krypton at 2 mm., while for 2 mm. gas pressure it is approximately 90.5%. Also, the voltages for 1 and 3 mm. gas pressures are approximately the same throughout the krypton-xenon series at each pressure and vary only from about 95% at pure xenon to about 105.5% at pure krypton.

A statement was made that the voltage in these low pressure mercury discharges containing inert gases varies directly with the ionization potential of the gas. This relation is shown by plotting the voltage against the atomic number of the gas which is correlated to the ionization potential. This correlation is further shown when the relative percentage voltage values and ionization potential values are tabulated with krypton as the reference point (Table 1).

Table 1

Gas	Atomic Number	Percent Voltage	Ionization Potential	Percent
Neon	10	166	21.5	155
Argon	18	126	15.7	133
Krypton	36	100	13.9	100
Xenon	54	91	12.1	87

ARC CHARACTERISTICS

The arc efficiency vs. composition curves of the discharge at constant current and constant temperature show that at all pressures from 1 to 5 mm. the addition of as much as 50% xenon to krypton causes an almost linear reduction in the visible efficiency. However, at 1 mm. gas pressure, between 50% xenon and 75% xenon, as shown by Fig. 2, a definite plateau develops to interrupt the smooth drop. This plateau generally becomes less pronounced as the gas pressure increases from 1 to 5 mm.

It is interesting to note that the arc visible output efficiencies for pure xenon show approximately the same large decrease as later observed in the ultraviolet and fluorescent-composition curves, shown respectively in Figures 3 and 4. On the other hand, pure krypton at all pressures from 1 to 5 mm. maintain a high efficiency showing a drop of only 6% over that pressure range. These curves, for pressures down only to 1 mm. compare with the curves previously published on the krypton-argon series which also showed the highest efficiency at 1 mm. pressure. However, at pressures below 1 mm., shown by Figure 2 for a pressure of 0.4 mm., the efficiency of a 25% krypton 75% xenon mixture reaches a maximum which is higher than the corresponding values for other pressures. The following table presents the maximum visible output efficiencies and the pressures at which they occur for representative mixtures with krypton at 2 mm., as shown in Figure 2, taken as the 100% reference point (Table 2).

Table 2

MAXIMUM ARC EFFICIENCY

Composition		Pressure, mm. of Hg	Efficiency, Percent
Kr	Xe		
100	0	1.0	100.6
75	25	0.9	99.4
50	50	0.5	100.1
25	75	0.4	102.1
0	100	0.2	98.8

It is noted that the maximum occurs at 1 mm. gas pressure for pure krypton and then shifts gradually down to 0.2 mm. gas pressure for pure xenon. This is in contrast to the characteristics previously published on krypton-neon mixtures which showed that the gas pressure for maximum efficiency gradually rose from 1 mm. for pure krypton up to approximately 2 mm. for pure neon. In the case of krypton-argon there was no shift in gas pressure for maximum efficiency. In connection with these maximum arc efficiencies, it should be noted that they do not occur at the pressure for minimum voltage which is the case with ultra-violet and fluorescent output efficiencies.

ULTRA-VIOLET CHARACTERISTICS

The ultra-violet (U. V.) efficiency vs. composition curves at constant current and constant temperature for krypton-xenon mixtures (Fig. 3) show that as the percentage of xenon is increased at 1 mm. gas pressure (and also at .75 and 1.5 mm. and intermediate pressures), unlike at higher pressures, there is a gradual rise in the U. V. efficiency until a maximum is reached at 25% krypton-75% xenon. This maximum corresponds for 1 mm. to the maximum observed in the published data for krypton-neon mixtures where the composition was 75% krypton-25% neon. Higher concentration of xenon in krypton reduces the efficiency again until for pure xenon at 1 mm. pressure the efficiency is about the same as that of pure krypton at 1 mm. pressure.

Raising the gas pressure of pure krypton from 1 mm. up to 2 mm. increases the efficiency over 4% up to the highest possible for pure krypton. At this constant pres-

sure of 2 mm., increasing the percentage of xenon has practically no effect on the efficiency up to 80% xenon. For mixtures containing less than about 60% xenon, the highest U. V. efficiency is obtained at 2 mm. gas pressure. This compares with the published data on the krypton-argon and krypton-neon mixtures where the highest ultraviolet efficiency was obtained at 2 mm. gas pressure for pure gases and all mixtures. At xenon concentrations higher than about 60%, the efficiency at 2 mm. gas pressure goes below that obtained for 1 mm. gas pressure. After this cross-over a decline in efficiency occurs for compositions containing more than about 80% xenon.

All the curves for 3, 4 and 5 mm. gas pressure with pure krypton show ultraviolet efficiencies higher than the efficiency at 1 mm. However, as the concentration of xenon is increased, the efficiencies cross the 1 mm. curve and decrease more rapidly for the higher pressures so that with pure xenon there is a 35% decrease in efficiency over the narrow pressure range from 1 to 5 mm. It should be noted that for this same pressure range, the ultraviolet efficiencies for pure krypton change only 4%. The corresponding range of efficiencies in pure neon and pure argon for these pressures is approximately the same as for pure krypton.

FLUORESCENT CHARACTERISTICS

In general the fluorescent output efficiency vs. composition curves at constant current and temperature for krypton-xenon mixtures (Fig. 4) have the same general shape and relative output as the ultraviolet efficiency vs. composition curves at the corresponding gas pressures.

The highest fluorescent output efficiency is obtained at approximately 1 mm. gas pressure for pure xenon and for mixtures down to about 60% xenon-40% krypton. Below this composition the highest fluorescent efficiency occurs at 2 mm. gas pressure, and the efficiency thus progressively decreases as the pressure increases. It is to be noted, also, that the fluorescent efficiency for pure krypton is approximately that for pure xenon at 1 mm. gas pressure.

The fluorescent output efficiency for pure krypton is better than that for pure xenon at all pressures except at 1 mm. gas pressure and lower where xenon is slightly better than pure krypton. As the pressure increases from 1 to 5 mm., the fluorescent output for mixtures far exceeds that of pure xenon so that at 5 mm. the fluorescent efficiency is only 65% that of xenon at 1 mm. The relative decrease in fluorescent output efficiency is approximately the same as with the ultra-violet efficiency. It can be seen that there again is a correlation between ultraviolet efficiency and fluorescent output efficiency in these xenon-krypton mixtures. This observation is in agreement with the data published in the krypton-argon and krypton-neon mixtures where a similar relation was found. These curves also have a maximum at 1 mm. gas pressure (and also at .75 and 1.5 mm. and intermediate pressures) at approximately 75% xenon—25% krypton, and therefore, coincide with the ultraviolet efficiency data. In the data for the krypton-neon mixture, a similar more pronounced peak was observed at about this composition where the mixture was 75% krypton—25% neon.

COLLECTIVE DATA

With the addition of pure xenon to the published data on the other pure gases, krypton, argon, and neon, the characteristics for all the pure inert gases except helium have been obtained.

The relative voltages for the above gases for 2 mm. gas pressure when compared show that the lowest voltage is obtained with xenon and the highest voltage with neon. The other two gases, krypton and argon, have intermediate values but in progressive sequence with

their atomic numbers and ionization potentials (Table 1).

The arc, ultraviolet and fluorescent efficiencies at 2 mm. gas pressure all follow the same general course when plotted against the atomic number of the gases. The maximum efficiency at 2 mm. gas pressure is obtained with krypton while the relative ultraviolet and fluorescent efficiencies for argon and xenon are about the same. The arc efficiency for pure xenon is relatively poorer than for any of the other gases. From these collective data it can be concluded that for the most efficient fluorescent or ultraviolet lamps at 2 mm. gas pressure, krypton or krypton-rich mixtures should be used provided there are no unusual maxima produced by the inert-gas mixtures.

With krypton-argon and krypton-neon gas mixtures, the ultraviolet and fluorescent efficiencies showed good correlation and there was very little spread in the relative efficiencies in the pressure range of 1 to 4 mm. The maxima in the curves for the fluorescent efficiency corresponded to the maxima in the ultraviolent efficiency curves. These efficiency curves, however, did not show any corresponding relation to the arc efficiency curves. With the present krypton-xenon gas mixtures, there not only is a correlation between the ultraviolet and fluorescent efficiency curves, but there also is reasonably good correspondence with the arc efficiency curves at pressures ranging from 1 to 5 mm.

It can also be seen from the curves that these ultraviolet and fluorescent efficiencies for pure xenon are comparable within a few percent with those of pure krypton at low gas pressures of 1 to 2 mm. but with pure xenon they progressively and rapidly decrease as the gas pressure is increased to 5 mm. The arc efficiencies, however, decrease rapidly from 1 to 5 mm. gas pressure for pure xenon and xenon-rich mixtures. Apparently there must be some property directly associated with xenon gas because the general shape of the efficiency curves agrees for all compositions of krypton-xenon gas mixtures.

In comparing some of the properties of the inert gases that may have a direct bearing on this phenomenon, it was noted that the metastable levels of xenon lie below the ionization potential of mercury. With neon and argon the metastable levels are above the ionization potential of mercury while with krypton there is one above and one below. When these gases, therefore, are excited by collision with electrons, they can influence the mercury discharge by collisions of the second kind. However, when the electrons collide with xenon atoms, all the energy is lost to the xenon and there is apparently no subsequent effect on the mercury atoms thus accounting for the results obtained.

SUMMARY

In this investigation of the krypton-xenon gas mixtures in the presence of mercury vapor at low pressure (about 9 microns corresponding to a wall temperature of 45° C.) a very slight maximum occurred in the ultraviolet and fluorescent output efficiency at 1 mm. gas pressure for 25% krypton—75% xenon. This indicates that for best results, the proportion should range between 70–80% xenon and 30–20% krypton, with the pressure about 1 or between ¾ and 1½ mm. for an operating temperature near or at 45° C.; that is, between 40° and 50° C. This maximum efficiency was found at a similar composition in the krypton-neon gas mixture at 2 mm. gas pressure where the higher atomic number gas constituent, krypton, in the mixture was 75%.

The voltage of the lamp was lowest at 2 mm. gas pressure for krypton and xenon and also for the krypton-xenon mixtures. This lowest voltage was also generally observed with the krypton-argon and krypton-neon mixtures. The voltages in the krypton-xenon series have a very narrow spread going from pure krypton to pure xenon.

The arc efficiency for visible light was highest at 1 mm. gas pressure for pure krypton, and at 0.4 mm. gas pressure for pure xenon and krypton-xenon mixtures having more than 30% of xenon. The efficiencies for pure xenon and xenon-rich mixtures showed a very rapid decrease with increasing pressure, 1 to 5 mm., comparable to the ultra-violet and fluorescent efficiency curves. The high efficiency values at 1 mm. gas pressure agree in general with the data obtained with krypton-argon and krypton-neon series.

The highest ultraviolet and fluorescent efficiencies occurred at 2 mm. gas pressure for all krypton-xenon mixtures containing more than 40% krypton. These highest efficiencies are observed where the voltage is lowest. They, therefore agree with those found in the krypton-argon, and krypton-neon series. The ultraviolet and fluorescent efficiencies in pure xenon and xenon-rich mixtures showed a very rapid decrease with increasing pressure, 1 to 5 mm., which was not observed in the krypton-argon or krypton-neon series.

The collective data on the characteristics of insert gases and their mixtures at 2 mm. gas pressure in the presence of low pressure mercury vapor show that the highest arc, ultraviolet and fluorescent efficiencies are obtained with krypton or krypton-rich mixtures and the lowest voltage is obtained with pure xenon.

Fluorescent lamps of the positive column type, one of which is illustrated in Figure 1, exhibit these experimental data. The lamp of said figure comprises an elongated translucent vitrous envelope **11**, with heated filamentary electrodes **12** and **13**, one in each end portion, and containing the selected noble gas mixture and some mercury, indicated by the globule **14**. If a fluorescent lamp, the selected phosphor **15** is applied to the inner surface of the envelope.

Although the experimental lamp described contained a 3500° white phosphor of zinc beryllium silicate and magnesium tungstate, the phosphor for commercial use may be any one which efficiently uses and, therefore, has a high absorption of, ultra-violet radiations in the region of 2537 A. U., that is, the mercury resonance radiation, and consequently a strong ultra-violet response giving a good light output. Another example of phosphors which may be employed are the halo phosphates described in the British Patent No. 578,192.

Although preferred embodiments of our invention have been disclosed, it will be understood that modifications may be made within the spirit and scope of the appended claims.

We claim:

1. A discharge lamp comprising a translucent vitreous envelope, a pair of electrodes in said envelope, and a contained mixture of xenon and krypton at a pressure between ¾ and 1½ mm. of mercury, admixed with mercury vapor, the proportion of the xenon being between 70% and 80%, and that of the krypton being between 30% and 20% of the gas mixture.

2. A discharge lamp comprising an elongated translucent vitreous envelope, an electrode in each end portion of said envelope, and a contained mixture of xenon and krypton at a pressure of about 1 mm. of mercury, admixed with mercury vapor, the proportion of the xenon being about 75% and that of krypton being about 25% so that the generation of ultra-violet radiation is approximately at a maximum when operating at a temperature between 40° and 50° C.

3. A discharge lamp comprising a translucent vitreous envelope, a pair of electrodes in said envelope, and a contained mixture of xenon and krypton at a pressure of between 1 and .4 mm. of mercury, admixed with mercury vapor, the proportion of the xenon being between 70% and 80% and that of krypton being between 30% and 20% so that the generation of visible light is approximately at a maximum.

4. A discharge lamp comprising a translucent vitreous envelope, a pair of electrodes in said envelope, and a contained mixture of xenon and krypton at a pressure of between 1 and .4 mm. of mercury, admixed with mercury vapor, the proportion of the xenon being about 75% and that of the krypton being about 25% so that the generation of visible light is approximately at a maximum.

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