Dec. 16, 1952 | N. C. BEESE | 2,622,221

FLUORESCENT DISCHARGE LAMP

Filed Nov. 23, 1945 | 2 SHEETS—SHEET 1

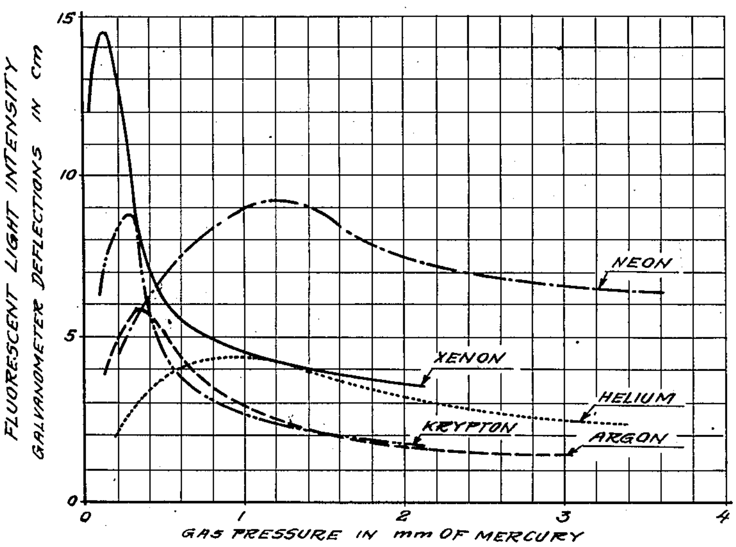


Fig. 1.

Fig. 3.

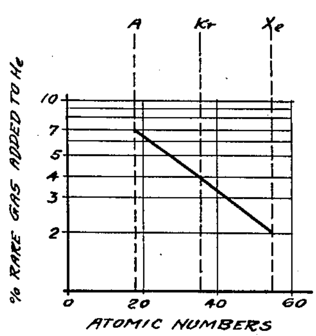


Fig. 2.

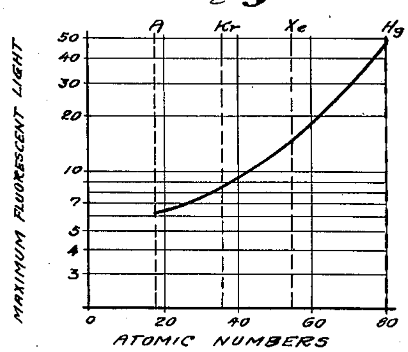
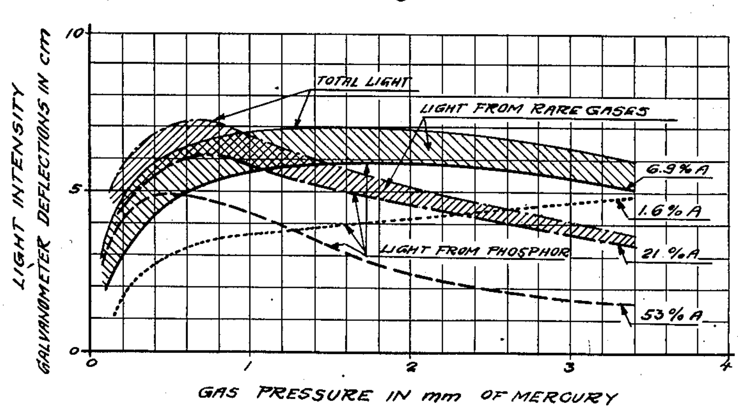


Fig. 4.



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FLUORESCENT DISCHARGE LAMP

Filed Nov. 23, 1945 2 SHEETS—SHEET 2

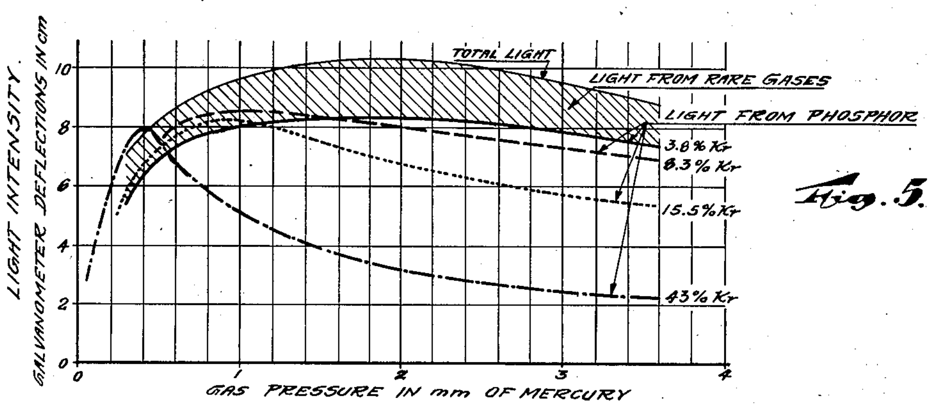

Fig. 5.

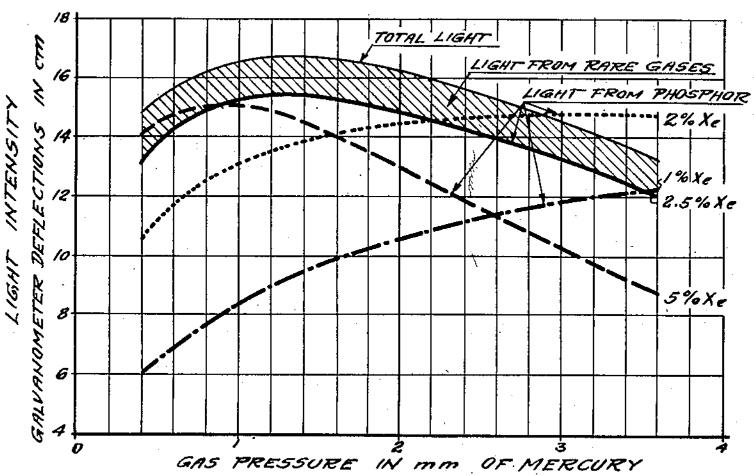

Fig. 6.

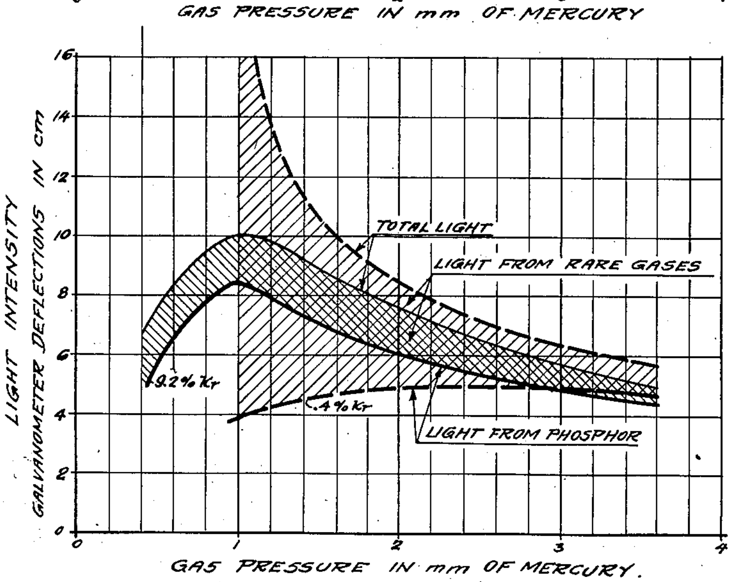

Fig. 7.

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FLUORESCENT DISCHARGE LAMP

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Application November 23, 1945, Serial No. 630,339

3 Claims. (Cl. 313—109)

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

The principal object of my invention, generally considered, is to produce a fluorescent lamp having a filling of a mixture of rare gases of such a composition that fluorescence is efficiently excited in the phosphor.

Another object of my invention is to produce a fluorescent discharge lamp comprising a mixture of rare gases in which either helium or neon is selected as a carrying gas to make it possible to get good efficiency at practical pressures, and either krypton or xenon is selected to determine the intensity of the light generated by increasing the amounts of fluorescent-exciting radiations produced by the mixture.

A further object of my invention is to produce a fluorescent lamp which has such characteristics that as the gas cleans up during life the generated light may increase, compensating for losses, including that of phosphor efficiency, whereby a practically constant output is obtained.

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

Referring to the drawing:

Fig. 1 is a graph showing the variation in fluorescent light output from manganese-activated zinc silicate as a function of the gas pressure in the pure rare gases helium, neon, argon, krypton and xenon.

Fig. 2 is a graph showing the increase in maximum fluorescent light from a manganese-activated zinc silicate phosphor with increasing atomic number or atomic weight of the exciting gas.

Fig. 3 is a graph showing the amount of rare gas in percentage which should be added to helium to produce a flat fluorescent response over a large pressure range.

Fig. 4 is a graph showing the light produced by a fluorescent lamp having a phosphor of manganese-activated zinc silicate excited by various argon-helium gas mixtures.

Fig. 5 is a graph similar to Fig. 4, but showing the light so produced when employing various krypton-helium gas mixtures.

Fig. 6 is a graph similar to Fig. 4, but showing the light so generated when using various xenon-helium gas mixtures.

Fig. 7 is a graph similar to Fig. 4 but showing the light so generated when using various krypton-neon gas mixtures.

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As is well known, mercury vapor is commercially employed for the generation of radiations which excite phosphors to give off visible radiations in fluorescent discharge lamps. This material has many inherent properties that make it well suited for that purpose. Important ones are the efficient production of useful ultra-violet radiations, the high quantum utilization of the energy of such in exciting phosphors, the fact that it has a suitable vapor pressure at room temperature, lasting indefinitely and giving a cool operating lamp of relatively low intrinsic brightness, that its glow does not seriously affect the color of the resultant light, that phosphors are available to produce almost any desired color using such vapor, and its ease to use in the manufacture of practical commercial lamps.

The light from such a device depends upon the efficient production of ultra-violet resonance radiations from the mercury vapor, and its efficient utilization by the phosphor. It is possible to convert approximately half the wattage into useful ultra-violet radiations at 2537 A. U. This energy can be utilized by suitable phosphors with nearly 100% quantum conversion. However, all lamps utilizing mercury vapor are temperature-dependent and require, for best results, an envelope temperature which is between 40° and 50° C. While this is an easy requirement in designing a lamp for normal room-temperature operation, it prevents fluorescent lamps from being used outdoors in cold climates, or any place where the ambient is abnormally low. This is one of the most serious defects inherent in such lamps.

Many investigations have been carried out in an endeavor to use inert gases, such as helium, neon, argon, krypton and xenon, as a substitute for mercury vapor in exciting phosphors within a discharge lamp. It is known that most of the fluorescent light given off by phosphors is that caused by "resonant" radiation, which can be produced more efficiently than any other type of ultra-violet radiation. It has been estimated that no more than 30% of the energy supplied to a neon discharge lamp is converted to the neon resonance radiation at 740 A. U. This value is appreciably below that for mercury vapor, which utilizes about 50% of the wattage supplied to the lamp. Hence, the maximum theoretical efficiency of fluorescent light produced by neon resonance radiation is below that for mercury vapor at suitable temperatures, but neon and other rare gases are not dependent on relatively high temperatures for their efficient operation.

In accordance with my work on the development of a mercury-free fluorescent lamp, I have investigated the response of many phosphors to various inert gases and mixtures in a similar manner in a positive-column discharge lamp, that is, one with a transparent glass envelope and containing fluorescent material as a coating on its interior surface. Most of the work was done with a special lamp in which a glass plate ⅞" wide and 10" long, coated with patches of different fluorescent materials, each about ⅞" sq., was placed. The fluorescent powders were mixed with a nitro-cellulose binder, painted on the glass plate, and when dry the plate was baked in air at over 500° C. to remove the binder. This simulated the phosphor coating in a fluorescent lamp. The discharge tube with the phosphor-coated plate within it was evacuated as a normal lamp and then various gaseous mixtures and gases admitted. The electrodes were heated during all measurements. Most of the time, alternating current of about 100 milliamperes was used.

Light measurements were made with a telescope 2½" in diameter and 10" long, using a hand magnifier to form an image of the fluorescent patches on a Lange photovoltaic cell fitted with an eye-sensitivity filter. A telescope was moved along a horizontal bar parallel to the fluorescent plate so that the various phosphors could be measured. The cell was removable from the telescope so that each spot could be centered with a ground-glass screen. One of the patches was aluminum oxide which did not fluoresce and was used to correct for the visible light of the discharge. The photronic cell was connected to a galvanometer shunted with a resistance box, so that a greater range of intensities could be measured. The final results were calculated on the basis of a 500 ohm galvanometer shunt resistance. After completing the work with the rare gases, mercury vapor was distilled into the tube so as to have a direct comparison with mercury resonance excitation. I have found that manganese-activated zinc silicate gives the best response to resonant radiations from the rare gases and mixtures.

Fig. 1 shows the relationship between the fluorescent light derived from such phosphor, when excited by the five rare gases mentioned, from pressures ranging from a small fraction of a millimeter of mercury to more than three millimeters. The data for the curves there illustrated was taken by maintaining a uniform alternating current of 100 milliamperes through the discharge tube. It will be seen that xenon is the most efficient of the gases and that it, krypton and argon, have their maximum efficiencies at pressures well below ½ millimeter, while neon and helium have their maximum efficiencies at considerably higher pressures. The relationship between the maximum output of the rare gases argon, krypton and xenon, as compared with mercury is further illustrated by Fig. 2, which shows the increase in maximum fluorescent light from such a phosphor with increasing atomic number of the exciting gas or vapor. The wave lengths of the resonant radiations of the rare gases and mercury vapor also increases with atomic weight to 2537 A.U. for mercury.

As in the case of mercury vapor, which has its maximum efficiency at a pressure of a few microns and which efficiency may be maintained by diluting it with rare gas at several millimeters pressure, I have found that by diluting one of the gases such as argon, krypton and xenon, with

one of the gases helium and neon, it is possible to maintain the relatively high output of the gas selected from the first three with a total gas pressure of from one to several millimeters. Such a phenomenon is shown graphically in Fig. 3 which indicates that about 7% of argon, about 4% krypton, or about 2% of xenon, should be added to helium to give a flat fluorescent response over a large pressure range.

The development of this information is illustrated in Fig. 4, which shows that with a mixture of 6.9% argon in helium, the variation in fluorescent light is small over a pressure range from about 1 to 3 millimeters of mercury. This figure also shows the variation in fluorescent light with other selected gas compositions over considerable pressure ranges, as well as showing the increase in light by the addition of that from the rare gases for two mixtures of the gases employed.

Fig. 5 shows the situation when krypton gas is diluted with helium, to maintain the relatively high output of krypton to a total gas pressure of several millimeters. This figure shows that with a mixture of 3.8% krypton in helium, a nearly constant intensity of fluorescent light is derived from a manganese-activated zinc silicate phosphor over a pressure range of 1 to 3 millimeters of mercury. The fluorescent light is almost as great as the maximum value obtained from krypton alone, while the contribution of light from the rare gas is much less than that produced by helium alone. The optimum effect is restricted to certain gas ratios of percentage compositions, as will be seen by comparing the 3.8% krypton curves with the other curves illustrated.

Fig. 6 shows a set of curves for xenon-helium gas mixtures, corresponding with those of Fig. 5 for krypton-helium gas mixtures. This figure, however, shows that the optimum percentage of xenon is between 2 and 2½% rather than about 4%, while the optimum pressure of the mixture is between 1 and 2 mm. of mercury.

Fig. 7 shows the fluorescent light from a manganese-activated zinc silicate phosphor excited by two krypton-neon gas mixtures. With a 9.2% krypton, 90.8% neon mixture, there is an almost constant ratio of fluorescent light to total light over an extended range of pressures, although the total light is not constant. With .4% krypton and 99.6% neon, the fluorescent output is quite constant over a considerable pressure range, but the contribution from neon increases very rapidly with decreasing pressures, so the result in color is greatly affected by gas pressure.

For comparison, mercury was distilled into the lamp after completing the work with the rare gases and mixtures. The efficiency in total fluorescent light was always greater with mercury excitation than with rare gas excitation. To obtain a pink fluorescent light, it might be desirable to use neon gas to excite the phosphor, since its orange-red color could be utilized and the efficiency of such a lamp would be quite comparable with a mercury-activated lamp giving a similar color. I have also found that the light given off by a phosphor when excited by various ultra-violet sources is very dependent upon chemical composition, the degree of purity, the amount of activator, and the physical processes through which it has passed.

Although preferred embodiments of my invention have been disclosed, it will be understood that modifications may be made within the spirit and scope of the appended claims, and that the phosphor or fluorescent matter reported in accordance with the specification was always manganese-activated zinc silicate in order to make for consistent comparisons.

I claim:

1. A fluorescent discharge lamp comprising a transparent envelope phosphor-coated on its interior surface and containing, as a filling, a mixture of only rare gases consisting of helium and xenon, the total pressure of the mixture being between ½ mm. and 3 mm. of mercury, and the percentage, by volume, of the xenon ranging from 2 to 2½%.

2. A fluorescent discharge lamp comprising a transparent envelope coated on its interior surface with a phosphor consisting of manganese-activated zinc silicate and containing, as a filling, a mixture of only rare gases consisting of helium and xenon, the total pressure of the mixture being between ½ mm. and 3 mm. of mercury, and the percentage, by volume, of the xenon ranging from 2 to 2½%.

3. A fluorescent discharge lamp comprising a transparent envelope phosphor-coated on its interior surface and containing, as a filling, a mixture of only rare gases consisting of helium as the carrying gas and xenon as the light-intensity-determining gas, the total pressure of the mixture being between 1 and 2 mm. of mercury, and the percentage, by volume, of the xenon ranging from 2 to 2½%, so that when the lamp operates said xenon generates radiation at its resonance frequency and efficiently activates the phosphor.

NORMAN C. BEESE.

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