Oct. 14, 1941. G. E. INMAN 2,259,040

ELECTRIC DISCHARGE LAMP

Original Filed April 22, 1936

Fig. 1.

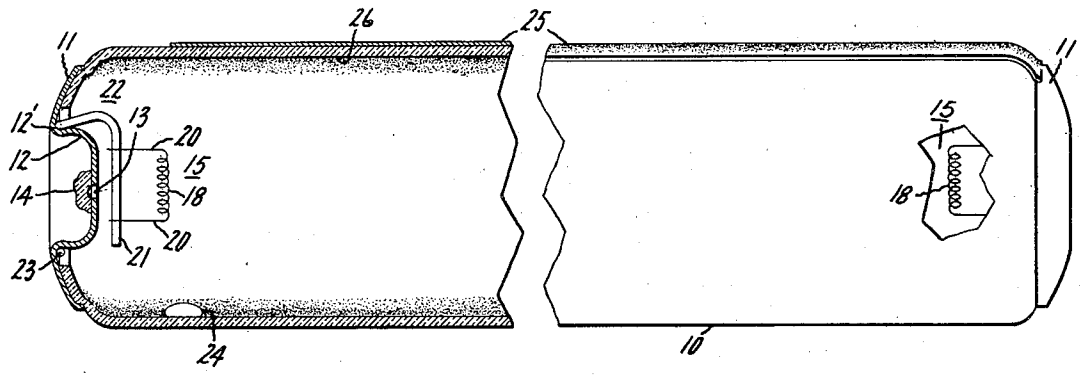


Fig. 3.

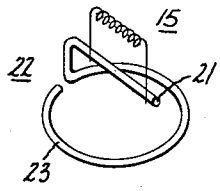


Fig. 2.

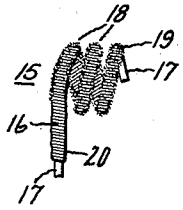
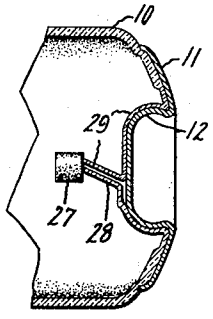


Fig. 4.



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UNITED STATES PATENT OFFICE

2,259,040

ELECTRIC DISCHARGE LAMP

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Original application April 22, 1936, Serial No. 75,772. Divided and this application August 6, 1938, Serial No. 223,493

9 Claims. (Cl. 176—122)

My invention relates to gaseous electric discharge lamps generally and more particularly to such lamps having associated therewith a coating of fluorescent material which transforms ultra-violet rays emitted by the discharge into visible light rays which complement and supplement the spectrum of the visible light emitted by the electrically excited gaseous atmosphere. The present case is a division of my application Serial No. 75,772, filed April 22, 1936, and now U. S. Patent Number 2,146,579, granted February 7, 1939.

One of the objects of my invention is to provide fluorescent lamps of the type described above having high luminous efficiencies with a long useful life. According to my invention, this object is attained by employing a low pressure discharge through a gaseous atmosphere, preferably mercury vapor, which produces ultra-violet radiation with very high efficiency. The fluorescent material is disposed so as to intercept the ultra-violet radiation, preferably by applying a coating of the material to the inner surface of the lamp container or envelope. Further features and advantages of my invention will appear from the following detailed description of species thereof.

In the drawing, Fig. 1 is a side elevation, partly in section, of a lamp illustrating my invention; Fig. 2 is an elevation showing in detail a portion of one of the electrodes; Fig. 3 is a detailed perspective view of the supporting structure for an electrode; and Fig. 4 is a side elevation, in section, of an end of a lamp having a modified electrode structure.

Referring to the drawing, the lamp shown therein comprises an elongated tubular glass container 10 having a metal disc 11 sealed directly to each end thereof and serving as an end wall and contact. The discs 11 are of the type shown and claimed in the United States patent application of Harold D. Blake, Serial No. 3,334, filed January 24, 1935, and may be made of an iron alloy containing about twenty-nine per cent of chromium, such as an alloy marketed by the Allegheny Steel Company as "Allegheny 55." The discs are preferably concave or dish-shaped as shown so that they may be made of thin material and still be adequately strong. Each of the said discs 11 has an annular recess or depression 12 at the center, preferably of an inverted conoidal form, that is, it preferably increases in diameter inwardly from the edge or surface of the disc forming a circular groove 12' therein. The recesses 12 are adapted to be engaged by resilient portions of suitable holders which snap into the depressions in the manner of glove fasteners. One of the discs has an opening 13 at the center of the recess 12 through which the container 10 is exhausted and filled with a suitable gas or gases, the said opening 13 being subsequently sealed by fusion of the residue 14 of a glass exhaust tube.

A pair of thermonic electrodes 15 are located at the ends of the container 10, each of said electrodes consisting of a filament 16 of refractory metal, preferably tungsten, coiled around a mandrel 17, also preferably of tungsten, the coil on mandrel being again coiled as shown at 18. The portion 18 of the electrode is covered with a coating, indicated by the dots at 19, of an electron-emissive material such as barium oxide. The straight end portions 20 of the electrode are attached, preferably by welding, to the transversely extending end portion 21 of a support member or wire 22, the other end 23 of which is in the form of a resilient split ring encircling the boss or shoulder formed at the inside of the disc 11 by the recess 12 and lying in the groove 12'. The electrodes 15 are thereby electrically connected to the discs 11 through the supports 22.

The container 10 has a starting gas therein such as argon at a pressure of about 4 mm. and a quantity of vaporizable metal, preferably .002 to .003 c. c. of mercury. During the operation of the device, the electrically excited mercury vapor emits visible and ultra-violet light. For ease of starting, a strip 25 of conductive material such as a metallic paint or graphite mixed with potassium silicate may be applied to the container 10 in contact with one disc 11 and extending to a position adjacent the electrode 15 at the opposite end of the container. The said strip 25 is of high resistance, preferably about 50,000 ohms or more.

The inner surface of the container 10 has applied thereto a coating 26 of fluorescent material such for example as the oxygenous salts, zinc silicate, cadmium silicate, calcium tungstate, or some specially prepared materials such as a mixture described and claimed in the United States patent application Serial No. 75,783, Willard A. Roberts, of even date, and now U. S. Patent Number 2,196,082, granted April 2, 1940, and consisting of about sixty parts of CdO, forty parts of SiO_2 and a small amount of manganese, or another mixture described and claimed in the United States patent application Serial No. 75,780, Willard A. Roberts, of even date, and consisting of about sixty parts of ZnO, forty

parts of SiO_2 and a small amount of manganese, or still another mixture described and claimed in the United States patent application Serial No. 75,782, Willard A. Roberts, of even date, and consisting of CaO and WO_3 in such proportions that there is from one to ten per cent more calcium oxide than is required by the chemical formula $CaWO_4$ with or without a small amount of lead. The coating **26** of fluorescent material may be applied to the surface of the container **10** by means of a binder, or it may be embedded in the glass itself by heating the glass to its softening point or, if the powdered material is fine enough, it will adhere by merely dusting it into the container. The powder may also be mixed with a binder and sprayed on the container. Among the various binders which may be used are glycerin; glycerin and twenty per cent of boric acid; phosphoric acid alone or diluted with acetone or alcohol; potassium silicate; an ester of glycerin with boric acid; castor oil or mineral oil; or an inorganic resin such as that sold under the name of Stacol by the Glyco Products Company, Inc., of Brooklyn, N. Y.

The fluorescent powder may be applied to the container **10** before the discs **11** are sealed thereto in the following manner:

A cork or stopper is inserted in one end of the container, an excess of binder (such as a mixture of 5 c. c. of eighty-five per cent H_3PO_4 and 40 c. c. of methyl alcohol) is poured in, a cork is inserted in the other end of the container and the container is shaken to distribute the binder over the inner surface thereof. The excess binder is then poured out and the container is set vertically and allowed to stand for about fifteen minutes. Next a dry sponge covered with a double layer of fine mesh cheesecloth is drawn back and forth through the container to remove the excess binder. This operation may be repeated with clean cloths to obtain minimum streaking and yet leave sufficient binder for the proper coating thickness. The container may then be set at an angle of about thirty to sixty degrees with a clean receptacle at the lower end thereof and the fluorescent powder poured in at the top while the container is being rotated. The ends of the container may then be reversed and this operation repeated. The container may then be held vertically and jarred at the ends to remove the excess powder. The container is then heated for about fifteen minutes at a temperature of about 425° to 450° C. to remove the volatilizable portion of the binder and fuse the remainder. The containers are now ready for the sealing of the discs **11** thereto with the electrodes attached.

During the operation of the lamp, the ultraviolet rays striking the fluorescent material are transformed thereby into visible light rays which complement and supplement the spectrum of the visible light emitted by the electrically excited gaseous atmosphere. A 15 watt lamp of the type shown having a container about one inch in diameter and about eighteen inches long requires a starting voltage of about 250 volts. In accordance with my invention, the lamp operates at about 65 volts and one-quarter ampere. The lamp therefore operates at a current density of about .05 ampere per square centimeter of cross section and with an energy consumption of about .04 watt per square centimeter of container surface. It may also be stated that the lamp consumes about 10 watts per foot length of the container. Moreover, under the conditions stated herein the lamp operates at a temperature of approximately 47° C. which corresponds to a mercury vapor pressure of about 10 microns. The lamp may be operated simply by a leakage transformer by connecting the discs **11** to the secondary thereof.

The low pressure mercury arc in the lamp described produces short ultra-violet radiation with very high efficiency, about fifty per cent of the wattage input to the lamp being converted into radiations of 2537 angstroms. These radiations are very efficient in exciting fluorescent light from phosphors such as zinc silicate, cadmium silicate and calcium tungstate. Efficiencies of 74 lumens per watt have been obtained in lamps of the type described using the special zinc-silicon-manganese phosphor described above, 26 lumens per watt with the special cadmium-silicon-manganese phosphor and 22 lumens per watt with the special calcium-tungsten-lead phosphor.

Fig. 4 shows a modified end and electrode structure. The electrode **27** may be of the type described and claimed in United States patent application Serial No. 16,614, Eugene Lemmers et al., filed April 16, 1935, and consisting of a porous body of refractory metal, such as tungsten, impregnated with an electron-emissive material such as barium oxide. The said electrode **27** is mounted on one end of a support wire **28**, the other end of which is secured, preferably by welding, to the disc **11**. The inner surface of the disc **11**, and the support wire **28**, may also be covered by insulating material **29**, such as a glaze.

While I have shown and described and have pointed out in the annexed claims certain novel features of the invention, it will be understood that various omissions, substitutions and changes in the forms and details of the device illustrated and in its use and operation may be made by those skilled in the art without departing from the broad spirit and scope of my invention.

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

1. The method of operating a gaseous electric discharge lamp comprising a sealed elongated tubular container, a gaseous atmosphere therein comprising mercury vapor, electrodes in the ends of said container and a layer of fluorescent material on the inner surface of said container highly responsive to radiations of 2537 angstroms which consists in maintaining a current density of approximately .05 ampere per square centimeter whereby the electrically excited mercury vapor produces an abundance of radiations of 2537 angstroms which are converted by the fluorescent material to visible radiations.

2. The method of operating a gaseous electric discharge lamp comprising a sealed elongated tubular container, a gaseous atmosphere therein comprising mercury vapor, electrodes in the ends of said container and a layer of fluorescent material on the inner surface of said container highly responsive to radiations of 2537 angstroms which consists in maintaining an energy consumption of approximately .04 watt per square centimeter of container surface whereby the electrically excited mercury vapor produces an abundance of radiations of 2537 angstroms which are converted by the fluorescent material to visible radiations.

3. The combination of a gaseous electric discharge lamp comprising a sealed elongated tubular container, a gaseous atmosphere therein

comprising mercury vapor, thermionic electrodes in the ends of said container and a layer of fluorescent material within said container surrounding the discharge path between said electrodes, said fluorescent material comprising an oxygenous salt which is highly responsive to radiations of 2537 angstroms, and means for supplying electrical energy to said lamp in such an amount that the current density is of the order of .05 ampere per square centimeter of tube section so as to maintain through the mercury vapor atmosphere therein a low pressure discharge such that at least about fifty per cent of the wattage input to the lamp is converted by said discharge into radiations of 2537 angstroms which are converted by said fluorescent material to visible radiations.

4. The combination of a gaseous electric discharge lamp comprising a sealed elongated tubular container, a gaseous atmosphere therein comprising a rare gas at a pressure of a few millimeters and a small quantity of mercury, thermionic electrodes in the ends of said container and a layer of finely divided fluorescent material on the inner surface of said container surrounding the discharge path between said electrodes, said fluorescent material comprising an oxygenous salt which is highly responsive to radiations of 2537 angstroms, and means for supplying electrical energy to said lamp in such an amount that the current density is of the order of .05 ampere per square centimeter of tube section so as to maintain through the gaseous atmosphere therein a low pressure discharge such that at least about fifty per cent of the wattage input to the lamp is converted by said discharge into radiations of 2537 angstroms which are converted by said fluorescent material to visible radiations.

5. The combination of a gaseous electric discharge lamp comprising a sealed elongated tubular container, a gaseous atmosphere therein comprising a rare gas at a pressure of a few millimeters and a small quantity of mercury, thermionic electrodes in the ends of said container and a layer of finely divided fluorescent material on the inner surface of said container surrounding the discharge path between said electrodes, said fluorescent material being of the class consisting of the silicates and tungstates which are highly responsive to radiations of 2537 angstroms, and means for supplying electrical energy to said lamp in such an amount that the current density is of the order of .05 ampere per square centimeter of tube section so as to maintain through the gaseous atmosphere therein a low pressure discharge such that at least about fifty per cent of the wattage input to the lamp is converted by said discharge into radiations of 2537 angstroms which are converted by said fluorescent material to visible radiations.

6. The combination of a gaseous electric discharge lamp comprising a sealed elongated tubular container, a gaseous atmosphere therein comprising mercury vapor, thermionic electrodes in the ends of said container and a layer of fluorescent material within said container surrounding the discharge path between said electrodes, said fluorescent material comprising an oxygenous salt which is highly responsive to radiations of 2537 angstroms, and means for supplying electrical energy to said lamp in such an amount that it consumes approximately .04 watt per square centimeter of container surface so as to maintain through the mercury vapor atmosphere therein a low pressure discharge such that at least about fifty per cent of the wattage input to the lamp is converted by said discharge into radiations of 2537 angstroms which are converted by said fluorescent material to visible radiations.

7. The combination of an electric discharge lamp comprising a sealed elongated container, a gaseous atmosphere therein including mercury vapor, widely spaced thermionic electrodes in said container, a layer of fluorescent material surrounding the discharge path between said electrodes, said fluorescent material comprising mainly an oxygenous salt particularly responsive to radiation of 2537 angstroms wave length and means for supplying electrical energy to said lamp, the amount of energy supplied and the construction and arrangement of parts being such that the lamp will consume at least ten watts per foot length of said container and the mercury vapor pressure will remain during operation of the order of several microns.

8. An electric discharge lamp comprising a sealed elongated container, a gaseous atmosphere therein comprising mercury vapor, widely spaced electrodes in said container, and a layer of fluorescent material within said container surrounding the discharge path between said electrodes, said fluorescent material being particularly responsive to radiation of 2537 angstroms wave length, and said mercury vapor having a pressure of the order of ten microns during normal operations so that at least half of the energy supplied to said lamp will be converted into radiation of 2537 angstroms wave length.

9. The combination of a gaseous electric discharge lamp comprising a sealed elongated tubular container having a diameter of the order of an inch, a gaseous atmosphere therein comprising mercury vapor, widely spaced electrodes in said container, and a layer of fluorescent material within said container surrounding the discharge path between said electrodes, said fluorescent material being particularly responsive to radiation of 2537 angstroms wave length, and means for supplying electrical energy to said lamp in such amount that the lamp consumes approximately 10 watts per foot length of the container and at least half of the energy supplied to said lamp is converted into radiation of 2537 angstroms wave length.

GEORGE E. INMAN.