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LOW TEMPERATURE LUMINESCENT LAMP

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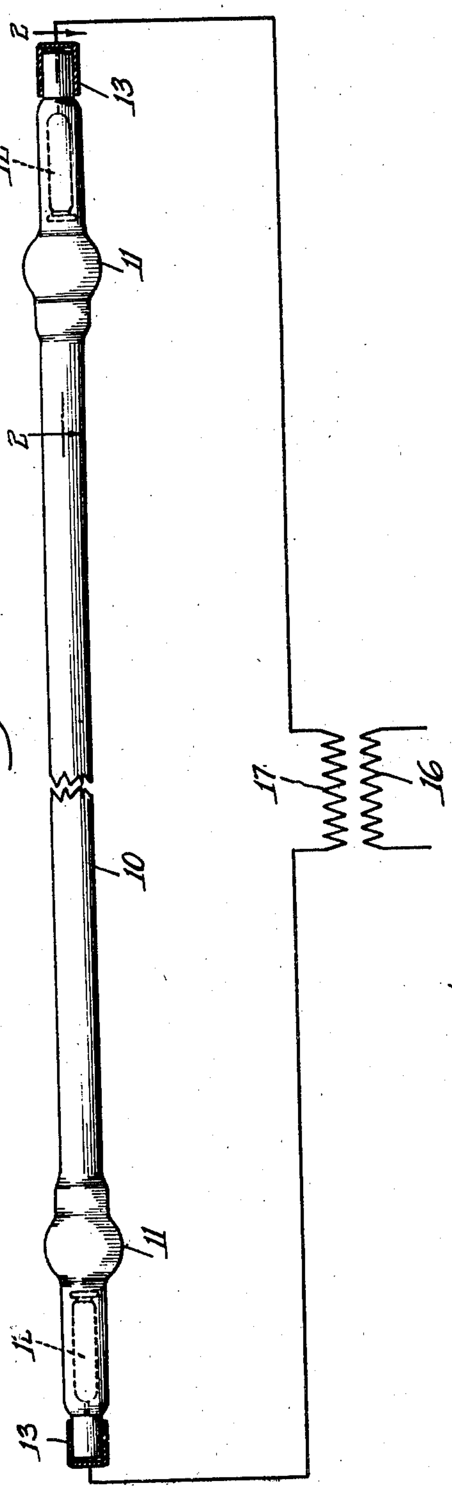

Fig. 1.

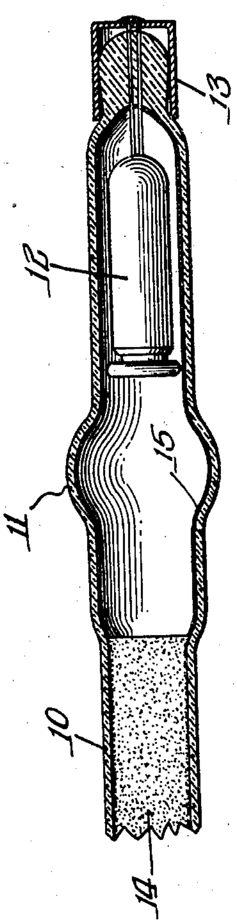

Fig. 2.

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LOW-TEMPERATURE LUMINESCENT LAMP

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1

My invention relates in general to low temperature space discharge devices adapted for illumination purposes, and more particularly to a low temperature luminescent lamp wherein at least the major portion of the light output is derived from activation of luminescent material.

With space discharge devices such as the usual type of luminescent tube, in which a luminescent material is activated through the ionization of a mixture of rare gases and mercury, proper operating characteristics are not obtainable except when the tube is operating substantially at ordinary room temperatures. Means have been suggested for improving the operating characteristics of devices of the character discussed at temperatures below ordinary room temperatures, but, in general, some of the usual characteristics desired in devices of this kind are required to be sacrificed if suggestions heretofore made are adopted.

Illustrative of the problem to which I have directed my attention is the use of a luminescent lamp at temperatures substantially below ordinary room temperatures. If a luminescent lamp of either the cold cathode type or hot cathode type, containing a rare gas at usual commercial pressures and enough mercury to produce a saturated mercury vapor under normal operating conditions, is operated in a refrigerator where a temperature of about 32 to 40 degrees F. is maintained, substantially only the center portion of the tube will be luminous and the very ends may be completely dark. The efficiency of such a tube expressed in lumens per watt, as well as the actual light output, may be decreased even 50 per cent or more, depending upon the conditions encountered. Decrease of light output in a luminescent lamp at lower temperatures is objectionable under any circumstances because it greatly limits the advantages of such a lamp over ordinary incandescent lamps now commonly used for exterior lighting. For this reason luminescent lamps have been used almost exclusively for interior lighting under circumstances that substantially normal room temperatures prevail. In refrigerator lighting a change in operating characteristics and light output is particularly objectionable, because so frequently light characteristics in a refrigerator are of great importance. A great deal of grading of meat and other produce is done in refrigerators. In the case of meat there are some fourteen factors which must be considered, many having to do with color, and all requiring proper

2

and uniform light conditions. If a conventional luminescent tube is modified for the purpose of meeting the problems of refrigerator lighting, not only will the intensity of the light be non-uniform with changes in temperature, but invariably the lower wavelengths tend to prevail and color differentiation is extremely difficult. One disadvantage, for example, is that it is difficult to distinguish between reds and browns. The described behavior of conventional tubes results from the changing of several factors influenced by change in temperature, all of which I have been able to control by relatively simple expedients, which, however, have not heretofore been employed. The tube of my invention is particularly adapted for refrigerator lighting, but may be used to great advantage in other locations.

One embodiment of my invention is illustrated in the accompanying drawings wherein—

Fig. 1 is an elevational view showing a tube constructed in accordance with my invention, and showing a simple form of power supply circuit; and

Fig. 2 is an enlarged longitudinal sectional view taken through one end of the tube along the line 2—2 of Fig. 1.

In overcoming the problems discussed and securing the objects and advantages sought by my invention, I have adopted several expedients which may be combined in a single tube, but which may preliminarily be discussed before the description of the preferred form of tube disclosed in the drawings. I have determined that as a tube is cooled below normal room temperature there is a greater condensation of mercury than at normal room temperature, and the mercury tends to condense near the center portion of the tube, with the result that mercury vapor is gradually substantially entirely lost from the ends of the tubes. Thermal and electrical factors both seem to influence this tendency, but, in any case, the result is that the only mercury available for ionization ultimately is found in substantially the center portion of the tube. This is probably due also to the marked tendency of the tube gases to striate, and the formation of striations is probably accentuated under certain temperature conditions such as those prevailing at lower temperatures. I have found that if I provide means for selectively condensing mercury near the ends of the tubes it is possible even at relatively quite low temperatures to maintain a fully luminous column between the two points of condensation such that substantially uniform brilliance is obtained throughout such column.

The mercury condensing means preferably comprises condensation chambers as close to the electrodes as possible, but not close enough to cause the temperature of the electrodes to appreciably affect the condensation of the mercury in the said condensation chambers. The condensation chambers in their simplest form comprise merely bulbar enlargements of the tube. In a bulbar condensation chamber I have found that there is always a visible deposit of unvaporized metallic mercury. I deem this condensation to be caused in part by the fact that the condensation chamber is the coolest part of the tube, having greater radiating surface than other portions of the tube, and also because the cross-section of the tube at this point is greater and the electrical resistance is reduced.

Preferably, I also employ a mixture of neon and argon, with the former greatly predominating, and enough mercury to produce a saturated mercury vapor under operating conditions. Other rare gases may be present in greater or lesser amount, providing the desired characteristics are not destroyed. I have found that while krypton has a low ionization potential its resonance potential is relatively low. Argon is preferably used as a readily ionizable medium desirable in striking an arc in starting, so that the impressed voltage at starting is not required to be too high above operating voltage. Preferably the neon is in excess of the argon because it has a somewhat higher electrical resistance and raises the temperature of the tube sufficiently to assist in maintaining the mercury in vaporized condition. In the tube of my invention, I prefer to employ about eight parts of neon to one part of argon. The total pressure of the rare gas within the tube is preferably between about 4 mm. and 12 mm., with a total pressure of about 8 to 9 mm. preferred. The total amount of neon present is at least double the argon and may be as much as twenty times the argon. I prefer, however, to include some argon in the tube rather than produce the tube entirely with neon and mercury.

Looking now to the drawing, the lamp of my invention may comprise a tubular portion 10, bulbar condensation chambers 11, electrodes 12 and electrode caps 13. The electrodes and electrode caps are electrically connected by lead in wires sealed through the glass at the end of the tube in a usual manner. In a desirable illustrative form of the invention the tube 10 is 18 mm. in diameter, 7′ 5″ in length, and 6′ 7″ in length between the two condensation chambers 11. The diameter of the condensation chambers is 1½″ and the electrodes are of a type providing electronic emission resulting from positive ion bombardment of the cathodes, as contrasted with the thermionic type. The form of electrode shown in the drawing is one wherein a tube of nickel, or Swedish iron coated with nickel has at least its interior surface coated with an alkaline earth oxide to provide for increased electronic emission. It may, for example, in a common form be about 1¼″ to 1½″ in length and have an inside diameter of approximately ⅜″.

The inside of the tube 10 is provided with a coating 14 of luminescent material, the specific character of the coating depending upon the use to which the lamp is to be put.

The material particularly adapted for coating the inside of tubes intended to be used in refrigerators, where meat or produce is graded, comprises a mixture of a relatively larger proportion of a type of zinc beryllium orthosilicate having a definite pink color on activation, and lesser proportions of magnesium tungstate and calcium tungstate. A zinc beryllium orthosilicate suitable for the purpose may be prepared, by mixing together

3 pounds—2 ounces zinc oxide (ZnO),
3 pounds of silicic acid (H_2SiO_3),
437 grams of iron free beryllium oxide (BeO),
280 grams of manganese chloride ($MnCl_2.4H_2O$),
10 grams of zinc permanganate

$$Zn(MnO_4)_2.6H_2O$$

and grinding the same for 3 or 4 hours. The resulting ground powder material is then placed in crucibles and fired for 4 to 6 hours at a temperature between 1200 degrees C. and 1250 degrees C. The fired material is powdered, sifted, and ground into a coating solution, suitably, a lacquer solution, in which the powdered material can be placed in suspension. When using a lacquer solution, one pound of the special zinc beryllium ortho-silicate is dispersed in 250 cc. of the lacquer solution. One pound of magnesium tungstate is dispersed in 250 cc. of a lacquer solution and one pound of calcium tungstate dispersed in 500 cc. of a similar lacquer solution. In the actual coating operation, 1000 cc. of the zinc beryllium orthosilicate suspension, 250 cc. of the magnesium tungstate suspension and 85 cc. of the calcium tungstate suspension are mixed together and the mixture cut to satisfactory coating consistency. Coating may be carried out in any conventional manner. The coating so produced does not form the most efficient light source for general illumination purposes, but is very suitable for interior illumination of refrigerators, where meat and other types of foodstuffs, required to be inspected, are stored. Reds, greens, and yellows are particularly discernible in the light produced by such a coating when the tube is suitably actuated in the manner contemplated by my invention.

Tubes for general illumination purposes, intended to be used at lower temperatures, may be prepared with a coating approaching conventional daylight or the known 3500° K. light. By the use of such coatings, tubes of higher efficiency and greater total light output may be obtained. For exterior lighting, a coating rich in the yellow and green portion of the spectrum may be used, due to the fact that somewhat greater brilliancy is obtainable and color discrimination is not of the utmost importance. An example of a luminescent material which may be used for exterior illumination is given below. A mixture is prepared of

Zinc oxide (7 pounds—2 ounces),
Silicic acid (3 pounds—13 ounces),
Manganese chloride (1 pound),
Beryllium oxide (66.3 grams),
Zinc permanganate (10 grams).

These materials are ground together, fired, suspended and coated onto the inside of a tube produced in accordance with my invention in manners known in the art.

The bulbar condensation chamber and portion of the tube containing the electrode 12 is preferably provided with a coating 15, such as a layer of black cobalt glass, for the purpose of masking the portions of the tube which are uncoated with luminescent material, and thereby to prevent undesirable radiation of lower wavelengths at the ends of the tubes. The ends of the tubes, including the condensation chambers, may also be coated with luminescent material, but no particular advantage is obtained thereby, since, with the design which I employ, only substantially that portion of the tube 10 between the condensation chambers is intended to comprise light radiating surface. Instead of an interior coating, the entire end portion of the glass may be of black or darkly colored glass, or the exterior may be coated such as with paint, lacquer, asphalt paint, or the like.

The tube of my invention may be introduced into any suitable power circuit, including, for example, the secondary of a transformer having a primary winding 16 leading to a commercial source of alternating current, and a secondary winding 17 connected in series with the tube. This simple arrangement is entirely illustrative, since many different types of power supply devices known in the art and capable of furnishing suitable power may be used.

A tube constructed in accordance with the preferred embodiment hereinabove described, and operated at 100 to 120 milliamperes, is uniformly luminous over its entire surface between the condensation chambers 11 when operated either at ordinary room temperature or at temperatures approaching the freezing point. The spectral distribution is not appreciably affected by change in temperature. I found that a tube constructed in accordance with the details described and filled with 8 mm. of neon, 1 mm. of argon, and enough mercury to produce a saturated vapor, shows the following electrical characteristics at 32 to 34 degrees F.

1. Primary voltage ------------volts----	113½
2. Primary current --------------------	1.62
3. Primary watts ----------------------	167
4. Power factor (primary) --------------	90
5. Voltage across tube (1640 v. across two tubes in series) ------------volts----	820
6. Tube amperage ---------milliamperes--	106
7. Tube wattage ----------------------	66
8. Power factor (tube) -----------------	74

The above values were obtained at the low temperature using two 7′ 5″ tubes operated from a single transformer. At room temperature (70° F.) these values were only slightly better.

The light characteristics of the tube when the first described coating was employed were as follows:

Lumens per foot ----------------------	265
Total lumens -------------------------	1700
Lumens per watt ----------------------	25.8

Using a coating of the 3500° K. type, the light characteristics were as follows:

Lumens per foot ----------------------	335
Total lumens -------------------------	2150
Lumens per watt ----------------------	32.6

At room temperature, these values were only slightly better, the total number of lumens per tube, particularly, being only slightly different. Those skilled in the art will understand that there is always some additional loss of energy when the tube is in a low temperature medium, as contrasted with a high temperature medium, and that, therefore, there is some necessary loss of efficiency as the temperature is lowered. With the tube of my invention, any loss of efficiency expressed in lumens per watt is due principally to increased current consumption, and not to loss of total light output at the lower temperature. My invention, therefore, admits somewhat decreased efficiency expressed in lumens per watt, but provides for substantially constant light output, both qualitatively and quantitatively, within a relatively great range of temperature variations.

At the lower temperatures the tube of my invention always causes some slight amount of mercury to condense in the condensation chambers 11, this usually manifesting itself as a mercury ring extending entirely around the chamber. The condensation, however, is not sufficient to deleteriously affect the operation of the tube, and being confined to the condensation chambers 11 does not affect the desirable characteristics of the luminous portion of the tube, but rather promotes the desirable results which I have described.

Those skilled in the art will understand that my invention is not limited to the details of the preferred embodiment. The features of the invention may be used with many types of electrodes, including both the so-called cold type and variations thereof, which have been proposed from time to time, but which have not gone into general commercial use. In the design of a tube of the character described, the diameter may be decreased, with usually some increase in the over-all length of the tube and the tube then operated at higher voltage and lower current. Contrariwise, a greater diameter tube may be designed of shorter length but with increased current and lower voltage drop between the electrodes. There are practical limits of design in either or all directions, and it is only these practical limits of design which determine the limits of design of a tube embodying the features of my invention. In the preferred form of invention I take an ordinary tube and insert a bulb between the tube ends and the electrode assembly to produce a structure generally similar to that shown in the drawings. It is to be understood that other shapes and dimensions of condensation chambers, and still other methods of fabrication may be employed. Preferably also, I employ luminescent material of relatively great brilliance and including appreciable proportions of "white" light, but the features of my invention may be utilized with various types of luminescent material. My invention is concerned rather with the control of ionization of the tube gases than to the particular manner in which such ionization is utilized to produce a desirable light emission.

The scope of my invention is defined by the claims.

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

1. A low temperature luminescent cold cathode positive column discharge lamp comprising a glass envelope and electrodes at ends thereof, said envelope containing an ionizable gas at a pressure between about 4 mm. and 12 mm. and enough mercury to produce a saturated vapor thereof at the maximum operating temperature of the tube, said envelope having a center tubular portion with an inner surface coated with a luminescent material, enlarged portions forming mercury condensation chambers at ends of said center portion, and extensions from said condensation chambers, said extensions housing said electrodes and being of restricted cross section as contrasted with said condensation chambers and of such length that one end of each electrode is immediately adjacent the said enlarged portion and said condensation chambers being axially aligned with the electrodes immediately adjacent thereto, and also being of sufficiently larger cross

section, as contrasted with remaining portions of the tube, that the said condensation chambers comprise the lowest temperature portions of the tube, when the tube is operated in an atmosphere between approximately 32° F. and 40° F.

2. A low temperature luminescent cold cathode positive column discharge lamp, comprising a glass envelope and electrodes at ends thereof, said envelope containing an ionizable gas at a pressure between about 4 mm. and 12 mm. and enough mercury to produce a substantially saturated vapor thereof at the maximum operating temperature of the tube, said envelope having a center tubular portion with an inner surface coated with a luminescent material, enlarged portions forming mercury condensation chambers at ends of said center portion, and extensions from said condensation chambers, said extensions housing said electrodes and being of restricted cross section as contrasted with said condensation chambers and of such length that one end of each electrode is immediately adjacent the said enlarged portion and said condensation chambers being axially aligned with the electrodes immediately adjacent thereto, and also being of sufficiently larger cross section, as contrasted with remaining portions of the tube, that the said condensation chambers comprise the lowest temperature portions of the tube, when the tube is operated in an atmosphere between approximately 32° F. and 40° F., said ionizable gas comprising a mixture of neon and argon with the former greatly exceeding the latter.

3. A low temperature luminescent cold cathode, positive column discharge lamp, comprising a glass envelope and electrodes at ends thereof, said envelope containing an ionizable gas and enough mercury to produce a substantially saturated vapor thereof at the maximum operating temperature of the tube, said envelope having a center tubular portion with an inner surface

coated with a luminescent material, enlarged portions forming mercury condensation chambers at ends of said center portion, and extensions from said condensation chambers, said extensions housing said electrodes and being of restricted cross section as contrasted with said condensation chambers and of such length that one end of each electrode is immediately adjacent the said enlarged portion and said condensation chambers being axially aligned with the electrodes immediately adjacent thereto, and also being of sufficiently larger cross section as contrasted with remaining portions of the tube, that the said condensation chambers comprise the lowest temperature portions of the tube, when the tube is operated in an atmosphere between approximately 32° F. and 40° F., said ionizable gas comprising approximately 1 mm. of argon, and approximately 8 mm. of neon.

RUDOLPH C. HULTGREN.

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