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ILLUMINATION

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Fig. 1.

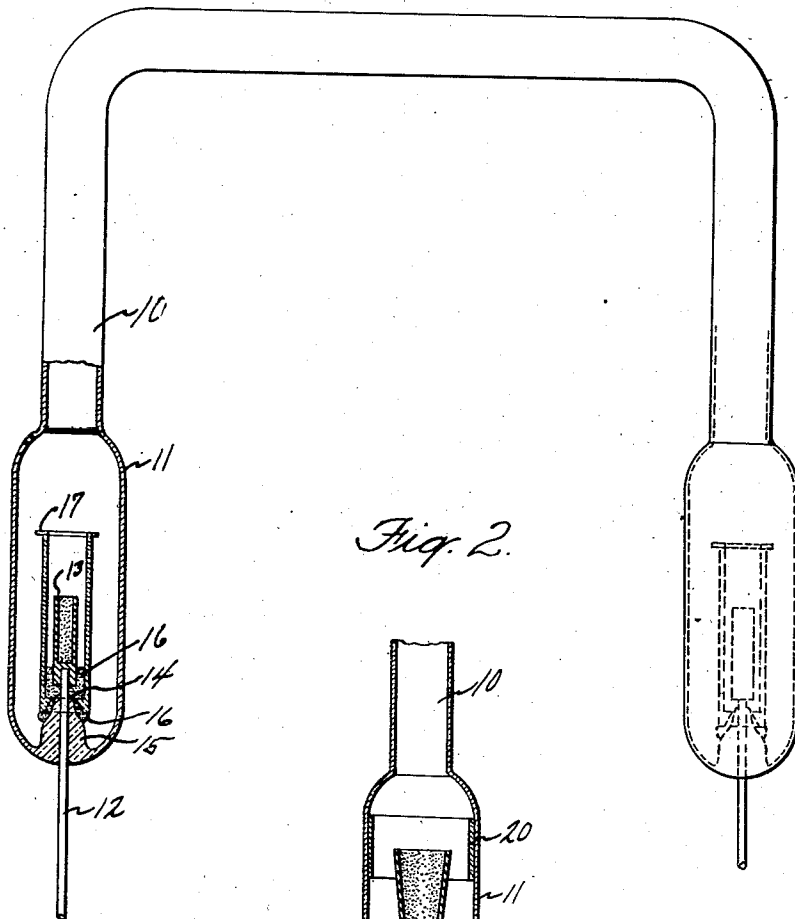
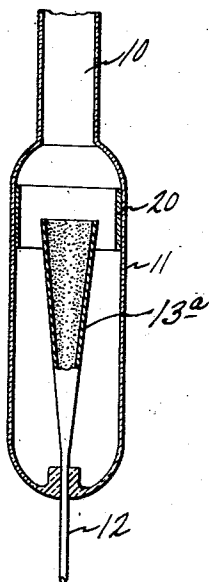


Fig. 2.



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ILLUMINATION

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Application May 20, 1932, Serial No. 612,408

22 Claims. (Cl. 176-122)

This invention relates to illumination and more particularly to the production of a substantially white light by means of an electric discharge through rarified gases, giving a banded spectrum.

5 In the past the so-called neon lights and similar methods of illumination by the passage of electricity through rarified gases in tubes have achieved widespread success by reason of their high illumination with low glare and by the fact that such illumination is economical in operation. However, such lamps when used with the rare monatomic gases have been open to very serious disadvantages because the light is colored and cannot be used where a white or substantially white light is desired. The production of white lights permitting illuminating effects comparable with those of sunlight or skylight has required the use of incandescent lamps with filters and a resultant low efficiency of illumination. 10 It has been proposed in the past to mix various gases having bright lines in different parts of the spectrum in such proportion that the light to the eye appears white. However, the illumination, that is to say, the light reflected by the parts illuminated with such devices, is in no way comparable to illumination by a true white light because practically all of the radiation from the light source is in a few narrow lines in the spectrum, leaving large gaps from which no illumination is obtained. 15

Various diatomic gases, such as nitrogen, carbon monoxide and the like, have been proposed because di- and poly-atomic gases exhibit the phenomenon of the so-called banded spectrum, that is to say, the light is not emitted from a few narrow lines but from rather broad bands. The stable diatomic gases produce, it is true, the banded spectrum, but the balance of the spectrum, that is to say, the proportions of the illumination from various zones, is not that required for white light. In the case of certain polyatomic gases, such as certain hydrocarbons, it is possible to obtain a fairly satisfactory white or substantially white light which exhibits a banded spectrum, but these gases are not stable and no practically useful lamp can be made which contains them unless they are constantly renewed as, for example, in the so-called Moore lamp where ingenious methods were evolved for a constant supply of fresh polyatomic gases to make up for the losses due to decomposition in the operation of the lamp. Such devices, however, are extremely complicated and expensive to operate and, except in very few instances, cannot compete from the standpoint of cost and 20

efficiency even with incandescent lamps provided with filters.

The present invention is based on the remarkable discovery that under certain conditions monatomic gases, such as the rare inert gases of the atmosphere, helium, argon, neon, krypton and xenon, and in some cases other monatomic gases, such as mercury, are transformed into a condition where, instead of emitting their typical line spectrum, they emit a spectrum which is banded and which in the case of the rare gases and their mixtures gives a light which has approximately the spectral balance of north skylight. The physical state of the gas atoms or nuclei has not yet been determined, but since the gases behave or seem to behave as if they had suddenly been transformed into diatomic gases it is believed that some form of association or change in the electron orbits takes place which permits a change in the rotational state of the atoms or molecules corresponding to that in diatomic gases and therefore results in the emission of light of wave lengths evenly distributed through the spectrum in the form of broad bands. Since the exact nature of the change in the gas is not known, the gases when so altered will be referred to in the specification and claims as "associated gases". It should be understood, however, that the invention is in no sense limited to the above theory and that the term "associated gases" does not limit the invention to gases where there has been an actual chemical union. 25

The phenomenon of association on which the present invention is based is a reversible one and appears to be a property of the gas or gas mixture itself, since by suitable changes in the operating condition of the lamps a non-associated monatomic gas or mixtures can be transformed into an associated gas and back again to the monatomic state. 30

When the gas or gas mixture has become associated it retains this property until subjected to electrical and/or heat conditions resulting in reversal to the original or dissociated state or to such other conditions which are sufficiently powerful to result in a dissociation of the gas. While associated the gas may be pumped from one lamp to another without any loss of its characteristic property. 35

The association of monatomic gases is brought about by operating them for various periods, depending on the length of the tube or lamp and on the current, at pressures lower than those normally used in a lamp of the type and with current densities higher than those normally 40

used and preferably including the employment of electrodes which are active electron emitters. The association, when observed by means of a spectroscope, begins by a gradual widening of the typical line spectrum of the monatomic gas into bands followed by the appearance of new lines in other parts of the spectrum which gradually merge into the bands, giving an excellent spectral balance. The association is more rapid the greater the current density and the greater the electron emission and takes longer with long, large tubes than with short, small tubes. The period of association will vary from a few minutes to many hours, depending on the choice of the electrical conditions.

In the accompanying drawing we have shown examples of tube and electrode construction in which our invention may be embodied:

Fig. 1 shows a tube in vertical elevation with one end and the contained electrode in vertical section.

Fig. 2 is a vertical section of another form of tube which may be used with the invention, showing only one end, e. g., the same portion as is shown in section in Fig. 1.

Referring to the drawing, the tube is indicated generally by the reference character 10. To each end of this tube is welded a bulb 11, which contains the electrode, and into which the conductor 12 is sealed.

In the manufacture of this tube, the nickel electrode 13 is preferably first formed by drilling a cylinder from both ends, and leaving an integral web uncut within the cylinder. Into one end of this, the electrode 12 is secured, e. g., by crimping or pressing the nickel to the electrode. A bead of glass 14 is preferably formed upon the wire 12, and the electrode 13 and the wire 12 are then inserted through a hole in the end of the bulb 12 until the bead 14 is well within the bulb. A further body of glass 15 is then pulled up around the wire 12, and serves to weld the bead 14 to the bulb 11. A body of cement 16 is then placed over the bead 14, and a refractory sleeve 17 is inserted into the bulb 11 from the opposite end, and is pressed into the cement, so that it is held, as shown in the drawing, in the desired relation to the electrode 13. The cement should sufficiently cover the wire 12 and the bottom of the electrode so as substantially to prevent discharge directly from the wire 12, and require all such discharge to occur at the surface of the electrode 13.

In Fig. 2 is shown a modified form of the invention, in which the electrode 13A is secured directly to the wire 12, and this may be sealed into the bulb 11 exactly as has just been described. In this case, however, a sleeve 20 of mica, or other refractory material, surrounds the end of the electrode so as to protect the bulb 11 against sputtering.

Apparently the phenomenon of association and its maintenance are influenced by the presence of certain elements. Thus certain substances, of which sodium is an example, appear to favor dissociation, presumably as dissociation catalysts and/or perhaps as poisons for catalysts which may normally maintain the desired association. Like sodium, the other alkali metals in compounds in which they are sufficiently loosely bound may also favor dissociation. Thus, for example, it is not possible to obtain an association with a resultant white light in a tube or ordinary glass which contains alkalis in a sufficiently active or loosely bound form to act as dissociation catalysts (or poison), and if a gas already associated is

introduced into such a tube it will rapidly reverse itself to the dissociated form. It is, therefore, necessary to use tubes of materials which are free from loosely bound alkalis. Thus, for example, the various grades of borosilicate glasses can be used effectively as can quartz or other transparent materials free from dissociating catalysts. A preferred refractory borosilicate glass obtainable on the market under the trade-mark "Pyrex", contains from 4 to 5 per cent. of alkalis and about 12 per cent. of boron oxides. This contrasts with from 10 to 18 per cent. of alkalis in ordinary lead or lime glasses. Some borosilicate glasses also contain a large amount of alkali metal oxides and are in that respect unsuitable. The phenomenon appears to depend also to some extent on the activity or looseness of chemical combination of the alkali in the particular glass for, of course, only the alkali which is sufficiently loosely bound to be in an active condition influences the behavior of the gas. The phenomenon is, of course, one of contact and it is therefore only necessary to be assured that the wall of the tube or lamp actually contacting with the rare gas is free from a sufficient concentration of dissociating catalysts to prevent association of the gas. Therefore, an ordinary glass tube, if coated on the inside with a layer of a glass or other material free from dissociating catalysts, will operate satisfactorily. The amount of dissociation catalyst which may be present in the glass depends also to some extent on the internal diameter of the glass tubes. Of course, the larger the internal diameter, the smaller the surface of contact per unit volume of gas. The effect of dissociating catalysts can be partially compensated for by an increase in current density. Thus, as will be pointed out below, large tubes of glass containing a small amount of dissociation catalyst may be operated safely at current densities slightly less than those required for smaller tubes. Of course, when a quartz tube is used the banded spectrum which extends well into the ultra-violet will be transmitted in these regions to a much greater extent than when refractory borosilicate glass or other suitable glasses are employed. The spectral balance in the ultra-violet remains excellent and still shows a banded structure, so that certain uses where the ultra-violet radiation of normal sunlight is desired can be served by the modification of the present invention, using quartz tubes or tubes of other materials which are capable of passing the desired amount of ultra-violet radiation.

While the present invention is applicable to tubes of any reasonable length, the higher current density required taken together with the low pressure of gas needed requires very high voltages in long tubes even with electrodes which are very efficient electron emitters. The present invention is, therefore, more particularly advantageous for short and medium length tubes, for example, up to about 10 feet, than for tubes of excessive length.

While the phenomenon of association and the corresponding phenomenon of reversal which takes place when a tube with associated gases is operated at current densities below the minimum for maintenance in the associated state are applicable to all stable monatomic gases, the results obtained with helium alone and with mercury are not very desirable because the current densities required with pure helium or with mercury are considerably higher than with the other monatomic gases, requiring in the case of helium

approximately 50% greater current densities. Mercury has the further disadvantage that while it can be operated alone at pressures considerably lower than with the rare gases of the atmosphere, it cannot be used in admixture with rare gases. The low pressures which must be used with mercury decrease to some extent the life of the electrodes. However, under suitable operating conditions tubes containing pure mercury at low pressure may be used and are included in the present invention. The pressure of the gas for association and maintenance in the associated state in general should be of the order of 4 millimeters absolute, the best results being obtained at from 2½ to 3 millimeters. Lower pressures may be used, of course, but troubles are more likely to be encountered with excessively low pressures due to electrode sputtering.

The current density required for association with gases other than pure helium is normally of the order of 2 milliamperes per square millimeter in a tube of 7 millimeters internal diameter. With larger tubes the current density may decrease somewhat, e. g., down to about one and three-quarters milliamperes. The lower current densities are applicable when electrodes are used which are efficient electron emitters, as apparently the electron stream plays some role in the association and much higher current densities are required where plain nickel electrodes are used without a coating of materials which are efficient electron emitters. All of the well known electron emitters such as oxides of the alkaline earths may be used. An electrode coated with barium azide which is transformed into a particularly active barium compound in use has been found to be very suitable.

The invention will be described in greater detail in connection with examples of typical lamps.

Example 1.—A 5 foot quartz or refractory borosilicate glass tube of 9 millimeters internal diameter is provided with nickel electrodes covered with barium azide and insulated with a suitable isolantite cylinder which should project beyond the cylindrical electrode to prevent material sputtered from the electrodes being projected against the glass walls of the lamp and consequently resulting in a collapse of the tube through overheating, and is filled with argon or a mixture of helium and argon at a pressure of 3 millimeters. A nickel cylinder of about 3 millimeters diameter may be used as electrode, and coated as described above. The internal diameter of the glass enclosing the electrode cylinder, should be about 20 millimeters. The tube is operated with an alternating current supply of 60 cycles providing a steady voltage, at 60 milliamperes current drain, of about 2000 volts which will permit generating a striking voltage of about 3000 volts. The argon or helium and argon mixture associates within a period of several hours which can be accelerated somewhat by increasing the current density and when fully associated gives a white light characterized by a very uniform banded spectrum. The efficiency of the lamp is from one and one-half to four times that of an incandescent lamp with daylight filter and is from one-half to two-thirds as great as with a neon lamp operated in the usual manner with a line spectrum at the customary pressures and current densities.

Example 2.—A 10 foot tube of quartz or "Pyrex" glass 9 millimeters internal diameter is built with electrodes of the same shape as described in Example 1 but coated with a mixture of barium

azide and radioactive material such as salts of radium or mesothorium. The lamp is filled with argon or a mixture of helium and argon in about equal proportions evacuated to a pressure of about 3 to 3.25 millimeters. The tube will start with a striking voltage of about 5000 volts and will run with a steady voltage of from 3000 to 3200 volts, depending on the amount of radioactive material present in the electrodes, as the radioactive material emits the more copious stream of electrons and therefore permits the same current density with a lower voltage.

The supply may be 60 cycle alternating current or a direct current of the same voltage which may, if desired, be made pulsating by any suitable interrupter. It will be noted that the voltages for a 10 foot tube are considerably less than double those required for a 5 foot tube because a considerable portion of the resistance of the tube is in the voltage drop from cathode to gas. This voltage drop is substantially constant with any given type of electrode irrespective of the length of the tube but, of course, in a long tube it forms a smaller percentage of the total resistance than in a short tube. From the standpoint of efficiency per watt, therefore, there is some advantage in using longer tubes where the higher absolute voltages required do not become prohibitive in cost. The use of radioactive or electron-emitting materials on electrodes reduces, of course, to a considerable extent the voltage drop.

Example 3.—A 10 foot "Pyrex" tube of 7 to 9 millimeters diameter is wound in the form of a tight spiral and is provided with electrodes as described in Examples 1 and 2. The tube is filled with argon or a mixture of argon with from 5 to 10 per cent. of krypton and xenon and about 10 per cent. of neon. The helix is placed in the output circuit of the power tube of a single sided television amplifier. The direct current voltage is adjusted to a point just below the voltage required for steady operation. The amplifier is then put into operation and the tube started by a temporary surge of sufficient magnitude. The tube will then operate at the frequency of the modulation of the television electric impulses and when viewed through a scanning disk properly synchronized will reproduce the picture televised in white light instead of the usual pink of the neon light television amplifier.

The lamps of the present invention have been described specifically in connection with ordinary illumination or in connection with television amplifiers. They can be used, of course, for any other purpose for which a lamp of the ordinary neon type is suitable, an excellent quality of white light being provided and, as the tube responds almost instantaneously to changes in voltage, it may be used to emit light in pulses corresponding to the frequency of the alternating or pulsating direct currents with which the tube or lamp is supplied. It should be noted, however, that in the case of a pure alternating current the wave form of the lamp response is not a true sine wave. On the contrary, the wave shows a broad peak with a delayed extinguishment. This makes it useful in applications where flickering would be serious with a light which follows the voltage changes applied to it instantaneously.

For some purposes it is desirable to produce a lamp having a limited portion operating at higher light intensity than the remainder of the lamp. This can be accomplished by using a lamp having a limited portion of smaller cross section than the rest of the lamp tube. In the smaller cross sec-

tion the current density per square millimeter of gas cross section is, of course, greater than in the rest of the lamp and correspondingly the brightness of this particular portion is greater. Such a lamp is particularly effective for spectrophotometry where a small light source is needed.

Having described the invention, what is claimed is:

1. A lamp of the class described comprising a tube filled with an associated stable monatomic gas at a pressure not exceeding about 4 millimeters, and an electrode at each end of the tube, the interior of the tube being free from any amount of dissociating catalysts which would cause cumulative dissociation of the gas when operated with current densities of not less than about one and three quarters milliamperes per square millimeter.
2. A lamp of the class described, comprising a tube filled with an associated stable monatomic gas at a pressure not exceeding about 4 millimeters, but sufficient to avoid objectionable electrode sputtering, and electrodes spaced apart in said tube, the inner walls of the tube being free from any amount of dissociating catalysts which would cause cumulative dissociation of the gas when operated with current densities for which the tube is designed.
3. A lamp of the class described comprising a tube filled with an associated stable rare gas of the atmosphere at a pressure not exceeding about 4 millimeters, and an electrode at each end of the tube, the interior of the tube being free from any amount of dissociating catalysts which would cause cumulative dissociation of the gas when operated with current densities of not less than about one and three quarters milliamperes per square millimeter.
4. A lamp of the class described comprising a tube filled with a stable rare gas of the atmosphere having an atomic weight greater than 4 at a pressure not exceeding about 4 millimeters, and an electrode at each end of the tube, the interior of the tube being free from any amount of dissociating catalysts which would cause cumulative dissociation of the gas when operated with current densities of not less than about one and three quarters milliamperes per square millimeter.
5. A lamp according to claim 1 in which the electrodes are coated with active alkaline earth oxides.
6. A lamp according to claim 3 in which the electrodes are coated with active alkaline earth oxides.
7. A lamp according to claim 4 in which the electrodes are coated with active alkaline earth oxides.
8. A lamp according to claim 1 in which the tube length does not exceed about 10 feet.
9. A lamp according to claim 1 in which the tube is of glass having not more than about 5% alkali.
10. A lamp according to claim 3 in which the tube is of glass having not more than about 5% alkali.
11. A lamp according to claim 4 in which the tube is of glass having not more than about 5% alkali.
12. A method of producing light having the spectral balance of white light and having a banded spectrum which comprises subjecting a stable monatomic gas at a pressure not exceeding about 4 millimeters in a tube provided with electrodes at each end, and in the absence of any

amount of dissociation catalyst which would cause cumulative dissociation of the gas in a discharge of the hereinafter specified current to an electric current having a density greater than about one and three quarters milliamperes per square millimeter of gas cross section until the line spectrum of the monatomic gas has been changed into a band spectrum having substantially the spectral balance of white light.

13. A method of producing light having the spectral balance of white light and having a banded spectrum which comprises subjecting a stable monatomic gas at a pressure not exceeding about 4 millimeters but sufficient to avoid objectionable sputtering, in a tube provided with spaced electrodes, and in the absence of any amount of dissociation catalysts as would cause cumulative dissociation of the gas in a discharge of the hereinafter specified current, to an electric current having a density greater than about $1\frac{3}{4}$ milliamperes per square millimeter of gas cross section until the line spectrum of the monatomic gas has been changed into a band spectrum having substantially the spectral balance of white light.

14. A method of producing light having the spectral balance of white light and having a banded spectrum which comprises subjecting a stable rare gas of the atmosphere at a pressure not exceeding about 4 millimeters in a tube provided with electrodes at each end, and in the absence of any amount of dissociation catalyst which would cause cumulative dissociation of the gas in a discharge of the hereinafter specified current, to an electric current having a density greater than about one and three quarters milliamperes per square millimeter of gas cross section until the line spectrum of the rare gas of the atmosphere has been changed into a band spectrum having substantially the spectral balance of white light.

15. A method of producing light having the spectral balance of white light and having a banded spectrum which comprises subjecting a stable rare gas of the atmosphere having an atomic weight greater than 4 at a pressure not exceeding about 4 millimeters in a tube provided with electrodes at each end, and in the absence of any amount of dissociation catalyst which would cause cumulative dissociation of the gas in a discharge of the hereinafter specified current to an electric current having a density greater than about one and three quarters milliamperes per square millimeter of gas cross section until the line spectrum of the rare gas of the atmosphere having an atomic weight greater than 4 has been changed into a band spectrum having substantially the spectral balance of white light.

16. A method of illuminating by a light having substantially the spectral balance of north sky-light and a banded spectrum which comprises operating a stable rare gas lamp containing an associated rare gas at a pressure not greater than about 4 millimeters by means of an electric current having a current density of not less than one and three quarters milliamperes per square millimeter of gas cross section, and in the absence of any amount of dissociation catalysts which would result in cumulative dissociation of the associated gas and production of a line spectrum in place of the banded spectrum.

17. A method of white light illumination with a banded spectrum which comprises passing an electrical discharge between electrodes in an associated rare gas at a pressure not greater than

about 4 millimeters, but sufficient to avoid electrode sputtering and in the absence of any amount of dissociation catalysts which would result in cumulative dissociation of the gas to produce a line spectrum in place of the banded spectrum of the associated gas.

18. A method according to claim 16 in which the rare gas has an atomic weight greater than 4.

19. A method according to claim 16 in which the rare gas is a mixture of helium and argon.

20. The method of treating a stable monatomic gas to give it the capacity of glowing with a white light under an electrical discharge which comprises subjecting it to a preliminary electrical discharge treatment in a container, the inner wall of which is substantially free from free and loosely combined alkali at a pressure not substantially greater than 4 mm. mercury pressure and a current density of at least about $1\frac{3}{4}$ m. a. per square mm. cross-section of the gaseous discharge path until the characteristic colored discharge of the gas is converted to an approximately white glow.

21. An artificially modified gas of the zero

group of the periodic table, being associated so as to exhibit a substantially continuous banded spectrum under excitation by an electrical discharge, and said gas being stable at a pressure not exceeding about 4 millimeters under an electrical discharge of more than about one and three-quarters milliamperes per square millimeter in the absence of dissociating catalysts.

22. The combination in a gas discharge lighting apparatus of a tube having electrodes for passage of current therethrough, a gas filling in said tube of an associated gas of the zero group of the periodic table, at a pressure not exceeding about 4 millimeters, and means for supplying to the tube during operation a current not less than one and three-quarters milliamperes per square centimeter of cross section of the gas discharge path, the interior of said tube being free from any amount of dissociating catalyst which would cause cumulative dissociation of the gas filling during operation from said current source.

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