March 14, 1933. C. G. SMITH 1,901,128

ELECTRIC LAMP

Original Filed April 15, 1924

Fig. 1

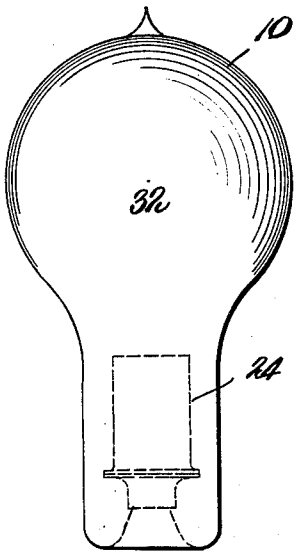


Fig. 2

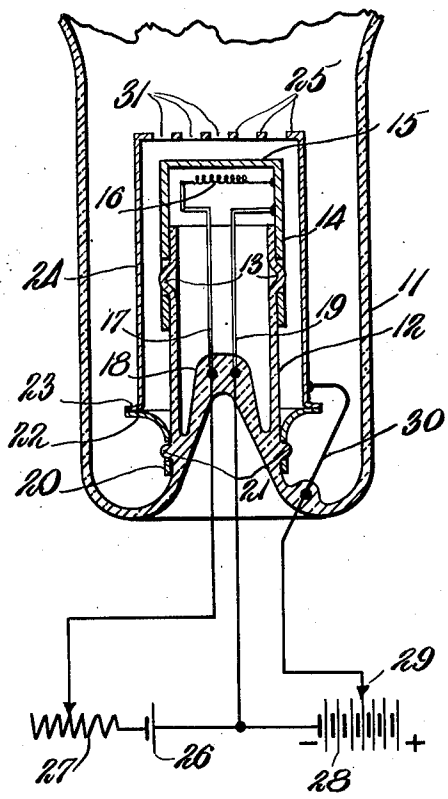
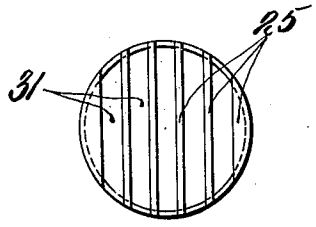


Fig. 3



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UNITED STATES PATENT OFFICE

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ELECTRIC LAMP

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This invention relates to the production of light by an electric discharge, and particularly to electric lamps of the kind utilizing electrodes spaced apart in a gaseous medium.

It is known that electric lamps of the incandescent filament type are, in general, relatively inefficient in converting electrical energy into light of useful color, being usually of less then 5% efficiency, as contrasted with lamps of the electric discharge type which are capable of converting electrical energy into useful light with an efficiency several times that of incandescent filament lamps. However, the resistance or impedance characteristic of prior lamps of the electric discharge type is unstable, being usually negative, in that increase of current through the lamp between certain values produced a decrease in resistance as contrasted with devices possessing a positive resistance in accordance with Ohm's law. On account of the negative resistance characteristic of the electric discharge type of lamp, it is necessary to insert a positive resistance in series with the lamp to balance the effect of the negative resistance and stabilize the operation. The efficiency obtainable with such a lamp is therefore largely offset by the losses incurred in the positive resistance. Even when using a positive resistance with these lamps the stability of operation is inherently poor and the apparatus is more complicated than a lamp of the filamentary type which may be connected directly to the line without the use of a ballast or series resistance.

When a gas or vapor is ionized by an electric discharge, a distinct color or spectrum is emitted. It has heretofore been proposed to mix several different gaseous elements and subject them to a discharge between electrodes in the mixture in order to produce a color corresponding to a mixture of the individual radiations of the constituent gases. However, so far as I am aware, attempts in the past have been unsuccessful in obtaining a color corresponding to the characteristic colors of the mixed gases through which the electric discharge is transmitted. When it has been attempted to produce such a mixed color, it has been found that the light emitted is, in general, characteristic of the gas having the lowest ionization potential in the mixture, owing apparently to the fact that the gas of lowest ionization potential, upon becoming ionized, produces such a relatively low resistance path having a negative resistance characteristic in shunt or through the gases of higher ionization potential that it is impossible to build up within the mixed gas a sufficient potential gradient to ionize the gases having higher ionization potentials. Whatever the true reason may be, all attempts to overcome these difficulties have failed.

In prior lamps of the electric discharge type the rapid disintegration of the cathode resulting from the ionization phenomena occurring adjacent thereto, has caused early failure of the lamp to operate properly. Furthermore, the walls of the lamp which originally are transparent become clouded and relatively opaque, so that the efficiency of the lamp is greatly decreased. Another difficulty apparently influenced by disintegration of the cathode and by continued use of the tube, is a "clean-up" effect which manifests itself as a continued decrease in gas pressure in the lamp, so that, unless the gas is replenished, the vacuum becomes excessively high and further operation of the lamp is impossible.

Objects of the present invention are to overcome the above difficulties, to provide a high efficiency lamp of the electric discharge type having a positive resistance characteristic instead of a negative characteristic and capable of producing a desired color mixture characteristic of the constituents of a mixed gas, to avoid cathode disintegration in an electric discharge lamp, to provide a shielded cathode, and generally to improve the construction and operation of lamps of the kind referred to.

In one aspect of the present invention an electric lamp is so designed as to efficiently radiate a blended light characteristic of the colors or spectra of a plurality of different gaseous elements mixed together. An electric discharge initiated between two elec-

trodes in a predetermined mixture of gases is utilized to excite the atoms of the gas and cause a radiation of light characteristic of the constituent gases. By positioning the electrodes relatively close to each other with a separation of the order of magnitude of the mean free path of electrons in the gaseous mixture and applying the proper potential, electrons from the cathode are accelerated at such a rate that they attain a velocity higher than that corresponding to the ionization potential of the gaseous constituents before traveling a distance in excess of that comparable to the mean free electron path in the mixture.

The electrons are emitted by an equipotential cylindrical cathode having a closed end heated by an electrical heating element within the cylinder, the electrons being propelled at a high velocity toward an apertured anode. The electrons passing through the apertures are projected into a light emitting portion of the lamp where they bombard the molecules of the mixed gas at a velocity in excess of that corresponding to the highest ionizing potential of any of the constituent gases which are to be excited. The constituent gases are thus ionized and caused to radiate light corresponding to their individual characteristics. In this manner various colors characteristic of different gases may be blended as desired.

For the purpose of illustrating the principles of this invention, a preferred embodiment is shown in the accompanying drawing, in which:

Fig. 1 is a side elevation of an electric lamp;

Fig. 2 is a vertical section of the base of the lamp; and

Fig. 3 is a plan of the anode.

The envelope or vessel 10 of material transparent to the radiations to be transmitted, may be of quartz, glass or other material of the desired light transmitting characteristics, and contains a rarefied predetermined mixture of gaseous elements having the desired light emitting characteristics, the proportion of the constituent gases being adjusted to give the desired proportions of the constituent colors which are to be blended. For example, the mixture may consist of a desired proportion of neon gas which has a relatively high ionization potential and emits a characteristic orange colored light, and mercury vapor which has a relatively low ionization potential and emits a characteristic green colored light.

The base 11 of the lamp is provided with a re-entrant portion integrally supporting the cylindrical neck 12, having the nubs 13 registering in holes through the cylindrical equipotential cathode 14 for locking the cathode in position on neck 12. The closed flat end 15 of the cathode is heated by the electrical heating filament or element 16, housed within the cathode in juxtaposition to the end 15, being supported at its right hand end from the cathode to which it is electrically connected and supported at its left hand end by lead 17 sealed into the press 18. Lead 19 electrically connected to cathode 14 is also sealed through press 18.

The sleeve 20 surrounding the base of neck 12 is held securely in place thereto by nubs 21 registering in holes in the sleeve. The upper flaring end 22 of the sleeve is welded or otherwise secured to the flanged end 23 of the cylindrical anode 24, which is positioned substantially coaxial with cathode 14 and has the apertured flat end 25, disposed substantially parallel to the end 15 of the cathode, and spaced therefrom at a distance of the order of magnitude of the mean free path of electrons in the gaseous mixture in vessel 10. While the anode-cathode spacing should not exceed a maximum value corresponding to a certain multiple of a mean free electron path, it may be any value less than this maximum spacing.

Current from the battery 26 or other source is supplied to heating element 16 and is controlled by variable resistance 27 to adjust the temperature of the end 15 of the cathode, to cause it to emit electrons at the desired rate. The negative terminal of the battery or other source of potential 28 is connected by way of lead 19 to cathode 14, a positive terminal of the battery being connected by way of the adjustable contact 29 and sealed-in lead 30 to anode 24.

Two methods are available in constructing a lamp according to the present invention, first, the anode-cathode spacing may be adjusted to a distance comparable with or less than the mean free path of electrons in a predetermined mixture of gases at a given pressure below that of the atmosphere, for example, at a pressure of one half a cm. of mercury, or secondly, the anode-cathode spacing may be adjusted to some convenient value, for example, 1 mm., the gas pressure then being preferably adjusted to a critical value, such that the mean free electron path is comparable with or greater than the anode-cathode spacing, and such that the light is most efficiently or satisfactorily produced. However, it is to be understood that the pressure may, if desired, be adjusted to any value below a limiting value above which the operation is unsatisfactory.

In operating the lamp the battery 28 is adjusted to apply a potential difference between anode 25 and cathode 15 of a value in excess of the highest ionizing potential of the constituent gases which are to radiate light, the electron emission from the portion 15 of the cathode being adjusted by rheostat 27. Electrons from the cathode are propelled at high velocity toward anode 25, large numbers of the electrons passing through the parallel

apertures 31 by which time they have been accelerated to a velocity corresponding to the potential difference between the anode and cathode. The electrons upon being transmitted through these apertures are projected into the light emitting region 32 beyond the anode where they bombard the gaseous molecules, thus ionizing the constituent gasses of the mixture and causing each gas to emit a radiation characteristic of its ionized condition.

By using an equipotential cathode 14, the tendency for the cathode to disintegrate or for an electric discharge to occur between two points on the cathode is reduced to a minimum or eleminated. It will be noted that cathode 14 is substantially enclosed by anode 24 which substantially limit the active area of the cathode to that portion opposite the anode apertures. When the source 28 is a source of alternating current, rectification takes place in the lamp, and the rectified current functions similarly to the direct current from the battery described.

By spacing the anode and cathode at a distance comparable with or less than the mean free electron path in the gaseous mixture, troublesome ionization between the anode and cathode is avoided and electrons may be accelerated to a much higher velocity corresponding to the potential difference between the electrodes than in lamps utilizing ionization between the electrodes. At the same time this arrangement of the electrodes results in a positive resistance characteristic between the terminals of the lamp so that the lamp may be directly connected to a source of current without using a series resistance as with prior lamps of the electric discharge type.

It is to be noted that in prior electric discharge devices having a filling of mixed gases, the ionization of the gas having the lowest ionization potential prevents the maintenance of a potential gradient in the gas large enough to cause ionization of the gaseous constituents having a substantially higher ionization potential, whereas, in accordance with the present invention, it is possble to produce light characteristic of the individual gaseous constituents blended together in various desired combinations.

From the foregoing it will be evident that while some electrons from the cathode do strike the anode instead of passing through the apertures the great majority of the electrons pass through the apertures, chiefly for the following reasons: the area of the anode portions between the apertures is small compared with the area of the apertures; and more electrons leave the cathode opposite the apertures owing to the fact that the bombardment of the cathode occurs opposite the apertures by ions passing through the apertures. It will of course be understood that the electrostatic attraction of the anode is confined chiefly to that side facing the cathode so that after the electrons from the cathode pass through the apertures they are influenced only to a comparatively small extent by the anode.

I claim:

1. An electric lamp comprising a vessel containing a rarefied mixture of a gas having a relatively low ionizing potential and a gas having a relatively high ionizing potential, a source of electrons, and means in said vessel whereby substantially all of said electrons are accelerated to a higher velocity than that corresponding to the ionization potential of the gaseous constituent of said mixture having the highest ionization potential and whereby said gas is bombarded by the accelerated electrons.

2. An electric lamp comprising a vessel containing a rarefied mixture of a gas having a relatively low ionizing potential and a gas having a relatively high ionizing potential, and means in said vessel for producing a stream of electrons accelerated to a velocity in excess of that corresponding to said higher ionizing potential, and for projecting said stream into contact with said gaseous mixture.

3. In an electric lamp having a pair of electrodes, the method of producing light of blended color, characteristic of the several constituents of a predetermined mixture of gas which method comprises adjusting the pressure of the gaseous mixture so that the mean free path of the electrons therein is substantially equal or greater than the electrode separation, supplying electrons at the negative electrode, applying to the electrodes a potential difference greater than the ionizing potential of the constituent gases, and bombarding the gaseous mixture with the accelerated electrons.

4. The method of producing a light of blended color, characteristic of the several constituents of a gaseous mixture, which comprises accelerating electrons at such a rate that they assume a velocity higher than that corresponding to the ionization potential of the gaseous constituents before traveling a distance in excess of the order of magnitude of the mean free electron path in the mixture, and bombarding the gaseous mixture with the accelerated electrons.

5. In apparatus of the character described, a vessel containing a predetermined mixture of gases, an electron emitting cathode, and an apertured anode spaced from said cathode at a distance of the order of magnitude of the mean free path of electrons in said mixture.

6. In apparatus of the character described, a vessel containing a predetermined mixture of gases, an equipotential electron emitting cathode, and an apertured anode spaced from said cathode by a distance of the order of

magnitude of the mean free path of electrons in said mixture.

7. In apparatus of the character described, a vessel containing a predetermined mixture of gases an electron emitting cathode, and an apertured anode shielding said cathode and spaced therefrom at a distance of the order of magnitude of the mean free path of electrons in said mixture.

8. In apparatus of the character described, a vessel containing a predetermined gas, a cylindrical cathode having a closed electron emitting end, and an anode substantially surrounding said cathode and having an apertured portion in juxtaposition to said cathode and spaced therefrom at a distance of the order of magnitude of the mean free path of electrons in said gas.

9. In apparatus of the character described, a vessel containing a predetermined gas, a cylindrical cathode having a closed electron emitting end, a coaxial cylindrical anode having an apertured end in juxtaposition to said cathode end and spaced therefrom at a distance of the order of magnitude of the mean free path of electrons in said gas.

10. In apparatus of the character described, a vessel containing a predetermined gas, a cylindrical cathode having a closed electron emitting end, means disposed adjacent said end for causing said end to emit electrons, and an anode substantially surrounding said cathode and having an apertured portion in juxtaposition to said cathode end and spaced therefrom at a distance of the order of magnitude of the mean free path of electrons in said gas.

11. An electric lamp comprising a vessel containing a predetermined mixture of gases, a cylindrical cathode having a closed electron emitting end, a heater disposed within said cathode adjacent said end for causing said end to emit electrons, and an anode substantially surrounding said cathode and having an apertured portion in juxtaposition to said cathode end and spaced therefrom at a distance of the order of magnitude of the mean free path of electrons in said mixture.

12. An electric lamp comprising a sealed container transparent to the light to be transmitted, electrodes in spaced relation in said container, means for causing an electron emission from one of said electrodes, said other electrode having passages for the free transmission of electrons projected from said cathode, and a filling of mixed gases of predetermined character so proportioned as to emit the desired relative intensity of light characteristic of the constituent gases, the pressure of said gaseous mixture being such that the mean free electron path therein is of the order of magnitude of the electrode separation.

13. An electric lamp comprising a sealed container having a light emitting portion containing a mixture of predetermined gases at less than atmospheric pressure, a pair of electrodes in juxtaposition to said portion, and having a separation of the order of magnitude of the mean free electron path in said mixture, one of said electrodes being nearer said portion than the other and being apertured for the passage of the electrons into said portion, the other said electrode being adapted to emit electrons and disposed on the opposite side of said first electrode from said light emitting portion to emit electrons for transmission through said apertures thereby to excite radiations characteristic of the constituent gases.

14. An electric lamp comprising a vessel containing a rarefied mixture of gases having different light emitting characteristics, one of the gases having a relatively low ionizing potential, and another having a relatively high ionizing potential, and means in said vessel for causing each of the said constituent gases to continuously radiate a substantial amount of light, thereby to produce a blended spectrum characteristic of the said constituent gases, the said means comprising a source of electrons accelerated to a velocity in excess of that corresponding to that of the higher ionizing potential.

15. A gaseous electric lamp comprising a gas tight vessel having a wall for passing radiation therethrough, a gas of low ionizing voltage and a gas of high ionizing voltage in said vessel, each gas being at a pressure at which on excitation by sufficiently accelerated electrons the gas radiates light, and means for generating and driving through said gases in the vessel a stream of electrons at a velocity higher than that corresponding to the ionization voltage of the gas having the higher ionizing voltage to cause excitation of both gases to simultaneous substantial radiation.

16. A gaseous electric lamp comprising a gas tight vessel having a wall for passing radiation therethrough, a gas of low ionizing voltage and a gas of high ionizing voltage in said vessel, each gas being at a pressure at which on excitation by sufficiently accelerated electrons the gas radiates light, and means for generating and driving through said gases in the vessel a stream of electrons at a velocity materially higher than that acquired by electrons limited in their continuous travel by collisions with molecules of the gas of the lower ionization voltage, and sufficient to excite to radiation the gas of the higher ionization voltage in materially greater proportion than in case of excitation by electrons limited in their continuous travel by collisions with molecules of the lower ionization voltage.

Signed by me at Boston, Massachusetts this 8th day of April 1924.

CHARLES G. SMITH.

CERTIFICATE OF CORRECTION.

March 14, 1933.

Patent No. 1,901,128.

CHARLES G. SMITH.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 1, line 2, for "an" read "a gaseous"; line 10, before "electric" insert "gaseous"; line 19, for "produced" read "produces"; line 21, strike out the words, "in accordance with Ohm's law"; line 85, before "electric" insert "gaseous"; line 95, for "an" read "a gaseous" and line 96, after "electric" insert "discharge"; page 2, line 8, after "mixture" insert "or less"; line 17, before "cylindrical" insert "hollow", and line 85, after "10" insert "or less"; page 3, line 8, for "gasses" read "gases"; line 16, for "eleminated" read "eliminated"; line 49, for "possble" read "possible"; and lines 116 and 117, claim 4, for "the order of magnitude of" read "substantially"; page 3, lines 124 and 130, and page 4, lines 1, 7, and 8, 16 and 17, 25 and 26, 35 and 36, and line 47, claims 5, 6, 7, 8, 9, 10 and 11, respectively, for "of the order of magnitude of" read "substantially equal or less than"; lines 62, 69 and 70, claims 12 and 13, respectively for "of the order of magnitude of" read "substantially equal or greater than"; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 2nd day of May, A. D. 1933.

M. J. Moore,

Acting Commissioner of Patents.

(Seal)