Nov. 1, 1938. C. G. FOUND 2,135,283

METHOD OF PRODUCING POLYCHROMATIC LIGHT

Filed Oct. 1, 1936

Fig. 1.

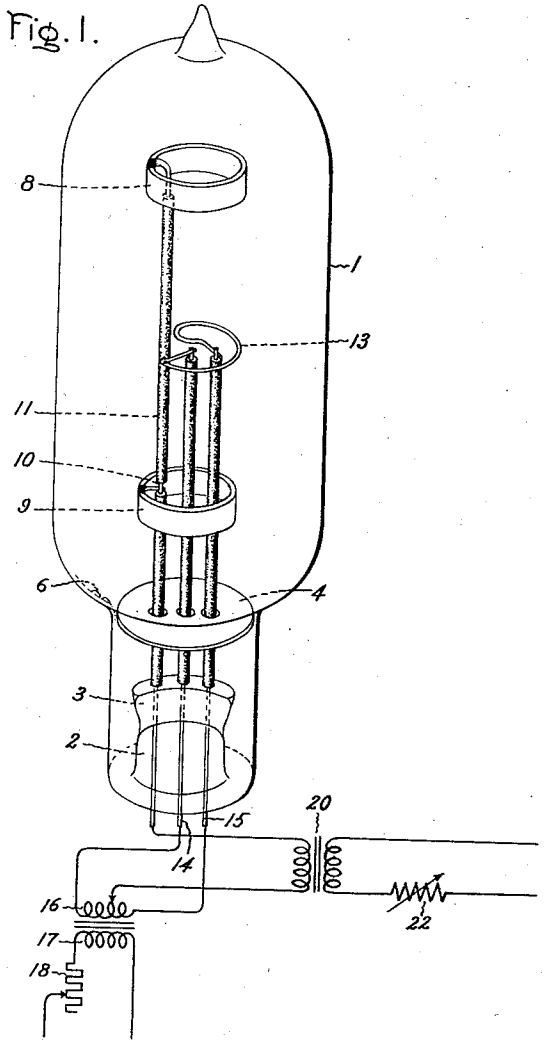


Fig. 2.

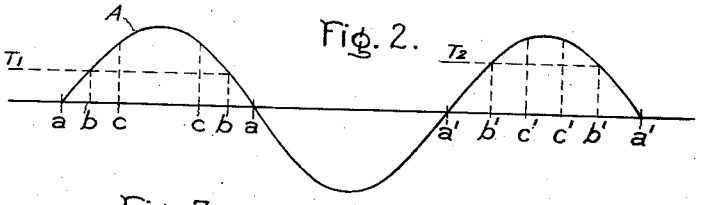
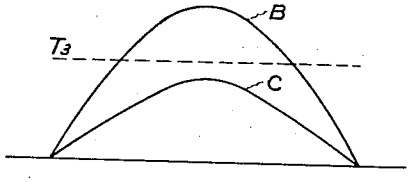


Fig. 3.



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METHOD OF PRODUCING POLYCHROMATIC LIGHT

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2 Claims. (Cl. 176—124)

The present invention relates to a novel method of operating luminous discharge devices of the type known as "cathodic lamps".

It is an object of the invention to provide an improved manner and means of operating cathodic lamps containing a mixture of gases or vapors whereby the characteristic spectra of each of said gases or vapors shall be sequentially emitted in such a fashion as to produce either blended or continuously variable lighting. Briefly stated, this object is attained by so regulating the cathode temperature at a given discharge current, or by so regulating the discharge current at a given cathode temperature, that at least during certain portions of the operating cycle of the lamp different components of the gaseous mixture in the lamp are caused to be preferentially excited to give light, thus varying the character of the instantaneous light output of the lamp. Since different gases emit different colored radiations when excited, the effect of these variations will be to produce the appearance either of blended polychromatic light or of a light of constantly varying shade, depending on the rapidity with which the variations are caused to occur.

The novel features which I desire to protect herein will be pointed out with particularity in the appended claims. The invention itself, however, will best be understood by reference to the following specification taken in connection with the drawing, in which Fig. 1 illustrates schematically a lamp and energizing circuit therefor suitable for the practice of the invention, and Figs. 2 and 3 are graphical representations useful in explaining the invention.

It is generally known that the luminescence produced by a gaseous discharge between relatively spaced electrodes is comprised of a plurality of zones having somewhat different characteristics. In such a discharge the principal sources of light comprise the "positive column" which forms in the intermediate space between the electrodes and the "cathodic glow" which occurs in a region very close to the cathode. It is also known that conditions of operation may be chosen such that essentially no positive column is present while the cathodic glow is raised to a maximum. In general, if the spacing between the cathode and anode is equal to or less than the least dimension of the discharge vessel within which the electrodes are enclosed, the light produced will be predominantly of a cathodic glow nature. For this reason lamps having a construction such as that specified are commonly referred to as "cathodic" lamps and will be so referred to herein.

In order to understand clearly the nature of my invention it is necessary to refer briefly to the principles governing the generation of light in a cathodic lamp. In such lamps the applied potential is concentrated as a "cathode drop" in a narrow sheath, perhaps $\frac{1}{10}$ centimeter in thickness, directly surrounding the cathode and it is in this sheath that electrons emanating from the cathode are accelerated. The acceleration actually produced depends on the conditions of operation and for discharge currents which are low with respect to the emission of the cathode will be on the order of the ionization potential of the gas or vapor which is carrying the discharge.

Electrons proceeding from the boundary of the sheath toward the anode will produce such ionization of the gaseous atmosphere as is required to maintain a plasma or condition of equilibrium in the discharge space. As is well known, ionization consists in the creation of positively charged particles and is a result of collisions between atoms and electrons and the absorption of energy by the former. Such collisions as do not result in the production of positive ions may produce "excitation" of the colliding atoms, the electron energy required for excitation being less than that required for ionization. It is this latter phenomenon (excitation) which is chiefly responsible for the production of light.

It may be shown that in a gaseous discharge device the rate of production of positive ions is determined jointly by the electronic current moving from the cathode and by the average velocity of the electrons which comprise that current. In a cathode discharge device the ratio I_e/I_p, in which I_e represents the electronic current and I_p represents positive ion current moving to the cathode, will remain a constant maximum as long as the electrons demanded by the discharge are not in excess of those supplied by the zero field emission of the cathode (i. e. the emission of which the cathode is capable without the presence of a positive field at the cathode surface). Otherwise stated, as long as the supply of electrons which will be generated thermally by the cathode without the assistance of an electrostatic field at the cathode surface is equal to or greater than the electronic current required by the discharge, each electron leaving the cathode will produce a definite and constant number of ions which number is determined by the average electron energy (i. e. by the cathode drop). Consequently, during the time that this

condition is maintained an increase in the discharge current will simply involve more of the thermally emitted electrons without requiring any change in electron velocity or in the magnitude of the cathode drop. This will be true, at least as long as the atoms of the gaseous constituent which is carrying the discharge are present in sufficient quantities to supply substantially all of the ions required by the discharge. Since this is the usual condition, it is the one which will be assumed to exist in the following discussion.

If, on the other hand, the magnitude of the discharge is such as to require a greater number of electrons than are supplied by the zero field emission of the cathode, then a compensatory change in condition must take place. This change is accomplished by an increase in electron emission from the cathode, which increase is produced by the action of an electric field as will be more fully explained in the following:

The electric field required to offset the inadequacy of the electron supply may be created either by an increased cathode drop or by the accumulation of positive ions in the vicinity of the cathode. As a matter of fact both these factors wil be involved in the equilibrium-seeking changes necessitated by an increase in discharge current with respect to the zero field electron emission of the cathode. This is true because an increased cathode drop, acting through an increase in electron velocity, raises the rate of production of ions per electron which in turn produces a greater electric field at the cathode. On account of the duofold nature of this adjusting process the cathode drop will seek a value at which the rate of generation of positive ions is exactly that which will produce the field required to stimulate the required electron emission.

It will be seen that as a consequence of the increased rate of production of positive ions with reference to electron emission the ratio I_e/I_p between these two quantities will have decreased. As still greater fields are required for further increasing discharge currents this ratio must again be decreased by a disproportionate change in the value of I_p. Thus, it will be seen that whereas throughout the range of zero field emission, a linear relation exists between the electron and positive ion currents, in the region of required field emission, we have a non-linear relation between these same quantities.

If the discrepancy between the zero field emission of the cathode and the electron current involved in the discharge is sufficiently great, a considerable increase in the cathode voltage drop will be noted, and the velocity imparted to the electrons passing through the cathode sheath will be substantially enhanced. Assuming that equilibrium is to be continually maintained, this velocity will increase with increasing arc current until a cathode drop is reached at which ions are produced not only from the gaseous constituents having lowest ionizing potentials but also from those having higher ionization potentials. Simultaneously, luminous excitation of these latter constituents sets in. This condition being attained, the discharge will then tend to emit light which comprises a mixture in varying proportions of the spectra of the several gases contained in the discharge space.

The further significance of the principles described above and the manner of their practical application in accordance with the invention may be most readily understood by reference to the specific structure illustrated in the drawing.

Referring to Fig. 1, I have shown a sealed envelope 1, suitably of glass, having at the lower end a reentrant stem 2 terminating in a press 3. A transverse septum 4, for example of mica, serves substantially to isolate the stem-containing portion of the envelope from the main discharge space. Within the envelope I provide an ionizable gas, for example, neon, at a pressure of from about one-half to several millimeters, for example, 1 millimeter, and a quantity of vaporizable easily ionizable material indicated at 6 as adhering to the walls of the discharge vessel, which latter material may suitably comprise a mixture of sodium and mercury. It will be understood, of course, that other gases, for example, argon, and other vaporizing materials, for example, cadmium, zinc, or various amalgams may be alternatively employed. In general, the conditions of operation should preferably be such that the concentrations of the various constituents are in inverse order to their ionization potentials. For example, in the case of sodium, mercury and neon, the conditions may suitably be such that the pressure of sodium is about 0.1 micron, the pressure of mercury about 0.1 millimeter and the pressure of neon about 2 millimeters.

An anode comprising a pair of similar sleeve-like metal rings 8 and 9 is supported on a vertical rod secured at its lower end to the press 3. This rod may consist of a conducting element 10 embedded for the greater portion of its length in a refractory insulating material 11, such as alumina, which serves to protect the conductor from the effects of the discharge. The anode parts 8, 9, are electrically connected by conductor 10 and are consequently maintained at approximately the same potential. Intermediate between these equi-potential parts is supported a thermionic cathode 13 suitably comprising a refractory base member, for example, of tungsten, coated with an electron emissive material, for example, barium oxide or thoria. The cathode is so positioned that its distance from the anode surface is less than the least dimension of the envelope 1, thus fulfilling the requisite conditions for the maintenance of a cathodic type of discharge. Heating current is supplied to the cathode through insulated lead-in connections 14 and 15 which also serve to support the cathode in place.

Externally of the envelope the lead-in connections 14 and 15 which are sealed through the press 3, may be connected to a source of heating current. In the case illustrated this comprises a transformer having a secondary 16 and a primary 17, the latter being provided with a serially connected current-limiting device 18 shown as a variable resistor. Across the anode and cathode terminals is impressed a discharge potential derived as shown from the secondary of a transformer 20. Here again, a current-limiting device such as a variable reactor 22 is provided in series with the transformer primary.

In the operation of a lamp such as that described, if the temperature of the cathode 13 is maintained sufficiently high to produce an adequate supply of electrons, the ratio I_p/I_e will be a minimum (or I_e/I_p a maximum, as previously explained) and the positive ion current will be preponderantly produced by ionization of the sodium. This requires electrons of a velocity equal to or slightly in excess of 5.1 volts and will result

in the production of light developed almost exclusively by the excitation of sodium atoms. Under the conditions stipulated substantially none of the electrons will possess a velocity sufficient to excite either the mercury or the neon to visible emission, since the former requires an electron voltage greater than 6.7 volts, while the latter requires a voltage of at least 18.5 volts.

If, however, the emission of the cathode is decreased as by placing a greater proportion of the resistance 18 in series with the heating transformer, this condition may be considerably altered. When the cathode emission is so reduced that during a portion of the discharge current cycle the zero field supply of electrons becomes insufficient to maintain the discharge equilibrium, an increase in cathode drop will take place in accordance with the principles explained above. As soon as the cathode drop becomes equal to the excitation potential of mercury (6.7 volts) a portion of the light emitted by the discharge will have the characteristics of the mercury spectrum. With a still further accentuated discrepancy of electron supply and electron demand the cathode drop may increase to the point where even the neon becomes excited.

Referring now to Fig. 2, I have shown graphically the nature of the results which may be obtained when using an alternating current discharge supply in connection with cathodic lamps employing mixed gases. In this figure the sinusoidal curve A represents the cyclical variations of the discharge current, and the horizontal dotted lines indicate the currents at which, for cathode temperatures T and T_2 respectively, the cathode drop exceeds the above-mentioned excitation voltage of mercury. With the temperature T_1, for example, the zero field emission of the cathode may be sufficient to take care of the demands of the discharge current in the time interval *ab*. However, as the current continues to increase, this condition no longer obtains and an increase in the cathode drop sets in so that in the interval *bc* the light emission from the discharge may be partially, or even predominantly composed of mercury luminescence. Furthermore, in the still higher current range *cc*, where the cathode drop exceeds the excitation potential of neon, the neon will become visible or even predominant. Inasmuch as these changes in luminescence take place very rapidly and are repeated very many times during each second, according to the frequency of the current supply, the apparent effect on the observer will be that of the generation of a mixed or blended light comprising the spectra of all three of the gaseous constituents. When these constituents comprise sodium, mercury and neon, respectively, characterized by yellow, blue, and red luminescence, the color distribution may be such as to produce a polychromatic or approximately white light.

Referring to the right-hand portion of Fig. 2, it will be seen that by changing the cathode temperature to a higher value T_2, the relative proportions of each cycle during which the various gaseous constituents are respectively most active may be varied at will. For example, in the case illustrated the interval *a'b'*, during which the luminescence is predominantly that of sodium, is increased. The interval *b'c'*, on the other hand, remains substantially constant, while the interval *c'c'*, representing the luminescent period of neon, is decreased. As a result luminous output of the lamp will contain a greater proportion of yellow and a lesser proportion of red. By taking advantage of these facts it will be seen that one may vary at will the spectral distribution of the emitted polychromatic light by changing the cathode temperature to produce the desired result.

Referring now to Fig. 3 the curves illustrated show how color regulation may be obtained in a slightly different manner by adjustment of the average value of the discharge current while leaving the cathode temperature constant. In curve B, which represents the greater value of the discharge current, the cathode is assumed to be set at a temperature T_3 at which zero field emission is less than that required to supply the current at the peak of the cycle. Consequently, color blending of the type previously described may occur. If, however, with the same cathode temperature, the discharge current is reduced to the value indicated by the curve C, no increase in cathode drop will occur at any time during the cycle. For this reason only sodium light will be apparent to the observer.

The method of color regulation described in the last paragraph also lends itself readily to the production of shifting or mobile color effects. By maintaining a discharge current (either alternating or direct) of relatively constant average value and cyclically varying the cathode heating current in slow degrees, the color of the emitted light may be made to change in a very pleasing manner. As the cathode temperature falls below that at which the zero field emission is less than the electronic current required by the discharge, the spectrum of the emitted luminescence will be more and more that of the gaseous constituent of highest excitation potential. On the other hand, as the cathode temperature again increases the spectrum of the constituents of lower excitation potential will again predominate. It will be clear that this mode of regulation may be accomplished either manually or automatically by the use of a rotating contactor device or other known means included in the cathode circuit, whereby the cathode current may be cyclically varied in a desired position.

While the method which comprises my invention should be clear from the description set forth in the foregoing specification, I may point out that its underlying principle is that the conditions of the discharge shall be such that the required positive ion current is caused to vary non-linearly with the electronic current. If this condition is fulfilled, no matter what the cause of such fulfillment, a change in discharge current will inherently produce a change in electron velocities. In a cathodic lamp this result may be obtained by the procedure which I have outlined in the foregoing. In other types of discharge lamps where the same principles of equilibrium do not necessarily apply other conditions may be required to produce a non-linearity of the character referred to.

In the interests of simplicity I have explained my invention in connection with a type of discharge in which single impact ionization is assumed to be exclusively involved. However, in cases where ionization is cumulative (i. e. produced by successive electron impacts) similar reasoning may be applied.

While I have described my invention in connection with a particular structure, it will be understood by those skilled in the art that many other structures including lamps adapted to be conductive in both directions may be alternative-

ly employed, and I aim by the appended claims to cover all such uses of my improved mode of operation as fall within the true spirit and scope of the invention.

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

1. A method of producing color variations in a cathodic lamp containing a plurality of ionizing media which comprises passing a discharge current of relatively constant average value through said lamp and cyclically varying the normal zero field emission of the cathode of the lamp in such a manner that such emission is less than the electron current required by the discharge during a substantial portion of the variation and is greater than said current during another substantial portion of such variation whereby sequential excitation of the various ionizable media is obtained.

2. A method of producing color variations in a cathodic lamp containing a plurality of ionizable media of different excitation and ionization potentials, which comprises passing a discharge current of relatively constant average value through said lamp and cyclically varying the temperature of the cathode of the lamp in such a manner that the zero field emission of the cathode is less than the electron current required by the discharge during a substantial portion of such variation and is greater than such current during another substantial portion of the variation whereby sequential excitation of the various ionizable media is obtained.

CLIFTON G. FOUND.