March 2, 1954

C. KENTY

2,671,184

FLASHING DISCHARGE DEVICE

Filed Dec. 1, 1949

Fig. 1.

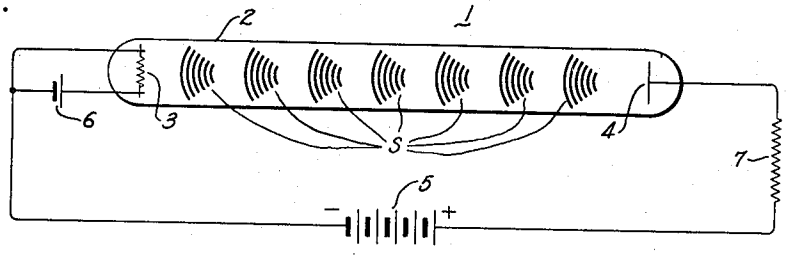


Fig. 2.

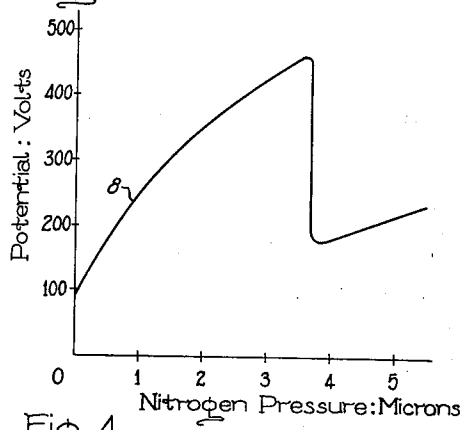


Fig. 3.

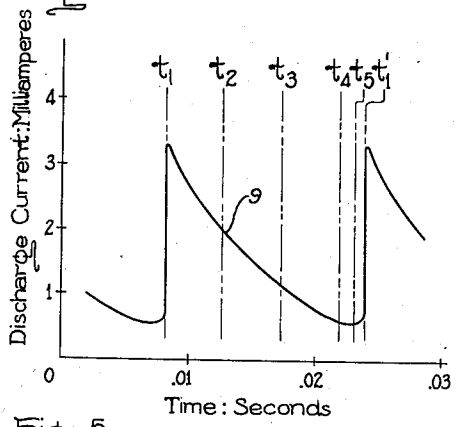


Fig. 4.

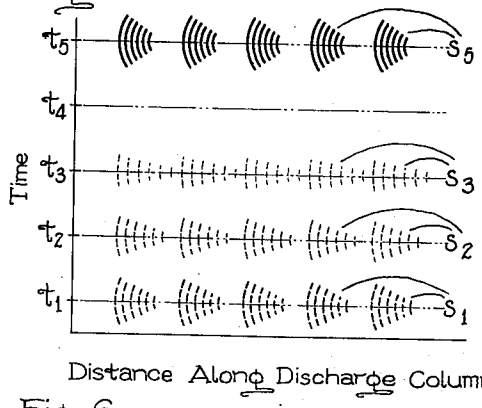


Fig. 5.

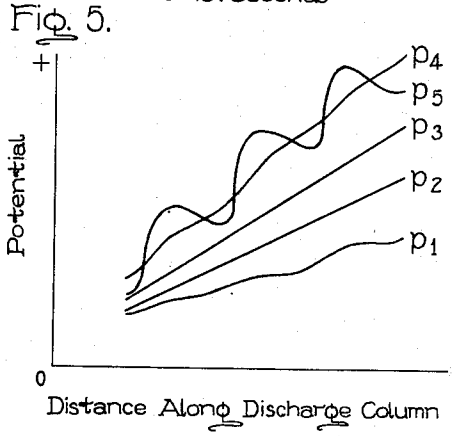
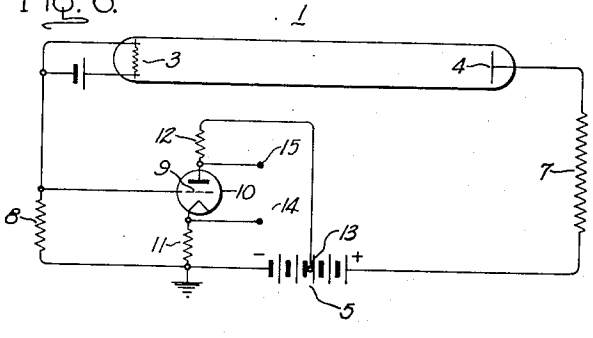


Fig. 6.



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UNITED STATES PATENT OFFICE

2,671,184

FLASHING DISCHARGE DEVICE

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Application December 1, 1949, Serial No. 130,463

7 Claims. (Cl. 315—358)

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This invention relates generally to the discharge of electricity through gases and more particularly to a new type of gaseous discharge tube which, amongst other characteristics, provides a flashing light output having a sharply peaked waveform.

The phenomenon of conduction through a mixture of a rare or inert gas and mercury vapor, as in the commercial fluorescent lamps, is relatively well known. In such lamps, the rare gas such as argon, for instance, is provided in order to give a lower starting voltage characteristic to the lamp. Once the discharge has started, the mercury vapor ionizes and produces its characteristic 2537 Å. radiation. In the fluorescent lamp, the 2537 Å. radiation is converted by means of suitable phosphors into visible light which is utilized for illumination purposes.

My invention is concerned with a new type of lamp which contains the usual mixture of a rare gas and mercury vapor, and to which a small quantity of a molecular impurity has been added. I have found that such an addition of a small quantity of a molecular impurity produces remarkable changes in the current conducting characteristics of the discharge device and also in the character of its radiation. Among other effects, the current through the lamp becomes pulsed and the discharge becomes characterized by transverse striations.

Accordingly, it is an object of my invention to provide a new type of electric discharge device which may be utilized to provide a flashing light output.

Another object of my invention is to provide an electric discharge device which has the characteristic of drawing a pulsed current when a constant unidirectional voltage is applied to it. Yet another object of my invention is to provide a generator of a particular voltage waveform as will be described herein.

Further objects and advantages of my invention will appear from the following description taken in conjunction with the accompanying drawings. The features of my invention believed to be novel will be more particularly pointed out in the appended claims.

In the drawings:

Fig. 1 is a simplified schematic illustration of an electric discharge device and operating circuit therefor in accordance with my invention.

Fig. 2 is a curve illustrating the variation in the potential across the device as a function of the pressure of a molecular gas therein.

Figs. 3, 4, and 5 contain a number of curves

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illustrating graphically various operating characteristics of the discharge device of Fig. 1.

Fig. 6 is a schematic diagram of a circuit embodying the flashing discharge device as a source of a particular voltage waveform.

Referring to Fig. 1, there is shown an electric discharge device 1, comprising an elongated glass tube 2 having sealed into one end thereof a thermionic cathode 3, and into the other end, an anode 4. Envelope 2 contains a rare gas such as argon under a pressure of a few millimeters, and a small quantity of mercury so that the envelope is filled with the vapor of mercury at the pressure corresponding to the temperature at which the device is operated, this normally being room temperature. Device 1 may, for instance, be a glass tube 1½" in diameter and 4 feet long.

The device is connected to operate on a suitable unidirectional voltage supply provided by a battery 5. Heating current for thermionic electrode 3 is provided by a small battery 6, and a resistor 7 serves as a ballast to limit the current through device 1. For the discharge device which has been previously mentioned, battery 5 may provide a potential between 1,000 and 2,000 volts and ballast resistor 7 may be approximately 250,000 ohms. The description of the operating characteristics of the device which will now follow assumes that different devices containing variable percentages of gas mixtures are available or that means are provided for varying the gas contents of the device 1 herein.

When a pure rare gas such as argon, and mercury vapor are present within device 1, and a discharge current not greater than 20 milliamperes and preferably in the range from 1 to 10 milliamperes is maintained, the arc occurs at a low voltage and contains the usual running striations. If now there is added a small quantity of a molecular gas which will not react chemically with the other elements in the device, such as, for instance, nitrogen (N_2), the voltage drop across the device rises and the running striations are gradually suppressed. As more nitrogen is added, the pressure due to nitrogen being gradually increased from 0.1 to 20 microns for instance, the voltage across the device continues to rise to approximately 400 to 500 volts, as illustrated by curve 8 in Fig. 2. At a certain pressure of nitrogen, which, in the particular tube previously mentioned, occurs about 3.5 microns of nitrogen, the voltage drop or potential across the device suddenly decreases to an average value, perhaps 40 percent lower; and the discharge assumes a completely different form.

In this new form, the discharge flashes on and off periodically; and the current shows a sharply peaked waveform somewhat in the manner of a saw-toothed wave, as illustrated by curve 9 in Fig. 3. The current through the device falls off steadily from a time t_1, to nearly zero at a time t_5, then jumps suddenly to a sharp maximum at time t'_1 and proceeds again to fall toward zero. The whole process is repetitive and may have a frequency in the range from 25 to 2,500 cycles per second, depending upon a number of circumstances.

I have found that there are various ways of controlling the frequency of flashing. The frequency may be raised by increasing the value of ballast resistor 7; this also decreases the degree of current modulation and raises the average voltage across the tube. The frequency may also be raised by increasing the nitrogen content or, more strictly, the ratio of nitrogen to mercury vapor. Other means of raising frequency are increasing the current and decreasing the pressure of argon. The average current characteristics of the device under these conditions show a strong positive current characteristic, that is, it behaves as a positive resistance in which the greater the current, the greater the voltage drop across the tube. Flashing is also favored by a high ratio of nitrogen to mercury vapor and by a low current.

In general, the upper limit of allowable current for the flashing to occur varies as the ratio of nitrogen pressure to mercury pressure. For the tube which has been described, flashing may occur with currents ranging from 0.1 to 20 milliamperes. This corresponds to a current density of 0.01 to 2.0 milliamperes per square centimeter, although it is to be understood that, with other sizes or diameters of tubes, some deviations from proportionality are to be expected. Beyond this range of current densities, another form of discharge occurs which may be used for identifying the nature of the molecular impurity. For instance nitrogen may be distinguished from carbon monoxide because in this range the former produces a positive volt-ampere characteristic, whereas the latter produces a negative volt-ampere characteristic. For a more complete description of the method, reference may be made to my copending application No. 139,774, filed January 20, 1950, entitled "Method of Measuring Molecular Impurities in Rare Gases," and assigned to the same assignee as the present invention.

The character of the discharge may be determined by means of a rotating mirror or a stroboscope; and it is to be understood that the description which now follows is based upon an inspection through the assistance of such laboratory devices and is not necessarily visible to the naked eye. At the beginning of the flash in the device and just before the occurrence of the peak in the current waveform, there spring into being bright striations along the tube which are spaced apart by a distance of approximately a tube diameter. These striations have sharp convex boundaries turned toward the cathode. This striations appear to be essentially stationary and of short duration and occur most brightly at time t_5 in Fig. 3, during the period just preceding the sharp current peak at time t_1. These striations are indicated by s in Fig. 1, and by s_5 in Fig. 4 which shows the variation in the intensity of the striations during a complete cycle. The intensity of the striations then decreases as indicated by s_1, s_2, and s_3 in Fig. 4, these intensities corresponding to the times t_1, t_2, and t_3, respectively, indicated in Fig. 3. By time t_4, the striations have completely disappeared; the tube is then substantially dark until time t_5, when a flash occurs, bright striations reappear, and the process repeats itself.

It is to be understood that whereas the striations are essentially stationary during any one flash through the tube, they do not recur at the same point along the tube at successive flashes. In other words, a subsequent set of striations is not in the identical location of a precedent set, so that if the flashes occur at a slow enough rate, the striations appear to be shifting back and forth continuously along the longitudinal axis of the tube. However, the flashes of light resulting from the continuous building up and wiping out of the striations can readily be seen with the naked eye if the repetition rate is made low enough.

I will now provide what I consider to be the scientific explanation of the flashing phenomenon occurring within my discharge device. However, it is to be understood that while I believe this explanation to be true, I do not wish to be bound by its accuracy or correctness.

The flashing discharge is due, apparently, to the strong excitation of the argon in the steep potential drops at the heads of the striations. The potential distribution throughout the length of the tube at this moment is illustrated by curve p_5 of Fig. 5. There follows a rapid diffusion of argon resonance radiation, and more particularly the side frequencies thereof, sometimes known as the wings, throughout the spaces between the striations and the concurrent formation therein of argon resonance and metastable atoms. It might be stated at this point that a metastable state of an atom, in accordance with the common understanding, is one in which an electron of the atom is in an orbit from which it does not immediately return to its normal unexcited state. However, in the metastable state, as also in the resonance state, the atom is capable of ionizing another atom of which the ionization potential is less than the potential of the said states of the first-mentioned atom. Accordingly, since the metastable and resonance potentials of the argon atoms are greater than the ionization potential of the mercury atoms, the argon atoms in these states immediately ionize the mercury throughout the space between the striations. The ionization of the mercury then produces a sudden large increase in conductivity throughout the space within the tube, so that the current through the tube increases as indicated by curve 9 in Fig. 3 at time t_1, and the voltage across it decreases as a result of the ballast resistance in series between the tube and the source of potential. The ensuing discharge is only partly self-sustaining, because it depends mainly on the two stage ionization of mercury. The upper metastable state of the mercury appears to be destroyed by the nitrogen. The lower metastable state of mercury however does not provide a process which is efficient enough to be self-maintaining at the lower voltage gradient which immediately follows the discharge, as indicated by p_1 in Fig. 5. As a result, the mercury deionizes and the current falls gradually to a lesser value again. Thereafter the voltage across the tube gradually increases, passing successively through the stages indicated by p_2, p_3, and p_4 in Fig. 5. At this level, the uniform voltage gradient through the tube becomes unstable again and changes precip-

itously to the sharply stepped one indicated by p_5, concurrently with the reformation of the striations indicated by s_5.

The function of the molecular impurity, which may, for instance, be nitrogen (N_2), carbon monoxide (CO), or hydrogen (H_2), is to raise the voltage gradient per striation high enough, through the destruction of the upper metastable state of mercury, from which ordinarily, most of the ions are produced, that the rare gas will be strongly excited and its metastable and resonance atoms produced. The rare gas must also have the quality that its metastable and resonance atoms have a potential or energy content greater than the ionization potential of the mercury. If this is not the case, the rare gas will not be able to ionize the mercury and the device will not operate; for instance, xenon will not do for a rare gas because its metastable potential is less than the ionization potential of mercury.

In the operation of my device as a source of flashing power, it is important that the current therethrough be maintained at relatively low values. If the current is allowed to rise much over 20 milliamperes in the particular tube which I have described, the molecular impurity will react chemically with other elements in the tube, or in other words, it will clean up and the flashing will cease.

I have found that it is possible to obtain considerable modulated electrical power with this device. For instance, flashing may be obtained with a discharge current through the device of 10 milliamperes and a voltage drop of approximately 300 volts, which represents 3 watts of flashing power. For such high currents, the frequency will be rather high. The modulated power may be drawn off from device 1 by means of either resistance or transformer coupling; and since the rise in the current waveform is very steep, high surge voltages may be obtained by means of transformer coupling.

Referring to Fig. 6, I have therein shown a circuit for obtaining a voltage modulated similarly to the current flowing through device 1. Device 1 is energized, as before, by the high potential source 5 in series with a ballast resistance 7. Inserted in series between cathode 3 of device 1 and the negative side of source 5, is a resistor 8, which is coupled to the control electrode 9 of a triode amplifying tube 10. Resistors 11 and 12 are provided in the cathode and anode connections to tube 10, and a continuous circuit provided through a suitable source of potential, as a tap point 13 in battery 5. A voltage of waveform similar to that illustrated by curve 3 of Fig. 3 may then be obtained at the cathode output terminal 14, or a like voltage of reversed polarity at the anode output terminal 15. In an application such as the present one, device 1 might profitably be reduced in size and made in a more compact form, such as a coil or helix.

Other uses and applications of my flashing discharge device may be made. It is evidently not restricted to the creation of flashes of light, or to the generation of voltage waveforms as described herein by way of non-limitative example only. Moreover, while certain specific embodiments have been shown and described, it is to be understood that various modifications may be made without departing from the invention. Thus, whereas I have shown the device herein operated on direct current, it may likewise be operated on alternating current and suitable thermionic electrodes provided for the different mode of operation. It will be appreciated that where the frequency of an alternating current source is substantially less than the frequency of the flashes, then the source is in effect unidirectional for periods substantially greater than the time interval required to develop the flashes or regions of unstable voltage gradient, and the mode of operation of the device during those periods is then essentially similar to what has been described. It is also possible to use cold cathodes, in which case, a higher anode voltage is required. The appended claims are, therefore intended to cover any such modifications coming 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. Apparatus for producing a flashing discharge, comprising an evacuated glass envelope having sealed into the ends thereof a pair of electrodes, said envelope containing an inert gas at a pressure of a few millimeters, a small quantity of mercury and a molecular gas chemically non-reactive with the other constituents within said envelope and at a pressure in the range from 0.1 to 20 microns, and a source of voltage and a ballasting impedance connected in series across said electrodes for developing, within said envelope, a current density of 0.01 to 2 milliamperes per centimeter square in order to establish localized regions of unstable voltage gradient therein, said source being unidirectional for periods substantially greater than the time interval required to develop said regions.

2. Apparatus for producing a flashing discharge, comprising an evacuated glass envelope having sealed into the ends thereof a pair of electrodes, said envelope containing an inert gas at a pressure of a few millimeters, said inert gas having a metastable state potential greater than the ionization potential of mercury, a small quantity of mercury, and a molecular gas chemically non-reactive with the other constituents within said envelope and at a pressure in the range from 0.1 to 20 microns, and a source of voltage and a ballasting impedance connected in series across said electrodes for developing, within said envelope, a current density of 0.01 to 2 milliamperes per centimeter square in order to establish localized regions of unstable voltage gradient therein, said source being unidirectional for periods substantially greater than the time interval required to develop said regions.

3. Apparatus for producing a flashing discharge, comprising an evacuated glass envelope having sealed into the ends thereof a pair of electrodes, said envelope containing an inert gas at a pressure of a few millimeters, said inert gas having a metastable state potential greater than the ionization potential of mercury, a small quantity of mercury, and a molecular gas in the range from 0.1 to 20 microns, said molecular gas being of a type such that it will not react chemically with the other elements contained within said envelope, and a source of unidirectional voltage and a resistance connected in series across said electrodes for developing, within said envelope, a current density of 0.01 to 2 milliamperes per centimeter square in order to establish localized regions of unstable voltage gradient therein.

4. Apparatus for producing a flashing discharge, comprising an evacuated glass envelope having sealed into the ends thereof a pair of electrodes, said envelope containing an inert gas at a pressure of a few millimeters, said inert gas having a metastable state potential greater than

the ionization potential of mercury, a small quantity of mercury, and a molecular gas in the range from 0.1 to 20 microns, said molecular gas being of a type such that it will not react chemically with the other elements contained within said envelope, and a source of unidirectional current and a resistance connected in series across said electrodes for developing, within said envelope, a current density of 0.01 to 2 milliamperes per centimeter square in order to establish an unstable stepped voltage gradient of sufficient intensity, within localized regions, to produce metastable atoms of said inert gas.

5. Apparatus for producing a flashing discharge, comprising an evacuated glass envelope having sealed into the ends thereof a pair of electrodes, said envelope containing argon at a pressure of a few millimeters, a small quantity of mercury and nitrogen at a pressure in the range from 0.1 to 20 microns, and a source of unidirectional current and a resistance connected in series across said electrodes for developing, within said envelope, a current density of 0.01 to 2 milliamperes per centimeter square in order to establish an unstable stepped voltage gradient of sufficient intensity, within localized regions, to produce metastable argon atoms, but of insufficient intensity to cause said nitrogen to clean up.

6. Apparatus for producing a pulsed voltage output comprising an evacuated glass envelope having sealed into the ends thereof a pair of electrodes, said envelope containing argon at a pressure of a few millimeters, a small quantity of mercury and nitrogen at a pressure in the range from 0.1 to 20 microns, a source of unidirectional current and a resistance connected in series across said electrodes for developing, within said envelope, an average current density of 0.01 to 2 milliamperes per centimeter square in order to establish an unstable stepped voltage gradient of sufficient intensity, within localized regions, to

produce metastable argon atoms, but of insufficient intensity to cause said nitrogen to clean up, and means connected to said source for translating the modulations of said current to corresponding voltage waveform.

7. Apparatus for producing a non-sinusoidal periodic current of generally sawtooth waveform from a source of unidirectional potential comprising an elongated, evacuated glass envelope having an anode electrode and a cathode electrode in opposite ends thereof, said envelope containing an inert gas at a pressure of a few millimeters, a small quantity of mercury and a molecular gas chemically non-reactive with the other constituents within said envelope and exerting a pressure within the range from 0.1 to 20 microns, and a source of unidirectional potential and a resistance connected in series circuit across said electrodes, the potential of said source and the proportions of the constituents within said envelope being such as to develop an average current density of 0.01 to 2 milliamperes per centimeter square thereby to cause the periodic development of localized regions of unstable voltage gradient within said envelope, whereby the current in said circuit is modulated to produce said waveform.

CARL KENTY.

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