Nov. 12, 1935. T. E. FOULKE 2,020,723

ELECTRIC GASEOUS DISCHARGE DEVICE

Filed May 20, 1935

Fig. 1

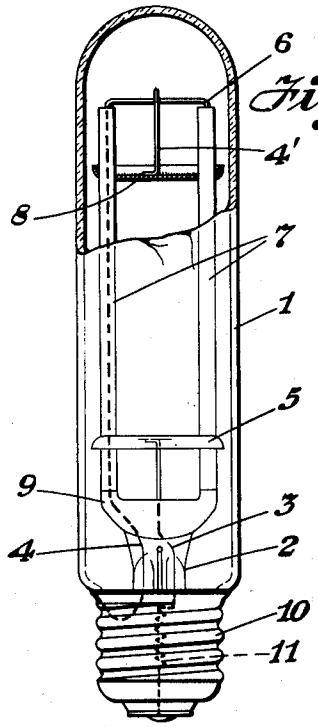


Fig. 2

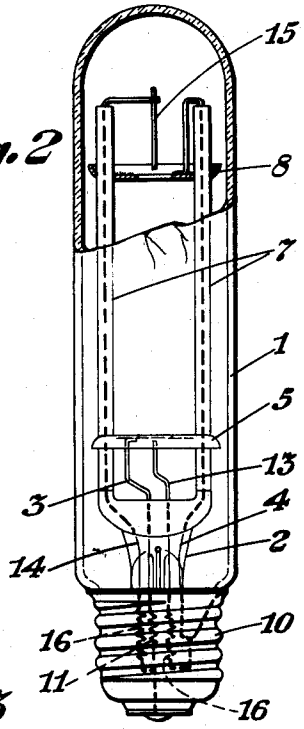


Fig. 3

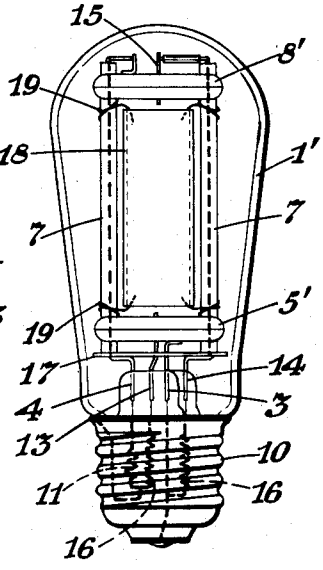


Fig. 4

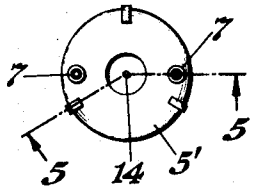
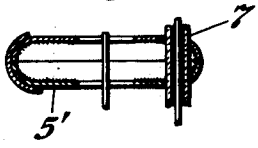


Fig. 5



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ELECTRIC GASEOUS DISCHARGE DEVICE

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8 Claims. (Cl. 176—122)

The present invention relates to electric gaseous discharge devices generally, and in particular to devices having a positive column discharge.

A particular object of the present invention is to provide a gaseous discharge device in which the luminous positive column occupies the entire distance between the electrodes. Another object of my invention is to provide an efficient light source. Still another object of my invention is to provide a novel source of ultra violet light. Another object of my invention is to provide light of different desired colors from a gaseous discharge. Still another object of my invention is to provide a gaseous discharge device of the positive column type which will start upon a relatively low potential. Another object of my invention is to provide a device which will have a low cathode fall. Still another object of my invention is to provide a device which will have a relatively high discharge maintaining potential. A further object of my invention is to provide a gaseous discharge device which will have a long useful life. Still other objects and advantages of my invention will appear from the following detailed specification or from an inspection of the accompanying drawing.

The invention consists in the new and novel structure hereinafter set forth and claimed.

In all electric gaseous discharge devices of the positive column type as heretofore constructed the discharge therein has been more or less sharply divided into well recognized regions or zones. Thus immediately adjacent to the cathode there is the well known Crookes dark space. This is followed by a luminous zone known as the negative glow. The next zone is entirely dark and is known as the Faraday dark space. The remaining part of the discharge is highly luminous and is known as the positive column. No way has been known heretofore to obtain a positive column without also having all of these other zones. In a relatively long lamp this has been of little importance due to the fact that these other zones then occupy but a small proportion of the total path of the discharge. As the discharge path is shortened, however, this proportion rapidly increases, so that where the electrodes are only separated by two inches, for example, as in a bulb type lamp, the positive column may occupy a half or less of the discharge path, depending upon the pressure. This not only gives a rather displeasing effect, but also makes it impossible to obtain a favorable efficiency from such a device when used as a light source. On alternating current this condition is somewhat masked in some cases by the reversal of the discharge, but even here the discharge path has very noticeable variations in intensity therein.

The greatest cause of these objectionable features is the Faraday dark space. This is a zone in which there is such a high concentration of ions and electrons as compared to the rest of the discharge path that diffusion alone is often sufficient to carry the discharge current. Thus this zone is always one in which the electric field is small. As a result the electron speeds are so low in this region that light producing excitation cannot occur therein, this accounting for the complete absence of light in this zone. While this zone has always been objectionable in short positive column discharge lamps, and has heretofore prevented the production of a satisfactory bulbous lamp of this type, it has been generally accepted that the positive column could not exist without it.

I have now discovered, however, that this Faraday dark space is eliminated in a discharge device having a novel structure of my invention. According to my invention the electrodes of a positive column discharge device are so arranged that the cathode glow occurs at a point thereon which faces away from the adjacent portion of the discharge path. I have found that this has the effect of restricting the diffusion of ions and electrons from the negative glow around the electrode into the discharge path, and thus so reduces the electron and ion concentration adjacent to the cathode that there is no Faraday dark space observable, the positive column extending all the way to the cathode with this novel construction. In the case of mixed gases of the type disclosed in my Patent 1,990,175, granted February 5, 1935, wherein there is a trace of a gas having an ionizing potential which is less than a metastable potential of the principal gas, this structure also prevents passage of resonance radiations from the negative glow into the discharge path, and thus eliminates the ionization which would be produced by these radiations in the zone adjacent to the cathode which would otherwise be occupied by the Faraday dark space.

When the discharge path is thus completely shielded from the negative glow, however, the voltage required to initiate a discharge between the electrodes is relatively high. I have discovered that this difficulty is overcome, especially in those cases where a mixture of gases such as hereinbefore referred to is employed, by provid-

ing a negative glow of controlled intensity which is exposed to the discharge path. This result is most conveniently attained by providing an auxiliary cathode of small size in a position which is exposed to the discharge path, as for example, behind a suitable opening in the anode. The negative glow at this auxiliary cathode produces ionization in the discharge path by diffusion and as a result of the beam of resonance radiations, and thus produces a conductive path of rather restricted cross section between the main electrodes. As a result the discharge is initiated between these electrodes at an extremely low potential. The increase in the concentration of electrons and ions along this beam tends, of course, to reestablish the Faraday dark space, but by limiting the current in this auxiliary discharge to a small fraction of that in the main discharge this effect is not noticeable during operation of the lamp, the sole apparent effect being the reduction in the breakdown voltage and a tendency for the positive column to be more or less confined to the neighborhood of this beam where the conduction is best.

I have found that this latter effect may be availed of in a novel manner to produce light of various desired colors. Thus practically all of the gases employed emit some ultra-violet radiation which is utilized to produce light of a color other than that characteristic of the discharge by placing a tubular screen of fluorescent material about the discharge path between the electrodes. Due to the great difference in conduction between the path within this screen and that external thereto, as a result of the beam path extending therein, the positive column is entirely confined within said screen, even though the latter is not in contact with the electrodes. Hence the light emitted by the lamp is entirely determined by the nature of the fluorescent screen. For this use it is, of course, desirable to use a gaseous atmosphere, such as xenon or mercury vapor, which provides an appreciable amount of ultraviolet radiation.

In most cases the light emitted by the negative glow is different both from that emitted by the positive column and from that emitted by the fluorescent screen, and hence this light may be objectionable. I have found that this difficulty is overcome by making the cathode hollow, with the glow completely confined therein, so that the only light emitted by the device comes from the positive column or from the fluorescent screen, as desired. In thus enclosing the glow, however, I have found that it is essential that the opening into the hollow cathode should be large enough to permit passage of the discharge current without formation of a secondary glow at the opening, since such a glow will produce such a strong ion and electron concentration in the adjacent discharge path that the Faraday dark space is reintroduced and in some cases the entire discharge path between the electrodes is thus rendered dark. The same precaution is to be observed where the discharge passes around the edge of the cathode, since if the space between the cathode and the tube wall is too constricted a glow will form on this space which will render the discharge path to the anode dark.

Any suitable gaseous atmosphere is provided for these devices, such as a rare gas or mercury vapor. In general, however, several factors determine the atmosphere which is employed. Thus where it is desired to obtain considerable ultraviolet radiation I prefer to use mercury vapor. With pure mercury vapor, however, at the pressure existing at room temperature, a relatively high voltage is necessary to initiate the discharge, and at this low pressure the cathode fall would likewise be high after the discharge has been initiated, with a resultant destructive effect upon the cathode. Hence mercury vapor alone is not desirable. By adding to this mercury vapor a gas, such as argon, however, as disclosed by my patent hereinbefore referred to, the breakdown potential can be reduced to an extremely low value in those devices which have an auxiliary discharge which irradiates the mixture. To obtain this result it is necessary, however, that the mercury vapor present should be within the range of more than .01% and less than 1%, and preferably of the order of 0.1% of the argon-mercury mixture. This limits the pressure of the argon to approximately 1.5 m. m., due to the fact that the mercury vapor pressure, which is determined by the room temperature, is only .0013 m. m. at 21° C. At such a pressure, however, the cathode fall is high in a device using cathodes of the cold type, and the discharge is very destructive of the cathode as a result thereof. Hence such a gas mixture is incompatible with a long life lamp of high efficiency. I have now found, however, that this difficulty can be overcome by adding neon to the argon-mercury mixture. This neon lowers the cathode fall, the maximum effect being obtained when the argon is approximately 5% of the neon. Thus a neon pressure of the order of 30 m. m. has been found to be ideal in combination with 1.5 m. m. of argon and mercury vapor at room temperature. The light emitted by a positive column discharge in such a gas mixture is exceedingly rich in the ultraviolet region, the 2537 Å. line being very strong. In addition the cathode fall is low, so that the device has a long life, while the maintaining potential is relatively high, so that a large proportion of the energy is used in the positive column, even in a relatively short bulb-type device. This latter feature is, of course, conducive to high luminous efficiency, especially in the ultraviolet region.

I have found that this novel result arises from the fact that when two gases, one of which has a metastable potential which is higher than the ionizing potential of the other, are intermixed there are two different percentage ranges where resonance radiations of the gas with higher metastable potential can efficiently produce ionization of the other gas. Thus there is a critical range where the gas of lower ionizing potential constitutes from more than .01% to less than 1.0% of the other gas, and another range where the gas of lower ionizing potential constitutes of the order of 4 to 6% of the other, when these resonance radiations produce unexpectedly marked results.

In either of these ranges an auxiliary discharge in the gas mixture produces resonance radiations of the gas of higher metastable potential. These radiations excite atoms of this gas, and many of these excited atoms in turn get into a metastable state as a result of collisions. Upon collision between these metastable atoms and an atom of the gas of lower ionizing potential, ionization of the latter may and frequently does result, the probability of ionization being greater the smaller is the difference between the potential of the metastable atom and the ionizing potential of the atom with which it collides. In the first range cited above this process proceeds throughout the device, at considerable distances from the auxiliary

cathode, as disclosed in my patent hereinbefore referred to, due to the penetration of the resonance radiations, and thus greatly lowers the breakdown potential of the device. With the larger concentration of the gas of lower ionizing potential which is present in the second range, however, the radiations do not penetrate very far, and the ionization produced is thus localized in the immediate vicinity of the cathode. The copious ionization thus produced adjacent to the cathode gives a low cathode fall and greatly increases the life of the cathode. Each of these results is desirable, but heretofore it has been necessary to give up one or the other thereof, since it is obviously impossible to have these two different ranges present at the same time.

I have now discovered, however, that by using a gaseous atmosphere having three component parts, as the neon-argon-mercury atmosphere hereinbefore described, with the gas of the lowest ionizing potential constituting from more than .01% to less than 1.0%, and preferably of the order of .1 to .2%, of another gas having a higher metastable potential, while the sum of these two gases constitutes from 4–6% of another gas having a higher metastable potential than the ionizing potential of either of the first two gases, the good results obtainable with use of both of these ranges are obtainable for the first time in the same device. With such a device the auxiliary discharge produces the resonance radiations of each of the two gases of higher metastable potential. Those of the gas of highest concentration are absorbed by atoms of that gas in proximity to the cathode and result in ionization at that point of atoms of the other gases, and particularly of the gas of intermediate concentration, with a resultant low cathode fall. The resonance radiations of the gas of intermediate concentration pass far down the discharge path, however, and there excite the atoms of that gas, some of which pass into a metastable condition as a result of collisions, and then ionize atoms of the gas of lowest concentration upon collision therewith. Thus these radiations result in a low breakdown potential due to the ionization produced throughout the discharge path. With this novel combination the gas of intermediate concentration thus cooperates with each of the other gases to produce different effects which are essential to the operation of a successful device.

While I have hereinbefore illustrated the application of this new discovery by use of a mixture of neon with argon and mercury it will be obvious that this is only one example of many suitable combinations. Thus the neon may be replaced with helium, although in this case the cathode fall will be slightly higher due to the decreased probability of ionization when a helium metastable atom collides with an argon atom. Or the neon can be only partly replaced by helium if desired. Likewise the argon can be entirely or in part replaced with krypton. So also the mercury can be replaced by other vapors or gases, such as the vapor of cadmium, zinc or the alkali metals. Various other gases or vapors may also be used in similar combinations of three, provided only that their metastable and ionizing potentials and relative proportions meet the rule which has been set forth hereinbefore.

With the relatively high potential across the positive column a discharge will occur between the inleads of my novel device if they are sealed in through a single pinch seal, unless some special precaution is taken to prevent it. Thus these leads may be completely enclosed within insulating sleeves or coatings. This tends, however, to give an unsightly appearance to the device. I have now found that the same result is obtained without this unsightliness by using a washer of mica or the like which is opaque to the resonance radiations of the gases mounted about the inleads in such a position as to shield the leads from the cathode glow. This shield not only keeps the radiations from the gas space about the leads, and thus raises the breakdown potential therebetween above the potential available, but also prevents the sputtering of active material from the cathode onto these leads, whereby the breakdown potential therebetween would be reduced. Thus this shield prevents the formation of a discharge between these leads adjacent to the seal throughout the long useful life of the device.

For the purpose of illustrating my invention I have shown several embodiments thereof in the accompanying drawing, in which

Fig. 1 is an elevational view, in part section, of an electric gaseous discharge device of the positive column type,

Fig. 2 is a similar view of a modification of the structure of Fig. 1,

Fig. 3 is an elevational view in part section of a modification of the structure shown in Fig. 2,

Fig. 4 is a plan view of the electrode assembly used in the device shown in Fig. 3, and

Fig. 5 is a sectional view of this electrode assembly, taken on the line 5—5 of Fig. 4.

As shown in the drawing, with particular reference to Fig. 1 my novel lamp has a tubular envelope 1 of glass or the like having a reentrant stem 2 at one end thereof. Said stem ends in a pinch seal through which are sealed a pair of inleads 3 and 4. The inlead 3 extends within said envelope 1 for a short distance and to the end thereof is welded an electrode 5 of nickel or the like in a plane normal to the axis of said envelope. Said electrode is preferably circular in shape with the edge thereof turned over toward the adjacent end of the envelope 1, the diameter of said electrode being substantially less than that of said envelope. The inlead 4 and a support wire 6 which is symmetrically sealed into the aforesaid pinch seal extend longitudinally within said envelope 1 and pass through insulating tubes 7 of porcelain or the like, to a point near the opposite end of said envelope, where they are bent toward each other and welded together. The tubes 7 pass through holes which they preferably just fit in the electrode 5 and a second electrode 8 of similar nature, the latter electrode being supported at a point 2 inches from the electrode 5 by a lead 4' welded thereto and to the transverse section of the inlead 4. An extremely rigid electrode structure is thus produced which permits spacing of two inches and more between the electrodes 5 and 8 without liability of dislocation during handling or shipment. The back faces of said electrodes 5 and 8 are coated with a substance of low work function, such as an alkaline earth metal, while the opposed faces are coated with a substance, such as finely divided aluminum, which will permanently confine the glow to the back surface of the electrodes. A preferred method of coating these surfaces is disclosed in my Patent 1,965,589, granted July 10, 1934, this method producing a coating having both an extremely low work function and a long useful life, and comprising a mixture of barium and strontium intermixed with oxygen. The inlead 4 and the support wire 6 are enclosed within

a suitable insulating cement 9 between the stem 2 and the tubes 7 in order to prevent a discharge centering thereon.

The envelope 1 is filled with any suitable gas such as neon or argon at a pressure of the order of 10–40 m. m. of mercury, the exact pressure being immaterial so far as the present invention is concerned. A suitable screw base 10 is affixed to the envelope 1 and contains a resistance 11 of several thousand ohms. The inlead 3 is connected to the tip of said base through said resistance, while the inlead 4 is connected directly to the sleeve of said base.

When a suitable potential, of the order of 300 volts A. C., is applied to the lamp of Fig. 1 the electrodes 5 and 8 alternately serve as cathodes. The cathode glow, however, is confined to the portion of each of said electrodes which is away from the other with the unexpected result that the positive column extends all the way from one electrode to the other with a uniform luminosity throughout its length. This device will, of course, also operate on D. C.

The device of Fig. 2 is somewhat similar to that of Fig. 1 but is designed to start upon application of a lower voltage. In this structure there are four inleads 3, 4, 13 and 14 which extend through the pinch seal. The inlead 3 goes to the lower electrode 5, the inlead 4 passes through one of the insulating tubes 7, and then is bent downwardly to support the electrode 8. Said electrodes are the same as in Fig. 1 save that they have an additional central hole therein of the order of a quarter of an inch in diameter. The inlead 13 extends to a point opposite this hole in the electrode 5, where it serves as an auxiliary electrode, while the inlead 14 extends through the other tube 7 and carries on its end an auxiliary electrode 15 which is opposite the central opening in the electrode 8. The electrodes 5 and 8 are coated in the same way as in the structure of Fig. 1, and during the process of producing the alkaline earth metal on the backs of these electrodes the adjacent auxiliary electrodes 13 and 15 have a similar coating produced thereon by sputtering of the active material from the main electrodes in a well known manner. The inlead 3 is connected to the tip of the base 10 through the resistance 11 and the inlead 4 is connected to the sleeve thereof, as before. In addition the inleads 13 and 14 are connected to the sleeve and tip of said base, respectively through similar high resistances 16, of the order of 20,000 ohms. With this construction the envelope is filled with any suitable gas, such as used in the device of Fig. 1, or with a mixture of gases such as the two component gas disclosed in my patent hereinbefore referred to. I prefer, however, to use a three component gas, as described hereinbefore, in which one gas constitutes of the order of .1 to .2% of another gas having a metastable potential which is higher than the ionizing potential of the first mentioned gas, and these two gases in turn comprise 4–6% of another gas whose metastable potential is higher than the ionizing potential of the first two gases. Thus in a preferred case I use mercury vapor at room temperature, 1.5 m. m. of argon and approximately 28.5 m. m. of neon.

In the operation of this device as soon as a suitable alternating current potential is applied a discharge occurs between each of the main electrodes 5 and 8 and the adjacent auxiliary electrodes 13 and 15. On alternate half cycles these auxiliary electrodes serve as cathodes and are covered with a cathode glow. The limited radiations from these glows pass out through the openings in the adjacent main electrodes in the form of a more or less constricted beam, and these radiations produce excitation of the atoms along the discharge path. Many of these excited atoms get into a metastable state as a result of collisions and these atoms in turn collide with atoms of the gas of lower ionizing potential, producing ionization of the latter. This results in a beam path of high conductivity between the main electrodes 5 and 8, whereupon the main discharge flows therebetween, the positive column occupying this entire distance due to the fact that no radiations from the cathode glow on these electrodes 5 and 8 escape into the path between the electrodes. In the mercury-argon-neon mixture preferred the cathode glow is the reddish-orange of neon while the positive column is the blue of mercury and is especially rich in the 2537° A. line. This positive column follows a more or less restricted path directly along the beam path between the electrodes. In a device having the preferred structure described this discharge will start upon a potential of 100 volts, D. C., or 70 volts A. C., and with a discharge current of 20 m. a. the discharge maintaining voltage is of the order of 95 volts D. C. or 90 volts A. C. Due to the presence of the neon the cathode fall is very low, however, most of this voltage being used in the positive column, with an ensuing relatively high luminous efficiency.

The device of Fig. 3 has a conventional bulb 1' of glass or the like, approximately 1¾ inches in diameter at the largest point. The electrode assembly is similar to that of Fig. 2, except that in this case each of the electrodes 5' and 8' is made of two identical members held together by suitable welded clips to form a hollow electrode, as best shown in the detail Figs. 4 and 5. The inside surface of these electrodes is coated with barium or the like, as before, and the outer surface of these electrodes is likewise coated with aluminum. In place of the cement 9 of the other structures, however, there is here used a mica disc 17 through which all of the inleads pass near the reentrant stem. The insulating tubes 7 rest upon this mica disc. A tube 18 of glass or the like of say ⅝ inch inside diameter is placed between the electrodes 5' and 8' with its axis concentric with that of the bulb 1', said tube being held in place by the clips 19 on the tubes 7. This tube, which serves as a mantle, either of itself consists of a glass which is fluorescent under the rays of the discharge, or else is coated on the inside with a fluorescent material. It is not essential that this tube be tight to the electrodes, for the beam from the auxiliary cathodes makes the conductivity so much higher within said tube that the discharge occurs entirely therein in any case. The bulb 1' is, of course, filled with any of the gases or gas mixtures hereinbefore described.

The operation of this lamp is similar to that of Fig. 2, except that due to the presence of the tube or mantle 18, the energy of the ultraviolet rays is converted to visible radiations, and the luminous efficiency of the device increased. Thus with the mercury-argon-neon mixture described, using a fluorescent coating of calcium tungstate, for example, the lamp gives a soft blue color, and the overall luminous efficiency is of the order of 2.5 lumens per watt, while the efficiency of the column itself is approximately 40 lumens per watt. Other colors can be ob-

tained by using coatings such as willemite, zinc orthosilicate, calcite, some of the sulphides, uranium glass and the like. Since all of the light is emitted as a desired color in any of these cases a very favorable efficiency is thus attained as compared to other sources of colored light.

The use of the mantle 18 affords a convenient way of obtaining this luminescence, since it permits the use of various glasses and coatings regardless of their ability to be fused to the inleads, and it likewise avoids changes in the fluorescent material which might occur in the fusion process. It is to be understood, however, that the bulb itself can consist of such a glass, or can be so coated, if it is desired. Likewise by making the envelope itself of quartz or an ultraviolet transmitting glass the lamp may be used as an ultraviolet generator for any purpose desired, the mantle here being omitted, of course.

The mica disc 17 as here used prevents resonance radiations from the discharge penetrating to the space about the seal, and thereby prevents the ionization of the gas which would permit the initiation of a discharge between the inleads at the applied potential. It likewise prevents barium or other active material from the cathodes being sputtered onto these leads and thus reducing the breakdown potential therebetween.

Due to the cathode glow of a discharge in the device of Fig. 3 being confined within the hollow cathodes 5' and 8' the light therefrom is concealed, and the light emitted by the lamp is therefore entirely determined by the visible lines of the positive column and the fluorescence of the mantle 18.

While I have described my invention by reference to certain specific embodiments thereof it is to be understood that it is not limited thereto, but that various changes, omissions and substitutions, within the scope of the appended claims, may be made therein without departing from the spirit of my invention. In particular it is to be understood that thermionic cathodes can be substituted for the cold cathodes shown, with a resulting increase in length of the column for a given operating voltage.

I claim as my invention:

1. An electric gaseous discharge device comprising a sealed envelope containing a gaseous atmosphere, electrodes sealed therein, said electrodes being so spaced that a positive column discharge can occur therebetween, and means to confine the cathode glow on said electrodes to a portion thereof which is not exposed to the discharge path therebetween, whereby said device operates with a positive column discharge of substantially uniform luminosity along the entire path between said electrodes.

2. An electric gaseous discharge device comprising a sealed envelope containing a gaseous atmosphere, electrodes of the cold cathode type sealed therein with a considerable separation therebetween, the opposing faces of said electrodes being coated with a glow resisting material, while the backs of said electrodes are coated with an alkaline earth substance of low work function, whereby said device operates with a positive column discharge of substantially uniform luminosity along the entire path between said electrodes.

3. An electric gaseous discharge device comprising a sealed envelope containing a gaseous atmosphere comprising a gas having a given metastable potential intermixed with a trace of a gas of lower ionizing potential, electrodes sealed therein with a considerable separation therebetween, means to confine the cathode glow on said electrodes to a portion thereof which is not exposed to the discharge path between said electrodes, and means comprising an auxiliary electrode to produce a controlled beam of radiations from a cathode glow along said discharge path to reduce the breakdown voltage therebetween, said device operating with a positive column discharge of substantially uniform luminosity throughout the entire path between said electrodes.

4. An electric gaseous discharge device comprising a sealed envelope containing a gaseous atmosphere in which a positive column discharge emits ultraviolet radiations, electrodes sealed therein with a considerable distance therebetween, and a mantle of fluorescent material mounted between said electrodes and enclosing the discharge path therebetween.

5. An electric gaseous discharge device comprising a sealed envelope containing a gaseous atmosphere, said atmosphere comprising three component parts in which one gas comprises more than .01% and less than 1% of another gas having a metastable potential which is higher than the ionizing potential of the first gas, and in which the sum of the two previously mentioned gases constitutes from 4–6% of the third gas which has a metastable potential higher than the ionizing potential of the second mentioned gas, electrodes sealed into said envelope, and an auxiliary electrode within said envelope so disposed as to irradiate the discharge path between said first mentioned electrodes with rays from a cathode glow discharge.

6. An electric gaseous discharge device comprising a sealed envelope containing a gaseous atmosphere substantially comprising saturated mercury vapor at room temperature, 1.5 m. m. of argon and 28.5 m. m. of neon, electrodes sealed therein with a considerable distance therebetween, and an auxiliary cathode so disposed with respect to one of said electrodes as to irradiate the discharge path between said electrodes with rays from a cathode glow discharge.

7. An electric gaseous discharge device comprising a sealed envelope containing a gaseous atmosphere substantially comprising saturated mercury vapor at room temperature, 1.5 m. m. of argon and 28.5 m. m. of neon, electrodes sealed therein with a considerable distance therebetween, said electrodes being coated on their opposing faces with a glow resisting material and on their backs with a substance of low work function, an opening in each of said electrodes, and an auxiliary cathode back of each opening, whereby the discharge path between said electrodes is irradiated with a beam of controlled intensity from said cathodes.

8. An electric gaseous discharge device comprising a sealed envelope containing a gaseous atmosphere substantially comprising saturated mercury vapor at room temperature, 1.5 m. m. of argon and 28.5 m. m. of neon, electrodes sealed therein with a considerable distance therebetween, said electrodes being coated on their opposing faces with a glow resisting material and on their backs with a substance of low work function, an opening in each of said electrodes, an auxiliary cathode back of each opening, whereby the discharge path between said electrodes is irradiated with a beam of controlled intensity from said cathodes and a mantle of fluorescent material extending between said electrodes and enclosing the path of said beam.

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