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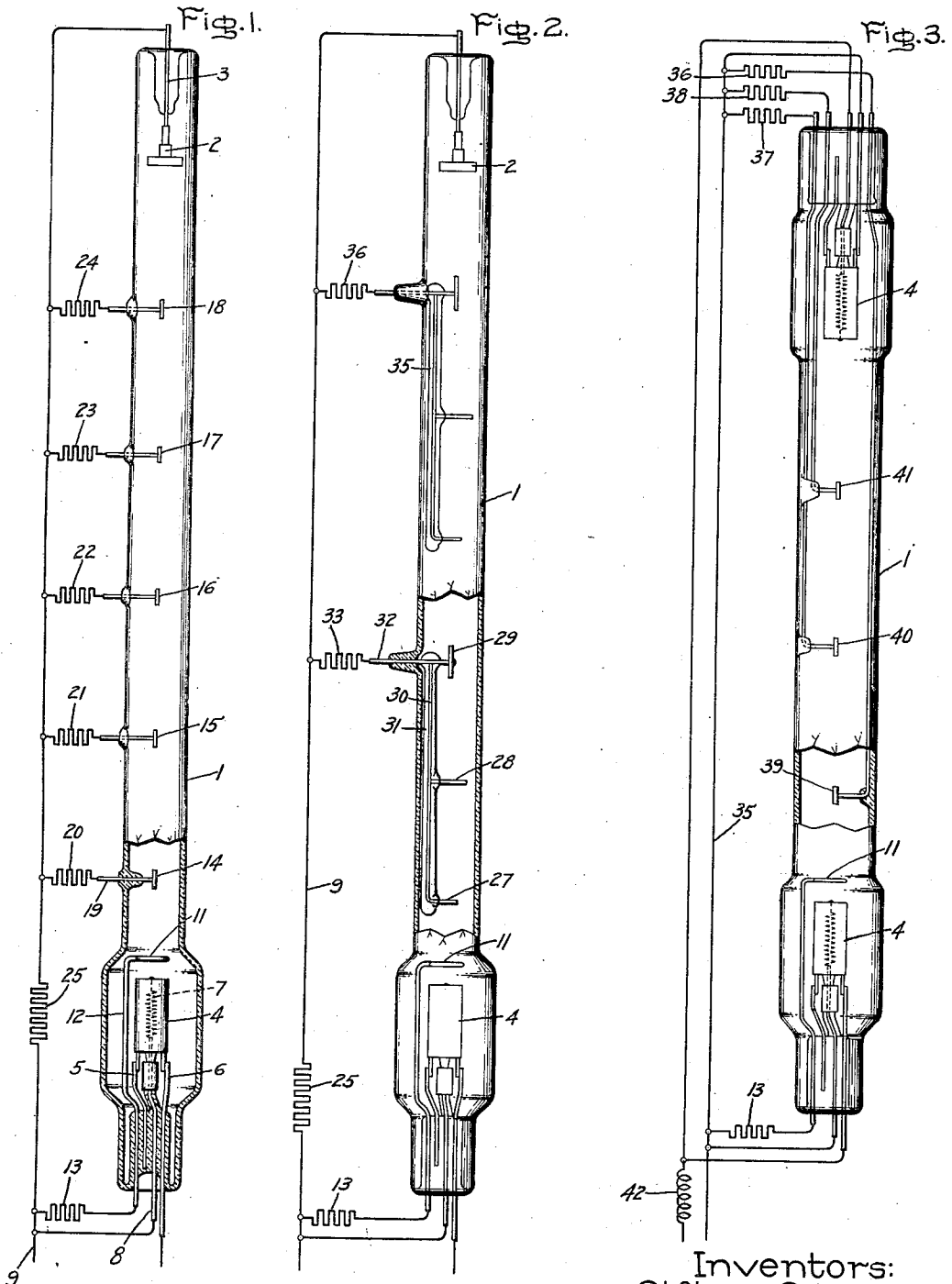
C. G. FOUND ET AL

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POSITIVE COLUMN DISCHARGE DEVICE

Filed April 13, 1931

2 Sheets-Sheet 1



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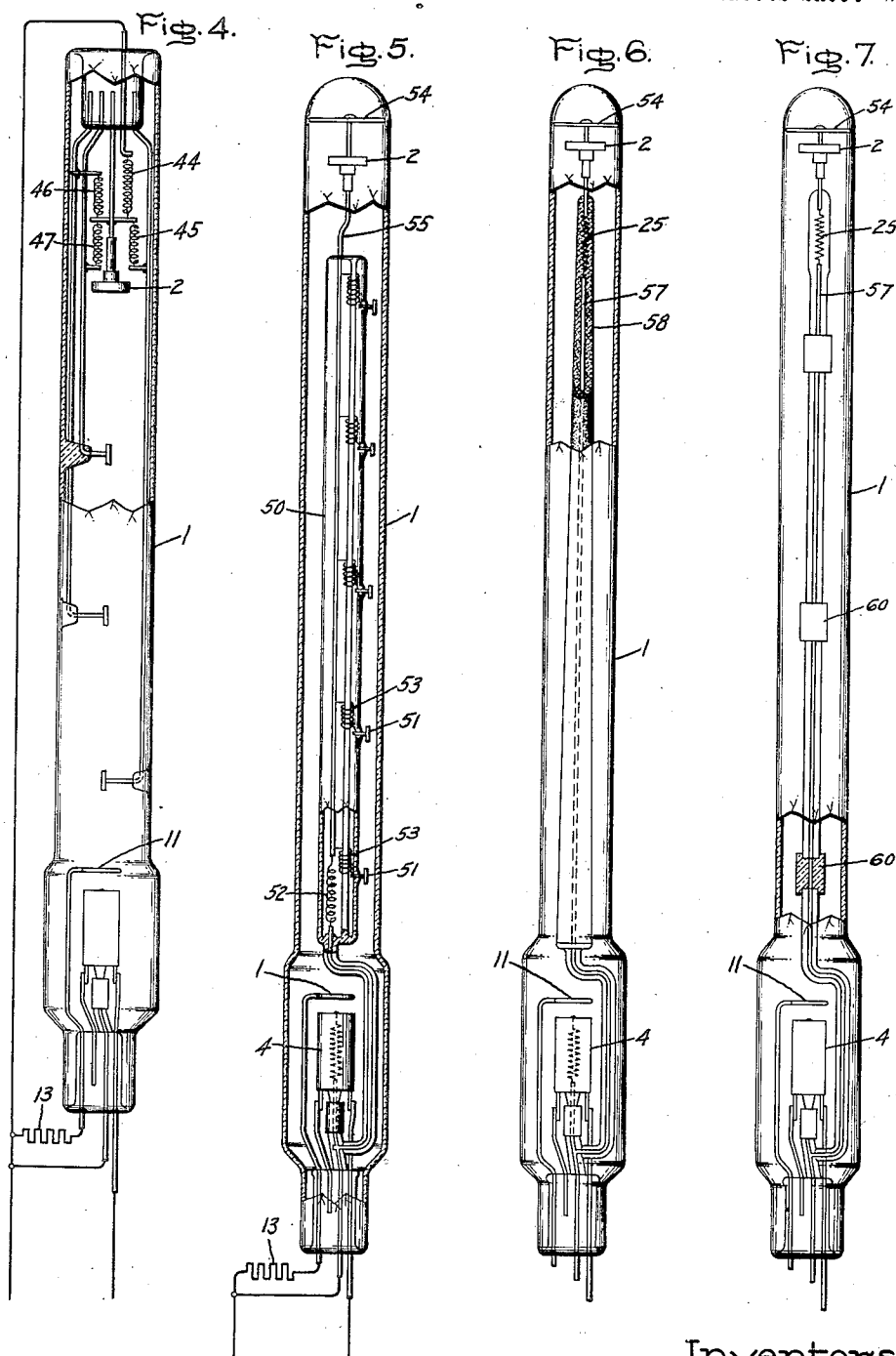
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POSITIVE COLUMN DISCHARGE DEVICE

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10 Claims. (Cl. 176—124)

Our invention relates to positive column discharge devices and particularly to devices of this character which are adapted to be used as lamps on low voltage circuits.

5 One object of our invention is the provision of a positive column discharge device having improved means by which the operation of the lamp is started. Another object of our invention is the provision of a device of this character which shall exhibit good regulation. A further object is the provision of an improved unitary lamp structure the light from which combines the spectrum of a positive column discharge and that of an incandescent solid.

15 When a low voltage, for example a voltage of 110 or 220 volts, is applied between an anode and an electron emitting cathode arranged in a columnar tube containing a vapor, such as sodium or mercury, or a gas, such as argon, neon, helium, krypton, or xenon, which when subjected to a discharge becomes luminous, a discharge takes place only when the anode is in close proximity to the cathode; that is, when the distance is equal to only a few diameters of the tube. In order to cause starting of a longer tube various starting means have been employed in the past such as the use of a high frequency coil near the tube or the application of a high voltage kick.

25 We have found that if a discharge is produced within the tube between the cathode and an anode in one portion of the tube, a discharge may be started to another anode arranged at a greater distance from the cathode than the first anode. We have found that the distance at which such a discharge to the second anode can be started depends upon the current in the first discharge and the potential difference between the second anode and the space at the end of the first or primary discharge. Our experience indicates that there are two processes which contribute to the starting of a discharge in such a tube at a distance from a discharge already operating; first, a diffusion of electrons, positive ions, excited atoms or radiation from the discharge to the region of the second anode; second, an ionization by collision phenomenon by which the electron concentration adjacent to the second anode is increased to a point where the discharge becomes an arc. We have found that by arranging one or more auxiliary anodes in the tube at proper distances between the cathode and the main anode a discharge may be started along the tube by going successively from one anode to the next at a greater distance. If the anodes are placed at proper distances, such a discharge may be started

by using small auxiliary currents of the order of 1 to 10 milliamperes. In the case of a tube containing an inert gas such as has been mentioned above which has a negative volt-ampere characteristic, it is necessary to increase the auxiliary currents as the discharge progresses along the tube in order to maintain as high a voltage as possible between the discharge and the next anode. If mercury is used in the tube, the spacing of the auxiliary anodes may be greater as a result of the greater increase by ionization by collision in mercury.

In the above we assumed that an initial discharge had been started between the cathode and an intermediate or auxiliary anode. In order that there shall be such an initial discharge it is important that this auxiliary anode shall be so placed with reference to the cathode that a discharge will take place therebetween when the operating voltage is applied. The small discharge current although only a few milliamperes in value plays a very important part in the subsequent starting of the tube. We have found that the resonance radiation from this discharge in traveling along the tube from the discharge is instrumental in the formation of metastable atoms of the gas employed. Such metastable atoms possess a high potential energy which makes them capable of producing a secondary electron emission from any material which has a work function less than the energy of the metastable gas atom with which it collides. As a result of this electron emission by metastable atoms, the tube space beyond the discharge is rendered more conducting and a discharge takes place at the lower voltages. We have found for example that it required 410 volts to initiate a discharge between two cold electrodes separated by about 1 mm. and placed 25 cm. from the cathode chamber when no discharge was passing from the cathode. When a discharge of 100 m. a. passed between the cathode and an auxiliary anode near the cathode, a voltage of only 118 volts was required to start a discharge between the two cold electrodes although there was no electrical connection between the cathode discharge and the electrodes. Thus the radiation from the discharge was instrumental in reducing the starting voltage. This has also been verified by means of a shutter employed to shut off the radiation.

Our present invention based upon the above will be better understood from the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

Referring to the drawing, Fig. 1 shows a posi-

tive column discharge device constituting one embodiment of our invention; Fig. 2 illustrates a modified form; Fig. 3 shows modification of the form shown in Fig. 1 having a cathode at each end adapting the device for full wave a. c. operation; Fig. 4 is a modified form of the device shown in Fig. 1 having the resistances of the auxiliary anodes arranged within the gas-filled envelope and adapted to become incandescent; and Figs. 5, 6 and 7 illustrate further modified forms.

In Fig. 1 we have shown a positive column discharge device having the elongated envelope 1, preferably tubular in form, and constructed of light transmitting material such for example as glass or quartz. The tube is filled for some purposes with an inert gas or gases, such as argon, neon, helium, krypton, or xenon, which gases become luminous when subjected to an electric discharge. The pressure of gas or gases in the tube may vary from .5 mm. to 10 mm. of mercury; we prefer however to use from 1 to 2 mm. of gas. For other purposes the tube may be filled with mercury vapor but when mercury is used we prefer to add a small quantity of one of the inert gases mentioned above as in these gases the radiation phenomenon is stronger than in mercury alone. In such cases the discharge is carried initially by the admixed gas until the temperature and therefore the vapor pressure of the mercury is increased to a point where the mercury takes over the discharge. In the case of mercury alone, radiation at room temperature is small so that in starting a mercury filled tube by means of auxiliary anodes we are dependent upon the diffusion of electrons and positive ions from one auxiliary anode to the next and upon the formation of new ions between those auxiliary anodes due to the electric field between them.

In the upper end of the tube is the main anode 2 which is supported by the conductor 3 sealed into the end of the tube and forming a terminal of the device. In the lower end of the tube is mounted the cathode 4 which is illustrated as a cylinder having supports 5 and 6 which are anchored into the tube. Support 6 is of conducting material and extends through the tube forming another terminal of the device. Cathode 4 preferably is constructed of nickel having a barium carbonate coating and having the heating coil 7 arranged within it, one end of the heating coil being connected with the cylinder and the other being connected with the terminal 8 which connects with the conductor 9 leading to the main anode 2. Conductors 6 and 9 are adapted to be connected with a suitable source of low voltage for the operation of the device. Arranged in the tube between the cathode and anode 2 and adjacent to the cathode is the starting or auxiliary anode 11 which preferably is in the form of a ring whose support 12 is sealed in the end of the tube and is connected with the conductor 9 by means of the resistance 13. Arranged at intervals between the auxiliary anode 11 and the main anode 2 are other auxiliary anodes 14, 15, 16, 17 and 18 shown as flat plates supported by conductors 19 sealed into the wall of the tube and connected respectively with the conductor 9 by resistances 20, 21, 22, 23 and 24. Inserted in series with the conductor 9 leading to the main anode is the ballast resistance 25, which resistance may, for example, have a value of 20 ohms while resistances 13, 20, 21, 22, 23, 24 may have values respectively of 10,000; 5,000; 2,000; 1,000; 500 and 100 ohms.

By connecting the several auxiliary anodes

with the conductor 9 through separate or individual resistances the current passing to one anode does not cause a voltage drop to the anode next beyond, hence each auxiliary anode starts with the maximum voltage available, namely, the line voltage. For example, with an applied D. C. line voltage of 110, the first auxiliary anode 11 will start and draw a current of about 7 milliamperes through resistance 13, of say 10,000 ohms, leaving the voltage on the second auxiliary anode 14 unchanged and equal to 110. At this voltage the discharge easily extends to anode 14 drawing a current of about 15 milliamperes through resistance 20 having a value of say 5000 ohms. Auxiliary anode 15 next in order still has substantially 110 volts applied to it, ignoring the small voltage drop in the ballast resistance 25, with which it will in turn take up the discharge and so on until the discharge has finally reached the main anode at the end of the tube. The resistances are not critical as only a lower limit for the current to the auxiliary anodes is of importance. Under certain conditions the hot cathode and first auxiliary anode may if desired be replaced as a unit by electrodes both of which are cold and by which a glow discharge is produced.

As a result of the construction which we have shown and described, better regulation may be obtained than with previous devices of this character. This is particularly true where the resistance connected with the last auxiliary anode is low so that even if the line voltage drops to a value which is too low to maintain the discharge to the main anode this auxiliary anode will take over the discharge and the device will not stop but will continue to operate although not at full intensity. Upon a resumption of full line voltage the discharge will return to the main anode.

The modification of our invention illustrated by Fig. 2 differs from what is shown in Fig. 1 in the form of the auxiliary electrodes. By the construction disclosed in this figure we reduce the number of auxiliary anode terminals and the number of resistances connecting the auxiliary anodes with the conductor 9; thus several auxiliary anodes are arranged in a group connected with the same terminal and with the same resistance. In this case auxiliary anodes 27, 28 and 29 are connected together by the conductor 30 shown having a glass covering 31 and have the common terminal 32 which connects with conductor 9 through resistance 33. Auxiliary anodes 27, 28 and 29 have progressively increasing areas, anode 28 being shown having substantially the same diameter as anode 27 but having a greater length and anode 29 being shown comprising a disc whose area is greater than anode 28. The surface of anode 27 is so small that in order to collect the current which is limited by resistor 33 there is a positive anode drop of the order of an ionizing potential of the gas or vapor at the electrode. This results in the potential of anode 28 being approximately an ionizing potential above the potential of the discharge in the vicinity of anode 27, which difference of potential results in the discharge starting to anode 28 which, due to its larger area, has a lower positive anode drop than anode 27. This makes the potential of the relatively large anode 29 above that of the discharge in the neighborhood of anode 28, thus causing the discharge to take place to anode 29 for which the anode drop is practically zero.

The condition for a positive anode drop is that the area of the anode times the random electron current density is less than the current limited by the resistor 33. Arranged above this group of auxiliary anodes we have shown a second similar group 35 which connects with conductor 9 by resistance 36 of materially lower value than resistance 33.

The forms of our invention shown by Figs. 1 and 2 while particularly adapted for D. C. operation may if desired be used on an A. C. circuit where they will operate as half wave tubes since because of their rectifying property they would utilize but one half wave. In this connection we desire to point out that when tubes such as shown in Figs. 1 and 2 are used on an A. C. circuit a much greater efficiency may be obtained if the ballast resistance 25 is replaced by a small inductance.

In the form of our invention illustrated by Fig. 3, we have shown the device adapted for full wave A. C. operation. The tube in this modification is in effect double ended being provided at both ends with a cathode member and heating device therefor whereby during one-half cycle the cathode member at one end functions as a cathode while the cathode member at the opposite end functions as an anode and during the other half cycle the cathode members function in the opposite manner. It is unnecessary to provide the tube with a double set of auxiliary anodes since it will start on the proper half-wave with but a single set as illustrated. The first auxiliary anode 11 connects through resistance 13 with conductor 35 to which also connects by the progressively decreasing resistances 36, 37 and 38 the other auxiliary anodes 39, 40 and 41 respectively. In this form of our invention we employ the small inductance 42 as ballast instead of a resistance as in Fig. 1.

The modification illustrated by Fig. 4 is similar to that shown by Fig. 1 with the exception that in this case the ballast resistance and the limiting resistances in circuit with the auxiliary anodes are arranged within the tube and are constructed to be rendered incandescent by the currents which they carry during the normal operation of the tube. In this modification the main ballast resistance is shown at 44 and the limiting resistances for the second, third and fourth auxiliary anodes are shown respectively at 45, 46 and 47. In this form of our invention the resistances and their connections with the several anodes are entirely enclosed in the upper end of the tube. Since the resistances operate at incandescence it may be found desirable to construct them as filaments of tungsten or other suitable material. If the tube in this form of our invention is filled with mercury, a combination of mercury and incandescent lighting may be obtained since the luminous mercury vapor together with the incandescent resistances would furnish a continuous spectrum.

In the modification illustrated by Fig. 5 there is mounted in the tube 1 a second tube 50 which may be of glass and may or may not be evacuated. This inner tube 50 supports the several auxiliary anodes 51 and also encloses the main ballast resistance or inductance 52 and the several limiting resistances 53 for the auxiliary anodes 51. The main anode in this case is shown supported in the upper end of the tube by the disc 54 which, for example, may be of mica and is connected with the resistance 52 by the conductor 55 extending through the inner tube 50, this conductor be-

ing insulated, as for example by a glass covering in the region of the auxiliary electrode 11 and the cathode.

Fig. 6 shows a form of our invention wherein the conductor 57 leading to the main anode 2 is carried through the tube and is covered by a refractory semiconducting material 58 whose thickness decreases uniformly from a point near the auxiliary anode 11 to a point near the main anode 2. The main ballast resistance 25 is shown embedded in the semiconducting material near the upper end of the tube. Below the lower end of the semiconducting material 58 the conductor 57 is insulated, as for example by a glass covering as in Fig. 5.

Fig. 7 shows a modification of what is shown in Fig. 6 in that the conductor 57 and ballast resistance 25 are enclosed in insulating material, such for example as glass, with the exception that at intervals short sections 60 of high resistance material are attached to the conductor and form auxiliary anodes.

In all of the various modifications by which we have illustrated our invention the voltage at which the device is adapted to operate is too low to cause a discharge to start from the cathode to the main anode without the aid of the auxiliary anodes. When the operating voltage is applied to the terminals of the device and the cathode is raised to the proper temperature an initial discharge takes place between the cathode and the first auxiliary anode 11. As a result of this initial discharge for the reasons already pointed out above, the discharge immediately extends to the next auxiliary anode and from that anode to the next throughout the series, finally reaching the main anode. In the case of the modified form shown by Fig. 6, the tube may be considered as having an infinite number of auxiliary anodes beyond the first auxiliary anode 11. After the discharge has once reached the main anode little or no discharge takes place between the cathode and the auxiliary anodes because of the high resistance in circuit therewith.

We have chosen the particular embodiments described above as illustrative of our invention and it will be apparent that various other modifications may be made without departing from the spirit and scope of our invention which modifications we aim to cover by the appended claims.

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

1. An electric discharge device comprising an elongated envelope containing a gas adapted to form a luminous positive column, a cathode, a main anode and a plurality of auxiliary electrodes mounted therein, said auxiliary electrodes being arranged between and at various distances from the cathode and main anode, and a separate resistance directly connecting each auxiliary anode with the main anode.

2. An electric discharge device comprising a tubular envelope containing a gas which when subjected to a discharge forms a luminous positive column, a cathode, an anode and a series of auxiliary anodes mounted therebetween between the cathode and main anode and separate resistances connecting the main anode with the auxiliary anodes, said resistances progressively decreasing in value from the cathode to the main anode.

3. A positive column discharge device comprising an enclosing envelope containing neon, a thermionic cathode, a main anode and a series of auxiliary anodes mounted therein between the cathode and main anode, a separate controlling

resistance connected with each auxiliary anode, and a conductor connecting the several resistances with the main anode.

4. A low voltage, self-starting positive column discharge device comprising a tubular envelope containing a gas which becomes luminous when subjected to an electric discharge, thermionic cathode and main anode members arranged at opposite ends of the envelope and means for causing the starting of the device by the low voltage comprising a series of auxiliary anodes having individual resistance connections with the main anode.

5. An electrical discharge device comprising a tubular envelope containing a gas which becomes luminous when subjected to a discharge, a thermionic cathode and a main anode, a group of spaced auxiliary anodes having progressively increasing areas from the cathode toward the main anode and a resistance connecting the group with the main anode.

6. An electric discharge device comprising an elongated transparent envelope containing a cathode, an anode and a gas which becomes luminous when subjected to a discharge therebetween, and a ballast resistance in circuit with the anode and arranged within the envelope and constructed to be rendered incandescent by the discharge current.

7. An electric discharge device comprising an elongated transparent envelope containing a cathode, a main anode and a gas which becomes luminous when subjected to a discharge there-

between, an auxiliary anode and a resistance connecting it with the main anode, said resistance being arranged in the envelope and constructed to be rendered incandescent during the operation of the device.

8. An electric discharge device comprising an elongated envelope containing a gas which becomes luminous when subjected to a discharge, a cathode in each end of the envelope and a plurality of auxiliary anodes between said cathodes having impedance connections with one of said cathodes.

9. An electrical discharge device comprising a tubular envelope containing a gas which becomes luminous when subjected to an electric discharge, anode and cathode members at opposite ends thereof and an auxiliary anode member extending between the anode and cathode and comprising a conductor connected with the anode and having thereon a coating of semiconducting material.

10. An electrical discharge device comprising a tubular envelope containing a gas which becomes luminous when subjected to an electric discharge, anode and cathode members at opposite ends thereof and an auxiliary anode member extending between the anode and cathode and comprising a sectionally insulated conductor connected with the anode and having between adjacent sections of insulation a coating of semiconducting material.

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