June 5, 1934. R. R. MACHLETT 1,961,617

LUMINOUS DISCHARGE TUBE

Filed June 26, 1930

Fig. 1.

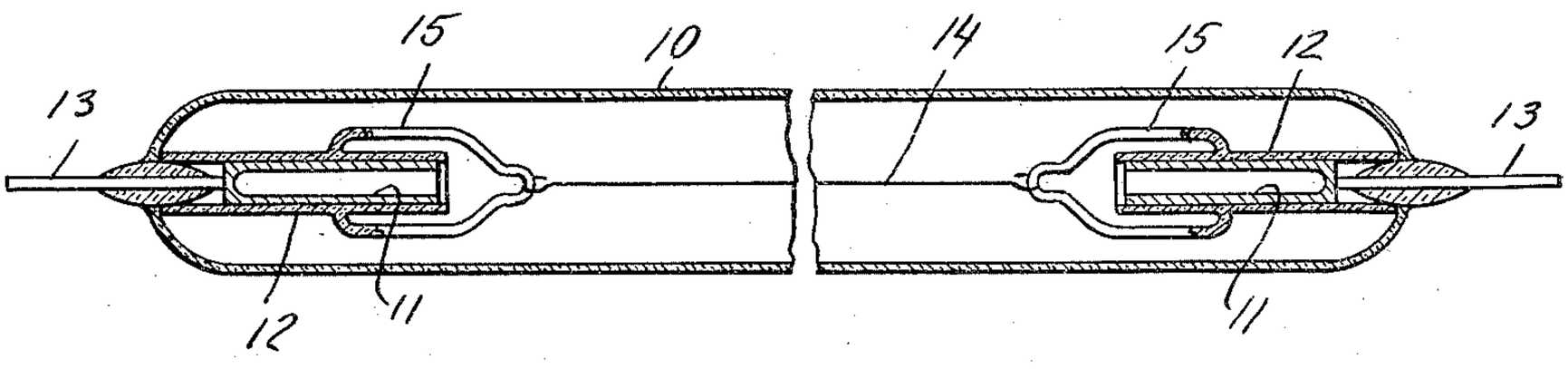


Fig. 2.

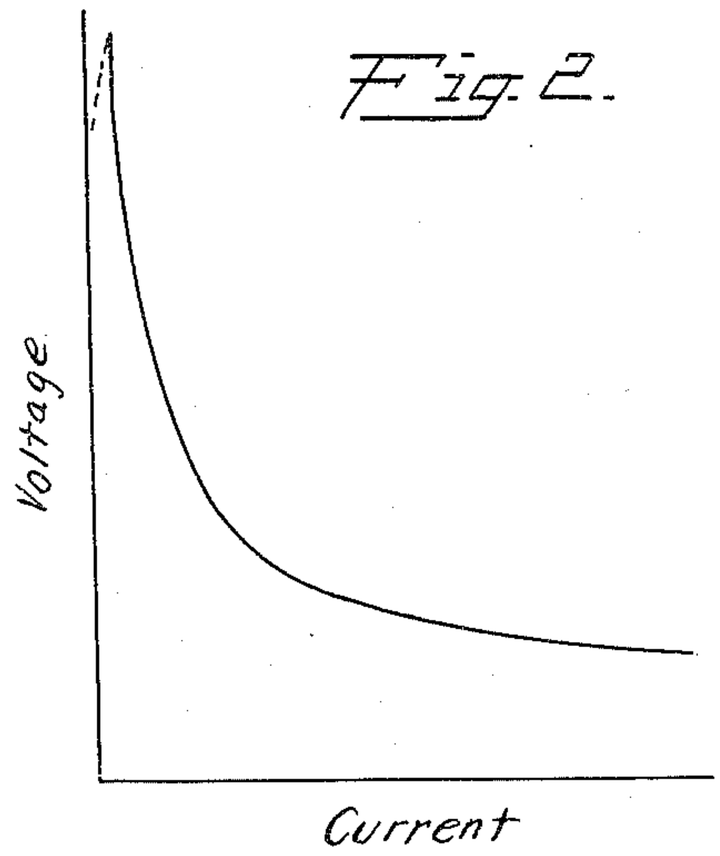


Fig. 3.

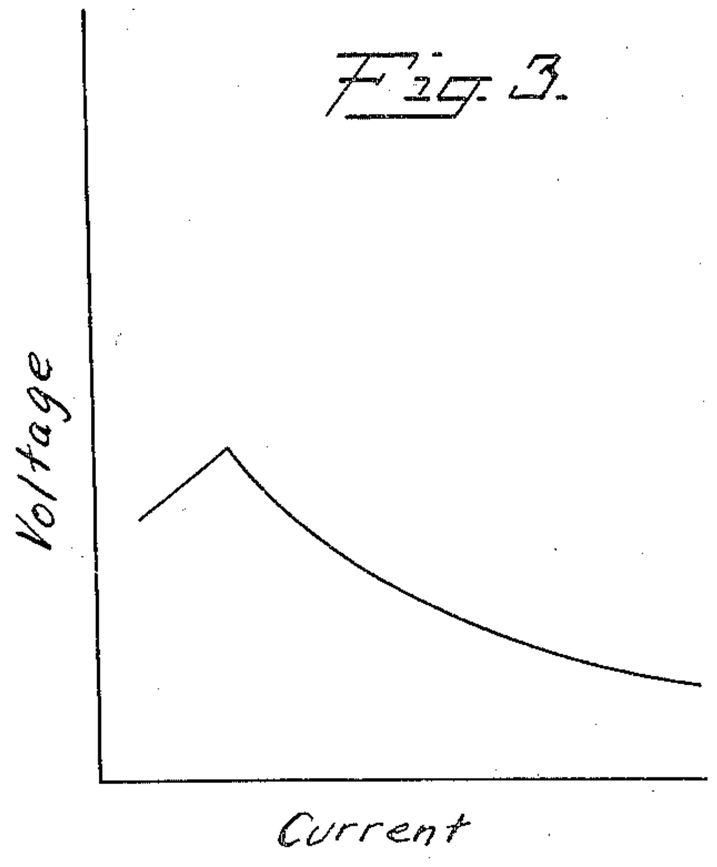


Fig. 4.

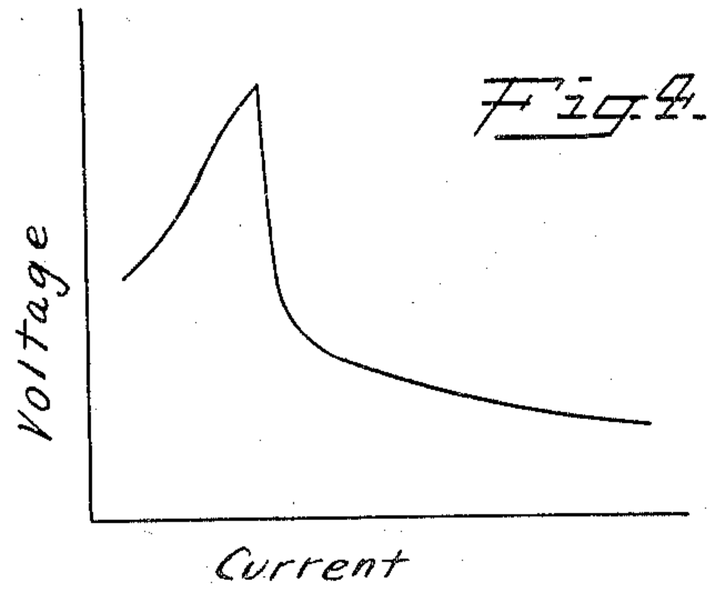
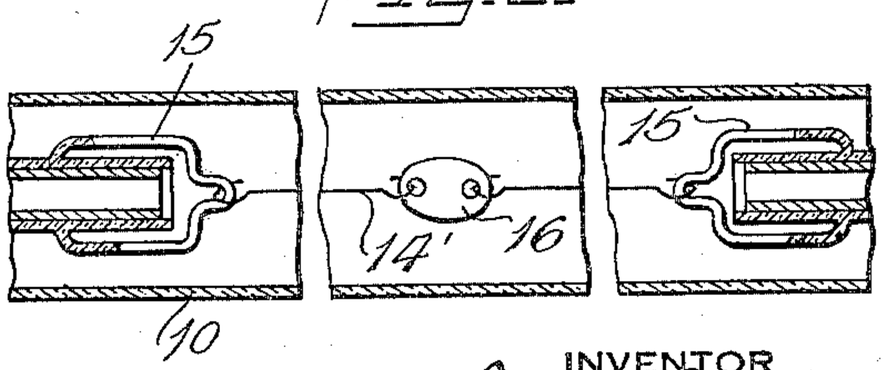


Fig. 5.



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LUMINOUS DISCHARGE TUBE

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Application June 26, 1930, Serial No. 464,077

13 Claims. (Cl. 176—122)

This invention relates to electric discharge tubes and is concerned more particularly with a novel gas discharge device which includes a pair of main electrodes and is provided with more than one path for the discharge between these electrodes, the characteristics of the paths being different so that in operation, the discharge will automatically leave one path and adopt another with consequent alteration in the resultant characteristic of the device taken across the main electrodes. In order to accomplish this transfer from one path to the other, the paths provided are of such character that the first path through which the discharge passes during starting has a rising voltage characteristic and includes a conductor within the positive column portion of the tube along which a negative glow occurs during the starting of the tube, while the second or operating path has a falling voltage characteristic and includes the main positive column of the tube.

In conventional ionic discharge devices a substantially higher tension is required to start the discharge than is required to continue it in operation. This is due primarily to the fact that when the tension is first applied to the electrodes of the device an electric charge accumulates on the wall of the container adjacent to the electrodes which prevents the discharge from passing until a substantially increased potential has been applied to the electrodes.

The object of the present invention is to provide a device which includes means by which the difficulty in starting is overcome by neutralizing such charge and which also provides a source of ions in the positive column itself so that the discharge between the electrodes and through the positive column may be started at a relatively lower voltage than would be the case in a similar tube of ordinary construction. The means employed for this purpose automatically ceases to function as soon as the main discharge is established and the principles of the invention, therefore, find application in numerous discharge tubes. In such tubes constructed in accordance with the invention, the tube has a characteristic in which the operating and starting voltages are much more nearly the same than is the case with tubes of the prior construction, this result being obtained without the use of auxiliary devices. The invention may also be embodied in ionic discharge devices wherein advantage is taken of the resultant characteristics of the new device which make it applicable, for example, to oscillators and amplifiers not only of current and voltage but also of light output.

In the conventional Geissler discharge tube of the prior art an elongated glass vessel is equipped with electrodes at either end and after proper exhaustion filled to a low pressure with any suitable gas. Light is produced from these tubes by causing an electric discharge to pass through the gas between the electrodes. Discharge tubes of this type employing the rare gases of the atmosphere, as, for example, neon, argon, argon with mercury, etc., have found a wide application in electric advertising and signal lighting. Such tubes are usually made relatively long and operated from high voltage transformers, which have a high inductance characteristic whereby the current in the luminous tube is limited to the proper operating value in spite of the difference between the starting and operating potentials of such tubes. As a consequence, such systems operate with relatively low power factor (the usual average being from 20% to 50%), which is a decided drawback.

Installations of such tubes also require frequent attention because of insulation breakdowns in the high voltage circuits feeding the tubes. Such service is expensive, as is also the original installation of such high voltage systems, since the usual voltage used is from 10,000 to 15,000 volts.

Another type of luminous discharge tube found in the art is adapted to operate on much lower voltages. Such tubes are also usually provided with gas fillings of the rare gases of the atmosphere, in particular, neon. These tubes are relatively short, three feet or less in length, and are provided with special electrodes to minimize the fall of potential at that point. Such electrodes are usually either of the heated electron-emitting type or are cold electrodes made or coated with a metal of the alkali metal group. Such tubes are generally operated at very much higher current densities than is the case with the Geissler type in order to take advantage of the falling voltage characteristic of all such tubes in general. All of these tubes, however, require some special mechanism for starting the discharge in the positive column to make them practical in operation. These mechanisms are invariably troublesome and expensive.

In general, there are three methods of starting tubes of the general types above referred to. By one method, a high voltage, high frequency source of potential is brought near or in contact with the tube to ionize the gas within it.

A second method involves the use of an auxiliary electrode near the cathode together with automatic switching means for eliminating this electrode from the circuit after the tube is started. By the third method, a separate mechanism is provided for supplying an instantaneous high voltage to the tube as, for example, by an inductive kick.

The present invention overcomes the principal difficulties in connection with both types of luminous discharge tubes and at the same time is inexpensive and requires no moving parts or auxiliary devices which are ordinarily expensive and unreliable in operation. As the new tube depends for its operation on phenomena which take place between the electrodes, its functioning is independent of the kind or characteristics of these main electrodes.

A simple embodiment of the invention takes the form of a short luminous tube of the Geissler type provided with cold electrodes and equipped with a conductor illustrated in the form of a wire which lies within the tube and extends substantially the entire distance between the electrodes but is wholly disconnected therefrom within the tube. This tube contains the usual gaseous filling and when potential is applied to the electrodes, a discharge first passes from the main electrodes through the short intervening gaps to the wire and through the conductor. The end of the conductor adjacent the negative electrode functions as an anode, while the other end adjacent the positive electrode functions as a cathode and is covered with the usual close fitting cathode glow at its extreme end. As the current is increased, the cathode glow on the conductor spreads along the conductor until it encompasses or nearly encompasses the entire conductor. The region in the tube in which the negative glow is produced is the region in which ionization of the gas is most vigorous due to the large potential drop in the gas at that point. Accordingly, ions are produced in the vicinity of the conductor and also in the positive column portion of the tube at a very rapid rate. As the current is increased, the voltage characteristic of the path which includes the conductor rapidly rises as the electrode current density of the conductor itself becomes abnormal. This rise in potential along the conductor continues until eventually the current seeks the gaseous path between the main electrodes and the discharge through the positive column is initiated. Once this flow is started and the current in the tube increases, the potential drop in the main positive column falls almost instantaneously below the value required for conduction through the path which includes the conductor and from that point on the gaseous path carries all or substantially all of the current flowing through the tube.

For a better understanding of the invention, reference may be had to the accompanying drawing in which

Fig. 1 illustrates conventionally a tube constructed in accordance with the principles of the invention;

Fig. 2 is a diagram illustrating the general form of the characteristic of an ordinary tube;

Fig. 3 is a diagram illustrating the characteristic of a tube constructed in accordance with the present invention and operating on alternating current;

Fig. 4 is a diagram illustrating the same tube but operated with direct current; and

Fig. 5 is a fragmentary longitudinal sectional view showing a modified form of tube.

Referring now to the drawing, there is illustrated conventionally in Fig. 1 a tube embodying one form of the invention and including the usual glass envelope 10, which may have an overall length of 12 inches. Within this tube are ordinary electrodes 11 which may be of standard construction such as iron cylinders enclosed within sleeves 12 of ceramic insulating material, such as isolantite. These electrodes are mounted on the ends of lead-in wires 13 and the internal area of the cylinders which is the active area may be approximately 150 square mms. In the tube illustrated, the distance between the ends of the electrodes may be approximately 10 inches and the tube may have a diameter of 15 mms. In such a tube containing a filling of neon at a pressure of 10 mms. or more, the electrodes will operate with a substantially normal cathode fall of potential and with a low rate of vaporization. In the operation of the tube, energy is supplied to the electrodes from a suitable source through the lead-in wires.

In the interior of the tube and running from end to end is a conductor illustrated as in the form of a fine wire 14. This conductor is entirely disconnected electrically within the tube from the electrodes, although it runs to within a few millimeters of the ends thereof. The conductor is preferably of a material which will not sputter readily when employed as an electrode in a tube of this sort and may conveniently be of iron and have a diameter of .005 inch. For convenience, the wire may be mounted at its ends in stirrups 15 attached to the insulating sleeves 12 in such manner that the wire lies substantially at the axis of the tube.

When an ordinary tube of these dimensions but without the conductor is operated on alternating current, it has a characteristic somewhat similar to that shown in Fig. 2. The normal operating current is approximately 25 milliamperes and a voltage of the order of 1000 volts is required to start the tube in operation and as shown by the characteristic diagram, the voltage falls rapidly as the current through the tube builds up until at the normal operating value of 25 milliamperes, a voltage of about 275 volts is required to maintain conduction.

With a tube of the same dimensions and constructed in accordance with the present invention and containing the conductor between the electrodes, the characteristic with alternating current is generally similar to that illustrated in Fig. 3. Conduction begins through the conductor or starting path at approximately 330 volts and the characteristic rises to approximately 400 volts where the discharge adopts the main positive column. From that point on, the characteristic falls rapidly until an operating voltage of about 320 volts corresponding to the normal operating current is reached. As will be evident, the tube of the present invention has a starting voltage which is not greatly different from the voltage at which the tube will operate with normal current. With alternating current operation, this affords a greatly improved power factor and with any conditions of operation, results in the elimination of troublesome starting devices and the difficulties and expense involved in providing insulation for the much higher voltages required with the prior tubes.

The characteristic illustrated in Fig. 4 is that of a tube similar to the one above described and

embodying the principles of the new invention when operated on direct current. Here again, it will be observed that after conduction starts, the voltage rises until flow through the main positive column occurs, whereupon the voltage falls rapidly and almost instantaneously to a substantially lower value.

By reason of the new device having a voltage characteristic having a sharp change, the device has many applications in the arts other than for illuminating purposes, for example, as an oscillator or amplifier, etc. The critical point in the electrical characteristic is also associated with a critical change in the light output, making the device suitable for use in the electrical transmission of still or motion pictures by wire or radio, and for recording sound photographically, etc. Also the device can be used as a rectifier, as, for example, by maintaining a direct current through the starting path of insufficient value to effect the transfer of the discharge to the operating path and applying the alternating current to be rectified to the main electrodes.

It will be apparent that the particular shape of the characteristic of the new tube and the point at which the main positive column starts can be regulated over wide limits by a proper choice of the factors which govern the two alternative paths through the tube. For example, the flow through the initial or starting path will be generally controlled by the normal current density of the particular material chosen, in the particular gas at the particular pressure, and accordingly a material will be chosen for the conductor with regard to its characteristics as a negative electrode, such for example, as its normal current density and normal cathode drop in the particular gas to be used, a material having a low normal current density being generally preferred. The factors which govern the characteristics of the alternative path through the main column of the tube are the kind of gas, the pressure of the gas, the diameter of the tube, and the current which passes through the positive column.

In embodying the principles of the invention in a practical device, it is important to select a conductor of proper material and to arrange the conductor within the tube in such manner as to avoid any disadvantageous results due to sputtering, such as increasing the area of the conductor by the sputtered film, thus changing the characteristic of the device. The sputtered film would also prove objectionable if it appeared in such places that it would darken the glass or impair light transmission through it.

A satisfactory arrangement where substantial gas pressures are allowable as, for example, 7–10 mms. involves mounting the wire substantially in the axis of the tube. With this arrangement, the building up of a sputtered film on the glass wall is retarded, by reason of the distance from the wire to the glass and the large number of intervening molecules of gas, particularly at such a pressure, which tend to prevent the sputtered particles from arriving at the wall. In alternating current operation, too high a pressure may cause sputtering difficulties due to the fact that the discharge passes through the starting path including the conductor at the beginning of each cycle and with a higher pressure, the normal current density of the conductor rapidly increases and thus the discharge continues along this path long enough to cause sputtering, whereas with a lower pressure, the discharge would transfer to the operating path more promptly and sputtering would be lessened. Another arrangement that may be employed includes mounting a shield between the conductor and the wall, this shield being so constructed that no continuous sputtered film of substantial length in a direction parallel to the conductor can be deposited on it and having openings to permit passage of ions therethrough into the main gas column. This shield may be limited to that portion of the conductor at which the most active sputtering takes place.

While in small tubes it will be satisfactory to employ a single conductor within the tube, the principles of the invention may be embodied in longer tubes in which a plurality of conductors will be used, spaced along the tube and laid end for end with gaps between. Any convenient means may be provided for mounting the conductors end to end, as, for example, that illustrated in Fig. 5, in which the conductors 14′ are each connected at one end to the electrode and at the other to a piece of suitable insulating material 16. The gaps between the adjacent ends of the conductors are of the order of a few millimeters and in that respect similar to the gaps between the ends of the conductors and the electrodes.

What I claim:

1. An electric discharge tube which comprises an envelope containing a gas, a pair of spaced electrodes within the envelope, lead-in wires extending from the electrodes through the wall of the envelope for connection to a source of energy, and a pair of paths for the discharge between the electrodes, one path including the gas within the envelope and having a relatively low starting potential and a substantially falling voltage characteristic in operation, and the second path including a solid conductor in the envelope and without electrical connection to said electrodes, said conductor lying in the space in the envelope normally occupied by the discharge during operation, and said second path having a relatively high starting potential and a substantially rising voltage characteristic in operation.

2. An electric discharge tube which comprises an envelope containing a gas, a pair of spaced electrodes within the envelope, lead-in wires extending from the electrodes through the wall of the envelope for connection to a source of energy and a pair of paths for the discharge in parallel between the electrodes, the first of said paths having a positive voltage characteristic within the range of current values from zero to normal operating current and including a solid conductor within the envelope, electrically disconnected from the electrodes, and lying in the space in the envelope normally occupied by the discharge during operation, and the second path including said gas and having a negative voltage characteristic within said range.

3. An electric discharge tube which comprises an envelope containing a gas, a pair of spaced electrodes within the envelope, lead-in wires extending from the electrodes through the wall of the envelope for connection to a source of energy and a pair of paths for the discharge in parallel between the electrodes, the voltage characteristics of the two paths being convergent within the range of current values from zero to normal operating current, one path including a solid conductor within the envelope, electrically disconnected from the electrodes, and lying in the space in the envelope normally occupied by the discharge during operation.

4. An electric discharge tube which comprises an envelope containing a gas, a pair of spaced electrodes within the envelope, lead-in wires extending from the electrodes through the wall of the envelope for connection to a source of energy and a pair of paths for the discharge between the electrodes, the voltage characteristics of the two paths being convergent within the range of current values from zero to normal operating current, and having at least one value in common, one of said paths including a solid conductor within said envelope, electrically disconnected from the electrodes, and lying in the space normally occupied by the discharge during operation.

5. An electric discharge tube which comprises an envelope containing a gas, a pair of spaced electrodes within the envelope, and means wholly within the tube and electrically disconnected from the electrodes for producing ions in the region within the tube between said electrodes, said means including a solid conductor lying in the space normally occupied by the discharge during operation.

6. An electric discharge tube which comprises an envelope containing a gas, a pair of spaced electrodes within the envelope, and a conductor solid within the tube electrically independent of the electrodes and extending from a point closely adjacent to one electrode to a point closely adjacent to the other, said conductor lying in the space normally occupied by the discharge during operation of the tube.

7. An electric discharge tube which comprises an envelope having electrodes sealed within it, insulating coatings on the electrodes, and a conductor mounted on the coatings and extending between the electrodes.

8. An electric discharge tube which comprises an envelope having spaced electrodes within it, an insulating sleeve enclosing each electrode, a neon filling in the envelope at a sub-atmospheric pressure, and a solid conductor within the tube extending from a point near one electrode to a point near the other.

9. An electric discharge tube which comprises an envelope having a gaseous filling, spaced electrodes within the envelope, and a plurality of solid conductors disposed end for end in spaced relation in a row lengthwise of the tube, the conductors being disconnected from one another and from the electrodes.

10. An electric discharge tube, which comprises an envelope having electrodes sealed within it, and a conductor mounted on the electrodes but insulated therefrom and extending between the electrodes, said conductor lying wholly within the path of the discharge between the electrodes.

11. An electric discharge tube, which comprises an envelope having electrodes sealed within it, a gaseous filling in the envelope at sub-atmospheric pressure, and a solid conductor connected mechanically but not electrically to the electrodes and extending between them, said conductor lying in the space between the electrodes normally occupied by the discharge during operation of the tube.

12. An electric discharge tube, which comprises an envelope with spaced electrodes within it, a neon filling within the envelope, and a solid conductor of low ohmic resistance connected mechanically to each electrode but electrically insulated therefrom, said conductor lying in the space between the electrodes normally occupied by the discharge during operation of the tube.

13. An electric discharge tube, which comprises an envelope, a pair of spaced electrodes within the envelope, and a pair of paths for the discharge between the electrodes, one path consisting of a body of gas and the other path including a solid conductor electrically disconnected from the electrodes and small gaps filled with the gas between the conductor and the electrodes, the conductor extending substantially the entire length of and in the space between the electrodes normally occupied by the positive column during operation of the tube.

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