June 5, 1934.

R. R. MACHLETT

1,961,618

LOW VOLTAGE ELECTRIC DISCHARGE TUBE

Filed Jan. 7, 1931

Fig. 1,

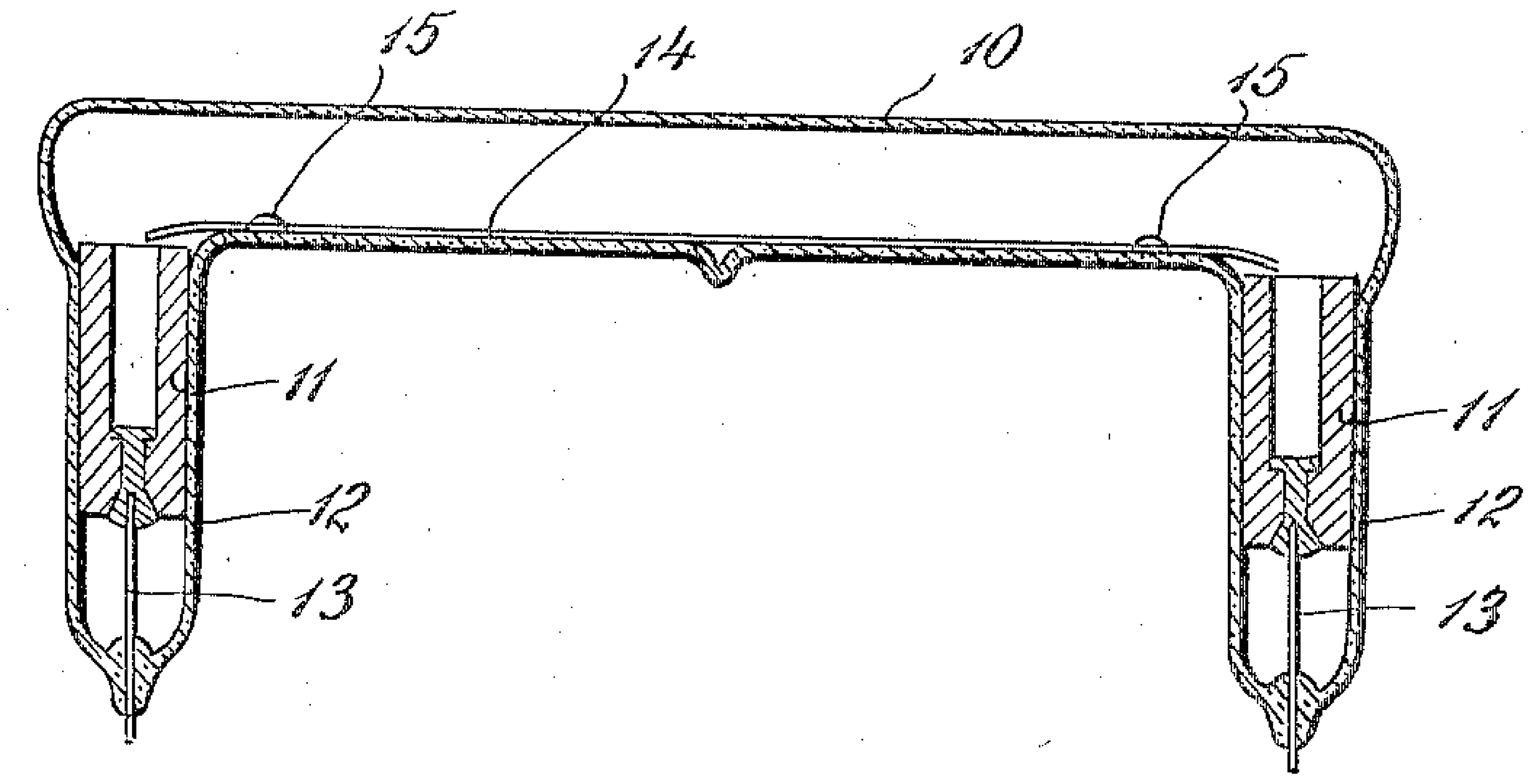


Fig. 2,

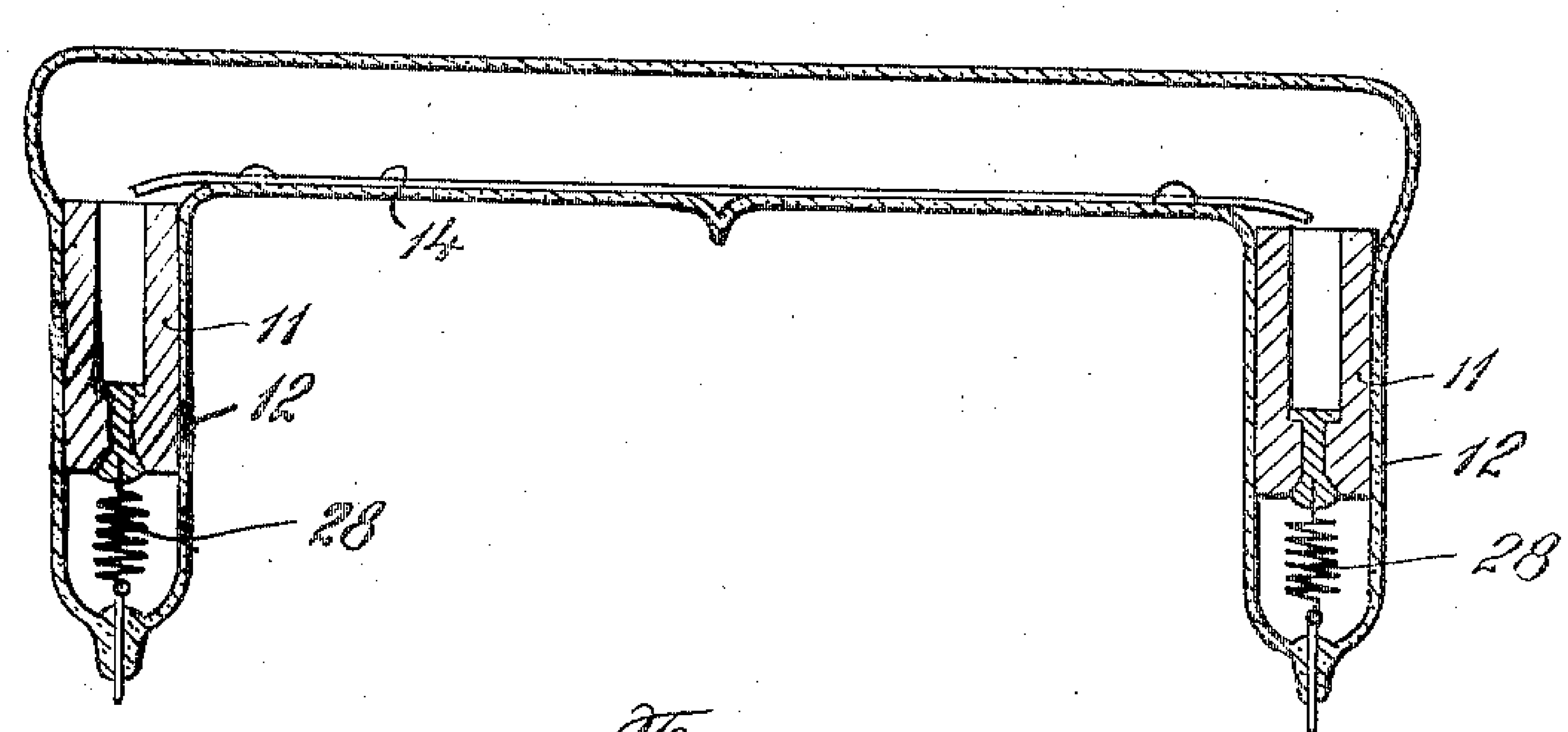


Fig. 3,

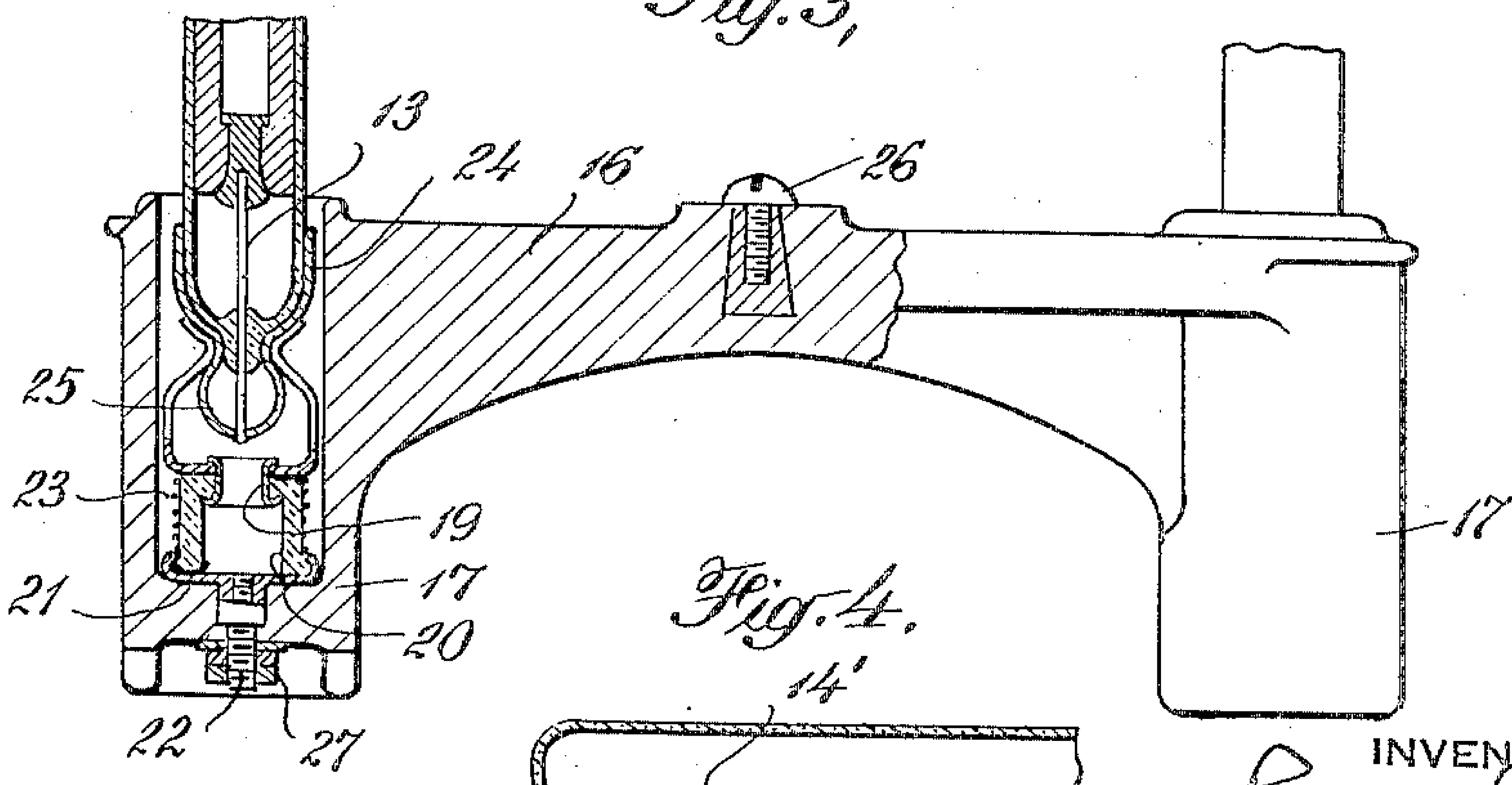
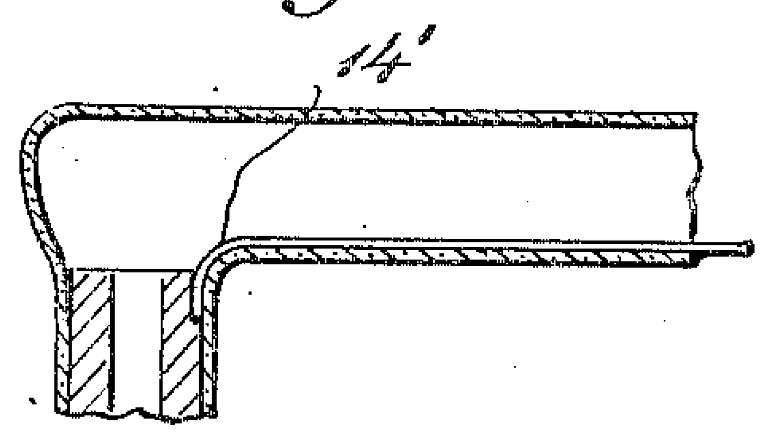


Fig. 4.



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UNITED STATES PATENT OFFICE

1,961,618

LOW VOLTAGE ELECTRIC DISCHARGE TUBE

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22 Claims. (Cl. 176—122)

This invention relates to electric discharge tubes and is concerned more particularly with a tube having a novel construction, by virtue of which the tube can be started and operated at relatively low voltages without the use of auxiliary starting equipment or auxiliary electrodes. The new tube is especially suitable for illumination and display purposes, and as one feature, the invention comprehends a tube of novel form and a mounting therefor, which simplify installation and maintenance.

In my co-pending application Serial No. 464,077, filed June 26, 1930, I have described and claimed a low-voltage discharge tube having a pair of main electrodes and so constructed as to afford more than one path for the discharge between the electrodes. The paths for the discharge have different characteristics so that upon starting, the discharge is primarily along one path, but, as the discharge continues it automatically leaves that path and adopts another, with consequent alteration of the characteristic of the device taken across the main electrodes. To accomplish this result, the paths are such that the one through which the discharge passes during starting has a low starting potential and a rising voltage characteristic, while the operating path later sought by the discharge has a high starting potential and a falling voltage characteristic and includes the main positive column of the tube. In that application, I have discussed in detail the theory and conditions of operation in such a tube.

The present invention is directed to a tube embodying the principles of construction and operation disclosed in my prior application, and constitutes an improvement on the prior tube, having certain novel features which make it possible to start and operate the new tube at lower voltages than those previously required, for example, at 220 volts or less.

The new tube comprises an envelope which contains a suitable gas, such as a rare gas of the atmosphere, for example neon or argon, with or without mercury vapor, a pair of internal main electrodes, and ionizing means for producing ions in the positive column space between the electrodes. The ionizing means used produces its effect by causing a negative glow to occur in the positive column space during starting and it is of a material which has a low normal cathode fall of potential in the gas present, such as less than about 120 volts and it has a shape which causes it to have a relatively low normal current density. In a neon tube the ionizer may conveniently take the form of a flat strip of an alkali or an alkaline earth metal, such as magnesium, extending along the tube in the positive column space and being wholly disconnected electrically from the electrodes but approaching them closely at its ends, although in some instances, one end of the strip may be connected to one electrode.

For display purposes, for example, in illuminated signs, the tube may be generally U-shaped with the ends containing the electrodes extending at right angles to the major portion of the tube. The ends of the tube are provided with caps carrying terminals adapted to be received in sockets in a receptacle, and the caps cooperate with receptacle parts to hold the tube in place and with its electrodes electrically connected to a supply of energy. With such a construction, the main length of the tube is exposed to view and a plurality of such tubes may be assembled to form letters, designs, etc.

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

Fig. 1 is a sectional view of one form of tube embodying my invention;

Fig. 2 is a sectional view of a slightly modified form;

Fig. 3 is a view partly in elevation and partly in section illustrating the mounting for the tube; and

Fig. 4 is a sectional view showing a modified electrode construction.

Referring now to the drawing, the tube illustrated comprises a glass envelope 10 having internal electrodes 11 mounted at the ends 12 and provided with lead-in wires 13 extending through the glass and sealed in the ordinary way. Lying in the space between the electrodes and extending from a point near one electrode to a point near the other is an ionizing element 14 which may be conveniently secured in place on the glass wall in any suitable manner, as by being cemented at the points 15.

The electrodes employed in this tube may be hollow and are preferably encased in insulating material, such as glass. In the construction illustrated, the same effect is obtained by making the electrodes of such a size that they fit the tube closely and lie with their outer surfaces in contact with the inner surface of the tube wall. While various materials may be used for the electrodes, it is desirable to employ a material having a low normal cathode fall of potential in the gas to be used, I have obtained highly satisfactory results from electrodes made of carbon and having an alkali metal occluded therein. An alkali metal can be readily introduced into carbon electrodes during the processing of the tube, and in my Patent No. 1,680,272, issued August 7, 1928, I have described electrodes of this type and a process for producing them.

The ionizing element 14 may be of various materials, such as alkali or alkaline earth metals. In a neon tube, such metals are preferred, and I have found magnesium most satisfactory, especially when employed in the form of a flat strip or ribbon approximately $\frac{1}{32}$'' wide and .005'' thick. A flat strip or ribbon of carbon, for example in the form of graphite is another material that may be used and a strip of carbon having an alkali metal, such as potassium or caesium, occluded in it is satisfactory in many instances. In tubes containing mercury vapor, for example, with argon, the possibility of amalgamation of the strip with the mercury must be considered, and for such tubes, I prefer to employ an element of iron.

In the operation of the tube, when voltage is impressed on the electrodes, current begins to flow through a starting path which includes the gas from one electrode to the adjacent end of the ionizing element, through the element, and through the gas from the other end of the element to the other electrodes. During the initial discharge, the end of the element adjacent the negative electrode functions as an anode, while the other end of the element adjacent the positive electrode functions as a cathode and is covered with a close fitting cathode glow at its extreme end. As the current is increased, the cathode glow spreads along the element and ionization occurs in the space between the electrodes which is occupied by the positive column under ordinary conditions of operation. Eventually as the glow continues to spread and when a sufficient degree of ionization has been obtained, most or all of the current leaves the first path which includes includes the element and adopts the path through the gas from one electrode to the other. This is due to the fact that the starting path which includes the element has a relatively constant or rising voltage characteristic in operation while the gaseous path between the electrodes has a falling voltage characteristic.

The characteristics of the material used in the ionizing element which determine whether or not it will serve its purposes satisfactorily are the characteristics of the material considered as a cathode and since the tube is to operate at a low normal voltage, it is preferable to employ a material for the strip which has a low cathode fall of potential in the particular gas present, such as the cathode drop associated with alkali and alkaline earth metals, since the starting voltage of the tube is in excess of the sum of the cathode falls of potential of the electrode and element materials. Magnesium in neon has a cathode fall in the vicinity of 94 volts and is, therefore, a desirable material for the strip and experience has shown it to be one of the best.

Another important factor to be considered in constructing the element is its normal current density. This depends on the shape of the element and I have found that an ionizing element which has a surface of a relatively large radius of curvature, for example in excess of one millimeter, is more satisfactory than one having a smaller radius. An element having a plane surface has proved highly satisfactory and it is probable that an element which has practically no thickness, such as a film metal deposited on the tube wall, would give the best results. However, it is difficult to attain such a film and excellent results have been secured in neon tubes by the use of a thin magnesium strip cemented to the tube wall.

In addition to proper selection of the material of the element and the surface which it presents, it is important for good results that the electrode drop of the element should not become much greater than the normal drop for the material of which the element is made in the particular gas present. I have found that with a long, thin element the current density is not necessarily constant throughout the strip during the time in which the strip is being progressively encompassed by the negative glow as the tube current increases. In the case of a relatively long element, it appears that the current density during starting may be considerably greater at the end adjacent the anode than at the middle or opposite end of the strip. As a consequence, the electrode drop of the strip may become abnormal before the strip is completely covered with a negative glow and this is objectionable since it causes sputtering of the strip.

The factors which appear to govern this situation are primarily the length of the strip and its shape, and the diameter or cross-sectional area of the tube or envelope, and since the tendency of the electrode drop to exceed normal increases with the length of the strip, this length should not exceed a certain maximum for a given tube diameter. I have found that with a neon tube of 15 mms. diameter in which a flat strip is employed, the length of the tube between the opposed ends of the electrodes and throughout which the strip extends should be about 4'' for best results, although this length may be considerably increased without impairing the life of the strip and tube to a substantial extent, provided the diameter or cross-sectional area of the tube is increased.

Experience indicates furthermore that it is highly desirable to utilize electrodes for the tube which have a substantially lower cathode fall of potential than that of the ionizing strip. This is particularly true in tubes, presently to be described, in which one end of the strip is connected to an electrode, but has also been observed in tubes in which the strip is disconnected from both electrodes. Apparently when the cathode fall of the electrode is considerably less than that of the strip, there is less likelihood that the strip will operate under abnormal conditions, and for that reason, sputtering is substantially reduced when the expressed relationship obtains.

In a tube of the construction described and containing neon, the gas pressure may vary from 5 or 6 mms. to 15 mms. of mercury. As the gas pressure approaches the lower end of the range, the life of the tube is shortened and starting is also more difficult. As the gas pressure is increased in a tube having an ionizing strip, the current tends to continue along the starting path for a longer period and this results in sputtering. On direct current operation, this is not particularly objectionable since the current flows through the strip only for a brief period during starting. On alternating current, however, there is a flow of current through the starting path in each half-cycle and consequently conditions which lead to sputtering are rapidly recurrent. The best pressure I have so far discovered is approximately 11 mms. although a considerable variation therefrom within the range mentioned is permissible.

In tubes which contain neon, the ionizing element may be disconnected from both electrodes, while in tubes containing the argon-mercury mixture, it is preferable to employ a strip connected to one electrode, since by employing that construction, the tubes may be started at voltages under 220 volts. The connected strip apparently functions in the same general manner as the disconnected strip and substantially the same phenomena occur during starting.

One manner of attaching one end of the strip to an electrode is illustrated in Fig. 4, where the end of the strip 14' lies in contact with the outer surface of the electrode and between that surface and that of the tube wall.

In tubes in which the ionizing strip is connected to one electrode, the starting voltage is considerably less than that of tubes containing a disconnected strip. In general, the reduction in voltage is of the order of the cathode fall of potential of the electrode. However, on alternating current such tubes operate effectively only during the half-cycle in which the strip functions as a cathode, and such tubes emit a fluctuating light and appear to "flutter" when operated on very low frequencies.

Also, a strip connected at one end to an electrode has a greater tendency to sputter than one wholly disconnected. For that reason, in tubes containing a connected strip, it is particularly important to prevent the strip from becoming abnormal in operation, and great care should be exercised to that end. In the use of a connected strip, it is also highly desirable to use an electrode at the connected end of the strip which has a substantially lower cathode drop than the strip itself; for example, with a magnesium strip, the electrode to which the strip is connected may be of carbon containing an occluded alkali metal.

Tubes containing the ionizing strip and having cold electrodes have been operated satisfactorily on voltages as low as 220 or less and such tubes can, therefore, be employed on ordinary wiring circuits and do not require the special and expensive insulation, transformers, etc. employed in connection with tubes which require thousands of volts for starting. For lower voltages of the order of 110, the tubes are of substantially the construction described but electron-emitting cathodes are preferably used.

For illumination and display purposes, the tubes may conveniently have the generally U-shaped form illustrated in Fig. 1 with the tube ends 12 in which the electrodes are mounted extending at right angles to the main length of tube containing the positive column. These tubes can be produced cheaply and by mass production methods, particularly when processed by the procedure described in my Patent No. 1,618,767, issued February 22, 1927. The tubes can then be mounted in a receptacle and arranged to form letters, designs and the like.

A convenient receptacle and tube mounting is illustrated in Fig. 3 and this mounting includes a base 16 of insulating material having socket portions 17 at its ends. In each socket are spring clips 18 secured by a tubular rivet 19 or the like to a cylinder 20 of insulating material, which is mounted on a plate 21 provided with a terminal screw 22. On the surface of the cylinder is a coil 23 of fine wire which serves as a limiting resistance and is connected to the clips and the screw. The tube is provided at each end with a metal cap 24 having a globular tip 25 to which the lead-in wire 13 is connected. When the tube is to be mounted in the receptacle, its ends are inserted in the sockets and the tips 25 pass between the leaves of the spring clips which secure the tube firmly in position. The clips not only support the tube but also serve as part of the electrical connections, the current flowing from a supply line not shown to the terminal member 22, and thence through the plate 21, the resistance coil 23, spring clip 18 and terminal tip 25 to lead-in wire 13. The insulating base is provided with means by which it may be mounted in place such as the screw 26.

For display purposes, a plurality of receptacles may be mounted on a base in the desired positions to spell out words, to outline figures, etc. The tubes are then slipped into the receptacles and the positive column of each tube provides an illuminated line. These lines of illumination may be arranged to produce a substantially continuous effect or may be used in any other way desired. Whenever a tube requires replacement for any reason, no change in the wiring is necessary and the damaged tube is simply pulled out of the receptacle and a new one inserted. The receptacle carries the limiting resistances required for use with such tubes and a resistance element in the base may be changed by removing the tube, screwing off nuts 27 on the terminal screw 22, drawing the entire terminal assembly out of the socket in the base member, and replacing it by another.

In the construction illustrated in Fig. 3, the limiting resistances are placed in the receptacle while in the tube shown in Fig. 2, there is a resistance 28 inside the tube at each end thereof. The latter construction produces a self-contained tube and insures that appropriate resistance will be employed for the tube, since this resistance is installed at the time the tube is manufactured.

What I claim is:

1. An electric discharge device which comprises the combination of a glass envelope containing a gaseous filling at low pressure, a pair of spaced electrodes within said envelope, and an ionizing element within said envelope and extending through the space between the electrodes, said element being a flat strip of a material having a relatively low normal cathode fall of potential of the order of less than about 120 volts in said gaseous filling.

2. An electric discharge device which comprises the combination of a glass envelope containing a gaseous filling at low pressure, a pair of spaced electrodes within said envelope, and an ionizing element within said envelope and extending through the space between the electrodes, said element having a flat surface exposed to the gaseous filling and being electrically disconnected from at least one electrode.

3. An electric discharge device which comprises the combination of a glass envelope containing a gaseous filling at low pressure, a pair of spaced electrodes within said envelope, and an ionizing element within said envelope and extending through the space between the electrodes, said element having a substantially plane surface exposed to the gaseous filling and being electrically disconnected from at least one electrode.

4. An electric discharge device which comprises the combination of a glass envelope containing a gaseous filling at low pressure, a pair

of spaced electrodes within said envelope, and an ionizing element within said envelope and extending through the space between the electrodes, said element being mounted against the envelope wall and being electrically disconnected from at least one electrode.

5. An electric discharge device which comprises the combination of a glass envelope containing a gaseous filling at low pressure, a pair of spaced electrodes within said envelope, and an ionizing element within said envelope and extending through the space between the electrodes, said element having the form of a substantially flat strip and being electrically disconnected from at least one electrode.

6. An electric discharge device which comprises the combination of a glass envelope containing a gaseous filling at low pressure, a pair of spaced electrodes within said envelope, and an ionizing element within said envelope and extending through the space between the electrodes, said element having the form of a substantially flat strip and being mounted with one face in contact with the envelope wall and being electrically disconnected from at least one electrode.

7. An electric discharge device which comprises the combination of a glass envelope containing a gaseous filling at low pressure, a pair of spaced electrodes within said envelope, and an ionizing element within said envelope and extending through the space between the electrodes, said element being of a material having a relatively low normal cathode fall of potential of the order of less than about 120 volts in said gaseous filling and having a surface of a large radius of curvature exposed to said filling.

8. An electric discharge device which comprises the combination of a glass envelope containing a gaseous filling at low pressure, a pair of spaced electrodes within said envelope, and an ionizing element within said envelope and extending through the space between the electrodes, said element being of a material having a relatively low normal cathode fall of potential of the order of less than about 120 volts in said gaseous filling and having a substantially plane surface exposed to said filling.

9. An electric discharge device which comprises the combination of a glass envelope containing a gaseous filling at low pressure, a pair of spaced electrodes within said envelope, and an ionizing element within said envelope extending between the electrodes and disconnected from at least one electrode, said element being of a material having a relatively low normal cathode fall of potential of the order of less than about 120 volts in said gaseous filling.

10. An electric discharge device which comprises the combination of a glass envelope containing a gaseous filling at low pressure, a pair of spaced electrodes within said envelope, and an ionizing element within said envelope and connected electrically to one electrode only, said element being a strip having a substantially flat surface exposed to the gaseous filling.

11. An electric discharge device which comprises the combination of a glass envelope containing a gaseous filling at low pressure, a pair of spaced electrodes within said envelope, and an ionizing element within said envelope and connected electrically to one electrode only, said element having the form of a strip affixed to the inner wall of the envelope.

12. An electric discharge device which comprises a glass tube, neon at low pressure in the tube, electrodes within the tube, and an ionizing element of magnesium within the tube in the space between the electrodes and electrically disconnected from at least one electrode, said element having a substantially flat surface exposed to the gaseous filling.

13. An electric discharge device which comprises a glass tube, neon at low pressure in the tube, electrodes within the tube, and a flat magnesium strip within the tube extending between the electrodes and electrically disconnected from at least one electrode.

14. An electric discharge device which comprises a glass tube, a gaseous filling of argon and mercury vapor at low pressure in the tube, and an ionizing element of iron within the tube and extending lengthwise thereof between the electrodes and electrically connected to one electrode, said element having a substantially plane surface exposed to the gaseous filling within said tube.

15. An electric discharge device which comprises an elongated glass envelope, a gaseous filling at low pressure in the envelope, electrodes within the tube, and an ionizing element within the envelope in the space between the electrodes, the electrodes being of a material having a substantially lower normal cathode fall of potential in said gaseous filling than that of the material of which said element is made, said element having a substantially flat surface exposed to the gaseous filling.

16. An electric discharge device which comprises an elongated glass envelope, a gaseous filling at low pressure in the envelope, electrodes in the envelope made of an absorbent conducting material having an alkali metal occluded therein, and an ionizing element in the envelope in the space between the electrodes, said element being made of a material having a substantially higher normal cathode fall of potential in said gaseous filling than that of said alkali metal and having a substantially flat surface exposed to the gaseous filling.

17. An electric discharge device which comprises an elongated glass envelope, a gaseous filling at low pressure in the envelope, electrodes in the envelope made of an absorbent conducting material having an alkali metal occluded therein, and an ionizing element in the envelope in the space between the electrodes and disconnected electrically from at least one electrode, said element being formed of a material having a substantially higher normal cathode fall of potential in said gaseous filling than that of said alkali metal and having a substantially flat surface exposed to the gaseous filling.

18. An electric discharge device which comprises an elongated glass envelope, a gaseous filling at low pressure in the envelope, electrodes in the envelope made of carbon and having an alkali metal occluded therein, and an ionizing element in the envelope in the space between the electrodes, said element being formed of a material having a substantially higher normal cathode fall of potential in said filling than that of said alkali metal and having a substantially flat surface exposed to the gaseous filling.

19. An electric discharge device which comprises an elongated glass envelope, a gaseous filling at low pressure in the envelope, electrodes in the envelope made of carbon and having potassium occluded therein, and an ionizing element of magnesium in the envelope in the space between the electrodes.

20. An electric discharge device comprising a

tube having its end portions turned at an angle to its middle portion and lying in a plane, electrodes in the end portions of said tube, a gaseous filling at low pressure in said tube, and an ionizing element extending through the middle portion of the tube and having its ends overlying and adjacent to the ends of said electrodes.

21. An electric discharge device comprising a tube having its end portions turned at an angle to its middle portion and lying in a plane, electrodes in the end portions of said tube, a gaseous filling at low pressure in said tube, and an ionizing element extending through the middle portion of the tube and having its ends overlying and adjacent to the ends of said electrodes, said element being secured to the tube wall.

22. An electric discharge tube for positive column light which comprises an envelope containing a gas under sub-atmospheric pressure, electrodes within the envelope spaced a substantial distance apart, and a strip within the envelope extending from one electrode to the other through the path of the discharge, said strip being electrically disconnected from at least one electrode and having a relatively flat surface exposed to the gaseous filling, said strip being of a material having a low normal cathode drop of the order of less than about 120 volts in the gas present.

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