Feb. 23, 1937. M. PENNYBACKER 2,071,426

LUMINOUS DISCHARGE TUBE

Filed Dec. 20, 1934

FIG. 1.

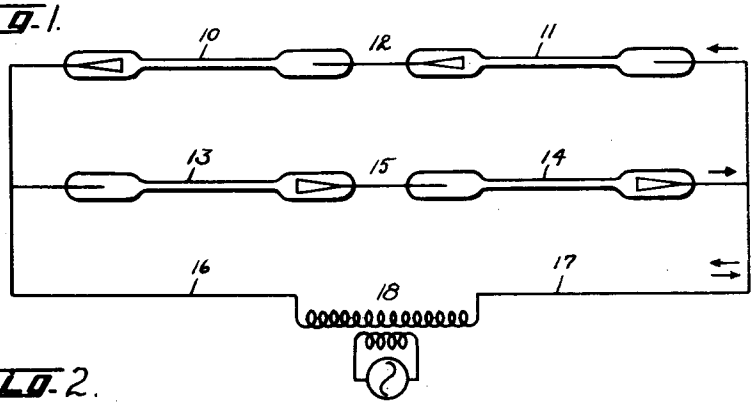



FIG. 2.

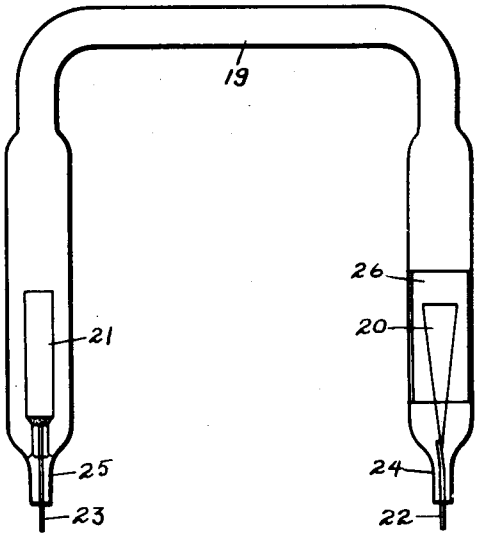



FIG. 3.

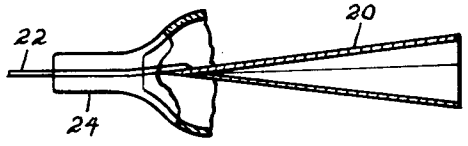



FIG. 4.

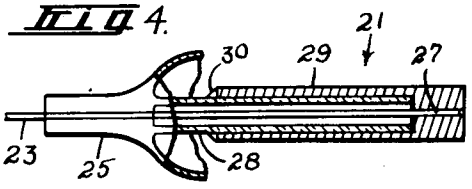
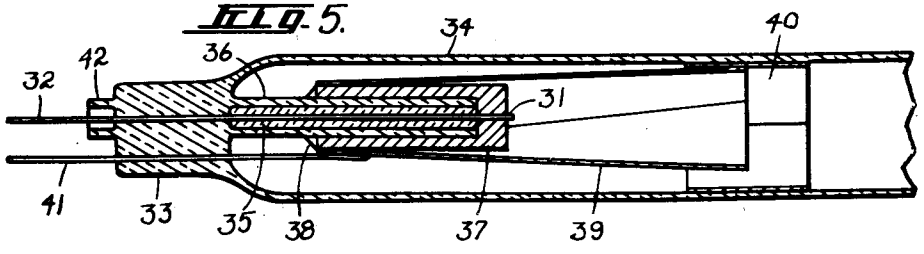



FIG. 5.




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## LUMINOUS DISCHARGE TUBE

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6 Claims. (Cl. 176—122)

This invention relates to new and useful improvements in luminous discharge tubes, and is in large part a division of my co-pending application Serial No. 592,931, filed February 15, 1932.

The main object of this invention is to provide a luminous discharge tube having unidirectional current conductivity.

A further object of the invention is to provide a luminous discharge tube, the anode of which is sufficiently restricted in area to impart unidirectional current conductivity to the tube.

Still another object of the invention is to provide a luminous discharge tube having unidirectional current conductivity and which is capable of withstanding high reverse voltages, and, more specifically, to provide an anode that is capable of withstanding the high voltage necessary to cause current conduction in a long luminous tube without permitting substantial reverse current to flow when the voltage is reversed.

Other objects and advantages of the invention relate to details of the electrode structures and their arrangement within the tube, and will appear more fully from the following description taken in connection with the accompanying drawing, in which:

Figure 1 is a circuit diagram illustrating a luminous discharge tube system in which a plurality of tubes constructed in accordance with my invention are connected for operation from a single source of alternating current;

Figure 2 is a view of a luminous discharge tube having substantially unidirectional conductivity adapted for use in a system such as shown in Figure 1;

Figure 3 is an enlarged sectional view of the cathode electrode of the tube shown in Figure 2;

Figure 4 is an enlarged sectional view of the anode electrode of the tube shown in Figure 2; and

Figure 5 is an enlarged sectional view of a modified form of anode construction adapted to be used in a tube of the form shown in Figure 2.

The resistance of luminous discharge tubes decreases rapidly as the discharge begins. As a result, it has heretofore not been practical to operate luminous discharge tubes in parallel from a single source of current except by the use of ballasting reactors, or resistances in series with each tube. Without such reactance or resistance, one tube will discharge before the others and thereupon the resistance of the discharging tube will decrease to such an extent that the other tubes will not discharge. Because of this fact, luminous discharge tubes which are to be energized from a single source of current commonly are connected in series, thereby necessitating the use of higher voltages than would be necessary if the tubes could be operated in parallel.

The tube of my invention overcomes this difficulty and permits the operation of two parallel branch circuits from a single source of current without employing separate external reactance or resistance in series with each tube or parallel branch. Each parallel branch may include two or more tubes in series as schematically illustrated in Figure 1.

The tubes 10, 11, 13 and 14 of Figure 1 have a unidirectional conductivity. The tubes 10 and 11 are connected in series, anode to cathode, to form a branch 12 which offers a relatively low resistance to the flow of current in the direction indicated by the arrow and a relatively high resistance to the flow of current in the opposite direction. The parallel branch 15 consists of tubes 13 and 14 connected cathode to anode, and offers a relatively low resistance to the flow of current in the direction of the arrow and a relatively high resistance to the flow of current in the opposite direction.

The two parallel branches 12 and 15 are connected across the alternating current mains 16 and 17 which, in turn, are connected to a suitable source of current as a high reactance transformer 18. Such high reactance transformers are commonly used in this art, and, as is well known, they serve to limit the current flowing through the load connected thereto. It is, therefore, apparent that as alternating current voltage is applied across the mains 16 and 17, the branch 12 will discharge only when the voltage is applied in one direction and the tubes in branch 15 will discharge only when the voltage is of opposite polarity.

In the system as shown in Figure 1, all of the tubes will discharge unidirectionally, but neither branch is required to withstand the maximum reverse voltage of the current supply mains because the lower resistance branch will discharge before the voltage wave reaches a maximum value. It is, therefore, apparent that the tubes in this system are more free from failure due to insulation breakdown, than tubes subjected continuously to a high voltage, as is necessarily encountered in a single series connected system of unidirectional tubes.

It is also apparent that tubes operating unidirectionally in the manner above described will have a longer life than when operated bi-directionally since, in the case of the former, each

parallel branch discharges only during alternate half cycles, whereas in tubes having bi-directional conductivity, each tube discharges on both half cycles. If 60-cycle current is used, the intermittent operation of the respective branches is not apparent to the eye, and, due also to retention of vision, the brilliancy of the tubes is apparently exactly the same as for continuous operation of the same tube on alternating current.

I have found that the brilliancy can be increased by increasing the current density either by reducing the tube diameter for the same current or by increasing the current with the same diameter. By this means a greater apparent brilliancy may be obtained with each tube with less power consumption per unit of tube than is obtained in the ordinary bi-directional operation and with greater total footage per tube on the same applied voltage. Consequently, by using the tube of my invention in the above-described manner, the length of luminous tubes operated from a single source of current supply may be greatly increased with an apparent increase in light output for the same power input.

It is, however, necessary to provide for the contingency that arises when one tube becomes inoperative, or when one of the two parallel branches becomes an "open circuit" from any other cause. If the remaining branch is to remain unidirectional, it must now withstand practically the full open circuit voltage of the transformer on alternate half cycles. This means that the anode must be capable of preventing substantial current flow even though the voltage is high enough to initiate a discharge, and the resistance of the remainder of the tube has been correspondingly lowered. In commercial neon sign installations, where 15,000 volt transformers are customarily employed, the total reverse voltage on the operating branch, in the case of an open circuit in the other branch, may approach the open circuit voltage of such a transformer. If there are seven tubes in series in the operating branch, the voltage drop at each of the seven anodes may be of the order of 1000 volts.

Anodes of prior art unidirectional tubes would pass a heavy current and be rapidly destroyed at any such voltages, and prior art unidirectional tubes have, therefore, been restricted in their commercial use to operation on low voltages. Even with unidirectional hot cathode tubes operating in the circuit herein described on 250 to 1000 milliamperes at voltages as low as 1200 volts, it is sometimes necessary for the anode itself to withstand more than 400 volts reverse voltage. The necessity heretofore of employing low operating voltages with unidirectional tubes seriously handicaps their use in advertising and display work, because only short sections of tubing are possible. On the other hand, long sections of tubing are desirable, partly because of the facility with which they may be bent into pleasing designs, and partly because of their increased life and saving in cost of terminals.

For a more complete description of my improved luminous discharge tube, reference will be made to Figures 2, 3, 4 and 5.

In Figure 2, the sealed tube 19 has enlarged ends in which are a cathode 20 and an anode 21 separated by a column of rarefied atmosphere of neon, helium or others of the noble gases. Ordinarily, such a tube may have a length of from five to ten feet and may be formed into suitable letters or figures. Electrical connection may be made to the electrodes 20 and 21 by means of terminals 22 and 23 passing through and sealed in externally extending press structures 24 and 25. A cylindrical shield 26 of insulating material such as mica may be employed around the cathode 20 on the interior of the tube.

The tube illustrated in Figure 2 has a substantially unidirectional conductivity by reason of the fact that at the range of gas pressures normally used, from 5 to 25 millimeters of mercury, and within the normal operating current range of from 15 to 60 milliamperes, the cathode has a relatively low cathode drop by reason of its large area and the anode has a relatively high cathode drop by reason of its small area. For example, in such a tube containing one or more of the noble gases at a given pressure, the exposed area of the anode desirably is less than the area required for normal cathode drop in the same gas and at the same pressure at an instantaneous current of 1.6 milliamperes, and the area of the cold cathode is desirably more than thirty times as great.

If it is assumed that the relatively small area required to maintain a low anode drop is available at the anode, it may be said that, in general, the lower the drop at the cathode during discharge and the higher the drop at the anode during reverse voltage, the stronger the unidirectional tendency, the more stable the operation of the tube and the greater the unbalance of relative lengths of tube permitted in two parallel branches.

I have found that a good working rule to follow to insure this difference in drop between the anode and the conventional designs of cathode is to have the exposed area of the anode such that its normal current density if used as a cathode would be exceeded when current in the reverse direction is less than 2% of the normal discharge peak current. In practice, I have used an area less than .01 square decimeters per ampere of normal discharge peak current.

The cathode electrode 20, as more clearly shown in Figure 3, comprises a conical metal member having its open end toward the column of gas contained in the tube, and its apex connected as by welding to the terminal 22. Conveniently, the conical electrode may be nickel or iron and its inner surface may be treated to reduce the cathode fall of potential. By using a conical electrode of narrow angle, the most efficient electrode diameter is assured for all reasonable variations of gas pressure within the tube.

The anode electrode 21, as shown in Figure 4, comprises a wire 27 which may be tungsten, tantalum or nickel connected as by welding to terminal 23. An insulating tube 28 preferably of glass is sealed to press 25 and surrounds anode wire 27 throughout the greater portion of its length leaving the end portion of the wire exposed. The anode wire 27 is preferably further insulated as by means of an outer tube 29 of lava or isolantite which telescopes over the end of the glass tube 28 and leaves only the end surface of the wire 27 exposed. The joint between the end of tube 29 and the glass tube 28 may be sealed with porcelain cement as shown at 30 for preventing discharge to the anode lead wire at high voltage.

A slightly modified anode arrangement is shown in Figure 5. The anode proper consists of a wire 31 connected as by welding to a lead-in connection 32 sealed into an external press 33 of tube 34. An insulating sheath 35 preferably of glass is fused about anode wire 31 prior to placing it into the tube 34. The anode 31 with its

glass sheath **35** may then be inserted within a glass tube **36**. Further insulation is provided by means of a closely fitting sleeve or tube **37** of high temperature insulation such as lava or isolantite which is closed at one end with the exception of a small bore through which the end of anode wire **31** protrudes slightly. Insulating tube **36** may be sealed with a discharge tight joint to the tube **37** by means of porcelain cement applied at the joint at the end of tube **37** as shown at **38**. Thus, upon the subsequent sealing of the lead-in connection **32** and the glass tube **36** into the press **33**, the anode **31** is insulated to the extent that it will limit the reverse current to such a small value as to permit the operation of the tube on an open circuit reverse voltage for several days without harmful effects. This condition may arise when one branch of the parallel system becomes defective, or, for some other reason, the branch circuit is broken, which consequently subjects the tubes in the other branch to maximum reverse voltage.

I have found that if the internal current discharge bombardment process is used in freeing the electrodes within the tube of occluded gases, it is desirable to provide an auxiliary electrode for carrying the heavy bombarding current, due to the small area of the anode **31**. This is accomplished in the structure shown in Figure 5 by providing the auxiliary electrode **39** of some suitable metal. The electrode **39** is preferably of frusto-conical shape having its small end in circumferential engagement with the tube **37**, and its larger end extending beyond the anode wire **31** toward the column of gas contained within the tube. A cylindrical shield **40** of insulating material, such as mica, may be employed around the auxiliary electrode **39** on the interior of the tube.

Electrical connection to the auxiliary electrode **39** is made by means of a lead-in conductor **41** sealed into the press **33**. Thus, during the process of evacuating the tube the heavy bombarding current is carried by the auxiliary electrode **39** and cathode **20**, each of which has an area sufficient for this purpose. When the tube is processed and filled with gas ready for use, lead-in connection **41** is clipped off flush with the press **33**. An insulating tube **42** is sealed to press **33** in surrounding spaced relation with the anode lead-in connection **32** to lengthen the air gap between connection **41** and connection **32** so that the same will withstand high voltage without arc-over even under adverse condition of operation. It is apparent that if arc-over is permitted to occur, the unidirectional conductivity of the tube is impaired.

The term "luminous discharge tube" as used herein is intended to include transparent or translucent tubes, bulbs and receptacles of various shapes and materials which are adapted to pass a luminous positive column electric discharge through an atmosphere of gas or gases. The term "discharge" is used to describe the main body of the luminous discharge, and not the small or transient discharge which may occur with the relatively small current which may flow in the reverse direction to the main current in each branch when the tubes are connected in parallel branch relationship. The term "high voltage" is used herein to designate alternating voltages in excess of the usual commercial service voltages of 110, 220 and 550 volts.

By "anode" is meant that electrode of a luminous discharge tube which readily permits a substantial flow of electric current when said electrode is of a positive polarity and which resists the flow of current when it is of negative polarity. By "cathode" is meant the other opposing electrode of a luminous discharge tube which contains an anode and which will readily permit the desired amount of current to flow when it is of negative polarity. A cathode for a luminous discharge tube may be characterized as an electrode which will usually conduct current readily regardless of its polarity.

The term "normal cathode drop" is used herein to designate the loss of potential on a cold cathode when the current is not sufficient to cause a glow over the entire exposed surface. The cathode drop remains normal as the current is increased to the point where the glow covers the entire exposed surface. If the current is increased beyond this point the cathode drop becomes "abnormal".

Although I have shown and described a specific tube structure, it is to be understood that the same is for the purpose of illustration, and many changes and modifications may be made by those skilled in the art without departing from the spirit or scope of the appended claims.

I claim:

1. In a luminous discharge tube, an elongated envelope, an outwardly extending press at one end of said envelope, a lead-in conductor sealed in said press, a wire anode connected to said conductor, an insulating tube surrounding said anode in part and having one end thereof sealed to said press, the exposed portion of said anode being restricted to an area so small as to permit the flow of substantial current in only one direction, an auxiliary tubular electrode carried by and surrounding said insulating tube, a second lead-in conductor sealed in said press and connected to said auxiliary electrode, said auxiliary electrode being adapted to carry bombarding current to liberate occluded gases during the manufacture of the tube, and an exterior tubular extension sealed to said press in surrounding spaced relation to said first-named lead-in conductor for increasing the insulation between said lead-in conductors.

2. A luminous discharge tube comprising an elongated envelope, an outwardly extending press at one end of said envelope, a lead-in conductor sealed in said press, a conical cathode connected to said lead-in conductor, a second outwardly extending press at the other end of said envelope, a second lead-in conductor sealed in said last named press, a wire anode connected to said last-named conductor, an insulating tube surrounding said anode in part and having one end thereof sealed to said last-named press, a second insulating tube surrounding said first-named tube adapted to seal the open end thereof and being provided with an aperture through which the effective area of said anode protrudes, said effective area being so small as to permit the flow of substantial current in only one direction, an auxiliary tubular electrode carried by and surrounding said last-named insulating tube, a third lead-in conductor sealed in said second-named press and connected to said auxiliary electrode, said auxiliary electrode being adapted to carry bombarding current to liberate occluded gases during the manufacture of the tube, and an exterior tubular extension sealed to said last-named press in surrounding spaced relation to said second-named lead-in conductor for in-

creasing the insulation between said two last-named conductors.

3. In a positive column luminous discharge, tube, an elongated glass envelope, a pair of electrodes within said envelope, at least one of said electrodes comprising a cone closed at its small end and with its large end open to and directed toward the positive column so that the discharge takes place on the inside surface of the cone, whereby the discharge is permitted to select the optimum electrode diameter for wide variations of gas pressure within the tube.

4. In a high voltage unidirectional luminous discharge tube, an elongated glass envelope, a lead-in conductor sealed in one end of said envelope with a vacuum-tight seal, an open-ended conical electrode connected to the said conductor, a second lead-in conductor sealed in the other end of said envelope with a vacuum-tight seal, and a second electrode in said tube adapted to permit substantial current to flow only in one direction, whereby said conical electrode is made to function as a cathode during the flow of said current, said conical electrode being arranged so that the discharge takes place on the inside surface of the cone, whereby the discharge is permitted to select the optimum electrode diameter for ordinary variations of gas pressure within the tube.

5. In a high voltage unidirectional luminous discharge tube, an elongated glass envelope, a lead-in conductor sealed in one end of said envelope with a vacuum-tight seal, an open-ended conical electrode connected to the said conductor, a second lead-in conductor sealed in the other end of said envelope with a vacuum-tight seal, a second electrode connected to said last named conductor and having an effective area so small as to permit substantial current to flow only in one direction, whereby said conical electrode is made to function as a cathode during the flow of said current, said conical electrode being arranged so that the discharge takes place on the inside surface of the cone, whereby the discharge is permitted to select the optimum electrode diameter for ordinary variations of gas pressure within the tube.

6. In a high voltage unidirectional luminous discharge tube, an elongated glass envelope, a lead-in conductor sealed in one end of said envelope with a vacuum-tight seal, an open-ended conical electrode connected to the said conductor, a second lead-in conductor sealed in the other end of said envelope with a vacuum-tight seal, a second electrode connected to said last named conductor and having an effective area so small as to permit substantial current to flow only in one direction, whereby said conical electrode is made to function as a cathode during the flow of said current, and means for insulating said second named electrode and lead-in conductor to withstand a high peak reverse voltage drop during reverse current in the tube, said conical electrode being arranged so that the discharge takes place on the inside surface of the cone, whereby the discharge is permitted to select the optimum electrode diameter for ordinary variations of gas pressure within the tube.

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