June 16, 1953 M. W. WALLACE 2,642,548

COLD CATHODE DISCHARGE TUBE

Filed Oct. 26, 1951

Fig. 1

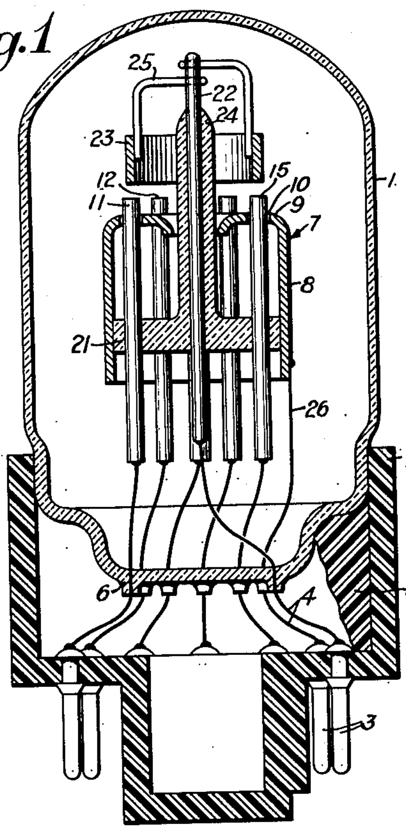


Fig. 3

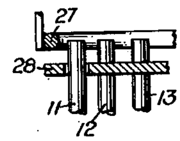


Fig. 4

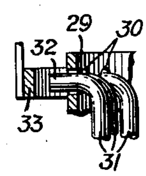
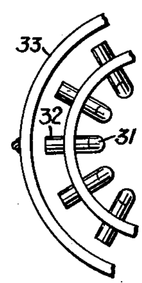


Fig. 5



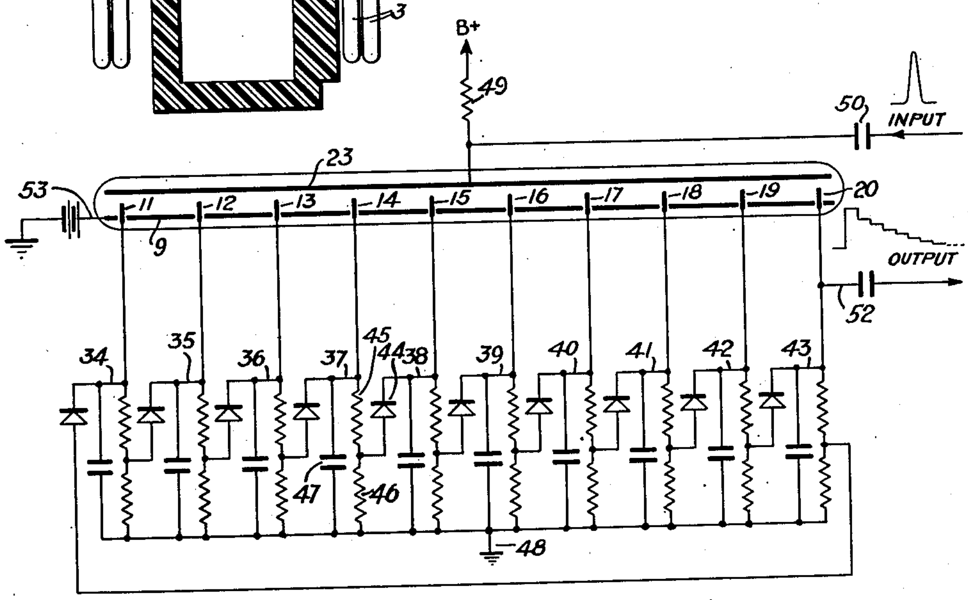


Fig. 2

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COLD CATHODE DISCHARGE TUBE

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13 Claims. (Cl. 313—196)

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This invention relates to electron switching and counting devices and more particularly to multi-gap cold cathode discharge tube for use in such devices.

In multi-gap tubes heretofore proposed for switching and counting devices, one anode and several cathodes are provided to form a number of cathode-anode gaps. In the use of these tubes it is desired that the gaps discharge in a given order. It is also desirable that the discharge transfer reliably from one gap to another particular gap, in some definite prescribed sequence. Heretofore attempts have been made to accomplish desired sequence of discharge by providing intermediate cathodes or special transfer electrodes together with external circuits or by shaping the cathodes to include transfer electrodes for unidirectional counting operation. Where the cathodes are specially shaped to effect directional transfer from gap to gap, such shaping tends to slow down the operation since special shaping increases de-ionization time or requires progression of the glow from the initial point of discharge to a point adjacent the next gap to be discharged. If rapid counting operation is not desired, then the slow shift of the glow across the shaped cathode is not troublesome. Howeper, if rapid count is important, then special shaping of the cathode impedes the operation and is, therefore, undesirable. Where additional cathodes or transfer electrodes are provided between counting cathodes, such arrangements add complications to the tube structure and the associated circuitry, and the time element required for each transfer again slows down the operation of the tube.

One of the objects of this invention is to provide a multi-gap cold cathode gas filled tube which avoids the use of specially shaped electrodes and/or the addition of transfer electrodes.

Another object of the invention is to provide a multi-cathode counting and switching device for use with a cathode biasing circuit capable of high speed counting and switching operation.

One of the features of the invention is the simplicity of construction of the tube, the cathodes being of simple rod or pin shape and substantially equally spaced from a common anode. By providing a biasing circuit network for the cathodes there is no need for specially shaped cathodes or the adjuncts of intermediate cathodes or transfer electrodes. Instead, I have found it preferable to have all cathode-anode gaps as simple and as nearly identical as possible and to rely on circuit biasing and adjacent gap priming for unidirectional operation.

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Another feature of the invention is the provision of means for controlling or limiting the cathodes so that they have substantially equal active areas. I accomplish this by placing a barrier, which may comprise a shield or control electrode extending over adjacent the part of the cathode to be maintained inactive. The active portion of the cathode is then the end portion that protrudes beyond this barrier. Where an apertured shield or control electrode plate is used as a barrier, another feature involved is the manner and method employed to support and align the cathodes in spaced axially extension through such apertures.

The above-mentioned and other features and objects of this invention will become more apparent by reference to the following description taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is a vertical sectional view of a multi-gap tube according to the present invention;

Fig. 2 is a schematic illustration of the tube together with a biasing circuit for the cathodes thereof;

Fig. 3 is a fragmentary view of a modified cathode-anode assembly with parts shown in section;

Fig. 4 is a fragmentary view of another embodiment of the cathode-anode assembly with parts shown in section; and

Fig. 5 is a plan view of the assembly shown in Fig. 4.

Referring to Fig. 1 of the drawing the tube comprises an envelope 1 mounted in a base 2 which is provided with terminals 3 for reception in a socket. The terminals 3 are connected by leads 4 through the envelope 1 to corresponding electrodes of the tube. The base and envelope are secured together by cement 5. One of the electrodes 7 contains at least in part an electrode assembly, and the electrode assembly as a whole is supported by the leads 4 which are sealed through the envelope 1 as indicated at 6. The electrode 7 is in the form of a hollow body, one part 8 being in the form of a hollow cylinder while a second part 9 is in the form of an end flange. The end flange 9 extends inwardly and comprises a barrier for determining the active area of the cathodes. The flange 9 is provided with a series of apertures 10 through which the cathode pins protrude.

As shown in Fig. 2, ten cathode pins 11 through 20 are provided. In Fig. 1, five of these cathodes are shown. The cathode pins are supported in an insulating web 21 which extends crosswise of the body 8 to which it is secured. This web may comprise glass or other insulating material. In order to insure proper alignment of the cathode pins axially of the apertures 10, the following operation is found satisfactory. The cathode pins and the body 8 are pre-oxidized so that the cathode pins are just large enough to fit into the apertures 10. The oxide layers act as spacers to locate the pins centrally of the apertures. After the application of the glass webbing 21, the oxides are removed by a cleaning operation including a water rinse and a dip in a solution of sulfuric and nitric acid, thus centering the cathode pins in spaced relation in the apertures 10. The clearance between the pins and the sides of the apertures is preferably within 0.002 to 0.004 inch.

A central stem 22 is provided for supporting a cylindrical anode 23. The stem 22 is beaded as indicated at 24 and made integral with the webbing 21 by known glass welding technique. This welding operation also secures the webbing 21 to the cylindrical portion of the electrode 7 which is preferably of Kovar. The cathode pins as well as the anode stem 22 are of Kovar which has a coefficient of expansion similar to glass. The anode 23 is supported by wires 25 which are welded to the anode and to the anode stem 22.

The member 7 which comprises the support for the assembly as well as the shield for defining the active areas of the cathodes is connected by a lead 26 by which the member may be raised to a desired potential. The member thus biased acts as a control electrode for the cathodes and limits the active areas thereof.

Referring to Figs. 3, 4, and 5 of the drawing, two alternative elements for the cathode-anode assembly are shown. In Fig. 3 the anode is indicated as a wire ring 37 which is disposed concentrically of the series of cathodes 11 to 20. The cathodes extend through apertures contained in a control electrode plate 28, similarly as illustrated in Fig. 1. It will be readily apparent to those skilled in the art that the anode 27 may be of various shapes so long as an anode surface is spaced a given distance from the active surfaces of the cathodes. For example, the ring 27 may overlie the ends of the cathodes as indicated in Fig. 1 or it may be disposed within the circle defined by the cathodes.

In Figs. 4 and 5, the control plate 29 is disposed as a hollow cylinder without the end flange shown in Fig. 1. In this form the apertures indicated at 30 are disposed in a circle, but may be in other configurations if desired, in the wall of the cylinder and the cathodes, such as indicated at 31, are turned at their ends so that the active portions 32 are disposed radially through the apertures 30. The anode 33 in the form of a ring is disposed concentrically of the control electrode 29 in spaced relation to the ends of the radially disposed cathodes.

While I have shown several possible cathode-anode assembly arrangements in Figs. 1, 3, 4, and 5, it will be clear that many other arrangements utilizing the simple cathode-anode relationship and the assembly features of the present invention are possible. The cathodes, for example, may be arranged in a straight line or if desired in an irregular fashion so long as the anode is spaced equally from each of the cathodes. The fundamental requirement is that the cathode-anode gaps have substantially identical operating characteristics.

The gaseous atmosphere preferred for the tube is a mixture of neon, argon and hydrogen, the percentage of which may be varied widely depending upon the gas pressure, the electrode voltages and the electrode geometry of the tube, and also the break-down voltage point desired. When hydrogen gas is used in small percentages the hydrogen accelerates de-ionization and is, therefore, desirable. The amount of hydrogen preferred is between 5 and 10 per cent. Argon is used principally to reduce the breakdown voltage point and is not critical. The percentage of argon is preferably between about 1 and 3 per cent. The remaining percentage of the gas mixture is neon. The gas pressure is not critical, but relative high pressures in the neighborhood of 125 mm. of mercury are preferred. The higher pressures favor rapid de-ionization and also give a wider spread between normal striking and maintaining voltages.

Referring particularly to Fig. 2 of the drawing, the cathodes 11 to 20 have associated therewith a bias control system comprising a plurality of cathode circuits 34 to 43 coupled together as a re-entrant circuit by rectifiers as indicated at 44. Each bias control circuit includes a pair of resistors 45 and 46 connected together in series and to one of the cathodes, such as cathode 14, together with a condenser 47 connected in parallel across the two resistors. The cathode biasing circuits are connected to ground as indicated at 48. The anode 23 has a source of positive potential connected thereto through resistor 49. The pulse input to be counted is applied, when the input pulses are of positive potential, through capacitor 50 to the anode circuit. Should the source of input pulses be of negative potential the ground connection 48 would then be provided with a resistor and the negative input pulses applied thereacross. An output connection 52 is connected to the cathode 20. A positive bias is applied over connection 53 to the control electrode 9.

While only one bias control circuit is shown for purposes of illustration of the present invention, other forms of bias control circuits may be used. For additional information on bias control circuits reference may be had to the copending application of J. Lair (case 27), Serial No. 248,999, filed September 29, 1951.

Before describing the operation of the tube, attention is called to the term "priming." When there are several gaps in a glow tube, conduction in one gap will reduce the striking or breakdown voltage of the others. This reduction is known as "priming." A gap closely adjacent one that is conducting will be primed more than a similar gap further away.

To initiate operation of the tube a high voltage is applied to the anode circuit causing one of the gaps to fire. Assuming that the gap of the cathode 14 has fired, the current flowing will develop a positive voltage across the associated resistors 45 and 46. Part of this voltage will appear on the next cathode 15 to the right through the connecting rectifier 44. A smaller positive voltage is developed on the second cathode 16 and so on around the series of cathodes so that the cathode 13 to the left of the one conducting has zero or nearly zero voltage across its resistors with the rectifier between it and the conducting cathode appearing as a high resistance. Thus, the potential difference between this left adjacent cathode and the anode is greater than that between any other cathode and anode. This, and the fact that both adjacent gaps are more exposed to the light and ionization products of the conducting gap than the other cathode-anode gaps, makes the left adjacent gap at 13 strike when the next input pulse is applied. During the application of an input pulse to the present illustrated circuit of Fig. 2, both the old and newly fired cathodes are conducting, but when the input pulse terminates, the old gap extinguishes as it is biased positive by the charge on its associated condenser. When the cathode network has readjusted itself to the newly fired cathode, the system is ready to receive a new input pulse. The bias voltage on the successive cathodes varies in stair-step fashion except possibly for the last two or three cathodes to the left of the firing cathode and these may be substantially equal.

The speed of counting ranges from less than one pulse per second to a rate well exceeding one hundred thousand pulses per second. In tests, the rate of one hundred thousand pulses per second has proved to be accurate but as the rate was increased, the counting became erratic as the rate of two hundred thousand pulses per second was approached. While the tube illustrated is shown to have only ten cathodes, it will be clear that a less or greater number of cathodes may be provided, as may be desired. It should also be understood that tubes made in accordance with the present invention have definite advantages over hard vacuum tubes. For example, the present tube saves space and weight and requires about 1/6 of the power required for a comparable circuit using hard tubes. The life of the present tube also far exceeds the life of the hard tube. Tubes operating at 100 kc./s. are found to be very useful in many applications, such as counting, switching and frequency division.

While I have described above the principles of my invention in connection with specific apparatus, it is to be clearly understood that this description is made by way of example only and not as a limitation to the scope of my invention as set forth in the objects thereof and in the accompanying claims.

I claim:

1. A cold multi-cathode-anode gap discharge device comprising an envelope containing a gaseous atmosphere, an anode, a plurality of cathodes spaced apart and from said anode to form cathode-anode gaps of substantially equal operating characteristic and means equalizing substantially the active areas of said cathodes.

2. A device according to claim 1, wherein the means for equalizing the active areas of the cathodes include a barrier disposed in association with the cathodes to limit the active areas thereof.

3. A device according to claim 1, wherein the cathodes are in the form of pins and the means for equalizing the active areas of the cathodes include a barrier to limit the activity of each cathode to the tip portion only of the cathode pin.

4. A device according to claim 3, wherein the barrier includes a control electrode having portions disposed adjacent the ends of the cathode pins and means for applying a potential bias to said control electrode.

5. A device according to claim 3, wherein the barrier comprises a shield having apertures therethrough and said cathode pins are disposed with the end thereof protruding through said apertures.

6. A device according to claim 1, wherein said cathodes comprise pin-shaped elements disposed in a circular arrangement and said anode is disposed in substantially equal spaced relationship with respect to said cathode pins.

7. A device according to claim 6, wherein the active portion of the anode is in the form of a ring and the cathode pins are disposed radially with respect to said anode ring.

8. A device according to claim 1, wherein said means for equalizing the active areas of the cathodes includes a hollow body having apertures in a wall thereof, and said cathodes comprise a group of pins disposed in said body with the ends thereof protruding through said apertures, and a web of insulating material disposed crosswise of said body to support said pins.

9. An electrode assembly for a cold multicathode-anode gap discharge device comprising a hollow body having a plurality of apertures through a wall thereof, means carried by said body to support a plurality of cathode pins with the end portions thereof protruding through said apertures whereby said body limits the active areas of said cathodes to the parts protruding outside said body.

10. An electrode assembly according to claim 9, wherein said body is cylindrical and the means for supporting said cathodes includes a web of insulating material carried by the inner surface of said cylinder.

11. An electrode assembly according to claim 10, wherein the apertures are contained in the cylindrical wall and the cathode pins have end portions disposed radially through said apertures.

12. An electrode assembly according to claim 10, wherein said cylinder includes an end flange extending inwardly toward the axis of said cylinder, and said end flange contains the apertures through which said cathode pins extend.

13. An electrode assembly according to claim 10 further including an anode and an anode stem supporting said anode, said stem being disposed axially of said body and supported by said web.

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