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M. A. TOWNSEND

2,575,371

COLD CATHODE GASEOUS DISCHARGE DEVICE

Filed Aug. 9, 1949

2 SHEETS—SHEET 1

FIG. 2

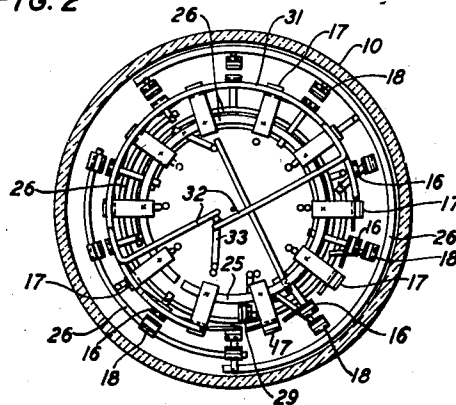


FIG. 1

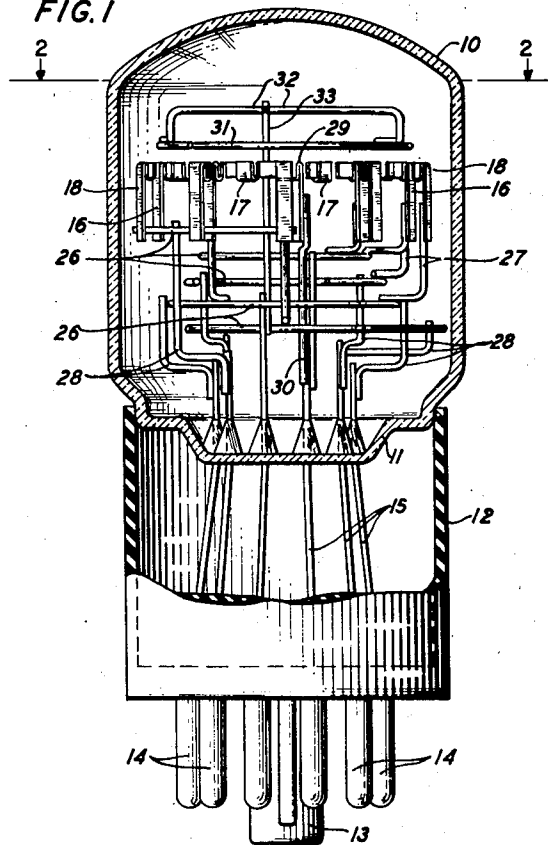


FIG. 3

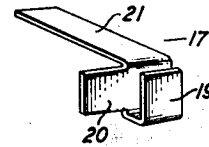
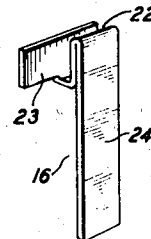


FIG. 4



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## UNITED STATES PATENT OFFICE

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COLD CATHODE GASEOUS DISCHARGE  
DEVICE

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10 Claims. (Cl. 313—182)

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This invention relates to gaseous discharge devices and more particularly to multiple cathode glow discharge devices of the type disclosed in the application, Serial No. 101,322, filed June 25, 1949 of M. A. Townsend.

One form of device of the type disclosed in the above-identified application comprises, in general, a row of cold cathodes and an anode in cooperative relation with the cathodes, one group of alternate cathodes, referred to as B cathodes, being connected together electrically and the remaining cathodes, designated as A cathodes, having individual load circuits coupled thereto. The several cathodes are so constructed and arranged that in response to signal pulses applied to the connected group a discharge is established which is stepped along the row in one direction advancing from one of the A cathodes to the next succeeding one for each applied pulse. Thus, any load circuit may be closed or energized by applying to the device the number of pulses requisite to move or step the discharge from a pre-assigned or normal position to the A cathode corresponding to that load circuit.

The number of load circuits which can be controlled by any particular device is determined by the number of A cathodes and in devices of the construction heretofore described an individual leading-in conductor or output terminal is required for each such cathode. This engenders both electrical and mechanical difficulties and entails complications and limitations in the construction of practical devices.

One general object of this invention is to simplify and facilitate the construction of multicathode glow discharge devices and particularly of such devices adapted for the control of a multiplicity of load circuits. More specifically, one object of this invention is to reduce or minimize the number of leading-in conductors and terminals necessary in such a device for effecting control of a given number of load circuits.

In accordance with one feature of this invention, in a device of the general construction above described, a plurality of auxiliary or load cathodes are provided each being mounted adjacent a respective one of the A cathodes, and the auxiliary and A cathodes are electrically interconnected in accordance with a prescribed numbering system, specifically on the basis of an arithmetic combination. For example, in one illustrative embodiment, these cathodes may be interconnected on a two-out-of-five basis so that ten load circuits may be controlled with a device having five output terminals.

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The invention and the above-noted and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawings in which:

Fig. 1 is an elevational view of a multicathode glow discharge device illustrative of one embodiment of this invention, the enclosing vessel and a portion of the base of the device being broken away to show the internal structure more clearly;

Fig. 2 is a cross-sectional view of the device taken along plane 2—2 of Fig. 1, a portion of the anode being broken away to expose certain of the cathodes;

Figs. 3 and 4 are detail perspective views illustrating the construction of the B and A cathodes respectively, in the device shown in Figs. 1 and 2;

Fig. 5 is a circuit diagram illustrating one manner in which the device of Figs. 1 and 2 may be operated; and

Fig. 6 is in part a perspective diagrammatic view and in part a circuit schematic of a multicathode gaseous discharge device illustrative of another embodiment of this invention.

Referring now to the drawing, the discharge device illustrated in Figs. 1 and 2 comprises a vitreous enclosing vessel 10 having therein an ionizable atmosphere, for example neon at a pressure of the order of 50 millimeters of mercury or hydrogen at a pressure of the order of 20 millimeters of mercury, and having also a dish-shaped stem 11. The vessel 10 is affixed to a base 12, which may be of conventional construction, having thereon a positioning stub 13 and a plurality of terminal pins 14 through which electrical connection to the electrodes of the device may be established by way of conductors 15 sealed in the stem 11.

Mounted within the vessel 10 are a plurality, ten in the specific embodiment shown, of A cathodes 16 and an equal number of B cathodes 17. As shown clearly in Fig. 2, the A and B cathodes are arranged in a circular row and in alternate relation. Adjacent each of the A cathodes 16 is a respective auxiliary or load cathode 18. All of the cathodes 16, 17 and 18 advantageously are sheet refractory metal such as molybdenum, tantalum or columbium.

Each of the B cathodes, as illustrated in detail in Fig. 3, comprises a channel-shaped portion 19, a tail portion 20 and a stem or mounting portion 21. Similarly, each of the A cathodes, as illustrated in Fig. 4, comprises a channel-shaped

portion 22, a tail portion 23 and a mounting portion 24. The auxiliary load cathodes 18 may be of the same construction as the A cathodes except that they do not include a tail portion 23. As shown most clearly in Fig. 2, the A and B cathodes are arranged with the tail portion of each in juxtaposition to the channel portion of the preceding cathode viewed clockwise. The channel portions of all the A, B and auxiliary cathodes and the tail portions of the A and B cathodes extend in the direction of the circular boundary in which the A and B cathodes lie.

In a specific and illustrative construction the several cathodes may be formed of .010 inch sheet molybdenum, the channel portions may be  $\frac{1}{8}$  inch deep by  $\frac{1}{8}$  inch long by .020 inch wide and each tail portion may be  $\frac{1}{8}$  inch wide by  $\frac{1}{8}$  inch long and spaced .020 inch from the next preceding cathode.

All of the B cathodes 17 are connected together electrically and supported by a metallic ring 25 to which the stem or mounting portions 21 are affixed as by welding, the ring 25 being supported from one of the leading-in conductors 15. The A cathodes 16 and auxiliary load cathodes 18 are electrically interconnected as described in detail hereinafter by arcuate wires 26 to which they are affixed either directly by way of the mounting portions 24 or by way of rigid connecting wires 27. The several connectors 26 are connected each to a respective one of the conductors 15 by rigid mounting wires 28.

A normal or reset cathode 29 is supported from one of the leading-in conductors 15 by a rigid wire 30 and, as illustrated most clearly in Fig. 2, has a substantially radial channel-shaped portion in juxtaposition to the tail portion of the B cathode 17 nearest thereto.

An annular anode, which in the specific embodiment illustrated may be of .020 inch molybdenum wire, overlies and is coaxial with the A and B cathodes. The anode-to-cathode spacing may be of the order of .040 inch. The anode is supported by rigid connecting wires 32 affixed to a rigid metallic support 33 connected to one of the leading-in conductors 15.

As has been pointed out heretofore, the A and auxiliary load cathodes 16 and 18 are electrically interconnected, specifically to the arcuate connectors 26 and through them to the corresponding terminal pins 14, in accordance with a prescribed code or numbering system, specifically in accordance with an arithmetic combination, whereby the number of terminals for these cathodes requisite to effect control of a given number of load circuits is minimized. The specific interconnection of these cathodes in the device illustrated in Figs. 1 and 2 will be most readily apparent from a consideration of Fig. 5. In this figure the five terminals associated respectively with the five connectors 26 are designated by 0 and the Roman numerals I, II, IV, and VII. The A cathodes are numbered 1 to 10 inclusive, considered counterclockwise from the normal or reset cathode 29. As shown in Fig. 5, terminal 0 has connected thereto the A cathodes 1, 2, 4 and 7. Terminal I has connected thereto the A cathodes 3, 5 and 8 and the auxiliary cathode opposite the A cathode 1. Terminal II has connected thereto A cathodes 6 and 9 and the auxiliary cathodes adjacent A cathodes 2 and 3. Terminal IV has connected thereto A cathode 10 and the auxiliary cathodes adjacent the A cathodes 4, 5 and 6. Terminal VII has connected thereto the auxiliary cathodes adjacent the A cathodes 7, 8, 9 and 10.

Thus the cathodes are connected to the terminals on an  $n$  out of  $x$ , specifically a 2 out of 5 basis.

As illustrated in Fig. 5, in the operation of the device, the anode 31 is connected to a source of positive potential through resistors 36 and 37, one of which may be short-circuited as by a switch 38, the potential applied to the anode being below the break-down potential of the anode-cathode gaps but somewhat greater than the sustaining potential for these gaps. The normal or reset cathode 29 is connected to a source 39 in circuit with a resistor 40 for applying to the cathode 29 a negative pulse of amplitude sufficient to initiate a discharge between the normal cathode and the anode. The B cathodes 17 are tied together electrically and to a source 41 for applying a negative pulse thereto of sufficient amplitude to enable the establishment of a discharge between any B cathode 17 and the anode. The A and auxiliary cathodes are connected to the terminals 0, I, II, IV and VII in the manner described hereinabove and via these terminals to respective output resistors 35.

In the operation of the device, a pulse is applied to the normal or reset cathode 29 sufficient to initiate a discharge between this cathode and the anode 31. In response to input pulses applied from the source 41 to the B cathodes the discharge is transferred from the normal cathode 29 to the A cathodes along the circular row in the manner described in detail in the application heretofore identified. Briefly, this transfer is effected as follows: In response to the first pulse applied from the source 41 the discharge transfers from the cathode 29 to the next adjacent B cathode 17 and upon cessation of this pulse the discharge transfers from this cathode 17 to the next succeeding A cathode 16, specifically, the A cathode at position 1 in Fig. 5. The discharge remains at A cathode 1 until the next succeeding pulse from the source 41. In response to such second pulse the discharge transfers first from the A cathode 1 to the next succeeding B cathode and upon cessation of this pulse to the A cathode at position 2. Succeeding pulses effect transfer of the discharge along the row of cathodes, the discharge advancing one step, that is from one A cathode to the next, for each applied pulse from the source 41. As pointed out in the aforementioned application, because of the construction of the A and B cathodes the channel and tail portions have different efficiency as glow discharge elements so that the discharge to any one of them concentrates at the channel portion thereof, whereby in response to input pulses the discharge is stepped always in the same direction, that is, counter-clockwise in Fig. 5. Thus, it will be appreciated that the discharge may be transferred from the normal cathode 29 to any desired one of the A cathodes by applying from the source 41 the proper number of pulses.

When the discharge is stepped to any of the A cathodes, because of the current flowing through the anode resistors 36, 37 and the associated output resistor 35 that cathode becomes positive with respect to the auxiliary load cathode 18 adjacent thereto and as a result at least a portion of the discharge shifts to such adjacent auxiliary load cathode. Thus, when the discharge is stepped to any A cathode voltages appear at the output resistor associated with that A cathode and also at the resistor 35 associated with the auxiliary load cathode adjacent that A cathode. For example, referring to Fig. 5, if the discharge is stepped to the A cathode at position 6, voltages will appear at the output resistors 35<sub>VI</sub> and 35<sub>IV</sub>. In similar

manner when the discharge is stepped to any other one of the A cathodes voltages will appear across two of the resistors 35. Specifically, the correlation between A cathode position and the terminals leading to the resistors 35 at which voltages will appear are as given in the following table:

| Position | Terminals  |
|----------|------------|
| 1        | 0 and I    |
| 2        | 0 and II   |
| 3        | I and II   |
| 4        | 0 and IV   |
| 5        | I and IV   |
| 6        | II and IV  |
| 7        | 0 and VII  |
| 8        | I and VII  |
| 9        | II and VII |
| 10       | IV and VII |

When the discharge is stepped to any A cathode, the switch 38 may be closed to short-circuit the resistor 37 thereby increasing the discharge current and assuring a discharge between the anode and both of the cathodes corresponding to the position to which the discharge has been stepped. The five resistors 35 may have associated therewith ten output or load circuits coupled to the resistors in such manner that each circuit will be energized when a respective pair of resistors has voltages produced thereacross. Thus each load circuit will correspond to a respective one of the A cathodes and may be completed by applying the proper number of pulses from the source 41 to the B cathodes 17.

The discharge may be returned from any A cathode to the normal or reset cathode 29 by application of a large negative pulse from the source 39 to the cathode 29.

It will be appreciated from the foregoing that any one of ten load or work circuits may be controlled by the device of Fig. 5 by the application of a corresponding number of pulses and that the circuits may be energized in random sequence by application of groups of pulses of different numbers, the discharge being returned to the normal cathode 29 following the application of each group of pulses.

As pointed out in the application heretofore identified, the form of the pulses applied from the source 41 is not critical. The pulse amplitude, of course, should be such as to effect transfer of the discharge. In a particular device of the specific construction heretofore described and containing neon at a pressure of 50 millimeters of mercury with the anode biased at 180 volts, input pulses of the order of 20 volts are sufficient to effect stepping of the discharge. As further pointed out in the application mentioned, the period between pulses should be sufficient to allow deionization at the gap from which the discharge is stepped so that false stepping of the discharge, that is, in the reverse direction, will be prevented. In particular devices utilizing neon, pulse lengths of the order of 0.4 millisecond at frequencies up to 1,200 cycles per second may be used. In devices wherein the gas filling is hydrogen, pulses of 8 microseconds duration at a frequency as high as 60,000 cycles per second may be employed.

In the embodiment of the invention illustrated in Fig. 6, the cathodes are of the same general construction and arrangement as in the device illustrated in Figs. 1 and 2 and heretofore described except that the channel portions of the A, B and auxiliary load cathodes 160, 170 and 180 respectively, extend transversely with respect to

the direction in which the discharge is stepped and the tail portions of these cathodes are substantially coplanar with each tail portion of the A and B cathodes extending into immediate proximity to the open end of the channel portion of the next preceding cathode, that is, the next cathode to the left in Fig. 6. The anode may be in the form of a metallic plate or strip overlying the A, B and auxiliary cathodes and also the normal or reset cathode 290. For simplicity of illustration only three A cathode positions have been shown in Fig. 6, it being understood that ten positions or a greater or lesser number may be employed. The several cathodes may be electrically interconnected in the same manner as in the device illustrated in Fig. 5 and also operated in like manner as in the latter device.

Although specific embodiments of this invention have been shown and described, it will be understood that they are but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention. For example, although in the device illustrated in Figs. 1 and 2 the cathodes are mounted in circular array, they may be arranged in a linear row or one of other geometric form. Similarly, although in the embodiment illustrated in Fig. 6 the cathodes are mounted in linear array they may be arranged in circular or other geometric form. Also, although the invention has been described with particular reference to devices including ten positions and the A and auxiliary load cathodes are interconnected on a two-out-of-five basis, a greater or lesser number of positions may be embodied and the cathodes may be interconnected in accordance with different numbering or code systems.

What is claimed is:

1. A gaseous discharge device comprising a plurality of cathodes each having two portions of different efficiency as glow discharge elements, said cathodes being mounted in a row with the portion of greater efficiency of each toward the portion of lower efficiency of the next succeeding cathode, an anode opposite said cathodes, means electrically connecting one group of alternate cathodes together, a plurality of auxiliary cathodes each adjacent a respective one of the other then connected cathodes, and means electrically interconnecting said auxiliary and other cathodes in accordance with a prescribed code system.

2. A gaseous discharge device comprising a first group and a second group of cathodes mounted in a row with the cathodes of the two groups in alternate relation, each of said cathodes having a channel portion and a plane portion and said cathodes being arranged with the channel portion of each in juxtaposition to the plane portion of the next succeeding cathode, an anode opposite said cathodes, means electrically connecting the cathodes of said first group together, a plurality of auxiliary cathodes each adjacent a respective cathode of said second group, a plurality of terminals of lesser number than said auxiliary cathodes, and means electrically connecting said auxiliary cathodes and said cathodes of said second group to said terminals on an  $n$  out of  $x$  arithmetic combination basis,  $x$  being the number of terminals and  $n \leq x$  being the number of auxiliary cathodes.

3. A gaseous discharge device comprising a plurality of cathodes each having two portions of different efficiency as glow discharge elements, said cathodes being mounted in a row with the

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portion of higher efficiency of each in juxtaposition to the portion of lower efficiency of the next succeeding cathode, an anode opposite said cathodes, a plurality of terminals, a plurality of auxiliary cathodes adjacent non-adjacent ones of said first plurality of cathodes, there being  $x$  terminals and  $nx$  auxiliary cathodes,  $n$  being smaller than  $x$ , and means connecting said auxiliary cathodes and those of said plurality of cathodes adjacent thereto to said terminals on an  $n$  out of  $x$  arithmetic combination basis.

4. A gaseous discharge device in accordance with claim 3 wherein  $x$  is 5 and  $n$  is 2.

5. A gaseous discharge device comprising a first group of cathodes mounted in a row, a second group of cathodes each adjacent a respective cathode of the first group, an anode opposite said cathodes, a plurality of terminals of lesser number than said first group of cathodes, means for selectively establishing a discharge between said anode and any pair of adjacent cathodes of said first and second groups, and means electrically connecting each pair of said adjacent cathodes to a corresponding pair of said terminals, each said pair of cathodes being connected to a different pair of said terminals.

6. A gaseous discharge device comprising a plurality of pairs of laterally adjacent cathodes mounted in a row, an anode opposite said cathodes, a normal cathode adjacent one end of said row, means for establishing a discharge between said anode and said normal cathode, means for stepping the discharge to successive pairs of adjacent cathodes in said row, a plurality of terminals, the number of pairs of cathodes being twice the number of terminals, and means electrically connecting each of said pairs of cathodes to a pair of said terminals, each cathode pair being connected to a different terminal pair.

7. A gaseous discharge device comprising a first group and a second group of cathodes mounted in a row with the cathodes of the two groups in alternate relation, each of said cathodes having two portions of different efficiency as glow discharge elements and said cathodes being arranged with the portion of higher efficiency of each in juxtaposition to the portion of lower efficiency of the next succeeding cathode, a third group of cathodes each adjacent a respective cathode of said second group, a plurality of terminals, the number of cathodes in said third group being double the number of said terminals, means electrically connecting the cathodes of said first group together, and means connecting each pair

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of adjacent cathodes of said second and third groups to a pair of said terminals, each of said cathode pairs being connected to a different terminal pair.

8. A gaseous discharge device comprising a first and a second group of cathodes mounted in a row with the cathodes of the two groups in alternate relation, each of said cathodes having a channel portion and a tail portion and said cathodes being arranged with the channel portion of each in juxtaposition to the tail portion of the next succeeding cathode, an anode opposite said cathodes, a normal cathode adjacent one of said cathodes of said first group, an auxiliary cathode adjacent each of the cathodes of said second group, means electrically connecting said first group of cathodes together, a plurality of terminals, there being twice as many auxiliary cathodes as terminals, means electrically connecting each auxiliary cathode and the cathode of said second group adjacent thereto to a pair of said terminals, each cathode pair being connected to a different terminal pair, means for establishing a discharge between said normal cathode and said anode, and means for energizing said first group of cathodes to step the discharge along said row.

9. A gaseous device comprising a plurality of cathodes mounted in a row, each of said cathodes having a channel portion extending transversely with respect to the row and having a plane portion extending in the direction of the row, the plane portions of said cathodes being substantially coplanar and said cathodes being disposed with the plane portion of each in juxtaposition to the channel portion of the next preceding cathode, and an anode opposite said cathodes.

10. A gaseous discharge device in accordance with claim 9 comprising a plurality of auxiliary cathodes respectively adjacent alternate ones of said first plurality of cathodes, each of said auxiliary cathodes having a channel portion opposite the respective adjacent cathode.

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