

Aug. 25, 1953

M. A. TOWNSEND

2,650,320

COLD CATHODE ELECTRIC DISCHARGE DEVICE

Filed Nov. 22, 1948

2 Sheets-Sheet 1

FIG. 1

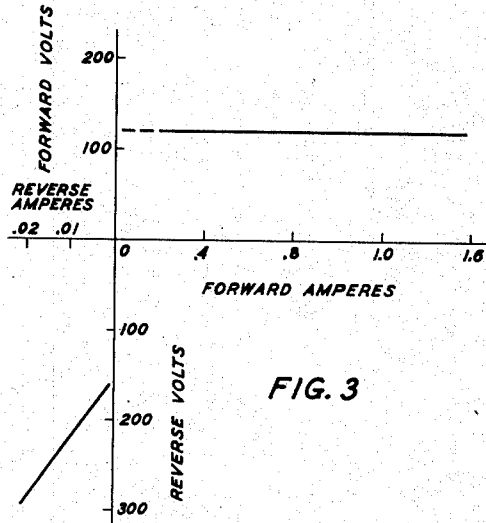
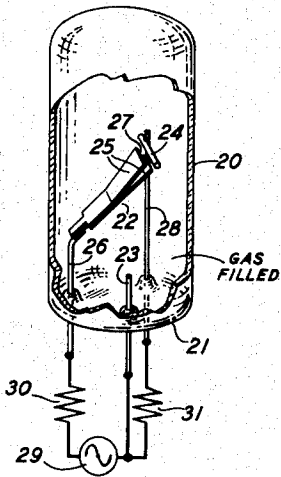


FIG. 3

FIG. 2

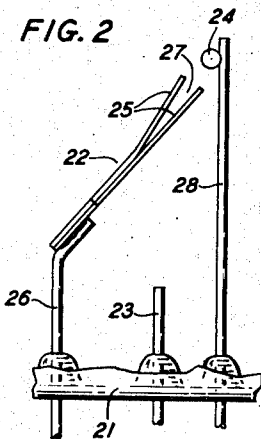


FIG. 6

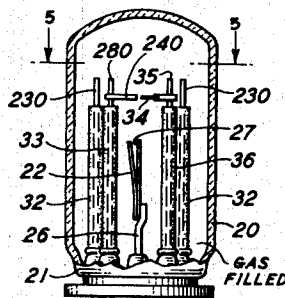


FIG. 4

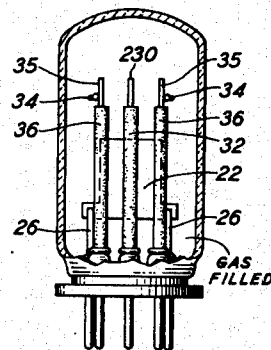
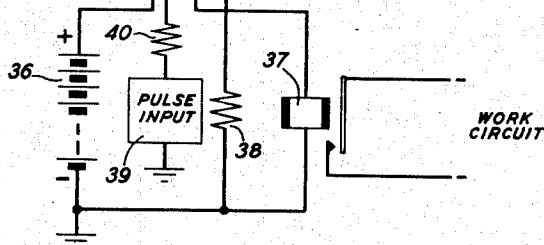
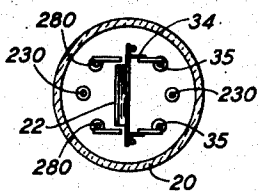


FIG. 5



INVENTOR
M. A. TOWNSEND
BY
[Signature]
ATTORNEY

Aug. 25, 1953

M. A. TOWNSEND

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FIG. 10

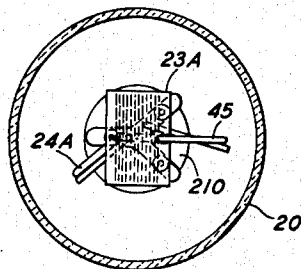


FIG. 8

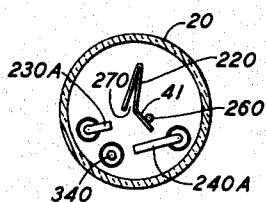


FIG. 7

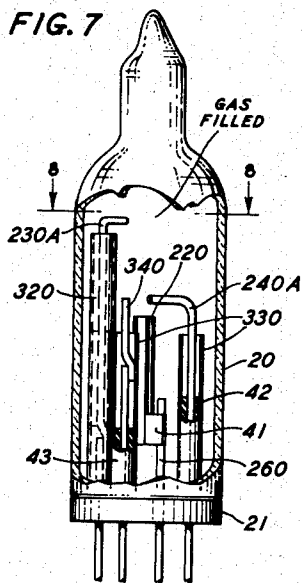
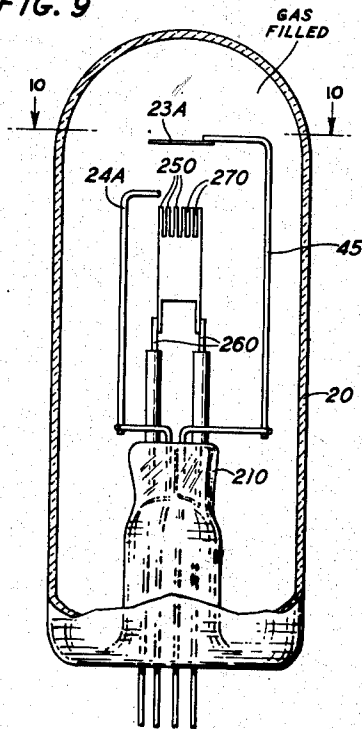


FIG. 9



INVENTOR
M. A. TOWNSEND
BY

J. Hunter

ATTORNEY

UNITED STATES PATENT OFFICE

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COLD CATHODE ELECTRIC DISCHARGE
DEVICE

Mark A. Townsend, Murray Hill, N. J., assignor
to Bell Telephone Laboratories, Incorporated,
New York, N. Y., a corporation of New York

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8 Claims. (Cl. 313—198)

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This invention relates to electric discharge devices and more particularly to such devices of the cold cathode type.

One general object of this invention is to improve the operating characteristics of electric discharge devices of the cold cathode type.

More specific objects of this invention are to increase the current carrying capacity of such devices, obtain high currents concomitantly with relatively low operating voltages, realize large differences between the breakdown and sustaining voltages, increase the operating life, and simplify the design and construction.

In one illustrative embodiment of this invention, a gaseous discharge device comprises a cold cathode and a main or work anode and an auxiliary or control anode in cooperative relation with the cathode.

In accordance with one feature of this invention the cathode is constructed or formed with a pair, or a plurality of pairs, of portions of refractory metal, such as molybdenum or tantalum, positioned to define a channel, or group of channels, and so spaced that in operation of the device the negative glow regions for the pair, or each pair, of portions overlap.

In a specific and illustrative construction, the two cathode portions are plates correlated to define a V-shaped channel of small width in comparison to its depth. The auxiliary or control anode may be a wire or rod opposite or in proximity to the open side of the channel and the main or work anode also may be a wire or rod positioned relatively remote from the cathode.

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 drawing in which:

Fig. 1 is in part a perspective view of an electric discharge device illustrative of one embodiment of this invention and in part a circuit diagram showing one way in which the device may be employed;

Fig. 2 is a fragmentary view to an enlarged scale of the cathode and auxiliary anode in the device illustrated in Fig. 1, showing the form and relation of these electrodes;

Fig. 3 is a graph illustrating typical operating characteristics of a device of the construction shown in Fig. 1;

Figs. 4 and 5 are elevational and top views, respectively, the enclosing vessel being broken away, of an electric discharge device illustrative of another embodiment of this invention and including electrodes defining a starter gap;

Fig. 6 is in part an elevational view of the device shown in Figs. 4 and 5 and in part a circuit diagram illustrating one manner of utilization of this device;

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Figs. 7 and 8 are elevational and top views, respectively, of an electric discharge device illustrative of still another embodiment of this invention, the enclosing vessel being broken away; and

Figs. 9 and 10 are elevational and top views, respectively, of an electric discharge device, with the enclosing vessel broken away, illustrative of another embodiment of this invention and particularly suitable for use where very large currents are desired.

Referring now to the drawing, the device illustrated in Figs. 1 and 2 comprises a vitreous enclosing vessel 20 having a base or stem 21 and having also a gaseous filling. The latter may be, for example, argon at a pressure of the order of 15 millimeters of mercury or a mixture of gases such as 99 per cent neon and 1 per cent argon at a pressure of the order of 65 millimeters of mercury. Mounted within the vessel are a cathode 22, a main or work anode 23 and an auxiliary or control anode 24.

The cathode 22 comprises two sheets or plates 25 of a refractory metal, for example molybdenum or tantalum, which are securely joined, as by welding, adjacent one end thereof and supported by a rigid wire or rod 26 sealed in the stem 21. The cathode sheets or plates 25 have divergent portions which define a V-shaped channel 27.

The main or work anode 23 is a short metal rod, for example of nickel, sealed in the base or stem 21.

The auxiliary or control anode 24 is a linear wire or rod, for example of molybdenum, opposite the open side of the channel 27 and parallel to and equally spaced from the ends of the cathode plates 25 in juxtaposition thereto. It is supported from a rigid wire or rod 28 sealed in the stem or base 21.

The cathode is dimensioned so that in the operation of the device the negative glow regions for the cathode surfaces bounding the channel 27 overlap. In a specific device intended for operation with potentials of the order of magnitude indicated hereinafter, the sheets or plates 25 may be one-half inch wide and the channel 27 may be three-eighths inch deep and one-sixteenth inch wide at its open side. The main anode may be one-quarter inch long and 0.05 inch in diameter and the auxiliary or control anode may be 0.060 inch in diameter and spaced one-sixteenth inch from the open side. The gases and gas pressure may be as indicated heretofore. The spacing between the main anode and open side of the channel 27 may be about three-quarters inch.

A typical rectifier circuit including this device is shown in Fig. 1. The alternating-current supply source 29 in series with the direct-current load 30, shown as a resistor, is connected between the cathode 22 and main anode 23. The auxil-

iliary anode 24 is connected to the main anode 23 through a high resistance 31, for example of the order of 50,000 ohms, and is utilized as a starter electrode.

In operation, the auxiliary anode 24 initiates conduction in the device during the half cycle when the main anode 23 is positive relative to the cathode, the current to the anode 24 being limited to a low value by the resistance 31. As soon as a discharge is established between the cathode 22 and anode 24, the gap between the cathode and main anode 23 breaks down and the discharge is transferred to the main anode. The load resistance 30 advantageously is small so that a large current can flow in the main circuit. The main gap discharge originates at the inner cathode surfaces bounding the channel 27.

During the reverse half cycle, that is when the cathode is positive relative to the anodes, a discharge may occur between the anode 24 and the cathode, with the former acting as the cathode. If the voltage applied by the source 29 is small, transfer of the discharge to the work anode-cathode circuit may not occur so that the reverse current is small, particularly because of the limiting action of the resistance 31. If this voltage is sufficiently large, during the reverse cycle, the main anode may act as a cathode and a reverse current will flow in the load. However, because of the characteristics of the device, as will be discussed presently, even for this case the reverse current is small. Consequently, a large rectification ratio is obtained.

Operating characteristics for a device of the construction shown in Figs. 1 and 2 and described hereinabove are illustrated in Fig. 3 wherein the abscissae are main anode currents and the ordinates are main anode voltages as indicated. To be noted especially are the large magnitude of the forward current and the small magnitude of the reverse current even at voltages several times that for which the high forward current is obtained. Also to be noted particularly is the relatively low voltage at which the high forward current obtains. Specifically, as to the current, it will be noted that for a forward current of 1.5 amperes and a cathode of the dimensions given heretofore, the current is about 4 amperes per square inch of cathode surface. Even higher values have been obtained. As to the matter of voltage, it is noted that the high current is obtained at a voltage of the order of 130 volts. This may be compared with a similar device having a plane cathode of the same material and area for which it was found that a voltage in excess of 130 volts was requisite to obtain a current of 0.1 ampere.

In addition to the high current, and the high current at low voltage obtainable, the V-shaped, refractory metal cathode has other very desirable advantages. One of these is long operating life. This is attributable in part to the fact that the activity of the cathode surface is not rapidly affected by sparking or by removal of the surface material and in part by the fact that because of the proximity of the active cathode surfaces, material sputtered from one deposits on the other. Another advantage is that the high currents can be obtained with a variety of gases and pressures so that deionization times and impedances may be controlled. Furthermore, the use of relatively high gas pressures is enabled whereby a large difference between breakdown and sustaining voltages for the main or work gap can be realized. Also, because of the high current densities which

can be used, the size and cost of devices for meeting a given current carrying rating can be reduced. Conversely, large currents can be obtained with small devices.

A device of relatively small size and high current rating and particularly suitable for control or switching applications is illustrated in Figs. 4, 5 and 6. The cathode 22 is of the construction described heretofore. The device comprises two main anodes 230, which may be used separately or together, each being in the form of a wire or rod sealed in the stem 21 and encompassed throughout the major portion of its length by an insulating, e. g., ceramic, sleeve or shield 32. Opposite the open side of the cathode channel 27 are substantially identical auxiliary anodes 240 each in the form of a short wire or rod supported by a rigid wire or rod 230 which is sealed in the stem 21 and encased throughout the major part of its length in an insulating sleeve 33. Aligned with each of the auxiliary anodes 240 is an auxiliary or starter cathode 34, advantageously of refractory metal, such as molybdenum, and of smaller diameter than the anodes 240. In a typical device, the auxiliary anodes may be 0.05 inch diameter nickel wires and the starter cathodes may be 0.012 inch in diameter and each spaced, end to end, 0.010 inch from the respective anode 240. The auxiliary or starter cathodes 34 are supported by rigid rods or wires 35 sealed in the stem 21 and encompassed by insulating sleeves 36.

The gas filling in the vessel 20 may be argon at a pressure of the order of 15 millimeters of mercury although higher pressures, say of the order of 30 millimeters of mercury, may be used if higher breakdown voltages and higher currents to the starter elements for effecting transfer of the discharge to the main anodes can be tolerated. Other gases such as neon or neon-argon mixtures may be used.

One way in which the device may be utilized is illustrated in Fig. 6. For the sake of simplicity of illustration, the connections to only one set of the duplicate electrodes, namely the main anodes, auxiliary anodes and starter cathodes, have been shown, it being understood that corresponding electrodes may be connected in parallel or the corresponding auxiliary anodes and cathodes may be operated independently. A direct-current voltage, less than the breakdown voltage, of the main discharge gap, that is, the main anode-main cathode gap, is applied between the anode 230 and cathode 22, from a source 36, a load such as a relay 37 being included in circuit as shown. The starter cathode 34 is connected to the negative side of the source through a resistor 38, which may be of the order of 10,000 ohms. Pulses for initiating a discharge in the device are applied to the auxiliary anode 240 from a suitable source 39 through a high resistance 40, which may be of the order of 50,000 ohms.

Upon the application of a pulse of appropriate amplitude to the auxiliary anode 240, the gap between this anode and the starter cathode 34 breaks down, the current being limited by the resistor 40. As soon as this breakdown occurs, the discharge transfers to the gap between the main anode and the auxiliary cathode. The current of this discharge is not limited by the resistor 40 so that a substantial voltage drop occurs across the resistor 38. As a result, the discharge transfers to the main anode-main cathode gap and the load circuit is energized, e. g., the relay 37 is operated.

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The embodiment of the invention illustrated in Figs. 7 and 8 is similar to that shown in Figs. 4, 5 and 6 and described hereinabove and is particularly advantageous from the standpoint of small size relative to current carrying capacity. The cathode 220 is provided with a flange 41 secured, as by welding, to the support rod or wire 260 and is mounted with the cathode channel 270 substantially parallel to the longitudinal axis of the enclosing vessel 20. The main anode 230A and auxiliary anode 240A are L-shaped wires or rods sealed in the stem 21 and having the major parts thereof surrounded by insulating tubes 320 and 330, for example of quartz, as shown, to which they are sealed by insulating cement 42. The starter cathode 340 is a wire or rod which extends from the stem through the quartz sleeve 43 and terminates in proximity to the inner end of the auxiliary anode 240A. The device of Figs. 7 and 8 may be utilized in the manner illustrated in Fig. 6 as described heretofore.

The embodiment of the invention illustrated in Figs. 9 and 10 is particularly advantageous in cases where very large currents are desired. The cathode, which may be machined of a block of refractory metal, such as molybdenum or tantalum, or built up of plates of such material, has at one end thereof a plurality of parallel plate-like portions 250 bounding a plurality of channels 270 which are of small width such that during operation of the device the negative glow regions of the side walls of each channel overlap. It is rigidly supported from the stem 210 of the gas-filled vessel 20 by rigid wire supports 260. The main or work anode 23A is a metal, e. g., molybdenum, plate opposite the channeled or slotted end of the cathode, parallel thereto, and supported from the stem 210 by a rigid wire or rod 45. The auxiliary or control anode 24A, which also is supported from the stem 210, is an L-shaped wire, for example of molybdenum, and terminates in proximity to the slotted or channeled end of the cathode. The gas filling may be of the type and at the pressures noted previously herein.

The cathode construction provides, in effect, a multiplicity of channeled cathode surfaces electrically in parallel whereby very large currents are obtained. In an illustrative device including a cathode the dimensions of the channeled end of which were three-quarters inch by 0.33 inch and wherein the channels 270 were one-quarter inch deep and 0.030 inch wide, currents of 100 amperes at a sustaining voltage below 135 volts, with a gas filling of 99 per cent neon, 1 per cent argon at a pressure of 70 millimeters of mercury, have been obtained.

The discharge device shown in Figs. 9 and 10 may be used as a rectifier in a circuit like that illustrated in Fig. 1 or to produce high current pulses in a circuit analogous to that illustrated in Fig. 6.

Although several specific embodiments of the 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.

What is claimed is:

1. A gaseous discharge device comprising a cathode having a pair of closely adjacent refractory metal surfaces bounding a V-shaped channel of depth at least several times the width thereof, a first anode having a portion in prox-

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imity to said channel, and a second anode relatively remote from said channel.

2. A gaseous discharge device comprising a cathode having a pair of substantially plane refractory metal surfaces bounding a V-shaped channel, the juxtaposed bounding walls of said channel being closely spaced such that in operation of the device the negative glow regions of said walls overlap a control electrode having a linear rod-like portion opposite the open side of said channel, and an anode relatively remote from said open side.

3. A gaseous discharge device comprising a refractory metal cathode having therein an open ended channel of width small in comparison to the depth thereof, a linear rod control anode immediately adjacent, extending across and substantially parallel to the open side of said channel, the transverse dimensions of said rod control anode being no greater than the width of said channel thereby to provide a substantially unimpeded opening for egress of electrons from said channel, and a linear rod work anode remote from said cathode.

4. A gaseous discharge device comprising a refractory metal cathode having a narrow channel therein, a control anode opposite the open side of said channel, a starter cathode in proximity to said control anode, and a main anode opposite said cathode.

5. A gaseous discharge device comprising a refractory metal main cathode having a V-shaped channel therein, the width of said channel being small in comparison to its depth, a pair of starter cathodes each beyond a respective end of said channel, a pair of control anodes each in juxtaposition to a respective one of said starter cathodes, and a pair of main anodes on opposite sides of said main cathode.

6. A gaseous discharge device comprising a cathode having a plurality of narrow channels in one end thereof, and an anode opposite said cathode.

7. A gaseous discharge device comprising a cathode of refractory metal having a plurality of substantially parallel slots in one portion thereof, and an anode opposite said cathode.

8. A gaseous discharge device comprising a refractory metal cathode having a plurality of channels in one end thereof, each of said channels being of such width that in operation of the device the negative glow regions of the side walls of each channel overlap, a control electrode member in proximity to said end, and an anode opposite said end.

MARK A. TOWNSEND.

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