

Sept. 7, 1954

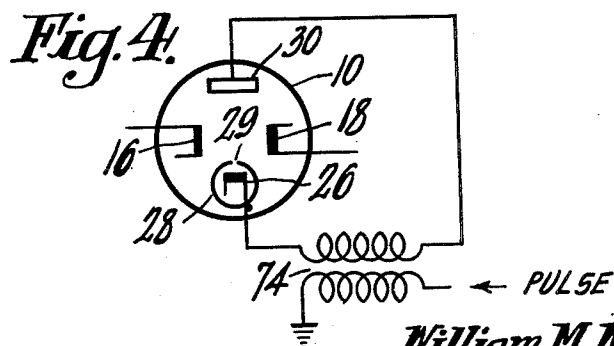
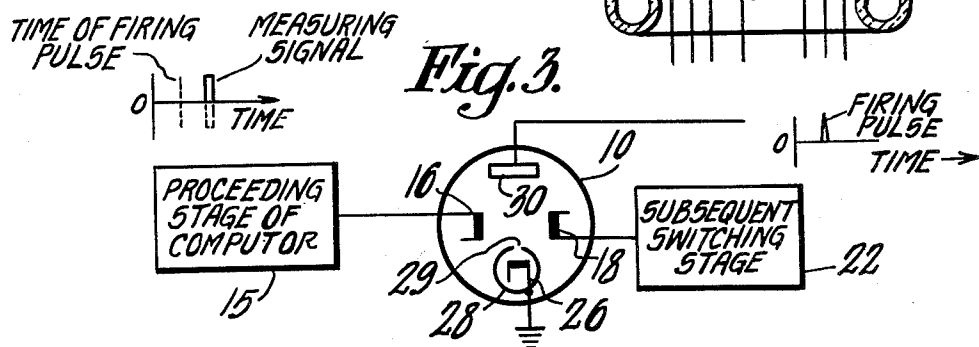
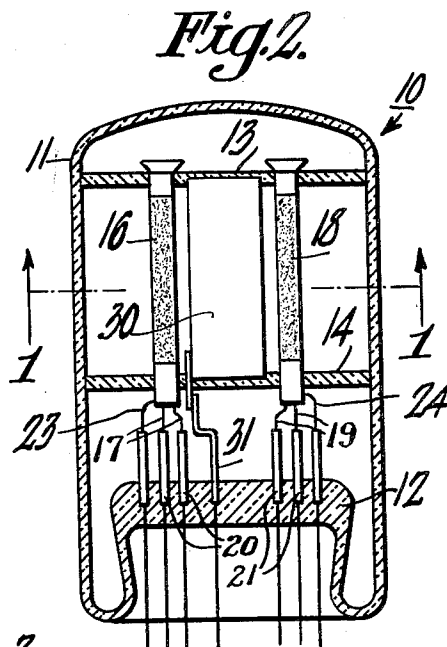
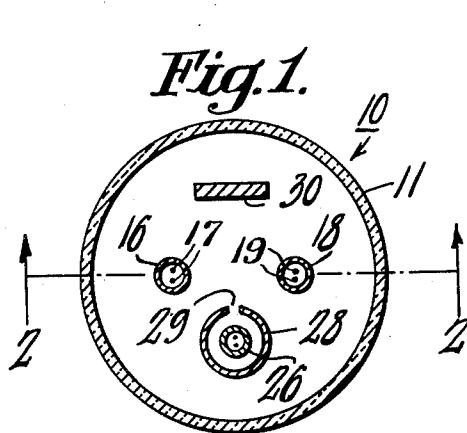
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2,688,710

GAS DISCHARGE SWITCHING DEVICE

Filed Nov. 20, 1952

2 Sheets-Sheet 1



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Fig. 5.

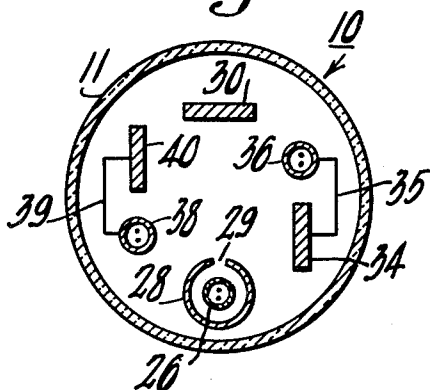


Fig. 6.

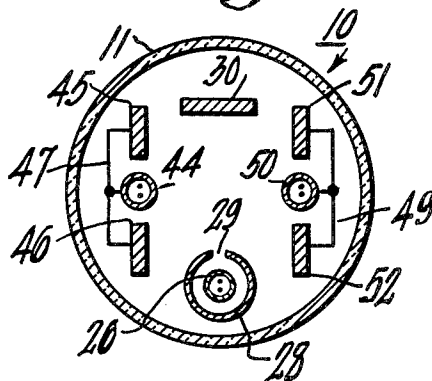


Fig. 7.

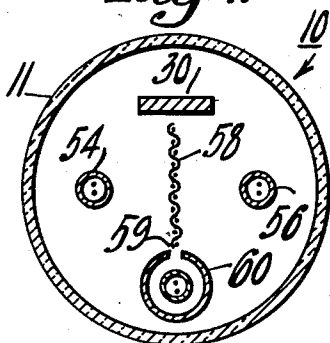


Fig. 8.

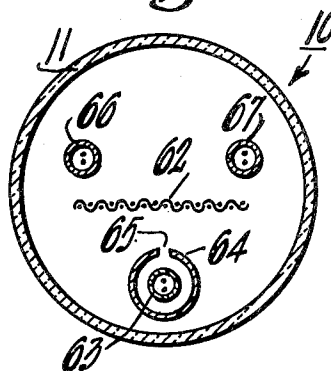
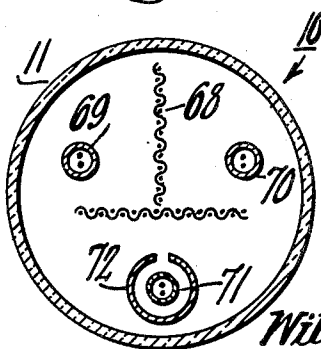


Fig. 9.



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GAS DISCHARGE SWITCHING DEVICE

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Application November 20, 1952, Serial No. 321,554

10 Claims. (Cl. 313—71)

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This invention relates to gas discharge devices and particularly to gas discharge devices that may be operated as a switching device at very high frequencies.

It has long been the object of continuous research and experiments to provide a gas discharge device, or tube, that can function as a bi-directional, low impedance, switch which will be the analogy of a high speed relay to be used for computer applications.

Prior to this time, some mechanical devices have been used as switches, or relays, but they have had the disadvantages of operating at comparatively low speeds. Certain types of vacuum tubes have been used as switches to overcome the low speed limitation but the vacuum tubes have the disadvantage of high impedance and thus a high voltage has been necessary to operate the devices.

It is an object of this invention to provide a new and improved high speed switching device of the gas discharge variety.

It is a further object of this invention to provide a new and novel low impedance switching device of the gas discharge type.

It is a still further object of this invention to provide a new and improved bi-directional, high speed, low impedance, switching device of the gas discharge type.

These and other objects have been accomplished in accordance with the general aspects of this invention by providing a gas discharge device having a bi-directional current path. The main current path comprises at least two thermionic cathodes so that the main current may flow in a bi-directional manner between the two cathodes. Adjacent the space intermediate the two cathodes, is an auxiliary group of electrodes that provides an auxiliary discharge and forms a highly conductive plasma which extends between the two thermionic cathodes when it is desired to have the cathodes conduct.

The novel features which are believed to be characteristic of this invention are set forth with particularity in the appended claims. The invention itself will best be understood by referring to the following description taken in connection with the following drawings and in which:

Figure 1 is a sectional view through line 1—1 of Figure 2 of a gas discharge device constructed in accordance with this invention;

Figure 2 is a sectional view through line 2—2 of Figure 1;

Figures 3 and 4 are schematic diagrams show-

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ing methods of operating a gas discharge device constructed in accordance with this invention;

Figures 5 through 9 are transverse sectional views of gas discharge devices illustrative of various embodiments of gas discharge devices constructed in accordance with this invention.

Referring now to Figures 1 and 2 in detail, a gas discharge device 10 comprises a gas tight envelope 11 having the usual stem 12 through which the lead-in conductors are sealed in a conventional manner. The electrode assembly is supported by means of the conductors within the envelope as indicated. Between the upper and lower insulating members 13 and 14 are mounted two main cathodes 16 and 18. Both cathode 16 and 18 are the usual oxide coated type of thermionic cathode having a non-inductive type of heater 17 and 19 respectively extending therein, the leads of which are each connected to support conductors 20 and 21 in the usual manner. The cathodes 16 and 18 are electrically energized by means of conductors 23 and 24 respectively. The upper ends of the main cathode 16 and 18 are crimped in the well known manner to lock the same in place between insulating members 13 and 14.

Included within the envelope is an auxiliary group of electrodes comprising an auxiliary thermionic cathode 26, surrounded by an apertured constricting electrode 28, and an auxiliary anode 30. The auxiliary electrodes are supported between insulating members 13 and 14 in a conventional manner and are spaced on opposite sides of the main current path formed by cathodes 16 and 18 so that the auxiliary discharge is substantially perpendicular to the main current path. The auxiliary anode 30 is energized by means of lead-in 31 in the usual manner. The auxiliary cathode 26 and apertured electrode 28 are also energized by means of conventional leads (not shown).

The auxiliary cathode 26 is also an oxide coated thermionic cathode and is supported between insulating members 13 and 14. The apertured constricting electrode 28 surrounds the auxiliary cathode 26 with a constricting aperture 29 arranged so that the auxiliary discharge is directly across the main current path. Auxiliary anode 30 comprises a metallic plate of conventional design and is spaced on the opposite side of the main current path from auxiliary cathode 26.

Gas discharge device 10 is processed in the well known manner and, as well known in the art, is provided with a gaseous atmosphere prior to sealing off. Any suitable gas or mixture of

gases may be utilized depending upon the electrode geometry and spacings for the separate embodiments. Furthermore, it is not believed that the gas pressure is critical except that it is preferable to utilize a pressure which will favor the formation of a self-sustaining ionizing discharge. In the tube now being described as being illustrative of this invention, helium may be used at a pressure of approximately 750 microns though other gases and other pressures may also be used.

During operation of the discharge device 10, a difference of potential greater than the ionization potential of the gaseous filling is applied to the auxiliary group of electrodes so that a discharge occurs between auxiliary cathode 26 and auxiliary anode 30. This discharge forms a plasma within the envelope that extends across the main current path. Since the plasma is an extremely low impedance conductor, the impedance across the main current path, i. e. the impedance between main cathodes 16 and 18 is extremely low. The potential difference applied between the main cathodes 16 and 18 is normally well below the ionization potential of the gaseous filling so that no electron discharge occurs between main cathodes 16 and 18 unless there is a plasma formed by the auxiliary discharge. In fact when there is no plasma present between the main cathodes 16 and 18, there is an open circuit between main cathodes 16 and 18.

After the auxiliary electrodes have discharged, and formed the plasma, the plasma remains for a short instant of time before deionization completely occurs. Because of the deionization time of the device, the main cathodes may conduct either during the auxiliary discharge or during the time immediately after the auxiliary discharge has been cut off and before the plasmas have depleted by recombination, diffusion, etc. When the auxiliary electrodes are discharging, or during the deionization time, currents of the order of an ampere may pass between main cathodes 16 and 18 at a relatively low applied voltage.

When gas discharge device 10 is used as a switching type of device the operation thereof is very similar to an extremely high speed mechanical relay. The maximum frequency at which this device is capable of operating may be in excess of 10,000 cycles per second. The device is constructed in such a manner that current may flow in either direction between two main cathodes 16 and 18 depending upon which is positive with respect to the other. The positive cathode 16 or 18 acts as an anode for current in one direction while the other cathode acts as an anode for current in the opposite direction.

The auxiliary discharge is perpendicular to the main load current path so that coupling between the auxiliary discharge and the main load current is substantially reduced. Another method of still further reducing coupling between the auxiliary discharge and the main load current is to pulse the auxiliary discharge. Thus when the switch is to conduct a given computation, the auxiliary discharge is pulsed and the plasma is formed. During the brief instance when the plasma is still present after the auxiliary discharge is pulsed the computation is made. Before the next computation is to be made, the residual plasma disappears. This action is extremely fast and devices of this type have been operated in this manner at 10,000 cycles per second.

The discharge device 10 may be controlled by several methods. One method is simple on-off control by varying the potentials on main cathodes 16 and 18. A second method is by modulating the density of the plasma formed by the auxiliary discharge. A signal may be placed on the apertured constricting electrode 28 by means of lead-in 31 and this signal will modulate the density of the plasma in the main current region. Because of the fact that ionization occurs outside the constricting electrode 28, the electrode 28 can completely cut off the electron flow of an auxiliary discharge and thus completely modulate the plasma density.

In Figure 3 there is shown a method of operating a gas discharge device constructed in accordance with this invention. The device as shown is the embodiment of a gas discharge as shown in Figures 1 and 2 however, it should be understood that the circuit is applicable to the other embodiments of the invention. In the schematic diagram shown in Figure 3, the auxiliary cathode 26 is connected to the apertured focusing electrode 28 and both are grounded. Main cathode 16 is connected to a proceeding stage 15 of a computer while main cathode 18 is connected to a subsequent switching stage 22 and a firing pulse is applied to anode 30. A firing pulse, i. e. a positive pulse greater than the ionization potential is applied to anode 30 to cause an auxiliary discharge to occur and thus break down the device. The pulse forms a plasma in the device that remains through the deionization time. During the time when the plasma is present, a given computation may be passed by making one of the main cathodes 16 or 18 positive with respect to the other. Preferably, to avoid coupling, the computation is made during the interval of time after the auxiliary discharge occurs and before the plasma is depleted. The proper timing between the auxiliary discharge and the main current computation may be adjusted by means of any conventional timing circuit (not shown).

In Figure 4 there is shown a similar circuit to still further minimize coupling between the auxiliary discharge and the main current path. Here again the embodiment of this invention that is shown in the schematic diagram is the embodiment described in connections with Figures 1 and 2 but the circuit diagram is equally applicable to the other embodiments. In this method of operating gas discharge device 10, the secondary of transformer 74 is connected between auxiliary cathode 26 and anode 30. Here again the auxiliary cathode is connected to the apertured focusing electrode 28. The main cathodes 16 and 18 are connected to proceeding and subsequent stages as shown in Figure 3. When it is desired to render the discharge device conductive for a given computation, a pulse greater than the ionization potential of the medium is applied to the primary of transformer 74 and the computation is made as has been described.

This embodiment of the circuit diagram further reduces the coupling between the main current path and the auxiliary discharge path because the auxiliary discharge electrodes are electrically floating except during the time when the auxiliary discharge occurs. In other words, if the pulsed operation of the auxiliary discharge is utilized as has been described, the auxiliary electrodes are electrically floating during the interval of time when the main current computa-

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tion is being made. Due to the fact that the auxiliary electrodes are electrically floating, they will assume the potential of the plasma and thus have no effect upon the main current electrodes.

Referring now to Figure 5 there is shown an embodiment of this invention wherein one of the main groups of electrodes includes an anode 34 and a thermionic cathode 36 electrically connected by conductor 35 within the envelope. The other main group of electrodes includes a thermionic cathode 38 and anode 40 also electrically connected by conductor 39. It should be noted that opposite thermionic cathode 36 is located anode 40 while opposite thermionic cathode 38 is located anode 34. Since each cathode is electrically connected to an anode, when the device is conducting in a given direction both the cathode and the anode of the electron receiving end are effectively an anode and thus larger currents may be transmitted through the device at the same high frequency and low impedance as was described in connection with Figures 1 and 2. The auxiliary electrodes include the same elements as was shown and described in connection with Figures 1 and 2 and further description is not deemed necessary at this time. Main cathodes 36 and 38 as well as main anodes 34 and 40 are supported within the envelope and energized in a conventional manner. The connections 35 and 39 may be any type of electrical conductor such as a rod, or wire between the respective electrodes.

An alternative structure that may be used in this embodiment of the invention is to utilize a composite anode-cathode for each end of the main current path. In other words, one portion of an anode may be sprayed with emissive material and may also have some type of heating means if desired.

Referring now to Figure 6 there is shown another embodiment of this invention which permits even larger currents to be passed through the main current path. In this embodiment one main group of electrodes includes a thermionic cathode 44 arranged intermediate a pair of spaced apart anodes 45 and 46, while the other main group of electrodes includes a thermionic cathode 50 arranged intermediate main anodes 51 and 52. All of the electrodes in a single group are joined by an electrical conductor 47 or 49, respectively. This embodiment has the advantage of being capable of passing extremely large current in a bi-directional manner.

Referring now to Figure 7 there is shown an embodiment of this invention that permits additional control between a pair of main thermionic cathodes 54 and 56. In this embodiment, an apertured electrode 58 is arranged intermediate the main cathodes 54 and 56 to modulate the main load current when the proper potentials are applied to the apertured electrode 58. The theory that permits a control electrode to modulate electron flow in a gas discharge device is explained in a co-pending application of Edward O. Johnson, Serial No. 185,745, filed September 20, 1950 and assigned to the same assignee as the present invention.

It should be understood that any of the main groups of electrodes that have been described in connection with Figures 1, 2, 5, and 6, may be utilized with a control electrode intermediate the main groups. It should be noted that one end of the control electrodes 58 is adjacent aperture 59 in the apertured electrode 60 to divide the plasma so that it is on both sides of the con-

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trol electrode 58 and thus a low impedance conductive path is connected between main cathode 54 and 56 when it is desired for the tube to conduct.

Referring now to Figure 8 there is shown an embodiment of this invention utilizing an apertured anode 62 in the auxiliary discharge electrode group. In this embodiment an auxiliary cathode 63 is surrounded by an apertured constricting electrode 64 having a constricted aperture 65 therein. The aperture 64 is arranged to constrict the electron stream and direct it toward apertured anode 62. The apertured anode 62 is arranged substantially parallel to the main current path between thermionic cathodes 66 and 67. The apertures in apertured anode 62 are greater than the mean free path of the plasma particles to allow diffusion of the plasma particles through the apertured anode 62.

In operation of the embodiment shown in Figure 8 is a potential greater than the ionization potential of the medium is applied between auxiliary cathode 63 and apertured anode 62 to form the plasma by means of the auxiliary discharge. When the auxiliary discharge occurs a plasma is formed in the spaced outside apertured electrode 64. This plasma fills the main current path partly by diffusion through apertured electrode 62 and partly by ions produced in the main current region by those high energy electrons which penetrate apertured electrode 62. If desired, pulsed type operation may be utilized as has previously been described. The operation of the main current path as well as other embodiments of the main current electrodes has previously been described and further description is not deemed necessary at this time.

An advantage of using an apertured anode 62 is that in the absence of a firing pulse the apertured anode 62 will electrostatically shield the balance of the tube from the auxiliary cathode 63.

Referring now to Figure 9 there is shown a further embodiment of this invention utilizing composite apertured grid-anode 68. In this embodiment, an auxiliary cathode 71 is surrounded by an apertured constricting electrode 72 as has been described. The main current path is between thermionic cathodes 69 and 70. Arranged intermediate the cathodes 69 and 70 is a portion of the composite grid-anode 68. The remainder of the composite grid-anode 68 is arranged substantially parallel to the main current path. The portion of composite grid-anode 68 that is parallel to the main current path should have apertures that are larger than the mean free path of the plasma particles to permit the plasma to diffuse through to the main current path.

In operation of the gas discharge device shown in Figure 9, a potential difference greater than the ionization potential of the medium is applied between auxiliary cathode 71 and the composite grid-anode 68. This potential difference causes a discharge to occur between these electrodes resulting in a plasma. The plasma diffuses into the main current path and will permit conduction between cathodes 69 and 70. The potential difference applied between cathodes 69 and 70 should be less than the ionization potential of the medium and the potential applied to both cathodes 69 and 70 should be near the potential of the composite grid-anode 68. The reason for this is that a signal applied to the composite grid-anode 68 should modulate the main

current flow between cathodes 69 and 70 but it should be greater than the ionization potential of the medium with respect to auxiliary cathode 71 to establish the auxiliary discharge.

While there have been described and illustrated specific embodiments of the invention, it will be obvious that various changes and modifications may be made therein without departing from the spirit thereof. It is, therefore, intended to cover all such modifications which come within the scope of the appended claims.

I claim:

1. A gas discharge device, comprising a sealed envelope having an ionizable medium therein, a pair of spaced apart thermionic cathodes defining a main load current path within said envelope, and a group of auxiliary electrodes including an auxiliary thermionic cathode surrounded by an apertured constricting electrode for producing an auxiliary discharge within said envelope.

2. A gas discharge device, comprising a sealed envelope having an ionizable medium therein, a pair of spaced apart thermionic cathodes defining a main load current path within said envelope, and a group of auxiliary electrodes including an auxiliary thermionic cathode surrounded by an apertured constricting electrode for producing an auxiliary discharge within said envelope, the aperture in said apertured electrode being arranged so that said auxiliary discharge is substantially perpendicular through said main load current path.

3. A gas discharge device as in claim 2 further comprising a control electrode intermediate said pair of cathodes.

4. A gas discharge device, comprising a sealed envelope having an ionizable medium therein, a pair of spaced apart thermionic cathodes defining a main load current path within said envelope, and a group of auxiliary electrodes comprising an anode and an auxiliary thermionic cathode surrounded by an apertured constricting electrode, said auxiliary electrodes being arranged on opposite sides of said main load current path whereby said auxiliary discharge is substantially perpendicular through said main current path.

5. A gas discharge device, comprising a sealed envelope having an ionizable medium therein, a pair of spaced apart main groups of electrodes within said envelope each group including at least one main anode and a thermionic cathode electrically connected together, each of said main groups of electrodes being one end of a bi-directional main load current path through said device, and an auxiliary group of electrodes comprising an auxiliary thermionic cathode and apertured focusing electrode and an anode, said auxiliary cathode being partially surrounded by said apertured focusing electrode, and said auxiliary electrodes being arranged on opposite sides of said main current path whereby an auxiliary discharge is substantially perpendicular through said main current path.

6. A gas discharge device, comprising a sealed envelope having an ionizable medium therein, a pair of spaced apart main groups of electrodes within said envelope each group including a main anode and a main thermionic cathode electri-

cally connected together, each of said main groups of electrodes being one end of a bi-directional main current path through said device, and an auxiliary group of electrodes comprising an auxiliary thermionic cathode, an apertured constricting electrode and an anode, said auxiliary cathode being partially surrounded by said apertured constricting electrode, and said auxiliary electrodes being arranged on opposite sides of said main current path whereby an auxiliary discharge is substantially perpendicular through said main current path.

7. A gas discharge device, comprising a sealed envelope having an ionizable medium therein, a pair of spaced apart main thermionic cathodes comprising a main current path within said envelope, a group of auxiliary electrodes arranged on one side of said main current path including an auxiliary thermionic cathode a constricting electrode and an apertured electrode, said constricting electrode partially surrounding said auxiliary cathode to direct an auxiliary discharge substantially perpendicular to said main current path, and said apertured electrode arranged substantially parallel to said main current path.

8. A gas discharge device as in claim 7 wherein the apertures in said apertured electrode are larger than the mean free path of the positive ions of said ionizable medium.

9. A gas discharge device, comprising a sealed envelope having an ionizable medium therein, a pair of spaced apart main thermionic cathodes within said envelope comprising a main current path, a group of auxiliary electrodes arranged on one side of said main current path including an auxiliary thermionic cathode a constricting electrode and an apertured electrode, said constricting electrode partially surrounding said auxiliary cathode to direct an auxiliary discharge substantially perpendicular to said main current path, and one portion of said apertured electrode being arranged substantially parallel to said main current path while the other portion of said apertured electrode extends intermediate said main cathodes.

10. A gas discharge device, comprising a sealed envelope having an ionizable medium therein, a pair of spaced apart main groups of electrodes within said envelope each group comprising a pair of spaced apart anodes and a thermionic cathode intermediate said anodes and electrically connected thereto, each of said main groups of electrodes defining one end of a bi-directional main current path through said device, and an auxiliary group of electrodes comprising an auxiliary anode and an auxiliary thermionic cathode surrounded by an apertured constricting electrode, said auxiliary group of electrodes being arranged on opposite sides of said main current path whereby an auxiliary discharge is substantially perpendicular through said main current path.

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