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GASEOUS DISCHARGE DEVICE CONTAINING PERFORATED STARTING ELECTRODES

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FIG. 1.

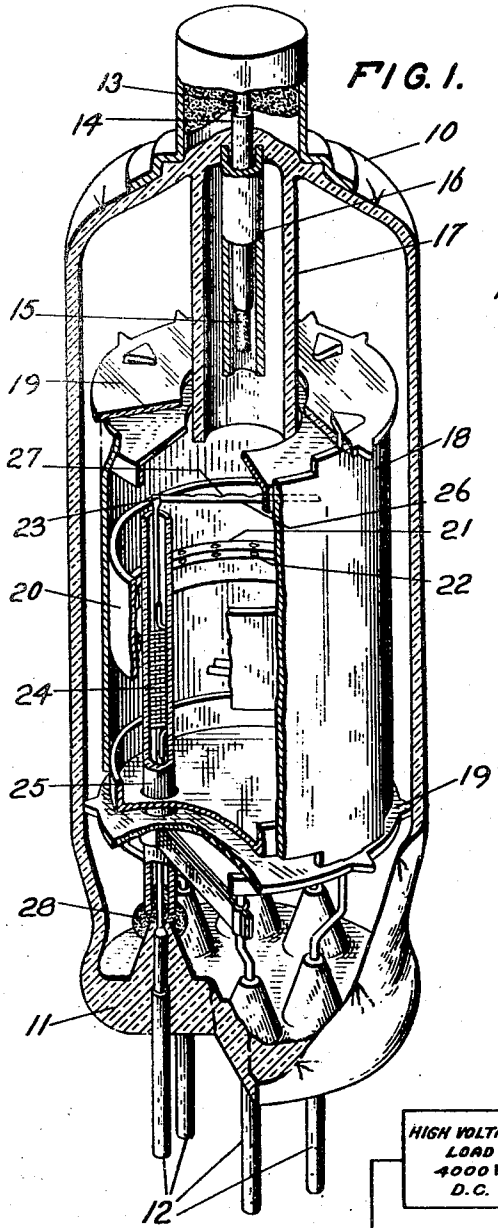


FIG. 2.

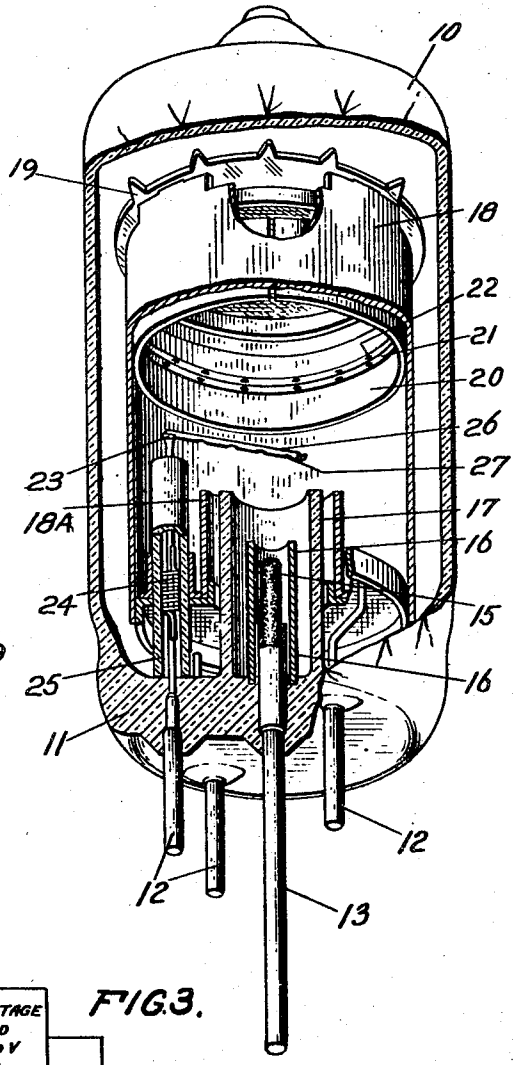
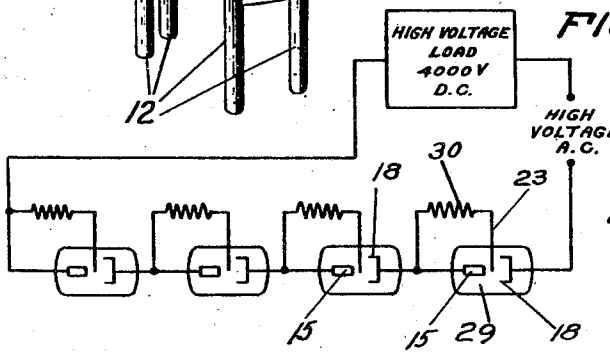


FIG. 3.



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GASEOUS DISCHARGE DEVICE CONTAINING PERFORATED STARTING ELECTRODES

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4 Claims. (Cl. 250—27.5)

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This invention relates to gaseous discharge devices, and more particularly to such devices employing, in addition to a cold cathode and an anode, a starting electrode.

Apparatus such as television, radar, electron microscopes and kindred devices employing relatively high potentials and comparatively small currents, usually entails the use of power supplies incorporating, in addition to the high tension transformer, rectifying devices which require a filament supply, said filament supply being heavily insulated against the high potentials used in the aforementioned apparatus. It can be readily observed that such combination adds considerable bulk to the apparatus under discussion, greatly increases the cost and limits the portability of same.

The expression relatively high potentials refers to a range of such potentials which may be at least 1,000 volts and higher.

It is a principal object of this invention to provide a device of the type described which shall be diminutive in size with respect to its ability to handle relatively high voltages.

Another object of this invention resides in the use of a cathode which has a diameter substantially that of the envelope enclosing same, said cathode having an electron-emissive material affixed thereto which can be evolved at a temperature which is lower than the softening point of said envelope.

A still further object is to provide a device of the type described having, besides the two main electrodes, a third electrode spaced a distance from the effective area of one of said electrodes substantially equal to the minimum breakdown-potential distance of said device, the distance between the effective area of said main electrodes being substantially different from the minimum breakdown-potential distance.

Another object of the device provides for the use of an electron-emissive material affixed to the starting electrode and placed in the path of discharge between the main electrodes whereby said discharge evolves the electron-emissive material and prolongs the usable life of said device.

These objects are attained in accordance with the general aspect of the invention by providing a device having a cylindrical envelope containing a cathode whose diameter is substantially that of said envelope and because of this close spacing between said envelope and cathode, providing, in one embodiment thereof, a device having overall dimensions which are approximately three quarters of an inch in diameter and two and one

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eighth inches long, and a second embodiment in which the arrangement of the electrodes therein provide a device which is approximately a half of an inch shorter than said first-mentioned embodiment. Despite the relatively small size of the aforesaid device, it is capable, in this particular embodiment, of withstanding inverse voltages of the order of 2,700 volts and can furnish a rectified output of about 1,000 volts, the device being a cold cathode type that does not require a filament transformer or other source of filament supply. This feature, coupled with its diminutive size, permits construction of power supply units of relatively small dimensions. By wiring the tubes in cascade, rectification of potentials employed in television, radar, electron microscopy and related high potential operated systems is readily accomplished.

These and other features and advantages of the invention are more clearly set forth in the following detailed description which, together with the accompanying drawing, represent various embodiments of the device of this invention.

In said drawing:

Fig. 1 illustrates one embodiment of the device in perspective and partial cross-section;

Fig. 2 represents a second embodiment presented in the same manner as Fig. 1; and

Fig. 3 is a schematic diagram of a rectifying circuit employing the present invention.

Referring now more particularly to Fig. 1, the device comprises a vitreous envelope 10, containing an ionizable gas, preferably xenon, at a pressure of about 14 mm. of Hg. A base 11 of similar material is fused to one end of said envelope 10 for supporting various electrodes within said envelope and a plurality of conductors 12 are sealed in said base 11 for conveying energy to said electrodes. The other end of said envelope is provided with a central conductor 13 placed within a sleeve member 14 and both sealed in said end of envelope. An output electrode or anode 15 which cooperates with the electrodes supported in said base 11 is connected within the other end of sleeve member 14.

The anode 15, as illustrated, comprises a rod, preferably composed of carbon. It was observed that carbon has a lower sputter rate than refractory metals, although the anode may, if desired, be formed of a refractory metal. Surrounding the anode 15 is an electrically-conductive member 16 which is insulated from the anode 15. Member 16 acts to shield the cathode 18 from having deposited thereon sputtered material which may be released from the anode 15. Such

material, if deposited on the cathode 18, greatly diminishes the emissive life of said cathode. The distance between the last-named members 15 and 16 is sufficiently small so that a discharge will not ordinarily occur in the space between them. A vitreous sleeve 17 surrounds the members 15 and 16. The function of member 17 will be treated further along in this specification. The member 17, in this particular embodiment, is integral with the envelope 10.

The hollow metallic member or cathode 18, preferably made of nickel, is maintained in axial alignment with respect to the other electrodes by spacers 19. Fixed within said cathode is an annular metallic member 20 made of nickel (other metals such as cobalt steel or iron may be used) for supporting, on its inner surface, hollow iron wire members 21 which contain therein an electron-emissive material (not shown). Means for readily releasing said electron-emissive material is provided by regularly spaced apertures 22. Positioned within said cathode 18 is a third electrically-conductive electrode 23 which will be referred to hereinafter as the starting electrode. The starting electrode 23 is connected to conducting member 12 through a helical metal spring member 24. The member 24 serves a two-fold function; first, as a positioning means to maintain starting electrode 23 in axial alignment with respect to the vitreous sleeve 25, and second, to permit expansion and contraction of member 24 without undue strain on said sleeve 25. Member 25 prevents sputtered material from members 21 and 26 being deposited on electrodes 18 and 23 and forming short circuit paths therebetween. How this feature is accomplished will be explained further along.

Affixed to and extending at right angles from starting electrode 23 is a hollow iron wire member 26, said member being a part of said starting electrode. Within said hollow iron wire member 26 is placed a quantity of electron-emissive material (not shown) which is released through the apertures 27 shown in said hollow iron wire member 26. The method by which the electron-emissive material is released will be pointed out hereinafter.

In the particular embodiment illustrated in Fig. 1, the vitreous sleeve member 25 is fastened to the base 11 by means of a suitable cement 28. However, the sleeve 25 can be fused to the base 11 directly, in which case, the positioning member 24 could be eliminated.

The particular arrangement of electrodes illustrated in Fig. 1 is known to the art as a double-ended device, whereas, Fig. 2 illustrates what is now known as a single-ended device, the latter expression indicating that connections to all the electrodes are made at one end in contra-distinction to the double-ended device shown in Fig. 1.

With the exceptions of the position of anode 15 in Fig. 2, the use of only one spacer 19, and the use of a reentrant tubular member 18A, the second embodiment is substantially the same as illustrated in Fig. 1. Therefore, the reference numerals applied to Fig. 1 are equally applicable to Fig. 2.

Fig. 3 illustrates a schematic diagram in which four of the devices 29 are connected in cascade. This arrangement permits rectification of four times the voltage each tube can handle individually. The use of resistors 30 will be explained as the specification progresses. Attention is called to the fact that Figs. 1 and 2 are enlarged approximately four times the actual size of the device in order to present a more detailed view of the structures therein.

A principal feature of the present invention is its diminutive size and the advantages accruing to such construction. The relatively small space between the cathode and the envelope presented a problem inasmuch as it was necessary to apply sufficient heat to the cathode in order to evolve the electron-emitting material onto the cathode without destroying the envelope which so closely surrounds said cathode.

Metallic barium was used as the activating material since it could be evolved at a temperature of about 800 degrees centigrade, such temperature being substantially below the softening point of the envelope yet high enough to evolve the electron-emissive material, and to drive out the gases from the supports holding said electron-emissive material and the other electrodes. It was found necessary to evolve only a relatively small amount of the electron-emissive material during the manufacturing process, the balance of the activating material being evolved during the operation of the device by bombardment from the positive ions present in the discharge. This arrangement serves to simplify the manufacture of the device with respect to time required for processing the tube. It was observed that the use of a flexible metal strip 20, made of nickel for example, as a support for the hollow iron wire members 21, provided a more satisfactory means of attaching said hollow iron wires 21 to the inner surface of the cathode 18. To attempt to weld the wires 21 directly to the cathode 18 would result in serious damage to said cathode as the heat required to make this weld causes a reaction between the iron wires 21, the cathode 18, and the active material within the iron wires 21 that results in burning a hole in the cathode material. This condition would permit the emissive material to leak outside of the cathode chamber 18 where its usefulness would be lost and in addition such burns would impair the appearance of the cathode. However, by first welding the iron wires 21 to the annular strip 20, it was then possible to weld this strip 20 to the cathode 18 without destroying the surface of the cathode 18 at the point of weld. In addition, it was less awkward to weld the iron wires 21 to the strip than it would be to weld the iron wires 21 directly to the inner surface of cathode 18. The prior art teaches the use of methods in which the cathode is sprayed with the activating material such as barium or strontium carbonates or is dipped in such active material. This method requires the application of temperatures in the range of 1,000 or 1,100 degrees centigrade to drive out the unwanted gases and must be applied over extended periods of time. Temperatures such as these when used to heat the base metal, upon which the electron-emissive material is coated, radiate enough heat to soften the envelope if it were not spaced a sufficient distance from the heated metals. The advantages of the present device are readily appreciated in view of the recited prior art.

Another feature which gives added life to the device is the use of a starting electrode having affixed thereto a quantity of electron-emissive material. On the inverse or negative cycle, the starting electrode behaves like a cathode and is consequently subjected to positive ion bombardment. This action evolves the active material onto the cathode surface. Added cathode surface is made available by the reentrant tubular member 18A as illustrated in Fig. 2, said tubular mem-

ber being a part of the cathode and is made emissively active by the deposit thereon of sputtered emissive material from the starting electrode extension member 26.

Still another feature of the present invention is the space relation of the starting electrode 23 with respect to the cathode 18 and anode 15. The starting electrode is spaced a distance from the effective area of the cathode, substantially equal to the minimum breakdown-potential distance of the device. The minimum breakdown-potential distance is defined herein as that distance at which a discharge will be initiated between two electrodes for a minimum applied potential. However, the anode is spaced a distance from the effective area of the cathode substantially different than the minimum breakdown-potential distance between the starting electrode and the effective area of the cathode, the distance being such with respect to the cathode that the anode can handle large inverse voltages. The aforementioned arrangement of the starting electrode with respect to the cathode permits a lower starting voltage for the device.

In connection with the spaced relation of the electrodes, particular attention is called to the novel construction of the starting electrode. The member 26 which is part of the starting electrode is spaced with respect to the anode 15 so that, when the initial glow discharge takes place between itself and the cathode, the potential on the anode becomes greater than the potential on the starting electrode, and the anode consequently pulls electrons out of the plasma surrounding said starting electrode, and as a result the main glow discharge is more readily accomplished. In order to maintain the initial glow discharge between starting electrode and cathode, in the vicinity of the anode, a vitreous sleeve member 25 surrounds that portion of said starting electrode 23 which is parallel with respect to the cathode 18. This arrangement confines the glow discharge to the portion 26 of the starting electrode and brings about the desired result mentioned above. The sleeve member 25 appreciably surrounds the entire starting electrode 23 to the junction of said electrode and the extended member 26. This sleeve arrangement prevents the deposit of sputtered material on said starting electrode 23 and therefore inhibits the possibility of an electrical short circuit between itself and the cathode 18.

In explanation of the difference of potential between the anode 15 and starting electrode 23, reference is had to Fig. 3. During those portions of the cycle when no appreciable current flows between cathode and starting electrode, the potentials on the anode and starting electrode are the same. However, when the glow discharge between the starting electrode 23 and cathode 18 takes place, current flows through resistor 30, which can have a value of about ten megohms, so that the resulting potential drop across said resistor lowers the potential on said starting electrode 23 with respect to said anode 15. The resistor 30 also serves to protect the member 26 from excessive currents during the inverse or non-conducting period of the device which may easily destroy said member 26.

A further advantage of the member 26 attached to starting electrode 23 is the use of this member as a support for electron-emissive material. The position of said member 26 in the path of the discharge enables it to increase the emissive capabilities of the cathode, especially that of the

effective area of the cathode represented by the reentrant tubular member 18A, Fig. 2. The electron-emissive material is readily released from the apertures 27 by the ionic bombardment during the discharge period and is sputtered therefrom on the cathode area 18A.

While Fig. 3 illustrates the use of four devices in cascade, it can readily be observed by those skilled in the art that at any desired magnitude of voltage rectification, the requirement would be n times 1,000, where n equals the number of tubes and 1,000 equals the rectified voltage output of each tube in this particular embodiment.

The use of gaseous discharge devices as rectifiers in connection with commercial power supply line frequencies is well known. However, attempts to use these devices in connection with radio frequencies have not met with much success. One of the limiting factors has been the time required for ionization and deionization. This limitation is quite marked in gaseous discharge devices operating at high pressures, for example, at pressures of about 14 mm. of Hg. At such pressure the deionization takes place at a relatively slow rate, so that the deionization time may be as long as 1,000 microseconds or longer. Ordinarily, the ionization time ranges from 1 to 50 microseconds. In both instances the element of time above mentioned would represent a severe limitation to the operation of gaseous discharge devices at radio frequencies.

In the present device the design and correlation of the electrodes permit the handling of current at radio frequencies regardless of the limitations above recited, such limitations being overcome in the following manner. When the device is made conducting the starting electrode 23 initiates the discharge and the anode 15 subsequently takes over the function of the main discharge. As a result, the plasma in the region between the anode 15 and cathode 18 will have a substantial positive ion population. When the anode becomes negative, the electrons are repelled therefrom, and positive ions in the vicinity of said anode 15, the anode shield 16 and sleeve member 17 will form a positive ion space charge. As a result, the field strength of the inverse potential of the anode will be greatly nullified exteriorly of member 17, this condition in turn reducing the mobility of the positive ion population in the region between the anode, and cathode and the number of positive ions reaching the anode will be greatly diminished. Were it not for this particular ability of the device, ion current would flow between said cathode and anode and excessive ionic bombardment of the anode would result. In addition, this condition would lower the efficiency of the device and its ability to handle large inverse voltages and also hamper its function as a rectifier. Whereas, in the prior art, the existence of a positive ion population in a rectifier was considered detrimental during the non-conducting cycle, in the present case this condition is used to advantage. On the positive cycle, the presence of the previous positive ion population serves to lower the reionization time and required voltage. It can be readily discerned that the process of reducing the mobility of the positive ions, brought about by the creation of the positive ion space charge in the vicinity of the anode, prevents destructive bombardment of the anode during the non-conducting portion of the cycle and so conditions the interelectrode space that, upon the succeeding positive portion of the cycle, conduction of current is provided.

It follows that regardless of the rapidity of change of polarity on the anode, adequate protection on the inverse or negative portion of the cycle is provided and sufficient ions to provide a conducting path on the forward or positive portion of the cycle will always be present.

Although several embodiments of this invention have been described and illustrated, it is of course understood that many modifications and alterations may be made wherein the relation of the electrodes may be altered to effect the primary conception of this invention. For example, the effective cathode area can be made larger, enabling the device to handle heavier current, this alteration being possible without substantially increasing the overall size of the device.

1. A gaseous discharge device comprising an envelope containing an ionizable gas, a plurality of electrodes supported within said envelope, said electrodes comprising an anode and a cathode therefor, and a third electrode, said last-named electrode having affixed thereto a hollow metallic tubular member, perforated at intervals, and containing an electron-emissive material therein, said last-named member being disposed in the path of a discharge between said anode and cathode, whereby said electron-emissive material is evolved by reason of the temperature normal in a discharge between said anode and cathode.

2. A gaseous discharge device comprising an envelope containing an ionizable gas, a plurality of electrodes supported within said envelope, one of said electrodes comprising a relatively large hollow metallic cathode, a flat annular member attached to the inner wall of said last-named electrode, and a perforated hollow wire containing an electron-emissive coating material therein, said wire member being attached to the inner surface of said annular member.

3. A gaseous discharge device comprising an envelope containing an ionizable gas, a plurality of electrodes supported within said envelope, one of said electrodes comprising a relatively large hollow nickel cathode, a flat annular member of nickel attached to the inner wall of said last-named electrode, and a perforated hollow iron wire containing barium metal therein, said wire member being attached to the inner surface of said annular member.

4. A gaseous discharge device comprising an envelope containing an ionizable gas, a plurality of electrodes supported within said envelope, one of said electrodes being surrounded by an electrically conductive shield extending above said first-named electrode and open at its upper end, means for insulating said shield from said first-named electrode, an insulating member, open at its upper end, surrounding said first-named electrode and shield member, and another of said electrodes adjacent the openings of said shield and insulating member and facing said first-named electrode.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,871,344	Rentschler	Aug. 9, 1932
1,875,151	Rentschler	Aug. 30, 1932