April 18, 1950 C. G. SMITH 2,504,231

GASEOUS DISCHARGE DEVICE

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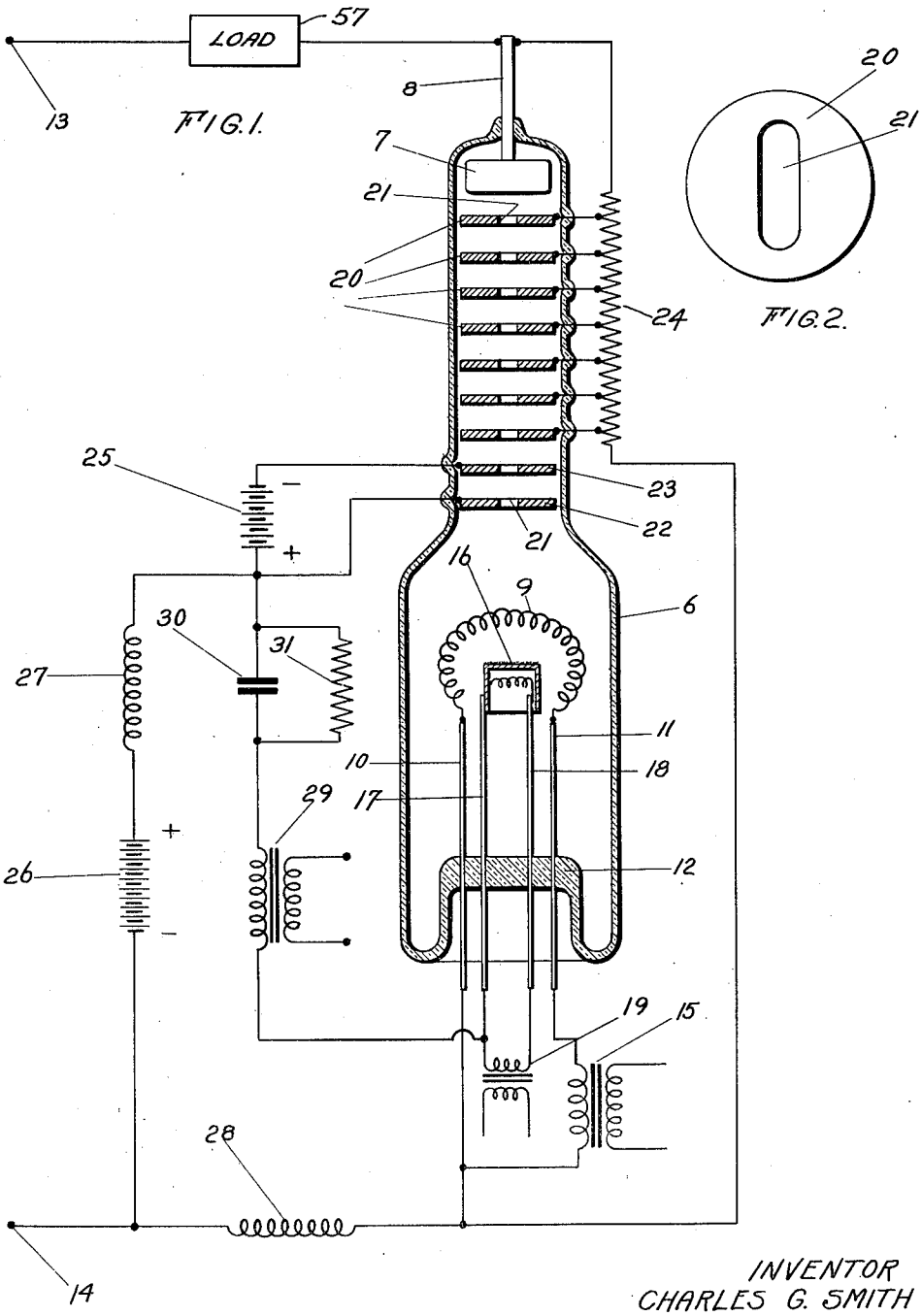


FIG. 1.

FIG. 2.

INVENTOR
CHARLES G. SMITH
BY Elmer J. Gow
ATTY.

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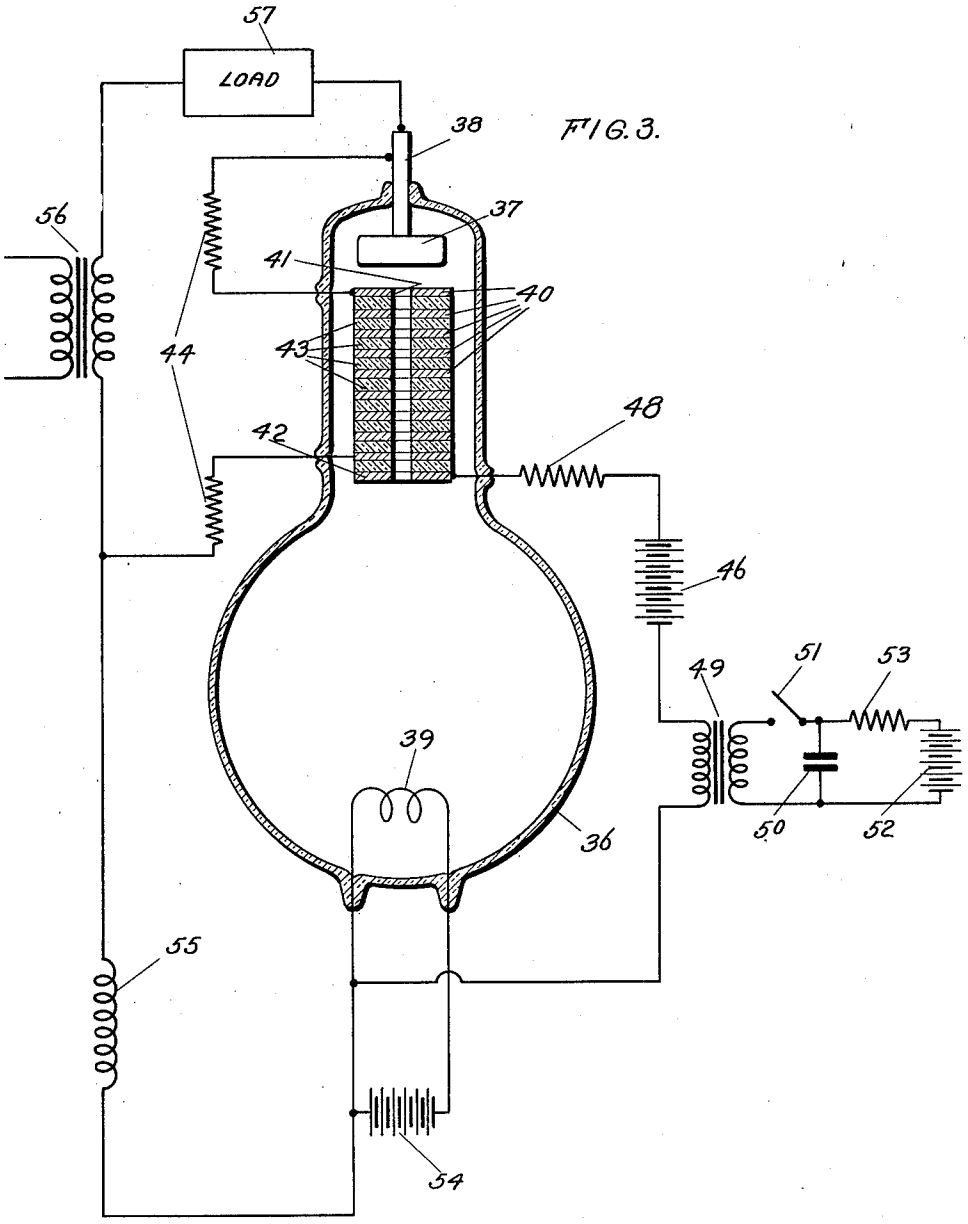


FIG. 3.

INVENTOR
CHARLES G. SMITH
BY Elmer J. Gorn
ATTY.

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FIG. 4.

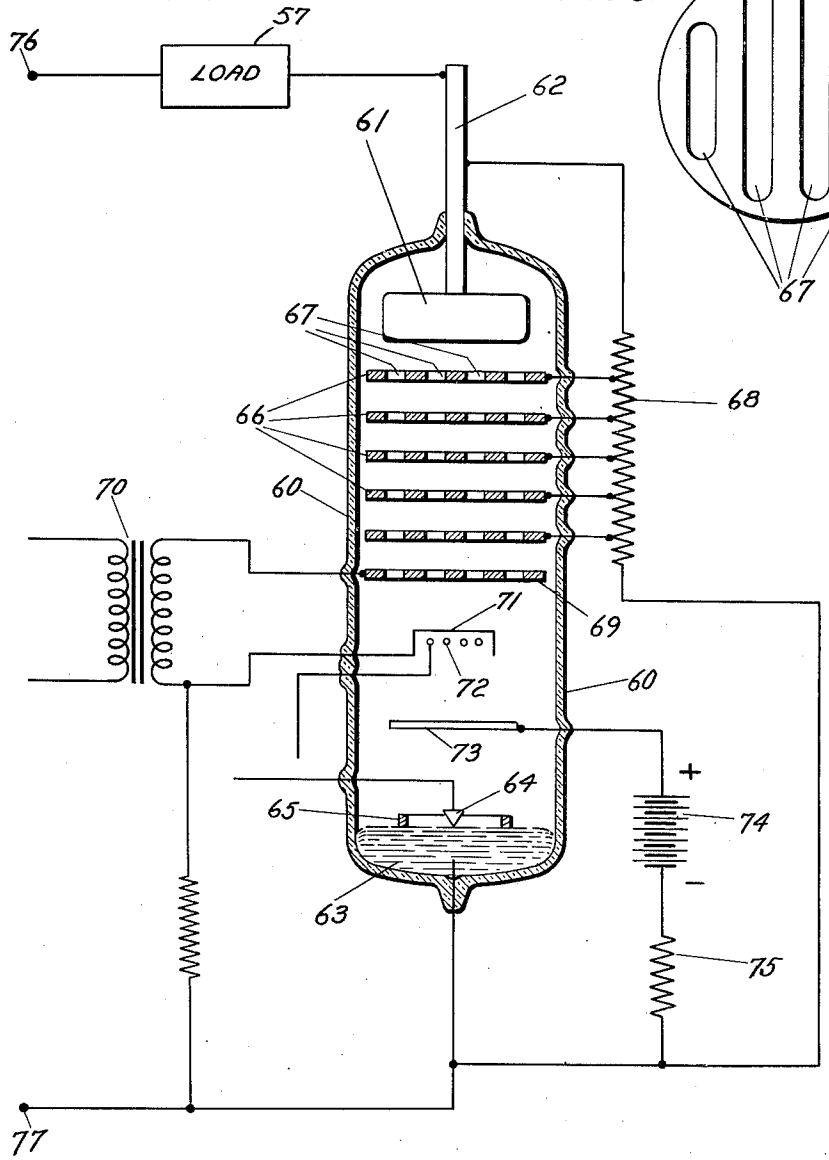


FIG. 5.

INVENTOR
CHARLES G. SMITH
BY Elmer J. Gorn
ATTY.

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GASEOUS DISCHARGE DEVICE

Charles G. Smith, Medford, Mass., assignor to Raytheon Manufacturing Company, Newton, Mass., a corporation of Delaware

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7 Claims. (Cl. 315—326)

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This invention relates to gaseous electrical discharge devices, and more particularly to arc discharge devices.

In arc discharge devices, such as thyratrons or ignitrons as heretofore constructed, the time required for deionization after the interruption of the anode current is of such duration as to limit the utility of such tubes, particularly the utility of tubes of the grid-controlled type. In prior arrangements deionization takes place mainly along lines in the direction of current flow. This has imposed great strain on the insulating properties of the space between the plate and the grid, and due to the long distances which the ions must travel for recombination, the deionization time is correspondingly long.

It is among the objects of the present invention to greatly decrease the deionization time in such arc discharge devices. To this end the invention contemplates the utilization of one or more narrow channels providing a discharge path and having lateral surfaces upon which great lateral deionization can take place. The deionization therefore takes place at a much more rapid rate, and accordingly the repetition frequency at which the tube may be discharged is greatly increased.

A further factor limiting the utilization of such tubes resides in the fact that an appreciable time is also required for the ionization of the gas in such tubes immediately prior to conduction therethrough. The ionization time is therefore an additional factor tending to decrease the repetition frequency at which controlled discharges can be effected through the tube.

It is a further object of the invention to greatly decrease the time required to ionize the gas in the discharge path of such tubes, and thus in conjunction with the great decrease in the deionization time, greatly increase the repetition frequency at which such tubes may be discharged.

The above and other objects and features of the invention will be made fully apparent to those skilled in the art from a consideration of the following detailed description taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a diagrammatic view of a space discharge device constructed in accordance with the invention, together with a suitable circuit diagram therefor;

Fig. 2 shows a plan view of one of the auxiliary electrodes of the tube shown in Fig. 1;

Fig. 3 shows a modified embodiment of the invention and the energizing circuit therefor;

Fig. 4 shows a further modification; and

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Fig. 5 shows a plan view of one of the auxiliary electrodes used in the form of the device shown in Fig. 4.

Referring to the drawings and first to Fig. 1 thereof, reference numeral 6 indicates an envelope which in this instance is of glass and contains an ionizable medium, for example, mercury at a pressure of 10 microns. An anode 7, supported by an anode rod 8 sealed through a wall of the envelope 6, is positioned at the outer end of an elongated tubular portion of said envelope. A cathode 9, which in the instance shown is of the thermionic filament type, is positioned in the body portion of the envelope 6, and is provided with lead-in conductors 10 and 11 sealed in a press 12. The anode rod 8 is connected to one terminal 13 of a suitable source of current to be rectified or controlled and the cathode 9 is connected to the other terminal 14 of such source. Heating current is supplied to the filament of the cathode 9 from any suitable source, such as a filament transformer 15.

An auxiliary cathode 16, which in the instance shown is of the heated type but which if desired may be of the cold type, is provided in the lower portion of the envelope 6. Lead-in conductors 17 and 18 also sealed through the press 12 supply the cathode 16 with suitable heating current from a source such as a heating transformer 19.

A plurality of deionizing electrodes 20 are provided in the elongated tubular portion of the envelope 6 between the anode 7 and the cathode 9. The deionizing electrodes 20 are each in the form of a flat metal disc of sufficient diameter to substantially block the discharge path between the anode 7 and the cathode 9 excepting through an elongated slot 21 provided centrally in each of the electrodes 20. The electrodes 20 are equally spaced, and the openings 21 are aligned to provide a continuous unobstructed channel through all of said electrodes. That one of the flat disc-like electrodes which is closest to the cathode 9 acts as an auxiliary anode 22, and the next adjacent acts as a grid 23. A resistor 24, having a pulrality of taps along the length thereof (one for each of the electrodes 20) is connected at one end to the anode rod 8 and at its opposite end to the cathode 9. The electrodes 20 are connected at the regularly spaced taps to the resistor 24, and thus the potential supplied to the electrodes 20 varies in successive steps, the one most adjacent the anode 7 being at almost anode potential, and the one most adjacent cathode 9 being at almost cathode potential. The electrodes 22 and 23 are connected respectively to the positive and

negative terminal of the battery 25 or other suitable source of potential. The electrode 22 is also connected to the positive terminal of a battery 26 through a radio frequency choke 27. The negative terminal of the battery 26 is connected through an inductance 28 to the cathode 9. The auxiliary anode 22 is also connected to one terminal of a source of very steep voltage pulses 29 through a condenser 30. The other terminal of the source of steep voltage pulses 29 is connected to one of the lead-in conductors 17 and 18 of the auxiliary cathode 16. A resistor 31 connected across condenser 30 provides a leak circuit to prevent the accumulation of a static charge on electrode 16.

In the operation of the device just described, a continuous current supplied by the battery 26 flows between the auxiliary anode 22 and the cathode 9 as long as the filament of said cathode is energized. At a time when the potential across the terminals 13 and 14 is in the direction in which the tube is conductive from the anode 7 to the cathode 9, conduction along this path may be initiated by supplying a very steep voltage impulse from the transformer 29 between the auxiliary anode 22 and the auxiliary cathode 16. This voltage pulse is so steep that ionization near the auxiliary cathode 16 has no time to reach a steady state before a cloud of high speed electrons is projected in the general direction of the hole 21 of the auxiliary anode 22. It will be seen that although the gases in that portion of the envelope 6 between the auxiliary anode 22 and the cathode 9 were ionized prior to the high voltage impulse supplied to the cathode 16, nevertheless conduction between the anode 7 and the cathode 9 could not occur until after the impulse, due to the lack of an ionized path between the auxiliary anode 22 and the main anode 7, and due to the effect of the grid 23 which is biased negative by a battery 25. However, when a stream of high speed electrons from the cathode 16 is projected through the openings 21 upon the application of the high voltage impulse, ions are produced all around the axis of the channel provided by the openings 21. Conduction through the discharge path provided by the channel is therefore initiated very rapidly. Thus, conduction through the external load circuit, not shown, which may be connected in series with a suitable source across the terminals 13 and 14, is initiated with great rapidity. In some instances it will be desirable that the impulse between the auxiliary anode 22 and the auxiliary cathode 16 exceed that of the saturation current of the cathode.

It will be understood that the source connected to the terminals 13 and 14, which it is desired to control, may be an alternating current source having a frequency of 1,000 cycles per second or more, or it may be a condenser which it is desired to discharge at a high repetition frequency. Where the applied potential is high, and current through the tube is heavy, the time required for the deionization after the extinction of conventional arc discharge tubes may be of the order of 1,000 microseconds or greater. This means that such tubes cannot be used to control heavy currents at frequencies of the order of 1,000 cycles per second since at such frequencies the tube would be extinct for only five hundred microseconds prior to the application of the next half wave of current in the direction in which the tube is conductive. The time available for deionization would not be sufficient.

In the device of the present invention, upon the reversal of the polarity at 13 and 14, that is when 13 becomes negative relative to 14, a negative potential is applied to the auxiliary electrodes 20. The ions are then in close proximity to charged surface areas. The distance which any ion must traverse before surface recombination may be effected is very small. Thus the deionization in the narrow column provided by passages 21 proceeds very rapidly. Preferably the potential applied to the electrode elements 20 varies in successive steps so that each electrode element is only moderately negative with respect to the adjacent ionized region. Accordingly, energetic bombardment of these elements by the positive ions is prevented. Disintegration of electrode elements 20 is thereby prevented or is greatly impeded. The tube is thus deionized and the grid 23 regains control of conduction within a few microseconds of the extinction of the immediately preceding conduction or discharge. The tube is thus again in condition to effect a controlled discharge upon the next alternation of the applied current source.

In the form of the invention shown in Fig. 1, the deionizing electrodes 20, the auxiliary anode 22, and grid 23 are insulated from each other by the evacuated space of the tube. If desired, these may be held in spaced relation and insulated from each other by insulating washers of the same general configuration as the flat disc-shaped electrodes. Also if desired a single cathode element may function as both the main cathode and the auxiliary cathode. An example of such a construction is shown in Fig. 3, in which reference numeral 36 indicates the envelope containing an ionizable medium as in the form previously described, 37 the anode having its conductive rod 38 extending exteriorly of the envelope, 39 the filamentary cathode and 40 the deionizing electrodes, each having a central elongated slot 41. The deionizing electrodes are spaced by semi-insulating washers 43 which may be, for example, of carbon. The washers 43 are of the same configuration as the electrodes 40, and each is provided with a central passage therethrough which registers with the openings 41 in each of the electrodes 40. As in the previously described construction, the anode lead-in conductor 38 is connected to the cathode 39 through resistors 44, but in this instance the washers 43 provide the potential gradient between successive electrodes 40, corresponding in function to the successive taps on the resistor 24 in the form shown in Fig. 1. The electrode closest to the cathode 39 is connected to the positive terminal of battery 46 through a resistor 48 and the negative terminal of the battery 46 is connected to the cathode 39 through the primary winding of an impulse transformer 49. The battery 46 thus provides a source of direct current to maintain a small current flow between the auxiliary anode 42 and the cathode 39. The transformer 49 functions to supply the steep voltage pulse between the electrode 42 and the cathode 39, in this case the impulse being superimposed upon the small continuous current between these two electrodes. In order to supply the steep voltage pulse to the transformer 49, a condenser 50 controlled by a switch 51 may be discharged through the primary winding of the transformer 49. The condenser 50 may be charged from a suitable source of direct current such as the battery 52 through a resistor 53. In the instance shown, a battery 54 supplies heat-

ing current to the filament of the cathode 39. The energy for the main discharge between the anode 37 and the cathode 39 is in this instance supplied from a transformer 56, the secondary winding of which has one terminal connected to the anode rod 38 through a load 57, and its other terminal connected to the cathode 39 through a radio frequency choke 55. The radio frequency choke 55 prevents the entrance of voltage impulses from the transformer 49 into regions where they would be of no value. The operation of this form of device will be apparent from the operation of the form previously described, the operation being generally the same except that the cathode 39 in the form shown in Fig. 3 performs the functions of both the cathode 9 and the auxiliary cathode 16 of Fig. 1.

Fig. 4 illustrates the application of the invention to an ignitron. Referring to this figure, reference numeral 60 indicates an envelope, which may be of glass or any suitable material, having an anode 61 connected to and supported by an anode rod 62 extending externally of the tube. A mercury pool type cathode 63 is provided in the lower portion of the envelope 60, this pool having a resistance immersion ignitor 64 to which igniting impulses may be supplied from a suitable source, not shown. The ignitor 64 may be enclosed by a ring 65 to confine the arc spot to a limited area of pool 63 if desired. A plurality of deionization electrodes 66 are provided in the upper portion of the envelope 60, between the anode 61 and the cathode 63. In this instance also the electrodes 66 are flat discs of metal and substantially block the discharge path between the anode 61 and the mercury pool cathode 63 except through the elongated slots 67. Since in this instance the current carried by the tubes is very heavy, a plurality of the slots 67 are provided in each of the electrodes 66, and these slots are so aligned as to provide a plurality of unobstructed conductive paths through all of said electrodes. The anode lead-in conductor 62 is connected to the cathode 63 through a resistor 68 having a plurality of taps distributed along the length thereof, each tap being connected to one of the electrodes 66. The lowermost of the disc-shaped electrodes 69 is connected to one terminal of the secondary winding of the pulse transformer 70. The other terminal of the secondary winding of the transformer 70 is connected to an auxiliary cathode 71. In this instance the auxiliary cathode 71 is of the indirectly heated type, being provided with a filament 72 to which heating current may be supplied from any suitable source, not shown. An auxiliary anode and baffle 73 is connected to the positive terminal of the battery or other source of direct current 74. The negative terminal of the battery 74 is connected through a resistor 75 to the cathode 63. The anode 61 is connected to one terminal 76 of a suitable source of supply and the cathode 63 is connected to the other terminal 77 of such source.

In the operation of this form of the device, when an igniting impulse is supplied to the resistance-immersion ignitor 64, a discharge is initiated between the cathode 63 and the auxiliary anode 73. A small current supplied by the battery 74 flows continuously between the anode 73 and the cathode 63. There will thus be continuous ionization in the region adjacent the cathode 63 and between this cathode and the auxiliary anode 73; however, there will be no ionization in the region adjacent the anode 61 and between this anode and the auxiliary electrode 69. As long as the electrode 69 is negatively biased, conduction through the main discharge circuit from the anode 61 to the cathode 63 will be held off. Upon the application of a very steep voltage pulse from the transformer 70 in such a direction that the electrode 69 is driven positive, and the cathode 71 is highly negative, a stream of high speed electrons emanating from the cathode 71 will be projected in the direction of and through the slots 67. Thus, in this form of the invention, ionization will take place all along the channels provided by the slots 67 and conduction through the main cathode and anode circuit will be initiated with great rapidity. Conduction will then continue until the reversal of the polarity of the potential applied at 76 and 77. Thereupon rapid deionization will be effected in the region of the deionizing electrodes 66, in a manner which will be apparent from the operation of the previously described forms. The tube is therefore in condition to effect a controlled discharge upon the next alternation of the applied current source. Since the time required for deionization is only a few microseconds, the frequency of the applied alternating current may be high.

While there have been herein disclosed certain preferred embodiments of the invention, other embodiments within the scope of the appended claims will be obvious to those skilled in the art from a consideration of the forms shown and the teachings hereof. Accordingly a broad interpretation of the appended claims, commensurate with the scope of the invention within the art, is desired.

What is claimed is:

1. A system for operating an electrical discharge device consisting of an electrical discharge device comprising an envelope containing an ionizable gaseous atmosphere, a cathode, an anode, and a plurality of additional substantially similar electrodes positioned in the discharge path between said cathode and anode, said additional electrodes having aligned openings therethrough and substantially blocking discharges between said cathode and anode except through said openings, said openings providing collectively a long channel affording rapid deionization of the gas in the discharge path, a source of electrical impulses of steep wave front, and a circuit connecting said source across a portion of said discharge path between said cathode and said channel to drive high speed ionizing electrons into said channel.

2. A system for operating an electrical discharge device consisting of an electrical discharge device comprising an envelope containing an ionizable gaseous atmosphere, a cathode, an anode, and a plurality of additional substantially similar electrodes positioned in the discharge path between said cathode and anode, said additional electrodes having aligned openings therethrough and substantially blocking discharges between said cathode and anode except through said openings, said openings providing collectively a long channel affording rapid deionization of the gas in the discharge path, a circuit for continuously maintaining an ionizing discharge in the space between said cathode and the additional electrode closest thereto, a source of electrical impulses of steep wave front, and a circuit connecting said source across a portion of said discharge path between said cathode and said channel to drive high speed ionizing electrons into said channel.

3. A system for operating an electrical dis-

charge device consisting of an electrical discharge device comprising an envelope containing an ionizable gaseous atmosphere, a cathode, an anode, and a plurality of additional electrodes positioned in the discharge path between said cathode and anode, said additional electrodes having aligned openings therethrough and substantially blocking discharges between said cathode and anode except through said openings, said openings providing collectively a long channel affording rapid deionization of the gas in the discharge path, a circuit for applying electrical potential to said additional electrodes which potential varies in successive steps between successive electrodes, a source of electrical impulses of steep wave front, and a circuit connecting said source across a portion of said discharge path between said cathode and said channel to drive high speed ionizing electrons into said channel.

4. A system for operating an electrical discharge device consisting of an electrical discharge device comprising an envelope containing an ionizable gaseous atmosphere, a cathode, an anode, and a plurality of additional substantially similar electrodes positioned in the discharge path between said cathode and anode, said additional electrodes having aligned openings therethrough and substantially blocking discharges between said cathode and anode except through said openings, said openings providing collectively a long channel affording rapid deionization of the gas in the discharge path, a circuit for applying electrical potential to said additional electrodes which potential varies in successive steps between successive electrodes, and a circuit for continuously maintaining an ionizing discharge in the space between said cathode and the additional electrode closest thereto.

5. A system for operating an electrical discharge device consisting of an electrical discharge device comprising an envelope containing an ionizable gaseous atmosphere, a cathode, an anode, and a plurality of additional electrodes positioned in the discharge path between said cathode and anode, said additional electrodes having aligned openings therethrough and substantially blocking discharges between said cathode and anode except through said openings, said openings providing collectively a long channel affording rapid deionization of the gas in the discharge path, a circuit for applying electrical potential to said additional electrodes which potential varies in successive steps between successive electrodes, a circuit for continuously maintaining an ionizing discharge in the space between said cathode and the additional electrode closest thereto, a source of electrical impulses of steep wave front, and a circuit connecting said source across a portion of said discharge path between said cathode and said channel to drive high speed ionizing electrons into said channel.

6. A system for operating an electrical discharge device consisting of an electrical discharge device comprising an envelope containing an ionizable gaseous atmosphere, a cathode, an anode, and at least one additionel electrode positioned in the discharge path between said cathode and anode, said additional electrode having a narrow elongated opening therethrough and substantially blocking discharges between said cathode and anode except through said opening, said opening providing a long channel affording rapid deionization of the gas in the discharge path, a circuit for applying electrical potential to said additional electrode which potential varies progressively along the length of said channel, a circuit for continuously maintaining an ionizing discharge in the space between said cathode and the end of said additional electrode closest thereto, a source of electrical impulses of steep wave front, and a circuit connecting said source across a portion of said discharge path between said cathode and said channel to drive high speed ionizing electrons into said channel.

7. A system for operating an electrical discharge device consisting of an electrical discharge device comprising an envelope containing an ionizable gaseous atmosphere, a cathode, an anode, and additional electrode means positioned in the discharge path between said cathode and anode, said additional electrode means having an elongated opening therethrough and substantially blocking discharges between said cathode and anode except through said opening, said opening providing a long channel affording rapid deionization of the gas in the discharge path, a circuit for applying electrical potential to said additional electrode means which potential varies progressively along the length of said channel from a value approaching the anode potential at the anode end thereof to a value approaching the cathode potential at the cathode end, and a circuit for continuously maintaining an ionizing discharge in the space between said cathode and the end of said additional electrode means closest thereto.

CHARLES G. SMITH.

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