

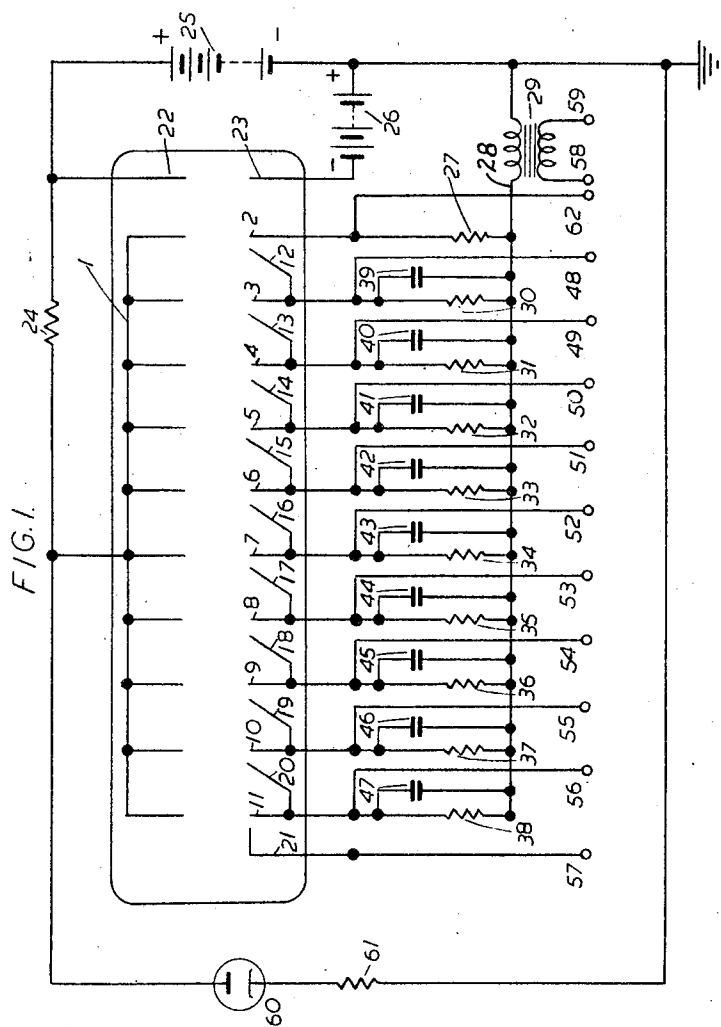
April 3, 1951

G. H. HOUGH
ELECTRIC PULSE GENERATOR

2,547,008

Filed Oct. 2, 1948

2 Sheets-Sheet 1



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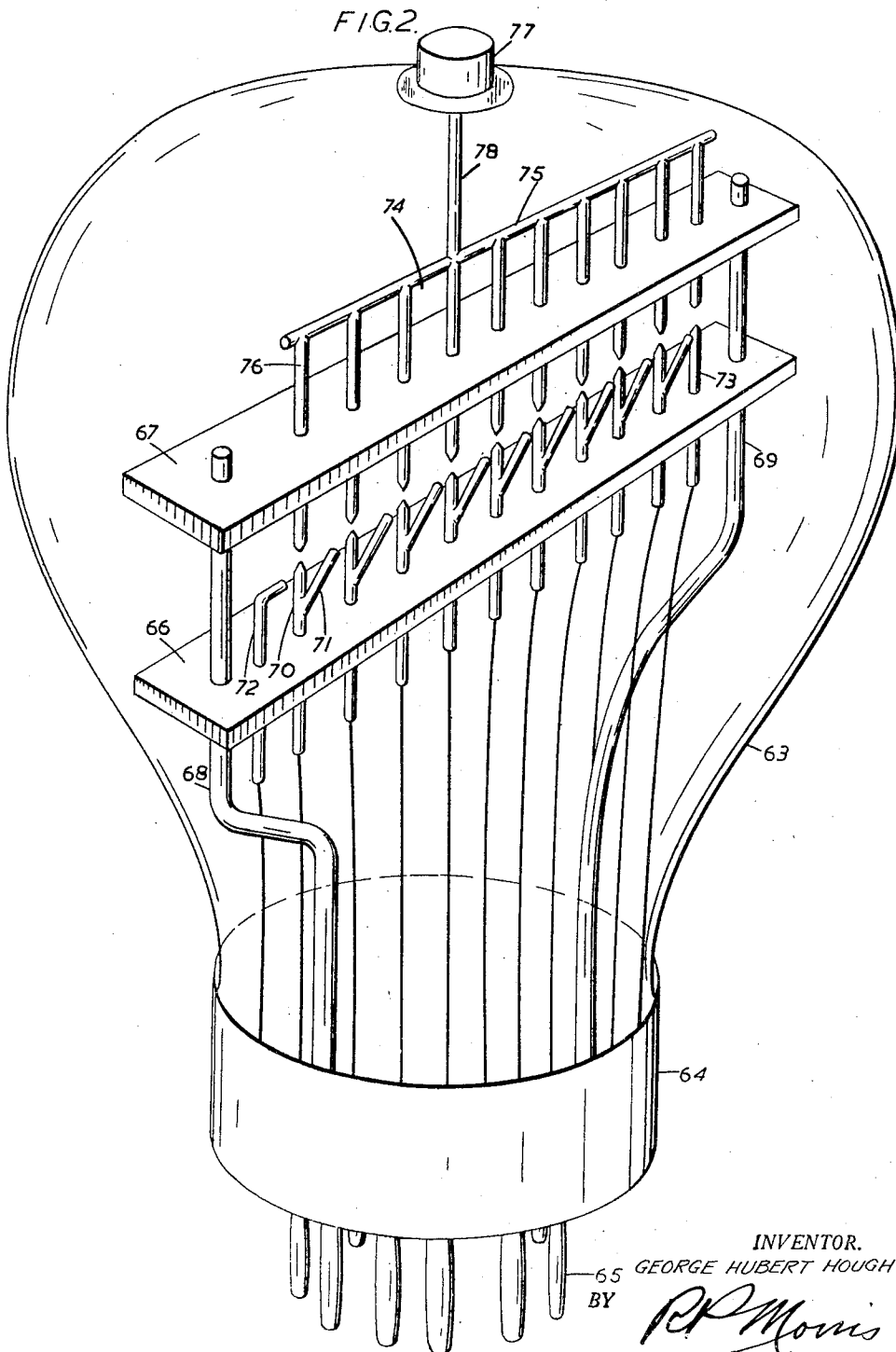
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UNITED STATES PATENT OFFICE

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ELECTRIC PULSE GENERATOR

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The present invention relates to improvements in cold cathode gas filled electric discharge tubes and to electric pulse generating circuits employing such tubes.

The principal object of the invention is to provide a sequence discharge tube having a series of discharge gaps so disposed that if one of the gaps be fired, the adjacent gap on one side is caused to fire after a certain delay, the gap on the other side being unaffected.

Another object is to apply a tube of this kind to the generation of trains of pulses.

The objects of the invention are achieved by providing a cold cathode gas filled electric discharge tube having a plurality of discharge gaps arranged in sequence, one of the electrodes of one of the gaps having connected thereto an auxiliary electrode arranged near the corresponding electrode of one of the other gaps for the purpose of forming with the said corresponding electrode a triggering discharge gap for the said other gap.

The invention will be described with reference to the accompanying drawings in which:

Fig. 1 shows diagrammatically a cold cathode electric discharge tube according to the invention, with an associated circuit adapted to generate pulse trains having a specified number of pulses; and

Fig. 2 shows a perspective view of an example of the tube diagrammatically shown in Fig. 1.

Fig. 1 of the accompanying drawing shows a discharge tube according to the invention, with an associated circuit for enabling it to generate trains of pulses. This tube is diagrammatically shown and may be constructed in any convenient manner, an example of which is shown in Fig. 2.

The tube comprises an anode 1 which may consist of a bar or wire with projecting wires or points forming a comb. It may alternatively comprise a plain bar or wire or a flat metal plate. Opposite the projecting wires of the anode are respectively arranged a number of wire cathodes designated 2 to 11 (inclusive) forming a corresponding number of discharge gaps. Corresponding auxiliary electrodes designated 12 to 21 (inclusive) are provided. Auxiliary electrodes Nos. 12 to 20 are connected, respectively to the cathodes 3 to 11, and their ends are arranged near the ends of the adjacent cathodes to the right hand side, Nos. 2 to 10, forming auxiliary or triggering discharge gaps therewith. A further auxiliary electrode 21 not connected to a cathode is arranged to form an auxiliary gap with the cathode 11. It will be noted that the

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extreme right hand cathode 2 has no auxiliary electrode connected thereto.

The tube may be provided with an additional pair of electrodes 22 and 23 unconnected with the other electrodes, to provide a priming discharge gap which is intended to be kept permanently discharging for controlling the general level of ionisation in the tube as explained in the specification of co-pending U. S. Application bearing Serial No. 19,084, filed April 5, 1948, by A. H. Reeves, now Patent No. 2,520,171. This priming gap may be placed in any convenient position with respect to the other electrodes of the tube and not necessarily at the end of the row, as diagrammatically shown in the figure. For example, if the electrodes are arranged in a circle, the priming gap might be placed at the centre.

It should be understood that the priming gap is not essential and could be omitted, but it is very desirable since more stable operation of the tube is secured by its use.

The tube which has been described will be recognised as generally similar to one of those described in the specification of co-pending U. S. application bearing Serial No. 763,655, filed July 25, 1947, by A. H. Reeves, but the feature which characterises the tube according to the present invention is the provision of the auxiliary electrodes 12 to 21.

In order to confine the discharges to the ends of the various electrodes, their surfaces may be covered with alumina or other suitable insulating coating except at the tips of the electrodes.

Any suitable gas filling may be provided for the tube, but a filling comprising 92% neon, 7% hydrogen and 1% argon at a total pressure of 100 mm./Hg has been found satisfactory.

The tube is shown in Fig. 1, associated with a circuit for generating trains of pulses containing a desired number of pulses from one to ten. The anode 1 is connected through a resistance 24 to the positive terminal of a high tension operating source 25, the negative terminal of which is connected to ground. The anode 22 of the priming gap (if provided) is connected directly to the positive terminal of the source 25, and the cathode 23 of this gap is connected to the negative terminal of a priming source 26, the positive terminal of which is connected to ground. Preferably a suitable current limiting resistance (not shown) will be connected in series with one of the electrodes of the priming gap.

The cathode 2 at the right hand end is connected through a resistance 27 to a common conductor 28 which is connected to ground through the primary winding of an output transformer 29. The remaining cathodes 3 to 11 are respectively connected to the conductor 28 through resistances 30 to 38 shunted respectively by condensers 39 to 47. The cathodes 3 to 11 and the auxiliary electrode 21 are respectively connected to corresponding trigger terminals 48 to 57. The secondary winding of the output transformer is connected to a pair of output terminals 58 and 59.

The anode 1 is also connected to ground through a diode 60 connected in series with a resistance 61. This diode may be replaced by a germanium or other rectifier, and operates to stabilise the discharges in the manner explained in the specification of co-pending U. S. application bearing Serial No. 19,086, filed April 5, 1948, by A. H. Reeves, since become abandoned.

The circuit is intended to operate in the following manner.

The potential of the source 25 should be such that it is incapable of initiating a discharge across any gap, but should be sufficient to maintain any discharge which is struck by any other means. The potential of the source 26 should be such that when added to the potential of the source 25, it is sufficient to strike and maintain permanently a discharge between the priming electrodes 22 and 23.

A positive potential of sufficient magnitude, for example, in the form of a pulse, is applied to one of the trigger terminals such as 53, for example. The corresponding trigger electrode 17 then acts as an anode in conjunction with the adjacent cathode 7 and a triggering discharge occurs between these electrodes, causing the main gap between the anode 1 and the cathode 7 to be fired. The potential of the electrodes 7 and 16 now rises from zero at a rate determined by the time constant of the resistance 34 and condenser 43 until the trigger electrode 16 reaches a sufficiently high potential to fire the next triggering gap between the electrodes 16 and 6. This fires the main gap between the anode 1 and the cathode 6, and the process is repeated, the gap between the anode 1 and the following cathode 5 being fired after a time determined by the time constant of resistance 33 and condenser 42, and so on, until the last gap between the anode 1 and the cathode 2 is fired. Each time a main gap is fired an increase in current flowing through the primary winding of the transformer 29 occurs, and the transformer may be designed to differentiate the leading edges of the current steps so produced, in order to deliver to terminals 58 and 59 short differential pulses corresponding with these steps.

In order to ensure that triggering only occurs in one direction, a suitably small ratio of the gap distance from a cathode such as 6 to the adjacent triggering electrode such as 16, to the gap distance from a cathode such as 6 to the adjacent cathode such as 7 should be used. Alternatively, or in addition, if the tube is required to have very small dimensions, a thin mica sheet (not shown) may be introduced in the gap between any cathode and the trigger electrode connected thereto.

It should be noted that when the pulse is applied to terminal 53, the gap between the cathode 8 and the anode 1 does not fire because the difference of potential across the gap has been reduced by

the pulse below the maintaining potential for the gap, and as triggering does not occur in the backward direction.

It will be clear that when a positive triggering pulse is applied to terminal 53, exactly six output pulses will be produced; if the triggering pulse is applied to any one of the terminals, 48 to 57, a corresponding number of output pulses from 1 to 10 will be obtained. It is evident also that all gaps once fired will remain discharging and may be extinguished in any convenient way (not shown) such as by interrupting the connection between the anode 1 and the resistance 24 or by applying an extinguishing negative pulse of sufficient amplitude to the anode.

The time intervals between successive output pulses are determined by the time constants of the corresponding resistance capacity networks, and these need not be equal, though it will often be desirable to have these output pulses repeated regularly, in which case all the resistance 30 to 38 and all the condensers 39 to 47 can be equal.

If, for example, it is desired to produce output pulses repeated at the rate of 2,000 pulses per second, the resistances may each be 50,000 ohms and the capacity of the condensers may be 0.01 microfarad, assuming a cathode current of 2 milliamperes. The tube in this case would have the gas filling specified above, the main gap lengths being 1.0 mm., and the potential of the source 25 being 200 volts. Assuming that the priming gap is of the same length as the others, the voltage of the source 26 could be 100 volts.

The circuit described has several possible applications. For example, it may be used in dialling circuits for producing a train of dialling pulses having any desired number of pulses by applying a single triggering pulse to the appropriate triggering terminal, and these dialling pulses may be given any suitable repetition period by suitably proportioning the resistances and condensers in the cathode circuits.

It is to be noted that it has been found that if the rectifier 60 and resistance 61 be omitted, the number of gaps which can be discharging at the same time is limited, for example to two. In this case, if a triggering pulse is applied to terminal 57, the cathode 11 and 10 will be fired in succession, but when the cathode 9 is fired, the source cannot supply enough current to sustain three gaps, and it is found that the first gap is extinguished. When the next cathode 8 is fired, the second gap is extinguished and so on, until at the end of the cycle, the last two stages corresponding to the cathodes 2 and 3 will remain discharging and the process terminates. Another cycle may now be initiated by applying a further triggering pulse to terminal 57, and this pulse will fire the first gap and extinguish the ninth, and the firing of the gaps in pairs then travels down the tube as before, terminating when the last two gaps are fired. It will be seen that this suggests another application of the circuit as a frequency multiplier since ten pulses will be obtained from the output transformer 29 for each triggering pulse. It will be clear that the multiplying factor will depend on the number of cathodes provided in the tube. Further, with a given number of cathodes various multiplying factors could be obtained by applying the triggering pulses to different ones of the triggering terminals 48 to 57.

A further application of this mode of operating the tube is to the production of trains of time modulated pulses for a multi-channel pulse com-

munication system. In this case the cathode 2 is provided with an additional terminal 62.

The circuit operates by the application of regularly repeated triggering pulses to terminal 57 (Fig. 1), and the modulating speech waves for the respective channels are applied to terminals 62 and 48, to 47. It will be clear that each time one of the cathodes is fired, an output pulse will be obtained from the transformer 29, and the time at which the cathode is fired and therefore the time of production of the pulse will depend on the instantaneous voltage of the corresponding signal wave, and which affects the potential of the cathode, since the adjacent triggering electrode must reach a voltage sufficient to produce the striking difference of potential before the triggering gap can be fired.

Thus it will be clear that an interleaved train of time modulated channel pulses will be obtained from the transformer 29.

It should be added, that if the circuit of Fig. 1 is operated without the rectifier 60 so that only a limited number of gaps can be discharging at the same time, a continuously repeated cycle of operations may be produced by connecting the cathode 2 directly to the trigger electrode 21, and by shunting the resistance 27 with a suitable condenser (not shown). Thus it is clear that when the last cathode 2 is fired, the first one 11 will be subsequently fired, in the manner already explained, and a new cycle will be commenced. Such cycles are repeated indefinitely, or until the tube is extinguished by some suitable means. The tube then acts as a generator of cyclically repeated pulses, the pulse intervals being determined by the time constants of the resistance-capacity circuits.

The pulses in each cycle evidently need not be spaced at equal intervals. In the case of a tube operated this way, the cathode and trigger electrode assemblies could, if desired, all be exactly alike and could, be equally spaced around a circle.

Fig. 2 shows to a large scale an example of the manner in which the tube diagrammatically shown in Fig. 1 might be constructed. The envelope 63 is fixed to a conventional base 64 with terminal pins 65. Inside the envelope are two parallel strips of insulating material 66 and 67 supported from the base on suitably bent rods or wires 68 and 69. The lower strip 66 carries 9 equally spaced Y-shaped wire electrodes 70 arranged in a line, each electrode consisting of a straight wire cathode with an inclined branch 71 acting as the trigger electrode, and arranged with its end close to the end of the adjacent cathode. At the left hand end is an L-shaped electrode 72 acting as the trigger electrode for the first cathode, and at the other end is a simple wire cathode 73 without a trigger branch. The electrodes 70, 72, and 73 are each connected to a corresponding one of the base terminal pins 65.

The anode 74 consists of a comb formed by a straight wire 75 having attached thereto wires 76 each of which projects opposite to the corresponding cathode 70 or 73. The anode is connected to a metal boss 77 on the outside of the envelope by a rod 78 which is sealed through the envelope 63 according to conventional practice.

It may be preferable, particularly when a priming gap is used, to arrange the electrodes in a circle or arc of a circle (instead of in a straight line as shown in Fig. 2), and the supporting plates 66 and 67 would then take the form of discs. The construction of the tube could, however, be

on quite similar lines, and the anode and cathode of the priming gap (not shown in Fig. 2) if provided, could be placed at the centres of the supporting discs, the anode being brought out if desired to a separate boss similar to 77.

What is claimed is:

1. A gas filled electron discharge device comprising an envelope enclosing therein an anode, a plurality of cathodes positioned in a sequential series and defining with cooperating anode portions a sequential series of main discharge gaps, a plurality of auxiliary electrodes, and means electrically coupling each auxiliary electrode to a corresponding cathode, each auxiliary electrode having an integral unidirectional projecting portion disposed adjacent a succeeding one of said cathodes, each of said auxiliary electrodes forming with a successive cathode an auxiliary discharge gap.

2. A gas filled electron discharge device comprising an envelope enclosing therein a first electrode, a plurality of additional electrodes positioned in a sequential series along a given curve and defining with said first electrode a sequential series of main discharge gaps, at least two of said additional electrodes having an integral unidirectional projecting portion disposed adjacent a succeeding one of said additional electrodes and defining a triggering discharge gap therebetween operative to initiate the main discharge between said succeeding additional electrode and said first electrode.

3. A cold cathode gas filled electron discharge device comprising an envelope enclosing therein an anode, a plurality of cathode members mounted in a sequential array and defining with corresponding anode portions a plurality of sequential main discharge gaps, and a plurality of auxiliary electrodes each constituting an integral projection of a corresponding cathode member and having its projecting outer end disposed in close adjacency with a succeeding cathode member along said sequential array to define an auxiliary discharge gap between said auxiliary electrode and its adjacent cathode.

4. A gas filled electron discharge device comprising an envelope enclosing therein an anode, a plurality of cathodes equally spaced from cooperating anode portions and positioned in a sequential series, said cathode defining with said cooperating anode portions a sequential series of equally spaced main discharge gaps, a plurality of auxiliary electrodes, and means electrically coupling each auxiliary electrode to a corresponding cathode, each auxiliary electrode having an integral unidirectional projecting portion disposed adjacent a succeeding one of said cathodes, each of said auxiliary electrodes forming with a successive cathode an auxiliary discharge gap.

5. A cold cathode gas filled electron discharge device comprising an envelope enclosing therein an anode, a plurality of Y-shaped cathode members mounted in a sequential array and one limb of each member defining with corresponding anode portions a plurality of sequential main discharge gaps, the other limb of each member having its projecting outer end disposed in close adjacency with one limb of a succeeding cathode member along said sequential array to define an auxiliary discharge gap between said other limb and the one limb of its adjacent cathode.

6. A device according to claim 1 wherein there is provided an additional pair of electrodes defining a priming discharge gap.

7. A device according to claim 1 wherein there is provided a single triggering electrode positioned adjacent the first cathode of said sequential series, and a single cathode positioned adjacent the last auxiliary electrode which is coupled to the last cathode of said series to define a discharge gap with said anode and a triggering gap with said last auxiliary electrode.

8. A device according to claim 7 wherein said single cathode is electrically connected to said single triggering electrode.

9. In combination, a gas filled electron discharge device comprising an envelope enclosing therein an anode, a plurality of cathodes positioned in a sequential series, and defining with corresponding anode portions a sequential series of main discharge gaps, and a plurality of auxiliary electrodes each connected electrically to a corresponding cathode and each having an integral unidirectional projecting portion disposed adjacent a succeeding one of said cathodes, each of said auxiliary electrodes forming with a successive cathode an auxiliary discharge gap; common conducting means; a plurality of impedance networks; connecting means coupling each cathode through a respective one of said networks to said common connecting means; a voltage source connected between said anode and common connecting means and furnishing an operating potential having a value sufficient to maintain a discharge across any anode-cathode gap but insufficient to initiate such discharge; means for applying a varying triggering voltage to at least one of said auxiliary electrodes; and output voltage deriving means connected in series with at least one of said cathodes.

10. The combination according to claim 9 wherein said means for applying a varying triggering voltage comprises means for applying triggering pulses.

11. In combination, a gas filled electron discharge device comprising an envelope enclosing therein an anode, a plurality of cathodes positioned in a sequential series and defining with corresponding anode portions a sequential series of discharge gaps, a plurality of auxiliary electrodes each connected electrically to a corresponding cathode and each having an integral unidirectional projecting portion disposed adjacent a succeeding one of said cathodes, each of said auxiliary electrodes forming with a successive cathode an auxiliary discharge gap, and priming means maintaining a given ionisation level within said device; common conducting means; a plurality of impedance networks; con-

necting means coupling each cathode through a respective one of said networks to said common connecting means, a voltage source connected between said anode and common connecting means and furnishing an operating potential having a value sufficient to maintain a discharge across any anode-cathode gap but insufficient to initiate such discharge; means for applying a varying triggering voltage to at least one of said auxiliary electrodes; and output voltage deriving means connected in series with at least one of said cathodes.

12. The combination according to claim 11 wherein each impedance network comprises a resistance shunted by a condenser.

13. The combination according to claim 11 wherein said output deriving means includes an output transformer connected between the negative terminal of said source and said common conducting means.

14. The combination according to claim 11 wherein there is further provided a stabilising rectifier device connected between said anode and said common conducting means.

15. The combination according to claim 11 wherein said electron discharge device further includes a single triggering electrode positioned adjacent the first cathode in said sequential series, and wherein there is further provided means for applying a triggering voltage to said single triggering electrode, and means for applying a different modulating signal to each of said cathodes, said output means comprising means including an output transformer for deriving time modulated pulses.

16. The combination according to claim 11 wherein said electron discharge device further includes an additional pair of electrodes defining a priming discharge gap.

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