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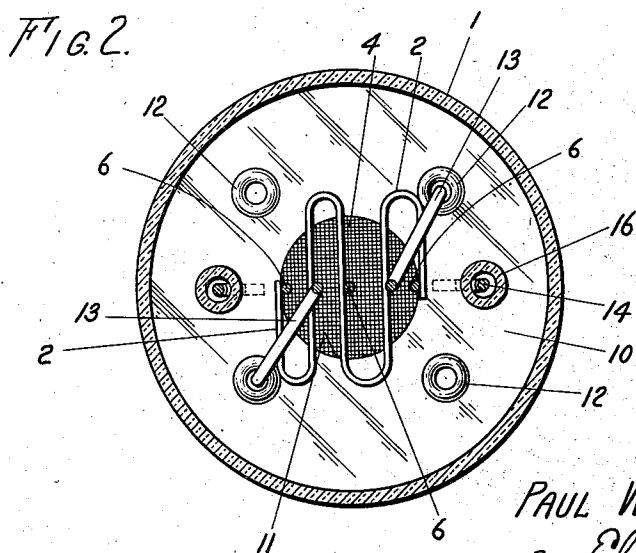
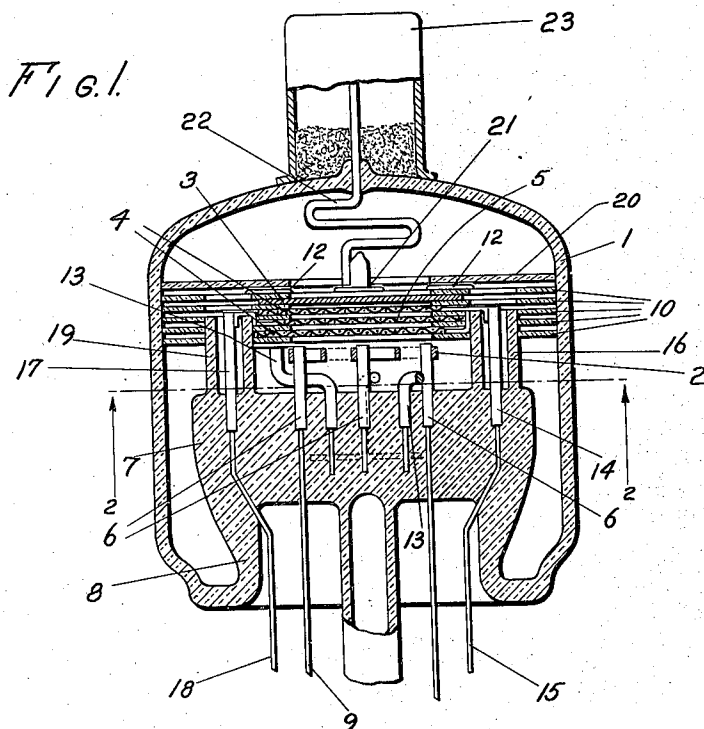
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2,428,048

ELECTRON DISCHARGE DEVICE

Original Filed May 6, 1944

3 Sheets-Sheet 1



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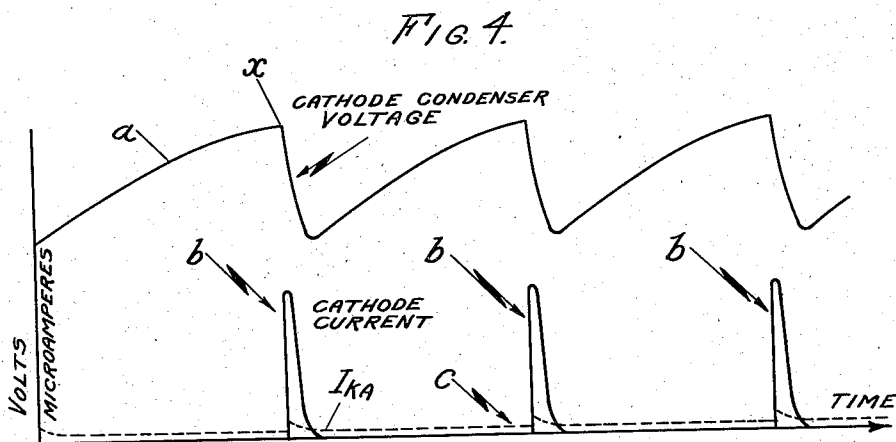
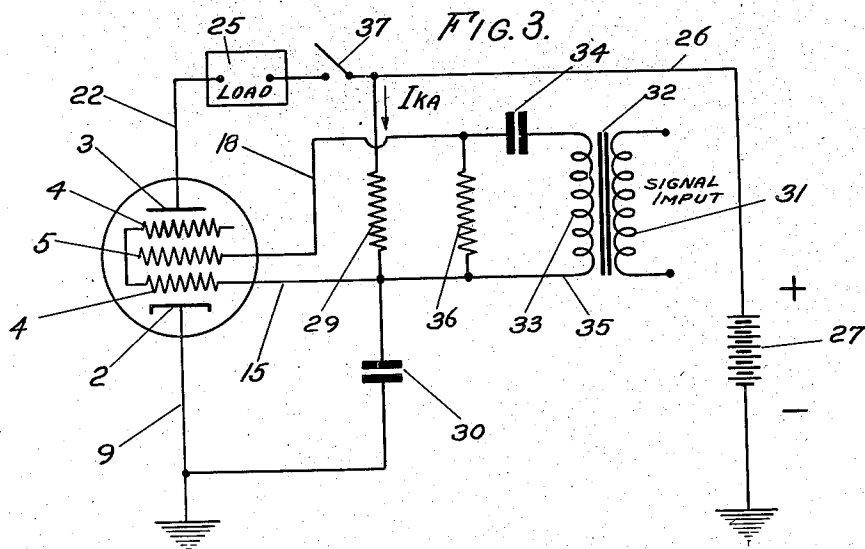
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3 Sheets-Sheet 2



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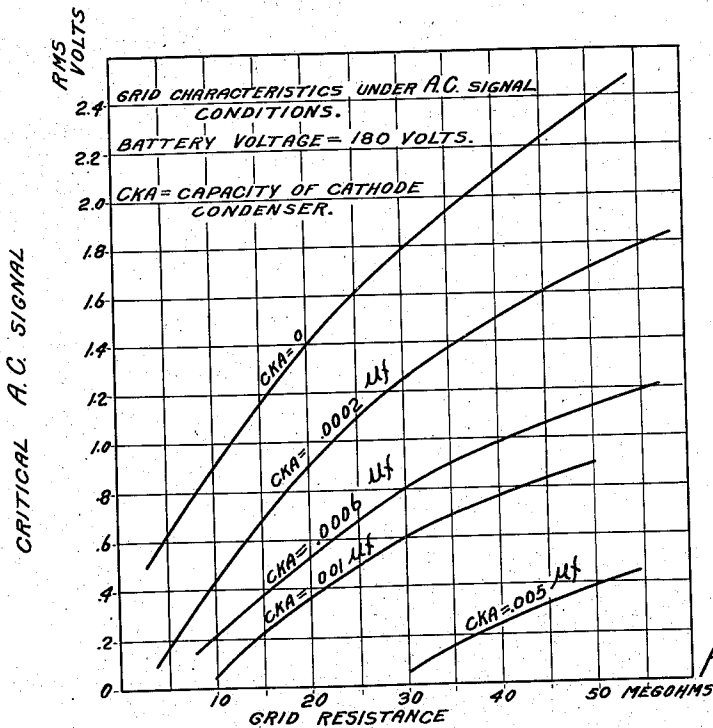
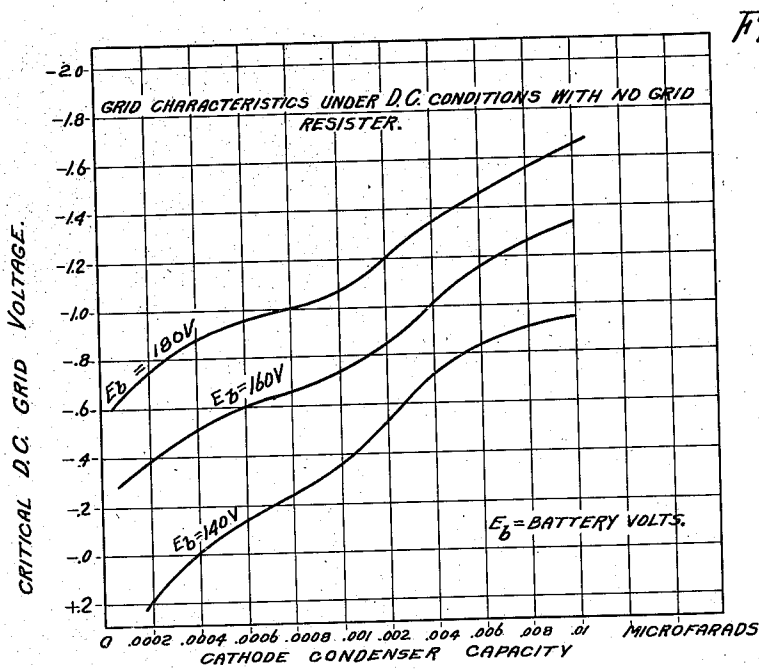
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ELECTRON DISCHARGE DEVICE

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3 Sheets-Sheet 3



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## UNITED STATES PATENT OFFICE

2,428,048

## ELECTRON DISCHARGE DEVICE

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mesne assignments, to Raytheon Manufacturing  
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Original application May 6, 1944, Serial No.  
534,494. Divided and this application Septem-  
ber 15, 1945, Serial No. 616,548

2 Claims. (Cl. 250—27.5)

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This is a division of applicant's copending ap-  
plication Serial No. 534,494, filed May 6, 1944.

This invention relates to an electrical system  
utilizing a gaseous discharge relay tube which  
conducts current between a cathode and anode  
in response to a predetermined value of signal  
voltage applied to a control grid or electrode.

An object of this invention is to devise such  
a tube and system having a high grid impedance  
and which operates reliably with very low grid  
power.

Another object is to devise such a tube and  
system which operates consistently under vari-  
able anode voltages with a substantially uniform  
maximum required signal voltage of the order  
of about one volt.

A further object is to devise such a tube and  
system which operates from a source such as a  
battery with a very low standby current of the  
order of a few micro amperes.

The foregoing and other objects of this inven-  
tion will be best understood from the following  
description of an exemplification thereof, refer-  
ence being had to the accompanying drawings  
wherein:

Fig. 1 is a vertical cross-section of one form  
of my novel tube for use in my novel system;

Fig. 2 is a cross-section taken along line 2—2  
of Fig. 1;

Fig. 3 is a circuit diagram of one embodiment  
of my novel system;

Fig. 4 is a set of curves illustrating the stand-  
by conditions in the system of Fig. 3; and

Figs. 5 and 6 are characteristic curves of a  
tube built and operated in accordance with my  
invention.

The tube as illustrated in Figs. 1 and 2 com-  
prises a sealed glass envelope 1 containing a glow  
discharge cathode 2, an anode 3, and a pair of  
cathode grids 4, 4 disposed on opposite sides  
of a control grid 5. The envelope 1 is filled with  
a suitable ionizable gas at a substantial pres-  
sure. For example, a mixture of krypton and  
xenon at about 10 mm. of mercury may be  
utilized.

The cathode 2 is supported by a plurality of  
conducting support rods 6 sealed in the upper  
end of a press 7 formed on the reentrant stem  
8 of the envelope 1. The cathode 2 may be made  
of a ribbon of a nickel alloy and coated with  
barium carbonate fused onto said ribbon in air  
at a pressure of about 5 mm. of mercury. One  
of the conducting rods 6 may be provided with  
a lead-in conductor 9 extending through the

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press 7 and affording an external electrical con-  
nection to the cathode.

The grids 4 and 5 are preferably made of a  
relatively fine mesh of nickel wire. The anode  
3 may also be made of a disc of nickel. If rel-  
atively small voltages are used between the  
cathode and anode, the electrodes 3, 4 and 5  
may be made of bright nickel. Under these con-  
ditions, voltages of about the order of 145 volts  
or less may be used. However, where higher  
voltages are present, it is desirable that the sur-  
face of the electrodes 3, 4 and 5 be coated with  
a poor electron-emissive material. Thus these  
electrodes are preferably carbonized by being  
coated with a layer of finely divided carbon. The  
electrodes 3, 4 and 5 are each in the form of  
a flat disc supported between a pair of insulat-  
ing washers 10. Each of these insulating wash-  
ers is provided with a central opening 11 so as  
to create an electron discharge passage between  
the cathode 2 and the anode 3. The insulating  
washers 10 are clamped together by a plurality  
of hollow rivets 12 which thus bind the assembly  
of the electrodes 3, 4 and 5 together into a com-  
pact unit. This unit is supported on the re-  
entrant stem 8 by means of a pair of wire stand-  
ards 13 sealed in the press 7. The upper ends  
of the standards 13 may be welded to two of the  
rivets 12. Each of the cathode grids 4 has  
welded thereto a conducting tab which in turn  
is welded to a conducting rod 14 likewise sealed  
in the press 7 and provided with an external  
lead-in conductor 15. The rod 14, as it pro-  
jects above the press 7, is surrounded by a glass  
sleeve 16 so as to protect said rod 14 against  
undesirable discharges. The glass sleeve 16 fits  
snugly into corresponding openings in the in-  
sulating washers 10. The control grid 5 likewise  
has welded thereto a conducting tab which in  
turn is welded to a conducting rod 17 likewise  
sealed in the press 7 and provided with an ex-  
ternal lead-in conductor 18. The rod 17 is also  
surrounded by a glass sleeve 19 fitting snugly  
into corresponding openings in the washers 10.  
The purpose of the sleeve 19 is similar to that  
described in connection with the sleeve 16. In  
order to cut off all discharge paths between the  
electrodes except through the discharge openings  
11 in the washers 10, an additional insulating  
washer 20 is placed over the top of the electrode  
assembly and is provided with a single central  
opening for the purpose of enabling an electrical  
connection to be made to the anode 3. How-  
ever, the washer 20 covers the openings in the  
washers 10 through which the sleeves 16 and 19

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project and also covers the upper ends of the rivets 12. The washers 10 and also the washer 20 fit snugly within the side walls of the envelope 1, the washer 20 being retained in place by coming into contact with the lower portion of the upper curved section of the inner walls of said envelope. The anode 3 has welded to its upper surface a conducting stub 21 to which is welded a flexible lead-in conductor 22. This lead-in conductor is sealed through the top of the envelope 1 and is connected to an external connector cap 23 cemented to the top of said envelope.

As is well known, if two electrodes in an ionizable gas are brought closer together, the voltage at which the gas breaks down and at which a discharge is initiated between said electrodes falls until a predetermined distance is reached at which said breakdown voltage is a minimum. This distance is known as the minimum breakdown distance. If the separation between the electrodes is decreased still further, the voltage at which breakdown occurs is increased. In the present arrangement the cathode 2 is preferably spaced from the lower cathanode grid 4 by substantially the minimum breakdown distance. Since the cathode 2 is made of a ribbon having a substantial width, it will be seen that if any substantial part of the active surface of the cathode 2 is at the minimum breakdown distance from the lower cathanode grid 4, breakdown at the minimum voltage value will occur between said electrodes. The anode 3 is spaced from the upper cathanode electrode 4 by a distance substantially less than the minimum breakdown distance. The spacing between the electrode 5 and each of the adjacent grids 4 is preferably substantially the same as that of the spacing of the anode 3 from the upper grid 4. In a practical case with the above-mentioned krypton xenon mixture at 10 mm., the cathode was spaced about .040" from the lower grid 4, while the spacings between the electrodes 3, 4 and 5 were each about .015".

The tube described above may be utilized in a circuit such as that illustrated in Fig. 3, wherein the same reference numerals are applied where the elements are identical with those of Figs. 1 and 2. In this circuit the cathode 2 is connected by its conductor 9 to ground. The anode 3 is connected through a suitable load 25, a conductor 26, and a source of potential 27, such as a battery, to ground. The battery 27 is polarized so as to make the anode 3 positive with respect to its cathode. The battery 27 is also connected through the conductor 26, a cathanode resistance 29, and a cathanode condenser 30 to the ground conductor 9. The cathanode 4 is connected by means of its conductor 15 to a point intermediate the resistance 29 and the condenser 30. A signal input voltage may be supplied to the primary winding 31 of a signal transformer 32 having a secondary winding 33. One end of said secondary winding is connected through a condenser 34 to the conductor 18 leading to the control grid 5. The other end of said secondary winding 33 is connected by a conductor 35 to the conductor 15 connected to the cathanode 4. A leakage grid resistance 36 is connected between the conductors 18 and 15.

During the standby condition, in which no signal voltage is supplied to the primary winding 31, the operation of the system illustrated in Fig. 3 is illustrated by the curves of Fig. 4. Under these conditions, relaxation oscillations will be generated between the cathode 2 and the cath-

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anode 4. These said relaxation oscillations are the result of the periodic charging and discharging of the condenser 30. The curve *a* in Fig. 4 represents the manner in which the voltage on condenser 30 varies during such charging and discharging. This voltage rises along said curve *a* until a point *x* is reached when the voltage between the cathode 2 and the cathanode 4 is at its breakdown value. Thereupon an ionizing discharge is initiated between said electrodes and the condenser 30 is discharged by the resulting flow of current between said electrodes. Thus, when the discharge is initiated at the point *x*, a current impulse *b* will flow between the cathode 2 and the cathanode 4. Due to the flow of the current impulse *b*, the voltage on the condenser 30 falls as indicated by the point *a* beyond the curve *x*. When this voltage falls to a value less than that which is sufficient to maintain the discharge, the current *b* decreases to substantially zero and the discharge between the cathode 2 and the cathanode 4 is extinguished. Thereupon condenser 30 is recharged and the cycle is repeated. The cathanode resistance 29 is sufficiently large so that the charging current to the condenser 30 remains at a substantially uniform value. This charging current  $I_{ka}$  is represented by the curve *c* in Fig. 4. The current  $I_{ka}$  is the standby drain which the battery 27 is called upon to deliver. In a practical case this standby current has been about 25 micro amperes. This value is so small that the drain on the battery is negligible and its shelf life is in nowise decreased thereby.

With the present device only a very small bias on the grid 5 is required to prevent a discharge from being propagated to the anode 3. A typical characteristic curve of the grid 5 is shown in Fig. 5 in which the value of D. C. grid bias voltage required to prevent a discharge to the anode 3 is shown with various values of voltage of the battery 27 and various values of capacity of the cathanode condenser 30. Values of grid voltage more positive than those indicated will cause a discharge to be propagated to the anode 3.

In the circuit of Fig. 3 the grid 5, due to the presence of the high leakage grid resistance 36, will assume a negative bias sufficient to hold off the anode discharge under conditions of zero signal voltage. The electron flow to the grid 5 to maintain said negative bias is only about .2 micro ampere in a practical case.

If a signal voltage is applied to primary winding 31, this signal voltage will be transferred through the transformer 32 and the condenser 34 and the grid 5. When the signal voltage swings in a positive direction so as to move the potential of the grid 5 more positive than the critical grid voltage, as shown for example in Fig. 5, electrons of sufficiently high speed projected into the space between the cathanode grids 4, 4 will be caused to pass in sufficient numbers to the anode 3 to initiate a self-sustaining discharge between the anode 3 and its cathode 2. As will be explained below, such projection of electrons occurs primarily at the beginning of each of the cathanode current impulses *b* as shown in Fig. 4. When the flow of current is initiated to the anode 3 the self-sustaining discharge which takes place is propagated throughout the entire discharge path between the cathode 2 and the anode 3. This causes the voltage drop between the cathanode 4 and the cathode 2 to fall to substantially the normal glow discharge value and thereafter the voltage drop persists at this value. Un-

der these conditions, the relaxation oscillations will be suppressed and the device continues to operate with a substantially steady discharge, for example, of the order of five milliamperes between the cathode 2 and the anode 3. In order to restore the circuit to its standby condition, it would be necessary to interrupt the flow of current in this circuit at least momentarily as by opening a switch 37 in the circuit leading from the battery 27. A typical operating characteristic curve of the grid 5 is shown in Fig. 6 in which the critical R. M. S. value of signal voltage necessary to fire the tube is shown with various values for the capacity of the cathanode condenser 30 and for various values of the grid resistance 36.

The effectiveness and reliability of the tube and the system as described above, are due, I believe at least in part, to the stabilizing of the tube conditions by the relaxation oscillations. The breakdown of the discharge space between the cathode 2 and the cathanode 4 tends to occur always at the same voltage, which voltage is dependent upon the gas, its pressure, the conditions of the surface of the cathode 2 and the spacing between the cathode 2 and the cathanode 4. Thus, the actual voltage of the battery 27 may vary over wide limits and still the voltage on the cathanode will rise along the curve *a* (Fig. 4), and the cathanode space will break down at substantially the same peak value *x*. It also appears that the speed at which the electrons from the cathanode space are projected into the space between the cathanode grids 4, 4 is a primary controlling condition in so far as the control exerted between the control grid 5 and the initiation of conduction to the anode 3 are concerned. During the non-conducting portion of the relaxation oscillation cycle, substantially no electrons are projected into the space between the cathanode grids 4, 4 and any electrons which do enter this space are of relatively low speed. When, however, the gap between the cathode 2 and the cathanode 4 breaks down, the discharge is rapidly propagated between said electrodes and substantially at that instant, electrons are projected through the lower cathanode grid 4 at substantially the maximum voltage attained by the cathanode 4 with respect to the anode 3. Thereafter the speed of the projected electrons falls off substantially as indicated by the falling portion of the curve *a* beyond the point *x* in Fig. 4. As already indicated the value of the cathanode voltage at the point *x* is fixed by the tube constants and thus it will be seen that the critical control voltage is fixed largely by said tube constants and varies over a relatively small range with additional circuit variations. The most important variation in circuit conditions which is met with in practice is the variation of the battery voltage due, for example, to the aging of the battery. The extent to which the critical grid voltage is independent of such battery voltages, is typically illustrated in Fig. 5. In this figure it will be seen that with various capacities for the cathanode condenser 30, the battery voltage may vary from 140 to 180 volts and yet the critical grid voltage remains below about one volt.

From the foregoing it will be seen that a tube and system, constructed and operated in accordance with my invention, satisfy the objects of this invention to a remarkable degree.

Of course it is to be understood that this invention is not limited to the particular details as described above as many equivalents will suggest themselves to those skilled in the art. For example, instead of using a source of direct current to energize the system and interrupting the anode discharge by a switch 37, the tube could be made to periodically discharge a condenser, or the anode voltage could be a pulsating or alternating voltage and in this way the anode discharge would be automatically interrupted in a periodic manner. Certain principles of this invention might likewise be utilized in a system in which the glow discharge cathode is replaced by a thermionic type of cathode. Various other equivalents will suggest themselves to those skilled in the art. It is accordingly desired that the appended claims be given a broad interpretation commensurate with the scope of the invention within the art.

What is claimed is:

1. An electrical space discharge tube comprising a sealed envelope containing an ionizable gas at a substantial pressure, a glow discharge cathode having an active surface, a foraminous cathanode electrode disposed adjacent said cathode at a distance substantially equal to the minimum breakdown distance from a substantial portion of the active surface of said cathode, a foraminous control electrode on the opposite side of said cathanode electrode from said cathode, an auxiliary foraminous electrode on the opposite side of said control electrode from said cathanode electrode, and an anode on the opposite side of said auxiliary electrode from said control electrode, said cathanode electrode, control electrode, auxiliary electrode and anode being spaced from each other by distances each substantially less than said minimum breakdown distance.

2. An electrical space discharge tube comprising a sealed envelope containing an ionizable gas at a substantial pressure, a glow discharge cathode having an active surface, a foraminous cathanode electrode disposed adjacent said cathode at a distance substantially equal to the minimum breakdown distance from a substantial portion of the active surface of said cathode, a foraminous control electrode on the opposite side of said cathanode electrode from said cathode, an auxiliary foraminous electrode on the opposite side of said control electrode from said cathanode electrode, an anode on the opposite side of said auxiliary electrode from said control electrode, said cathanode electrode, control electrode, auxiliary electrode and anode being spaced from each other by distances each substantially less than said minimum breakdown distance, and means for blocking off all discharge paths between said electrodes except through the foramina of said cathanode, control and auxiliary electrodes.

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