

Dec. 15, 1953

L. MALTER

2,662,993

ELECTRON DISCHARGE DEVICE AND SYSTEM

Filed March 10, 1950

2 Sheets-Sheet 1

Fig. 1.

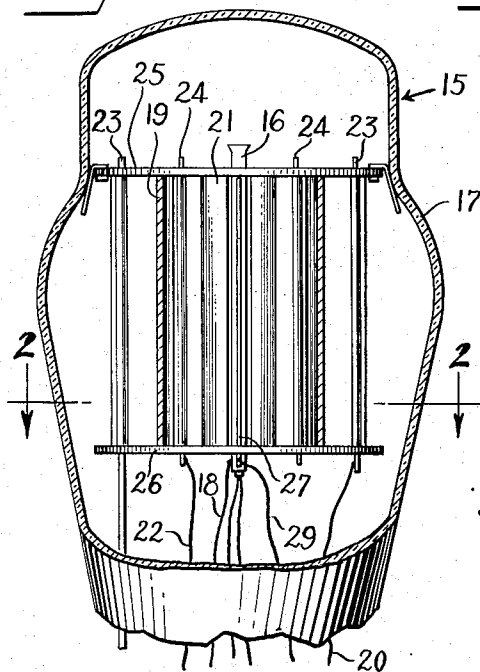


Fig. 2.

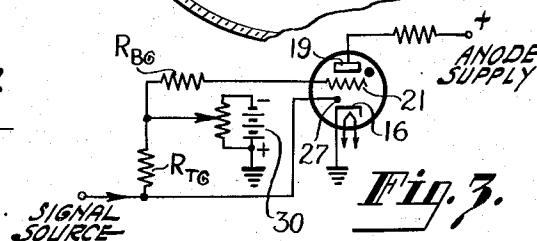
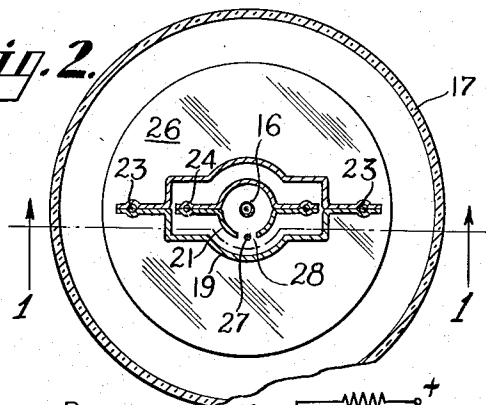


Fig. 3.

Fig. 5.

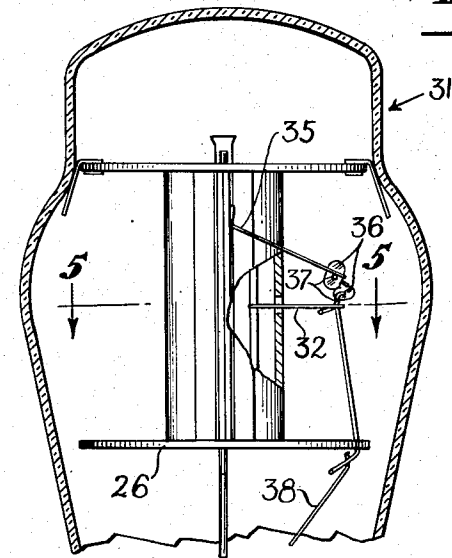
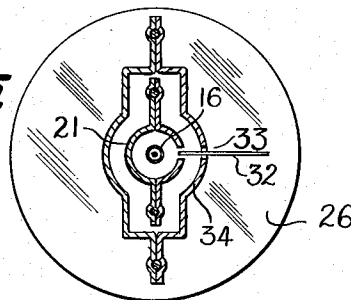
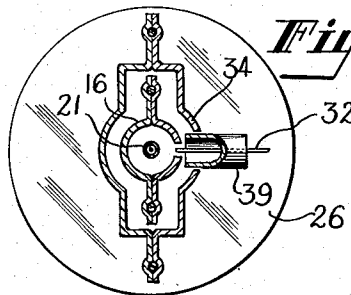


Fig. 4.

Fig. 6.



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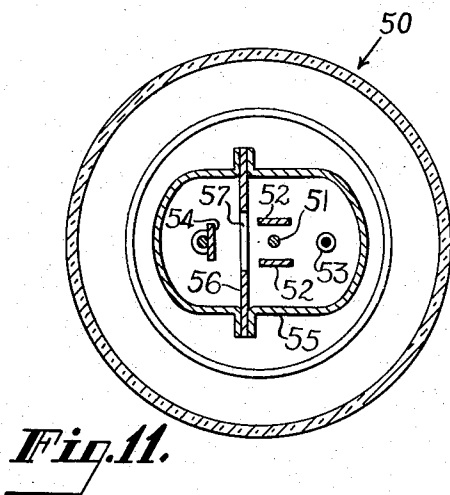
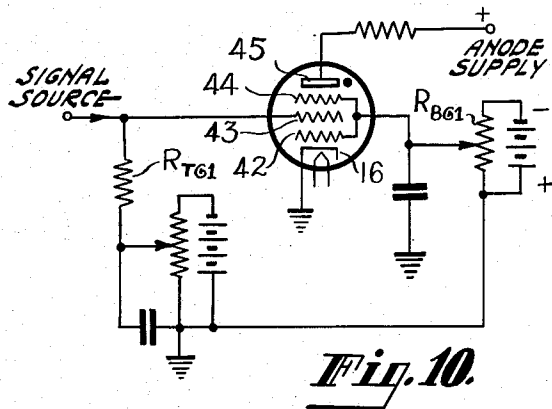
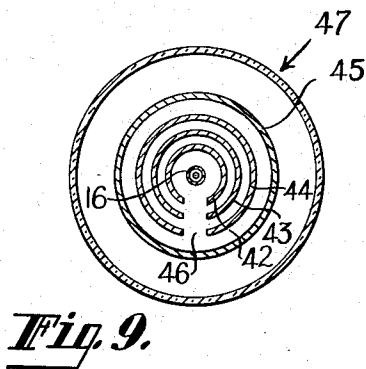
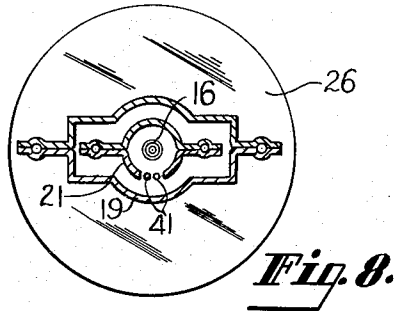
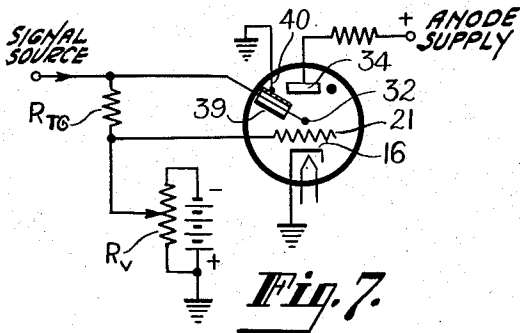
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ELECTRON DISCHARGE DEVICE AND SYSTEM

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2 Sheets-Sheet 2



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Application March 10, 1950, Serial No. 148,976

14 Claims. (Cl. 315-341)

1 My present invention relates to electron discharge devices of the type in which an ionizable medium is employed to support a discharge as well as to a system and method for operating the same.

One limitation of such devices has been the amount of time required to restore full non-conductivity after a period of conductivity. This interval of time has commonly been referred to as the deionization time of the device and has set the upper limit to the frequency at which it could be operated. When full non-conductivity has been restored in such devices having a grid, it may be said that the grid has recaptured control. The grid may then effectively block a discharge even though favorable potentials are applied to the cathode and anode. I have found that the grid may regain control even though the ionizable medium has not become fully deionized. I, therefore, prefer to call this time interval the recovery time or RT of the device since this seems more accurate. In order to make such devices available for operation at higher frequencies it is necessary to shorten the recovery time.

A further drawback has been the upper limit on the impedance which may be connected in series between the grid and source of bias potential. During the recovery time of such devices, the grid current flows to ground, in the usual circuit arrangement, through the grid circuit resistance. Thus, the series grid resistance develops a voltage opposite to that of the bias. The voltage available at the grid is therefore reduced. This may be expressed as follows:

$$E_g = [C + I_g R_g] \text{ volts}$$

where E_g is the potential available at the grid; C is the grid bias; I_g is the grid current in amperes; and R_g is the series grid resistance in ohms. It is apparent then that for a given grid current, I_g , the loss in grid bias at the grid increases with increasing grid resistance, R_g . This is particularly undesirable when such a device is to be responsive to a relatively weak signal. In such a case, it is necessary to operate with a grid bias fairly close to the potential necessary to initiate the discharge. However, in view of the loss in bias from grid current pointed out above it is then necessary to reduce the grid resistance to avoid instability which would otherwise result. This reduction in grid circuit resistance in turn leads to a loss in sensitivity to signal current.

Still another disadvantage of such devices is

2 the instability resulting from grid emission. Grid emission is a substantially steady component of grid current when the tube is conducting. This is true too when the device has short rest periods of the order of approximately $1/60$ of a second or less. However, with longer tube rest periods or when the tube is warming up to its operating temperature, grid emission varies directly with grid temperature. The tube firing characteristic is unstable during the period of grid emission variation. This limits the usefulness of such devices.

5 There are other limitations on the use of such devices which vary with each form such as the capacitance between electrodes particularly the grid and anode. These too are improved by my invention.

A principal object of my invention is therefore the provision of means for reducing the recovery time of electron discharge devices containing an ionizable medium.

Another object is to provide such an electron discharge device having reduced recovery time for a given grid circuit impedance.

25 Another object is to provide such a device which is highly sensitive to weak signal currents while at the same time having improved stability.

Another object is to provide such a device in which the functions of initiating a discharge and of recapturing control are performed by separate electrodes.

Another object is to provide such a device having separate electrodes for initiating a discharge and restoring non-conductivity which may operate in a stable manner with high grid circuit impedance, while at the same time having enhanced sensitivity and a substantially reduced recovery time.

Another object is to provide such a device in which the adverse effects of grid current are eliminated.

Another object is to provide such a device in which the adverse effects of grid emission are eliminated.

Another object is to provide such a device in which grid-anode capacitance is substantially reduced and the adverse effects from such capacitance is substantially eliminated.

Another object is the provision of a system which utilizes an electron discharge device containing an ionizable medium and which has improved sensitivity and stability.

Further objects and advantages will become evident as my invention is more fully understood. In the embodiments exemplifying my inven-

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tion, I preferably use separate electrodes to perform the two functions of initiating the discharge and of recovering control. A trigger grid initiates the discharge while a blocking grid regains control and restores the device to a condition of full non-conductivity. The blocking grid is of relatively large surface area and is connected to a source of bias potential. The trigger grid is also connected to a source of bias potential but has extremely small surface area particularly with reference to the blocking grid. Even though the trigger grid series impedance has an extremely large value, there is no loss in stability. The blocking grid impedance is small and only of sufficient value to limit the current which flows in the blocking grid circuit while the device is firing.

Additional objects and advantages will appear as the nature of my invention is more fully understood. The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. The invention itself will be best understood by reference to the following description taken in connection with the accompanying drawing wherein:

Figure 1 is a sectional view through the line 1—1 of Figure 2 partly cut away of an electron discharge device constructed in accordance with my invention;

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

Figure 3 is a schematic diagram of one system in accordance with my invention employing the device of Figure 1;

Figure 4 is a side elevational view partly cut away of another embodiment of my invention;

Figure 5 is a sectional view on the line 5—5 of Figure 4;

Figure 6 is a sectional view corresponding to Figure 5 and shows a further modification thereof;

Figure 7 is a schematic diagram of a circuit in accordance with my invention employing the device of Figure 6;

Figure 8 is a sectional view corresponding to Figure 2 and is illustrative of a modification thereof employing two thin elongated wires which function as the trigger grid;

Figure 9 is a transverse sectional view of another manner of carrying out my invention;

Figure 10 is a schematic diagram of a system in accordance with my invention employing the device of Figure 9; and

Figure 11 is a sectional view of still another device constructed in accordance with my invention.

In general, thyratrons contain an ionizable medium such as argon, xenon or one or more of the noble gases or other gas or metal vapor. They also have a thermionic cathode, a grid and an anode mounted therein. In a thyatron firing can be prevented or blocked when a positive potential is applied to the anode, by the simultaneous application of a sufficiently negative potential to the grid. If the grid bias is decreased, the tube will fire when the bias crosses the critical characteristic curve of the device. After the tube is fired, in the case of the usual thyatron making the grid more negative than the value corresponding to the critical characteristic does not result in an interruption of the discharge. During the discharge the grid is surrounded with the so-called grid sheath. In order to enable the grid to regain control, it is necessary to inter-

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rupt the discharge by dropping the anode potential below a definite value. After the interruption of the discharge, an interval of time must elapse before the grid recaptures control. It is this interval of time which is customarily designated the deionization time. I have found it is more accurate to designate this time interval the recovery time or RT. I use the designation deionization time to denote the time it takes the device to return to the state it was in just before firing.

For a given bias, RT increases as the magnitude of the grid resistance R_g increases. It has been the general belief that large values of R_g result in a decrease of the positive ion current through the grid circuit and in a decrease of the rate of deionization. Contrary to this, I have found that the grid positive ion current decays with time from the instant the discharge is interrupted and is substantially independent of the grid bias or resistance. I have further found that the grid series impedance increases RT primarily only by delaying the return of the grid voltage to its bias value.

It should be understood that the grid current referred to herein is that which flows after interruption of the discharge. During the discharge the grid current of course represents a loss of power. This is readily kept within reasonable bounds by a series impedance of relatively low value.

From the foregoing it might be supposed that an increase in the bias might solve the problem of reducing RT. As a matter of fact, in the presence of an appreciable grid resistance, this does not serve to appreciably shorten the recovery time. Under these conditions, the grid remains stabilized at cathode potential for an appreciable length of time following the interruption of the discharge. Increased bias introduces several serious disadvantages. One is that it then takes a large signal to initiate the discharge. Another is that as bias increases clean up also increases.

Referring to Figures 1 and 2 electron discharge device 15, except as will be pointed out, is a conventional thyatron registered under the number 884 as manufactured by Radio Corporation of America. Tube 15 has mounted therein a conventional oxide coated thermionic cathode 16 connected to the exterior of gas tight envelope 17 by lead in 18. Anode 19, having arcuate portions is also conventional and has lead in 20 connected thereto. Blocking grid 21 having arcuate portions forming a cylinder is essentially the control grid of the type 884 and is connected to lead in 22. The parts so far described and the mount structure conform to that of tube type 884; the electrodes being mounted in spaced relationship as in that type of tube by anode side rods 23, blocking grid side rods 24 and top and bottom micas 25, 26. The cathode and the arcuate portions of anode 19 and blocking grid 21 are concentric and coaxial. I preferably add trigger grid 27 to such a device in the form of an elongated extremely small surface area self-supporting wire. As shown most clearly in Figure 2, I preferably mount trigger grid 27 in the center of opening 28 in blocking grid 21 and parallel with cathode 16. Lead in 29 is connected to trigger grid 27 and serves as an external connection.

The system of Figure 3 illustrates a preferred manner of operating device 15. The means for initiating the discharge comprising trigger grid

27, is connected to a source of bias potential as indicated by battery 30 through impedance R_{RG} . The means for recapturing control comprising blocking grid 24 is also connected to bias source 30 through an impedance R_{BG} . As indicated cathode 16 is connected to ground while anode 19 is connected to a supply of positive voltage through a load impedance as indicated. The cathode heater is of course connected to the usual source of heater current (not shown).

The specific values of impedance R_{RG} and R_{BG} may vary over wide limits, however the relative values thereof form an important feature of my invention. The signal current is introduced between the trigger grid and cathode across impedance R_{RG} which may be substantially resistive in character as generally is the case. I have found that with a relatively small area trigger grid 27 an R_{RG} may be as high as 10 megohms without introducing any instability. The tube type 884 is unstable with a grid resistance as little as .5 megohm. R_{BG} may also be substantially resistive and preferably is relatively small in value; a value of the order of 1000 ohms usually being sufficient to limit the blocking grid circuit current.

I have also found the small trigger grid area results in an important reduction in emission therefrom as compared to the grid emission of tube type 884. Tube type 884 has excessive grid emission when the anode current is raised over 75 ma. On the other hand device 15 is stable in operation at anode currents in excess of 200 ma. Furthermore, the capacitance between the anode and trigger grid is low enough to permit operation at high frequencies. When this capacitance is high the rapid variations of anode voltage are transferred to the grid by capacitive coupling within the tube thereby causing the tube to fire even when a large negative bias supply voltage is used.

In operation when favorable potentials are applied to the cathode, blocking grid and anode the negative bias on the trigger grid prevents a discharge from taking place between the cathode and anode. The incoming signal current generates a potential drop across R_{RG} and device 15 fires. The tube is conductive and continues in this state after the signal is removed. As is well known, a drop in the anode potential interrupts the discharge. However, the favorable anode potential may not be reapplied until the blocking grid has recaptured control. During the discharge each of the electrodes is enveloped in a sheath. Substantially immediately after termination of the discharge the blocking grid returns to its bias potential since there is no appreciable potential drop across R_{RG} . Thus, the blocking grid sheath or field extends across opening 28 substantially immediately after the blocking grid has returned to its bias potential as compared to the action of the grid field in known devices. The blocking grid is then capable of preventing the tube from firing should the favorable potential be applied to the anode and in the absence of the signal or favorable potential on the trigger grid.

I have found it is not necessary for the blocking grid to be connected to the same bias voltage as the trigger grid. It is only necessary that the blocking grid be connected to a sufficient value of bias voltage a negative to the anode a as to be able to stand off a discharge between the anode and cathode in the absence of the favorable or triggering voltage on the trigger grid. This

makes available a wide range of critical or firing characteristics and renders the device highly flexible in use.

Another embodiment of my invention is shown in Figures 4 and 5. Electron discharge device 31 has a mount structure similar to that of device 15 as is clearly apparent. However, in this instance trigger grid 32 lies in a plane transverse to blocking grid 24 and extends through aperture 33 formed in anode 34 and into slot or opening 23. Trigger grid 32 is supported from a pair of support members 35 only one of which is visible in Figure 4. Insulators such as glass beads 36 and connecting straps 37 serve to connect trigger grid 32 to support members 35 in insulated relation. Support members 35 are in turn connected to the ears of anode 34. The trigger grid is connected to lead in 33 which serves as an external connection. This construction has the particular advantage of even less grid emission in view of the reduced area of the trigger grid.

The anode to trigger grid capacitance of device 31 may be reduced by providing a shield around trigger grid 32 along that portion thereof which is adjacent the anode. As most clearly shown in Figure 6 this may be a cylindrical sleeve 39 insulated or spaced from the trigger grid and anode and which has a lead in 40 connected to it; thereby permitting any desirable potential to be placed on the shield such as ground.

Device 31 is suitably operated in the system shown in Figure 7. The system is generally similar in arrangement and operation to that shown in Figure 3. R_{BG} has been omitted while shield 39 is connected to cathode or ground potential. Here, too, R_{RG} may have substantial value without introducing any instability. Variable resistance R_v serves as the current limiter for the blocking grid during the discharge.

In the modification of Figure 8 two small area members which are electrically tied together form trigger grid 41. This form is similar in other respects to the device of Figure 1 but has increased sensitivity. I believe this to be the case because the effective grid opening for initiating the discharge is now the space between the trigger grid members 41.

In device 47, Figure 9, three substantially cylindrical grids 42, 43, 44 are provided. Each is concentric and coaxial with cathode 16 and have aligned slots forming an opening 45 for the discharge. Anode 45 is also concentric and coaxial with cathode 16 and surrounds the array of grids. Grid 43 functions as the trigger grid or means for initiating the discharge. Grids 42 and 44 are tied together and function as the blocking grid or means for recapturing control.

As shown in Figure 10, I preferably maintain grids 42 and 44 negative to trigger grid 43. In this way the thermionic electron emission from trigger grid 43 is suppressed and it functions as though there were none. A substantially high value of impedance such as resistance R_{RG1} may then be connected in series with the trigger grid 43; the latter being connected to the source of signal current as shown. The emission from grids 42 and 44 may be considerable. However, this has no harmful effects since this grid current flows to ground through small impedance or resistance R_{BG1} which also serves to limit the power loss.

Though I have shown several specific embodiments of my invention and described my invention in connection therewith, my invention may be applied to tubes having widely different geom-

etries. As for example, electron discharge device 50, Figure 11, is a thyatron type registered under the number 2050. Device 50 apart from trigger grid 51 is described in detail in United States Patent No. 2,296,324, issued September 22, 1942. Blocking grid 52 is in the form of an inverted U with the closed end supported by the top mica as shown and claimed in the application of G. G. Carne, Serial Number 65,817 and filed December 17, 1948. Device 50 further comprises oxide coated thermionic cathode 53 and anode 54. Shield 55 encloses all of the electrodes and has a partition 56 separating the interior thereof into an anode region and a cathode region. The cathode and anode regions communicate with one another through the discharge opening 57 formed in partition 56. In this case blocking grid 52 is connected to a bias voltage through a low value current limiting resistance.

Though the devices described and shown are commonly referred to as having a negative characteristic my invention is equally applicable to positive characteristic thyatrons. Therefore, while my invention is subject to modification, it is intended to cover all such modifications as come within the scope of the appended claims.

I claim:

1. An electron discharge device, comprising an enclosing envelope, an ionizable medium within the envelope for supporting a discharge therein, concentric and coaxial cathode and anode in spaced relationship within said envelope, a substantially cylindrical blocking grid having a discharge opening formed therein and positioned between said cathode and anode, said blocking grid being coaxial with said cathode, and an elongated trigger grid having a relatively small surface area with respect to said blocking grid and extending in said discharge opening.

2. An electron discharge device, comprising an enclosing envelope, an ionizable medium within the envelope for supporting a discharge therein, a cathode and anode in spaced relationship within said envelope, a blocking grid having a discharge opening between the cathode and anode, said anode having an opening formed therein in registration with said discharge opening, and a trigger grid extending through said anode opening into said discharge opening.

3. An electron discharge device, comprising an enclosing envelope, an ionizable medium in said envelope for supporting a discharge therein, an elongated cathode and anode in spaced relationship within said envelope, a blocking grid having a discharge opening between the cathode and anode, said anode having an opening formed therein in registration with said discharge opening, and a trigger grid extending transversely with respect to said cathode and through said opening into said discharge opening.

4. An electron discharge device, comprising an enclosing envelope, an ionizable medium in said envelope for supporting a discharge therein, a cathode and anode in spaced relationship within said envelope, a blocking grid having a discharge opening between the cathode and anode, said anode having an opening formed therein in registration with said discharge opening, and a trigger grid extending through said opening into said discharge opening and presenting a small surface area to said cathode.

5. An electron discharge device, comprising an enclosing envelope, an ionizable medium in said envelope for supporting a discharge therein, a cathode and anode in spaced relationship with-

in said envelope, a blocking grid having a discharge opening between the cathode and anode, said anode having an opening formed therein in registration with said discharge opening, a trigger grid extending through said opening into said discharge opening and presenting a small surface area to said cathode, and a shield extending through said opening surrounding a portion of said trigger grid and insulated from said trigger grid and anode.

6. An electron discharge device, comprising an enclosing envelope, an ionizable medium within the envelope for supporting a discharge therein, a cathode and anode in spaced relationship within said envelope, blocking means having a discharge opening formed therein between said cathode and anode, trigger means for initiating said discharge and including a pair of small area members in said opening.

7. An electron discharge device, comprising an enclosing envelope, an ionizable medium in said envelope for supporting a discharge therein, concentric and coaxial cathode and anode in spaced relationship within said envelope, a substantially cylindrical blocking grid having a discharge opening formed therein and positioned between said cathode and anode, said blocking grid being coaxial with said cathode, and a trigger grid comprising a pair of elongated members having small surface area compared to said blocking grid and extending in spaced relation in said discharge opening.

8. An electron discharge device, comprising an enclosing envelope, an ionizable medium in the envelope for supporting a discharge therein, a cathode and an anode in spaced relationship in said envelope, blocking means comprising a pair of coaxial spaced substantially cylindrical members between the cathode and anode, said members each having an opening formed therein, and trigger means between said members insulated therefrom only by being spaced therefrom and comprising a substantially cylindrical member coaxial with said blocking means and having an opening formed therein, all of said openings being in registration one with the other.

9. An electron discharge device, comprising an enclosing envelope, an ionizable medium in the envelope for supporting a discharge therein, a cathode and an anode in spaced relationship in said envelope, a shield enclosing said cathode and anode and having a partition between the cathode and anode dividing the interior thereof into a cathode region and an anode region, said partition having a discharge opening formed therein, blocking means in said cathode region having an opening in alignment with said first-mentioned opening, trigger means in said cathode region and extending within said second-mentioned opening for initiating said discharge when favorable potentials are applied to said cathode, anode, blocking means and trigger means, said blocking means being adapted immediately after the termination of the discharge for preventing a discharge between the cathode and anode in the absence of said favorable potential on said trigger means.

10. An electron discharge device, comprising an enclosing envelope, an ionizable medium in the envelope for supporting a discharge therein, a cathode and an anode in spaced relationship in said envelope, a shield enclosing said cathode and anode and having a partition between the cathode and anode dividing the interior thereof into a cathode region and an anode region, said partition having a discharge opening formed

therein, blocking means in said cathode region, said blocking means having an opening in registration with said discharge opening, and a trigger grid extending in the opening in said blocking means.

11. A discharge system, comprising an electron discharge device having an enclosing envelope, a cathode, an anode, a trigger grid and a blocking grid in spaced relationship within said envelope, the space between all closely adjacent portions of the trigger grid and the blocking grid being free of any solid dielectric, an ionizable medium within said envelope for supporting a discharge therein between said cathode and said anode when favorable potentials are applied thereto, a source of biasing direct potential connected to said trigger grid and blocking grid to bias the same with respect to said cathode, a high impedance in series between said trigger grid and said bias source, and means for supplying a signal to said trigger grid in response to which said discharge is initiated.

12. A discharge system, comprising an electron discharge device having an enclosing envelope, a cathode, an anode, trigger means for initiating a discharge responsive to a signal current, blocking means for preventing a discharge in the absence of said signal current, the space between all closely adjacent portions of said trigger means and the blocking means being free of any solid dielectric, an ionizable medium within said envelope for supporting a discharge therein between said cathode and anode when favorable potentials are applied thereto; a source of biasing direct potential connected to said trigger means and blocking means to bias the same with respect to said cathode, a high resistance in series between said trigger means and said bias source, and means for supplying a signal to said trigger means.

13. A discharge system, comprising an electron discharge device having an enclosing envelope, a cathode, an anode, trigger means for initiating a discharge responsive to a signal current, blocking means for preventing a discharge in the absence of said signal current, the space between

all closely adjacent portions of said trigger means and blocking means being free of any solid dielectric, an ionizable medium within said envelope for supporting a discharge therein between said cathode and anode when favorable potentials are applied thereto, means including a source of direct potential for biasing said trigger means and said blocking means with respect to said cathode, a substantially resistive impedance in series between said trigger means and said source of potential in said bias means, a current limiting impedance between said blocking means and said biasing means, and means connected to said trigger means for impressing a signal thereon.

14. An electron discharge device, comprising a sealed envelope, a thermionic cathode, blocking electrode means surrounding said cathode, said blocking electrode means having a restricted aperture therein, trigger electrode means arranged in spaced relationship within said aperture, an anode surrounding all of said electrodes, an ionizable medium within said envelope for supporting a discharge therein between said cathode and said anode, said discharge occurring through said aperture when favorable potentials are applied to said cathode, anode, blocking electrode means and trigger means, said blocking means being adapted immediately after the termination of said discharge for preventing a discharge between said cathode and anode in the absence of said potential on said trigger means, the space between all closely adjacent portions of said trigger means and said blocking electrode means being free of any solid dielectric.

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