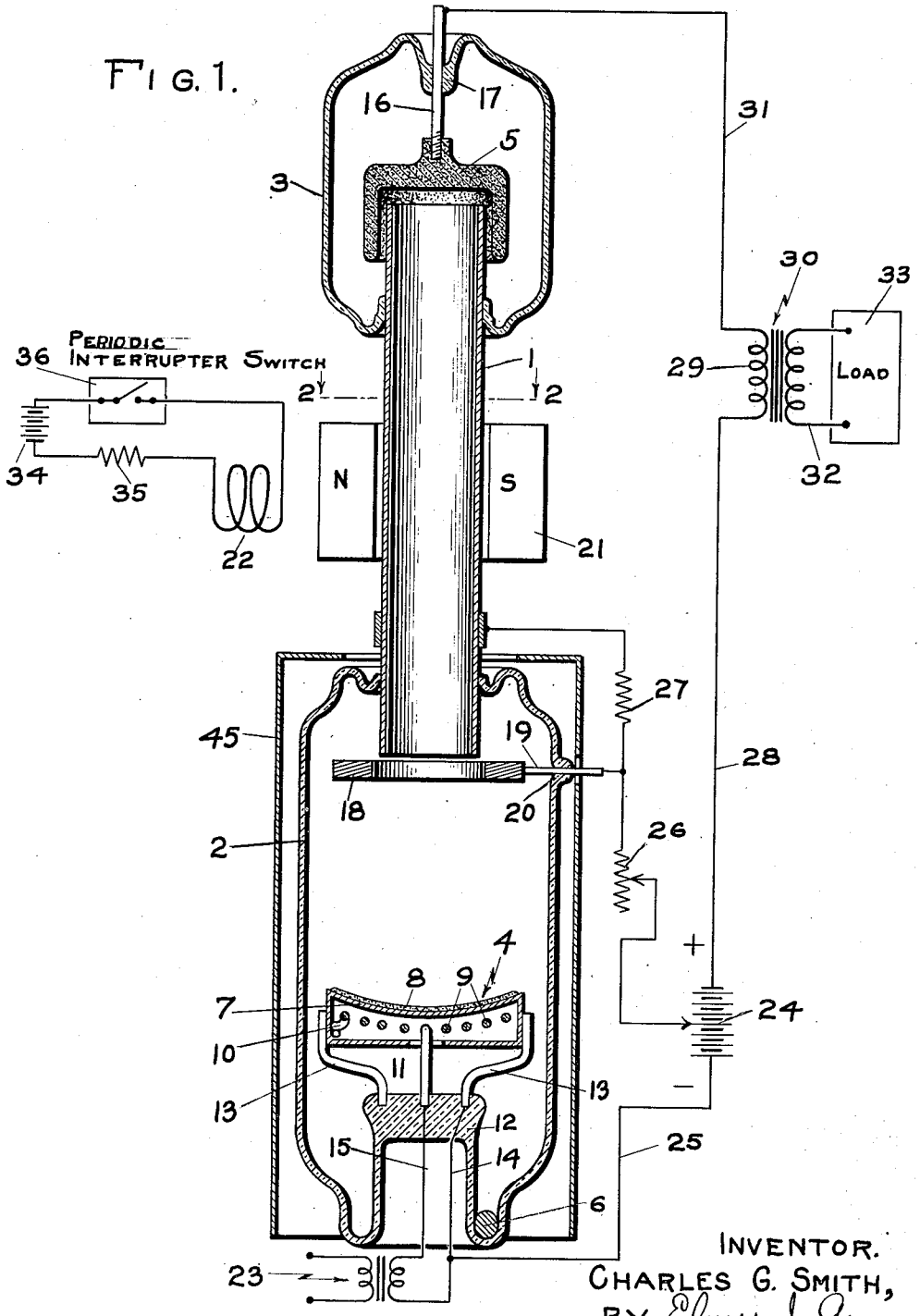
Feb. 3, 1942. C. G. SMITH 2,271,666

CONTROLLED ELECTRICAL DISCHARGE DEVICE

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FIG. 1.




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FIG. 2.

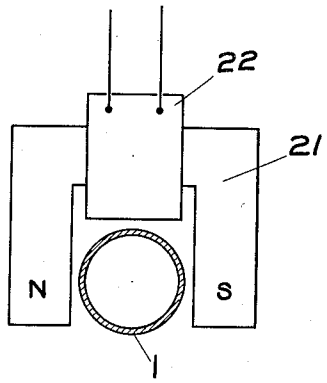
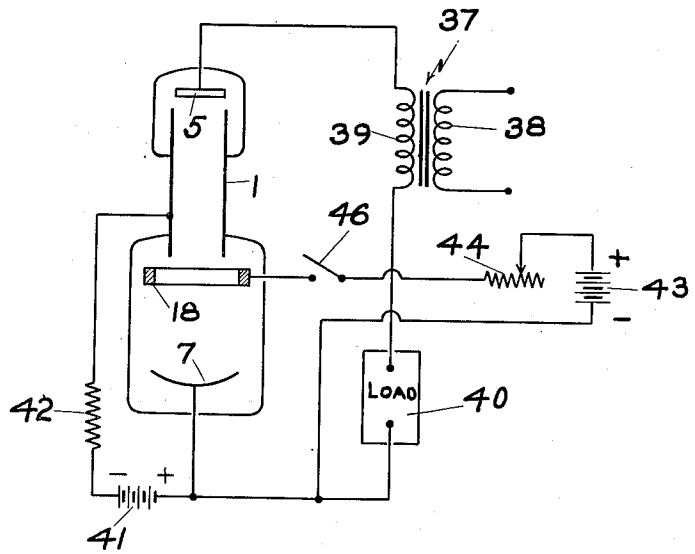



FIG. 3.




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# UNITED STATES PATENT OFFICE

2,271,666

## CONTROLLED ELECTRICAL DISCHARGE DEVICE

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Application August 27, 1940, Serial No. 354,386

15 Claims. (Cl. 250—27.5)

This invention relates to an electrical discharge device in which the current is directed through a restricted aperture and in which control of said current flow is readily produced.

Heretofore ionizing discharges passing through restricted apertures have been limited to relatively low saturation currents through said apertures. I have discovered, however, that by directing the electronic flow under proper conditions through restricted apertures, the magnitude of the current which may be passed may be greatly increased.

An object of this invention is to devise a gaseous discharge device utilizing the directional effects of an electron stream through a restricted orifice.

Another object of this invention is to cause such a discharge to pass through a relatively elongated restricted channel without substantial interference under proper conditions.

A further object is to provide means for controlling the electron flow through such apertures and channels.

A still further object is to devise arrangements of the foregoing type capable of handling high currents and voltages.

The foregoing and other objects of this invention will be best understood from the following description of exemplifications thereof, reference being had to the accompanying drawings, wherein:

Fig. 1 is a cross-sectional view of the tube embodying my invention, together with a diagrammatic representation of a circuit with which it may be used;

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

Fig. 3 is a diagrammatic representation of another circuit with which the tube of Fig. 1 may be utilized.

In the arrangement shown in Figs. 1 and 2, the discharge tube comprises a relatively elongated metal tube 1 having a predetermined cross-sectional area. The lower and upper ends of the tube 1 are sealed respectively to glass vessels 2 and 3. The glass vessel 2 contains a cathode construction 4 while the vessel 3 contains an anode 5. A quantity 6 of mercury or other vaporizable material is placed within the lower vessel 2 for the purpose of supplying an ionizable atmosphere within the discharge tube. It is desirable to maintain the vapor pressure within the discharge tube at a relatively low value, such as of the order of magnitude of one micron of mercury, although somewhat higher vapor pressures may be used under favorable conditions. In order to maintain the vapor pressure at the desired value, the vessel 2 may be surrounded by an enclosure 45 within which a corresponding predetermined temperature may be maintained by any suitable means, such as a constant temperature liquid bath.

The cathode 4 consists of a hollow metal box having a top member 7 whose surface constitutes a section of a sphere, the center of which is located substantially at the center of the opening in the lower end of the metal tube 1. The surface of the member 7 is coated with a suitable electron-emitting material 8 which may consist of alkaline earth oxides. Within the hollow box of the cathode 4 is placed a heating filament 9 which may be in the form of a flat spiral. One end 10 of the heating filament is connected to the hollow cathode box while the other end is connected to a center lead 11 extending through an opening in the lower part of said cathode box and which is sealed in a reentrant stem 12 of the vessel 2. The cathode 4 is supported by a pair of cathode standards likewise sealed in the press 12. A lead-in conductor 14 is connected to one of said cathode standards to provide an external electrical connection to the cathode. A lead-in wire 15 is connected to the center lead 11 to provide an external electrical connection for the heating filament 9. Likewise the anode 5 is provided with a lead 16 sealed through an upper seal 17 in the vessel 3.

An auxiliary anode 18 in annular form is provided adjacent the lower end of the metal tube 1. The opening in the auxiliary anode 18 is preferably slightly larger than the opening in the lower end of the metal tube 1, and said openings are located substantially concentrically with each other. A lead 19 sealed through a seal 20 in the side wall of the vessel 2 supports the auxiliary anode 18 and provides an external electrical connection thereto. Preferably a control magnet 21 is placed with its opposite poles on opposite sides of the metal tube 1. Where such a magnetic control is to be used, the tube 1 is made of a non-magnetic material, such as chrome steel or nickel alloy. The control magnet 21 is adapted to be energized from an energizing coil 22.

In the circuit illustrated in Fig. 1, the heating filament 9 is provided with current from a heating transformer 23. A source of direct current, such as a battery 24, has its negative terminal connected by means of a conductor 25 to the lead 14 of the cathode 4. An intermediate point on

said battery 24 is connected through an adjustable resistance 26 to the lead 19 of the auxiliary anode 18. The metal tube 1 is connected through a resistance 27 to the lead 19, and thus to the auxiliary anode 18. The positive terminal of the battery 24 is connected through a conductor 28, the primary winding of an output transformer 30, and a lead 31 to the anode 5. The output transformer 30 is provided with a secondary winding 32 which is connected to some suitable load device 33. A suitable source of current, such as a battery 34, has one terminal thereof connected through a current-limiting resistance 35 to one side of the energizing coil 22. The other terminal of said battery 34 is connected through a control switch 36 to the other side of said energizing winding 22. The switch 36 preferably operates to periodically interrupt current flow to the energizing winding 26 at a predetermined frequency.

When the system illustrated in Fig. 1 is energized, the heating filament 9 raises the temperature of the member 7 and its coating 8 to thermionic emission, and a relatively large number of electrons are emitted substantially normally to the surface 7. In this way a directional effect is given to the electron stream tending to cause said electrons to be focused at the center of the lower opening to the tube 1, and thus said electrons tend to enter said opening directed substantially along lines parallel to the axis of said tube 1. If the vapor pressure is not too high but of the proper order of magnitude as described above, the electrons tend to enter the tube 1. If the total current which is caused to pass between the cathode 4 and the auxiliary anode 18 in tube 1 is raised to a point where the positive ion sheaths created as a result of the ionization of the vapor within the tube are smaller than the radius of the opening in the tube 1, then the electrons penetrate deeply into the passageway extending through the tube 1. Under proper conditions practically all of the electrons directed from the cathode 4 to the opening in the tube 1 will pass through said tube and emerge at the anode 5, where they will be collected by said anode. The tube 1 may be of relatively extensive length, for example a foot, and may be relatively restricted in diameter, for example one-half inch, if desired. Of course these dimensions may be varied considerably. The tube 1 need not be straight but may be bent into an arc or other curve, and the electron stream will still pass through it substantially unimpeded. Here likewise I believe that the reason for such unimpeded passage is that under conditions of sufficient current, the ionization of the vapor inside the tube 1 gives rise to the positive ion sheath on the inside of said tube 1. The electrons passing through said tube, due to the fact that they are directed along the tube, have velocities with only small components normal to the inside walls of said tube 1. Most of the electrons, therefore, do not strike said interior walls, and repeatedly are reflected from said walls toward the anode 5.

By directing an electron stream through a restricted aperture, as described above, the saturation effect of such an aperture on the current which has heretofore been encountered is largely eliminated. In accordance with the present invention, an aperture of about one centimeter in diameter in vapor pressure of the order of one micron of mercury might carry currents of the order of magnitude of 100 amperes without substantial voltage loss in the region of the aperture.

The electron stream flowing through the tube 1 may be readily controlled by the control magnets 21. If the switch 36 is closed so that a magnetic field transverse to the discharge path through the tube 1 is created, the electrons flowing through the tube 1 are deflected so that they acquire relatively large velocity components normal to the interior walls of the tube 1. Under these conditions the electrons are readily captured by the tube 1, and the current flow through said tube may be readily shut off by said magnetic field. Thus periodic operation of the switch 36 will periodically interrupt the current flow between the cathode 4 and the anode 5, thus sending periodic pulses of current through the primary winding 29, creating an alternating current output in the secondary winding 32 which is supplied to the load 33. In this way the arrangement of Figs. 1 and 2 operates as an effective and efficient inverter of direct current.

The control which may be exerted within the tube 1 is not limited to magnetic control inasmuch as the electrons in this region may also be subjected to other types of influences. Such an alternative arrangement is illustrated in Fig. 3 in which identical reference numerals are applied where the elements are identical with those of Figs. 1 and 2. In Fig. 3 alternating current is supplied to the discharge tube from a transformer 37 having primary winding 38 adapted to be connected to a source of alternating current and a secondary winding 39. One end of the secondary winding is connected through a load 40 to the cathode 7, while the other end of said secondary winding is connected to said anode 5. A negative bias potential is impressed upon the tube 1 by means of a battery 41 connected through a resistance 42 between the cathode 7 and the tube 1. A positive potential is applied to the auxiliary anode 18 by means of a D. C. source, which is a battery 43 connected through a variable resistance between the cathode 7 and the auxiliary anode 18.

In the arrangement of Fig. 3 when the current to the auxiliary anode 18 is increased by varying the resistance 44, for example, the sheath thickness around the opening in the auxiliary anode 18 and the opening through the tube 1 decreases until a value is reached at which the electrons penetrate into the passageway through the tube 1 and reach the anode 5. If, however, the current to the auxiliary anode 18 is less than that required to produce such a thin sheath, the current to the anode 5 is cut off. Therefore, the current to the anode is under control of the current to the auxiliary anode 18. By interposing a switch 46, for example, in the circuit of the auxiliary anode 18, under conditions in which the proper value of current is flowing to said anode, opening of the switch 46 will cut off current flow to the load 40 while closing the switch 46 will permit current to flow to said load. Of course the discharge tube being a rectifier will cause rectified current to be delivered to the load 40.

The arrangements which I have described are capable of handling large currents and are capable of withstanding extremely high inverse voltages. Therefore tubes of this nature are particularly effective for a wide variety of uses in which particularly those in which high currents and high voltages are to be handled.

Of course it is to be understood that this invention is not limited to the particular details as described above as many equivalents will sug-

gest themselves to those skilled in the art. For example, other types of cathodes such as a mercury pool with an anchored arc spot could be used, and instead of causing the electron beam from the cathode to be directed by the shape of the cathode, other means such as electrostatic or electromagnetic focusing and directing means might be utilized. Also the arrangement might be incorporated into tubes having a larger number of anodes and discharge paths. Other equivalents will also 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. A gaseous discharge device comprising an envelope containing an ionizable gaseous atmosphere, a conductive electrode having a restricted aperture therethrough, means for maintaining an ionizing discharge in said atmosphere through said restricted aperture, the pressure of said atmosphere being sufficiently low to produce appreciable limitation of current flow through said aperture, means for directing the flow of electrons in said discharge in an axial direction through said aperture to substantially decrease said limitation, and means for maintaining said electrode at a predetermined potential.

2. A gaseous discharge device comprising an envelope containing an ionizable gaseous atmosphere, means for maintaining an ionizing discharge in said atmosphere through a restricted aperture, the pressure of said atmosphere being of the order of one micron of mercury or less, and means for directing the flow of electrons in said discharge in an axial direction through said aperture.

3. A gaseous discharge device comprising an envelope containing an ionizable gaseous atmosphere, means for maintaining an ionizing discharge in said atmosphere through an elongated tubular member having a restricted cross-sectional area, the pressure of said atmosphere being sufficiently low to produce appreciable limitation of current flow through said tubular member, and means for directing the flow of electrons in said discharge in an axial direction through said tubular member to substantially decrease said limitation.

4. A gaseous discharge device comprising an envelope containing an ionizable gaseous atmosphere, means for maintaining an ionizing discharge in said atmosphere through a restricted aperture, the pressure of said atmosphere being sufficiently low to produce appreciable limitation of current flow through said aperture, means for directing the flow of electrons in said discharge in an axial direction through said aperture to substantially decrease said limitation, and means for impressing a field deflecting said electrons transversely of said aperture.

5. A gaseous discharge device comprising an envelope containing an ionizable gaseous atmosphere, means for maintaining an ionizing discharge in said atmosphere through a restricted aperture, the pressure of said atmosphere being sufficiently low to produce appreciable limitation of current flow through said aperture, means for directing the flow of electrons in said discharge in an axial direction through said aperture to substantially decrease said limitation, and means for impressing a magnetic field deflecting said electrons transversely of said aperture.

6. A gaseous discharge device comprising an envelope containing an ionizable gaseous atmosphere, means for maintaining an ionizing discharge in said atmosphere through an elongated tubular member having a restricted cross-sectional area, the pressure of said atmosphere being sufficiently low to produce appreciable limitation of current flow through said tubular member, means for directing the flow of electrons in said discharge in an axial direction through said tubular member to substantially decrease said limitation, and means for impressing a field deflecting said electrons transversely of said tubular member.

7. A gaseous discharge device comprising an envelope containing an ionizable gaseous atmosphere, means for maintaining an ionizing discharge in said atmosphere through an elongated tubular member having a restricted cross-sectional area, the pressure of said atmosphere being sufficiently low to produce appreciable limitation of current flow through said tubular member, means for directing the flow of electrons in said discharge in an axial direction through said tubular member to substantially decrease said limitation, and means for impressing a magnetic field deflecting said electrons transversely of said tubular member.

8. A gaseous discharge device comprising an envelope containing an ionizable gaseous atmosphere, means for maintaining an ionizing discharge in said atmosphere through an elongated tubular metal member having a restricted cross-sectional area, the pressure of said atmosphere being sufficiently low to produce appreciable limitation of current flow through said tubular member, and means for directing the flow of electrons in said discharge in an axial direction through said tubular member to substantially decrease said limitation.

9. A gaseous discharge device comprising an envelope containing an ionizable gaseous atmosphere, means for maintaining an ionizing discharge in said atmosphere through an elongated tubular metal member having a restricted cross-sectional area, the pressure of said atmosphere being sufficiently low to produce appreciable limitation of current flow through said tubular member, means for directing the flow of electrons in said discharge in an axial direction through said tubular member to substantially decrease said limitation, and means for impressing a field deflecting said electrons transversely of said tubular member.

10. A gaseous discharge device comprising an envelope containing an ionizable gaseous atmosphere, means for maintaining an ionizing discharge in said atmosphere through an elongated tubular metal member having a restricted cross-sectional area, the pressure of said atmosphere being sufficiently low to produce appreciable limitation of current flow through said tubular member, means for directing the flow of electrons in said discharge in an axial direction through said tubular member to substantially decrease said limitation, and means for impressing a magnetic field deflecting said electrons transversely of said tubular member.

11. In a gaseous discharge device comprising an envelope containing an ionizable gaseous atmosphere, means for maintaining an ionizing discharge in said atmosphere through a restricted aperture, the pressure of said atmosphere being sufficiently low to produce appreciable limitation of current flow through said aperture, and means for directing the flow of electrons in said

discharge in an axial direction through said aperture to substantially decrease said limitation, the method which comprises maintaining a discharge adjacent said aperture of sufficient intensity to reduce the thickness of the positive ion sheath at said aperture to less than the size of said aperture to permit flow of said first-named discharge.

12. In a gaseous discharge device comprising an envelope containing an ionizable gaseous atmosphere, means for maintaining an ionizing discharge in said atmosphere through a restricted aperture, the pressure of said atmosphere being sufficiently low to produce appreciable limitation of current flow through said aperture, and means for directing the flow of electrons in said discharge in an axial direction through said aperture to substantially decrease said limitation, the method which comprises maintaining a discharge adjacent said aperture of sufficient intensity to reduce the thickness of the positive ion sheath at said aperture to less than the size of said aperture to permit flow of said first-named discharge, and reducing said second-named discharge to a value at which said positive ion sheath is of the same or greater thickness than the size of said aperture to substantially decrease said first-named discharge.

13. In a gaseous discharge device comprising an envelope containing an ionizable gaseous atmosphere, means for maintaining an ionizing discharge in said atmosphere through a restricted aperture, the pressure of said atmosphere being sufficiently low to produce appreciable limitation of current flow through said aperture, and means for directing a flow of electrons in said discharge in an axial direction through said aperture to substantially decrease said limitation, the method which comprises maintaining a discharge adjacent said aperture of sufficient intensity to permit flow of said first-named discharge.

14. In a gaseous discharge device comprising an envelope containing an ionizable gaseous atmosphere, means for maintaining an ionizing discharge in said atmosphere through a restricted aperture, the pressure of said atmosphere being sufficiently low to produce appreciable limitation of current flow through said aperture, and means for directing the flow of electrons in said discharge in an axial direction through said aperture to substantially decrease said limitation, the method which comprises maintaining a discharge adjacent said aperture of sufficient intensity to permit flow of said first-named discharge, and reducing said second-named discharge to a value to substantially decrease said first-named discharge.

15. A gaseous discharge device comprising an envelope containing an ionizable gaseous atmosphere, means for maintaining an ionizing discharge in said atmosphere through a restricted aperture, the pressure of said atmosphere being sufficiently low to produce appreciable limitation of current flow through said aperture, and means for directing the flow of electrons in said discharge in an axial direction through said aperture to substantially decrease said limitation.

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