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CONTROLLABLE SPACE CURRENT ELECTRON DISCHARGE TUBE WITH MAGNETIC FIELD

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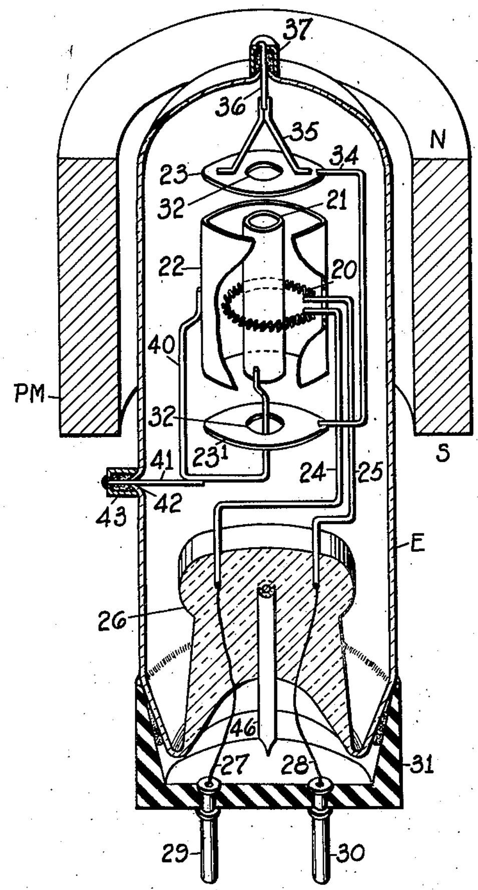

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CONTROLLABLE SPACE CURRENT ELECTRON DISCHARGE TUBE WITH MAGNETIC FIELD

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2 Claims. (Cl. 313—157)

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This invention relates to electronic devices, and more particularly to controllable electron discharge devices suitable for amplifiers, oscillators, and the like.

This application is a division of my prior application, Ser. No. 647,007, filed February 12, 1946, for Electron Discharge Devices, now Pat. No. 2,543,739 dated February 27, 1951.

In the usual type of controllable electron discharge tubes, such as exemplified by the ordinary and well known triode, electrons are attracted to the grid whenever it assumes a positive potential with respect to the cathode; and the resultant grid current imposes limitations upon the efficient and effective use of such tubes in various applications. These and other limitations in the efficiency and use of their usual type of grid controlled electron discharge tube are due primarily to the attraction of electrons to the grid when it assumes positive potential with respect to the cathode; and these limitations can be mitigated and in many respects entirely overcome and the efficiency and utility of such tubes clearly increased, if the flow of electrons to the positive grid can be effectively prevented.

With these considerations in mind, one of the objects of the present invention is to provide a controllable electron discharge device which may be proportioned to have the desirable operating characteristics of the usual grid control triode or similar multiple electrode tube, but which does not have any appreciable electron current to the grid or control electrode, even when this grid or control electrode assumes relatively high positive potentials with respect to the cathode.

A further object of the invention is to attain this desirable objective by a simple and effective structural organization, in which the component parts may be readily proportioned and arranged to obtain any desired rating and operating characteristics.

Various other objects, attributes and characteristic features of the invention will be in part apparent, and in part pointed out, as the nature of the invention and certain specific embodiments are hereinafter described.

Generally speaking, and without attempting to define the nature and scope of the invention, it is proposed to combine a magnetic field with a cathode, anode, and a control electrode in such a way that, although the control electrode may perform its usual function of controlling the electron space current in accordance with variations in its impressed potential, the electrons

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emitted by the cathode and forming the electron or space current are influenced by the magnetic field so as not to reach the control electrode or grid, even though it assumes a relatively high positive potential with respect to the cathode in the operation of the tube.

Considering the general attributes of the invention from another viewpoint, the control element or electrode, instead of being the conventional grid with spaces between its wires for the passage of electrons and located between the cathode and anode in the path of direct movement of electrons from the cathode to the anode, is disposed to one side of the direct or normal path of electrons emitted by the cathode and attracted to the anode, but in such a position that variations in the electrostatic field due to potentials on the control electrode may influence the intensity of the electron current and exercise the same controlling function as the grid of the conventional triode; and this arrangement or disposition of cathode, anode and control electrode is supplemented by a magnetic field acting in a direction and with such intensity as to confine the movement of electrons emitted from the cathode into a beam or stream over a discharge path of the appropriate area which does not touch the control electrode even though it assumes a relatively high positive potential with respect to the cathode.

In the accompanying drawing, the single figure is a general view, partly in section and partly in perspective which illustrates one specific form of a controllable electron discharge tube embodying this invention, and which was illustrated as a modification in my prior application, Ser. No. 647,007, filed February 12, 1946, now Pat. No. 2,543,739, the parts being shown more with a view of facilitating an explanation and understanding of the nature of the invention than for the purpose of illustrating the details of any particular structure that may be advantageously employed in practice.

In the embodiment of the invention illustrated, the cathode is in the form of an interrupted ring **20**, the control electrodes are cylinders **21**, **22**, inside and outside of this cathode, and the anodes are circular plates **23**, **23**[1] disposed at the ends of the cylindrical control electrodes **21** and **22** in planes substantially parallel with the plane of the annular cathode **20**. The cathode **20** may be a directly heated wire of tungsten or other emissive metal, a wire thoriated or oxide coated, or a cathode of the indirectly heated type, the particular form of cathode not being material to the present invention. The cathode shown is assumed to be a nickel core wire spirally wound with a fine nickel wire to aid adherence of the emissive coating and to help in maintaining a uniform temperature. The oxide coating on this cathode is preferably formed and treated in the manner disclosed in the prior patents to D. V. Edwards et al., No. 1,985,855, December 25, 1934, and No. 2,081,864, May 25, 1937.

In the structure illustrated, the cathode **20** is connected to non-emissive supporting rods **24**, **25** bent at their upper ends and extending through an opening in the outer cylindrical control electrode **22**, with a suitable insulating bushing (not shown) if desired; and these supporting rods **24**, **25** are bent and anchored at their lower ends in the reentrant stem **26** of the tube envelope E and connected by leads **27**, **28** to terminal pins **29**, **30** on the usual base **31** in accordance with the usual tube construction.

The circular plates **23**, **23**[1] constituting the anodes are preferably provided with a central hole **32** to facilitate heating of these plates by induction heating during the outgasing process, and are connected by a welded brace **34** and supported by a bifurcated rigid supporting element **35** connected to a rod **36**, which is sealed in the top of the envelope E and connected to a terminal cap **37**, in a manner that can be readily understood from the drawings.

The inner and outer cylinders **21** and **22** constituting the control electrodes are connected and held in their relative position by a bent rigid cross member **40** welded thereto, which in turn is welded to a rigid support **41** extending through a seal **42** in the side wall of the envelope E, and provided with a terminal cap **43**. The connection to the control electrodes is preferably made through the side wall of the envelope E in this manner, instead of through the stem or press **26** of the tube adjacent the cathode leads, in order to permit the use of higher potentials on the control electrodes with respect to the cathode.

The magnetostatic field as shown is provided by a permanent magnet PM of annular form which is magnetized as indicated to provide a field directed along the axis of the tube.

After the tube elements have been mounted in the envelope, which is provided with the usual exhaust tube, as indicated at **46**, the electrodes, supporting elements and envelope are freed of occluded gases by a suitable baking, induction heating and bombardment procedure; and the envelope is thoroughly evacuated of all air and gases, in accordance with recognized practice to provide what is known as a "hard" tube.

Considering now the function and operation of the controllable electron discharge tube of this invention, it is found that a disposition of electrodes, together with a magnetic field, such as illustrated and described, provides a control of the electron or space current to the anodes in accordance with the variations in the potential of the control electrodes with respect to the cathode, and that there is no appreciable movement of electrons to the control electrodes and a resultant electron current, even though the control electrodes assume a relatively high positive potential with respect to the cathode. Theoretical consideration indicates that this action or performance of the device of this invention may be attributed to certain recognized phenomena in connection with the emission and movement of electrons in discharge tubes and in magnetic fields; but it should be understood that the following discussion of a theory of operation is not comprehensive, nor necessarily applicable in all details to the various forms which the tube of this invention may take.

With regard to the controlling effect of the potential on the control electrodes, it may be said that the number of electrons emitted from the cathode and attracted to the anodes in an electron discharge tube is dependent upon the potential gradient to the cathode, and primarily the electrostatic field adjacent the cathode. In the tube of this invention, the electrostatic field of the existing potential on the control electrodes acts to modify this potential gradient provided by the space charge and anode voltage in such a way as to control the electron current actually flowing to the anodes and through the external output circuit. It may be assumed that the control electrodes of the tube of this invention act in this respect much like the grid of the conventional triode, negative potentials tending to reduce and cut off electron current to the anodes, and positive potentials acting to neutralize the effect of the space charge and also supplement the anode potentials tending to draw electrons from the cathode. In this connection, the relative spacing of the elements as well as the voltages involved, are factors in determining the intensity of the anode current and the effectiveness and range of control of the potentials on the control electrodes.

Speaking generally, it is contemplated for ordinary uses of the tube that the cathode will be capable of emitting a surplus of electrons at the maximum anode operating voltage, so that the anode current is limited by space charge effects. Under such conditions, the anode current for a given anode voltage increases with a decrease in anode to cathode spacing; and in general the anode to cathode spacing may be chosen for certain anode voltages to provide the desired anode current.

Considering now the important feature of this invention of utilizing the magnetic field in a way to minimize or eliminate electron current to the control electrodes at positive potentials, it is a familiar phenomena that a magnetic field will influence the path of movement of an electron. More specifically, an electron as a negatively charged particle while moving in a magnetic field is acted upon by a force which is perpendicular to the direction of movement of the electron as of a given instant and also perpendicular to the direction of the magnetic field. This force is dependent upon the strength of the magnetic field, and also upon the component of the instantaneous velocity of the electron which is perpendicular to the direction of the magnetic lines of force. In this respect an electron in motion in a magnetic field may be said to be subjected to forces similar to those acting on a current carrying conductor moving in a magnetic field; and the same quantitative relations apply. While an electric field, such as produced by voltages on electrodes in the tube, exerts a force on an electron whether at rest or in motion, and in the direction of the field, a magnetic field exerts force on an electron only when it is in motion, and in a direction at right angles to the direction of such magnetic field. Consequently, a magnetic field does not accelerate or retard the motion of an electron under the influence of an electric field, but merely changes its direction of movement.

In the embodiment of the invention illustrated, the magnet PM acts axially of the cylindrical control electrodes 21, 22; and it can be seen that electrons leaving the surface of the cathode 20 and moving either up or down toward the anode plates 23, 23^1 are not affected by the magnetic field and move in straight lines toward such anode under the influence of the electric field of the anode voltage. In the case of electrons leaving the surface of the cathode with a component of velocity at right angles to the magnetic lines of force, however, such electrons will be deflected by the magnetic field in accordance with well known principles; and since these electrons are subject to the influence of the electric field as well as the magnetic field, they will move in what may be called a spiral path toward one of the anodes. In other words, it may be said that the magnetic field acts to converge or focus the electrons leaving the cathode into a beam or stream directed toward each of the anodes.

Since the tube of this invention involves the influence of a magnetic field upon the electrons moving from the cathode to the anode, it is desirable to avoid any weakening or distortion of this magnetic field by employing nonmagnetic metals for the electrodes and many of the supporting elements. For ordinary purposes it is considered preferable to employ tantalum for the electrodes, on account of the facility with which this metal gives up occluded gases and its tendency to absorb gases given off during operation. Molybdenum, or other nonmagnetic metals of similar characteristics, are preferably employed for the mounting and supporting elements of the tube, except at the glass seals, rather than nickel, commonly employed for such purpose, in order that the magnetic qualities of nickel may not adversely affect the magnetic flux distribution.

Various adaptations, modifications, and additions may be made to the specific embodiments of the invention illustrated and described without departing from its underlying principles, functions, and mode of operation; and I desire to have it understood that the invention is not limited to the specific structural organizations illustrated or described, but may take a wide variety of other forms.

What I claim is:

1. An electron discharge tube comprising, a circular filamentary thermionic emissive cathode, concentric cylindrical control electrodes disposed inside and outside of said cathode with their axes substantially at right angles to the plane of said cathode, anode plates disposed on opposite sides of said cathode beyond the ends of said control electrode in planes substantially parallel with the plane of said cathode, and a magnet providing magnetic lines of force directed along the axes of said control electrodes and acting to prevent electron current to said control electrodes for relatively high positive potentials thereon.

2. A controllable electron discharge tube comprising, a heated thermionic emissive cathode in the form of a filament bent into a circle complete except for a small separation at its ends to permit heating current to be conducted through the filament, a cylindrical control electrode concentric with said cathode on an axis substantially at right angles to the plane of the cathode, said control electrode extending substantially the same distance in opposite directions from the plane of the cathode, an anode having surfaces on opposite sides of the plane of the cathode beyond the ends of the control electrode in planes substantially parallel with the plane of the cathode, and a permanent magnet providing a magnetic field directed along the axis of said control electrode.

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