May 29, 1956 J. S. HICKEY, JR 2,748,307

MAGNETICALLY FOCUSED ELECTRON DISCHARGE DEVICE

Filed March 6, 1952

Fig. 1.

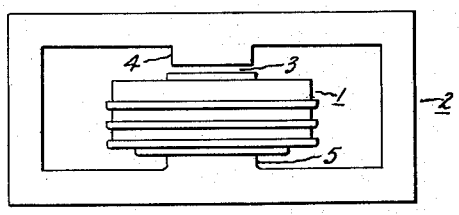


Fig. 2.

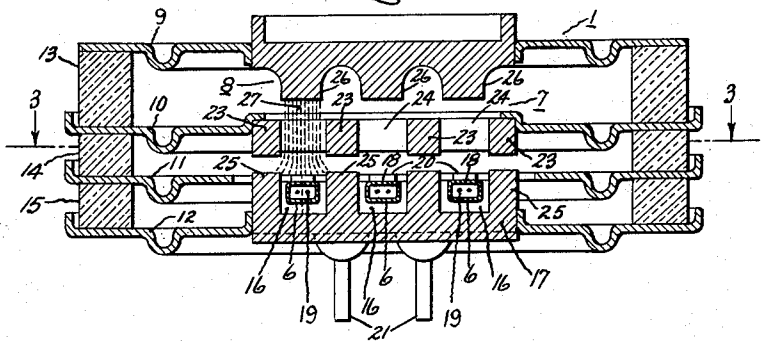
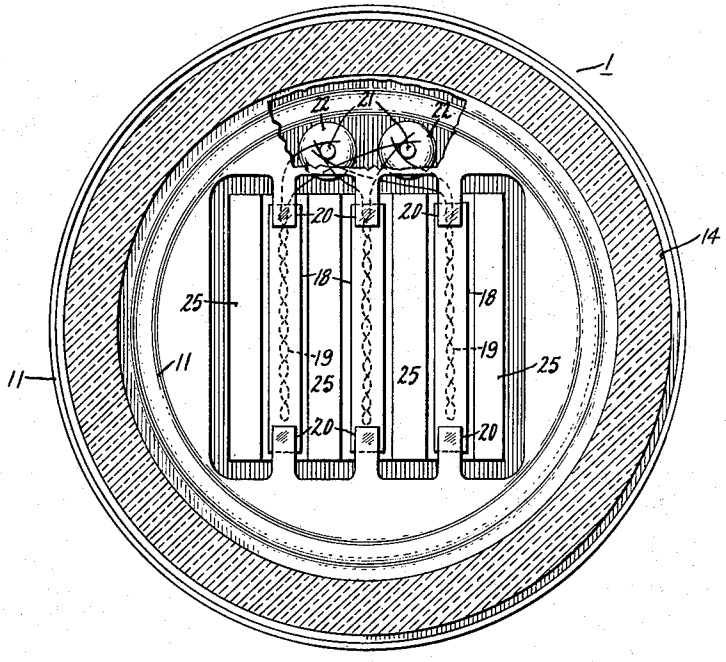


Fig. 3.



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MAGNETICALLY FOCUSED ELECTRON DISCHARGE DEVICE

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5 Claims. (Cl. 313—155)

This invention relates generally to electron discharge devices and, in particular, to electron discharge devices wherein a magnetic field is employed to focus the discharge current.

A limiting factor in the application of controllable electron discharge tubes resides in the presence of control electrode current. Control electrode current may appear whenever the control electrode assumes a positive potential with respect to the cathode thereby resulting in the collection of electrons by the control electrode. Control electrode current not only tends to overheat the electrode but also deleteriously loads the input circuit connected thereto. Moreover, high values of control electrode current represent such a substantial portion of the electron discharge current that the resulting power loss frequently causes a circuit utilizing an electron discharge tube to become practically inoperative or prohibitively inefficient. These and other restrictions upon the employment of controllable electron discharge tubes are primarily the result of the attraction of electrons to the control electrode when it assumes a positive potential with respect to the cathode.

To overcome the collection of electrons by the control electrode in an electron discharge device, it has been proposed heretofore that the electrons emanating from the cathode be focused to follow defined paths which traverse the interstices of the control electrode. Such focusing has been attempted by the employment of magnetic fields generally aligned with the direction of flow of the electron current. With such an arrangement, the electrons having a velocity component normal to the magnetic flux lines are forced into helical paths following the magnetic flux lines and thus are prevented from dispersing and striking the surface of the control electrode. However, these magnetic focusing means, while theoretically attractive, have not yet found favor as a commercially acceptable solution to the problem of efficiently controlling large electron space currents in discharge devices. The chief difficulty experienced in this connection has been that of obtaining a properly shaped magnetic field which is effective to produce substantial focusing of the electrons emanating from the cathode.

It is, accordingly, a general object of the present invention to provide an improved, high current, controllable electron discharge device.

Another object of my invention is to provide an improved means of magnetically focusing the discharge current of a controllable electron discharge tube to minimize collection of electrons by the control electrode.

In accordance with the invention, which may be conveniently described as incorporated in a high vacuum triode but which should be understood as being equally applicable to discharge devices having a plurality of grids, a static magnetic field is arranged to traverse the space between the cathode and anode through an aperture in the control electrode such that the magnetic lines of force or flux lines are substantially parallel to the desired direction of electron flow. The cathode, which

is a relatively long electron-emissive member, is positioned in a groove or slot in the face of one of the pole pieces of the magnetic circuit providing the flux. The lines of flux emanating from opposite sides of the groove or slot in the pole piece tend to converge whereby substantially all the electrons leaving the cathode are very effectively focused into a relatively narrow beam which passes through the aperture in the control electrode. This focusing is especially effective since the electron velocities near the cathode are very low.

My invention will be better understood from the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

In the drawing, Fig. 1 is a simplified view which illustrates the invention in general fashion; Fig. 2 is a section view of the electron discharge tube of Fig. 1; and Fig. 3 is a view taken along lines 3—3 of Fig. 2.

Referring now to the figures of the drawing, there is shown according to the invention a magnetically focused electron discharge device which comprises a controllable electron discharge tube **1** and a magnetic circuit **2**. Magnetic circuit **2** may be formed of a permanently magnetized, high coercive force material, such as an iron-nickel-cobalt alloy, to produce a static magnetic field extending axially of the electron discharge tube **1**. To facilitate the production of the desired axially extending magnetic field, electron discharge tube **1** is positioned within the gap **3** between pole pieces **4** and **5** of magnetic circuit **2**. As will be understood, magnetic circuit **2** need not be composed entirely of a high coercive force material but may conveniently include portions of a low reluctance material such as soft iron. Moreover, magnetic circuit **2** may, if desired, be constructed entirely of soft iron and the required magnetic flux produced therein by means of a direct current carrying winding, not shown, positioned about a portion thereof.

Electron discharge tube **1** is represented as a triode vacuum tube of the planar electrode type having cathodes **6**, a control electrode **7** and an anode **8**. Support for the various electrodes of electron discharge tube **1** is provided by a plurality of convoluted washers **9**, **10**, **11** and **12** which are disk-sealed as shown to concentric cylinders **13**, **14** and **15** of a material such as glass or ceramic. Cathodes **6** are elongated and are positioned within slots or grooves **16** in a pole piece **17** which is supported by disk or washer **12**. Cathodes **6** are preferably of the indirectly heated type and include elongated metallic cylinders **18** within which conductive heater wires **19** are insulatingly inserted. Cylinders **18** have their upper surfaces coated with a layer of thermionically emissive material and are attached by any convenient means such as spot welding to inwardly extending flanges **20** of disk or washer **11**. Power may be supplied to heater wires **19** through a pair of conductive leads **21** which are insulatingly introduced into discharge tube **1** through hermetic seals **22** of glass or ceramic material sealed into disk or washer **12**.

Control electrode or grid **7** is formed of a plurality of elongated, spaced-apart, conductive, non-magnetic members **23** suitably attached to the inner periphery of disk or washer **10** to provide apertures **24** which are aligned with grooves **16** in pole piece **17** and substantially coextensive in cross-sectional area therewith. To provide thusly apertures **24**, elongated members **23** are aligned with bosses or projections **25** of pole piece **17**. Anode **8**, a portion or all of which may serve as a pole piece, is fluted as illustrated to provide bosses or projections **26** which are aligned with apertures **24** and grooves **16** and which are substantially coextensive in cross-section with the cross-sections of apertures **24**.

The novel operation and advantages of the invention

can be more readily understood by reference to the magnetic flux lines 27 which are shown in Fig. 2. For the sake of simplicity of the drawing, flux lines have been represented only with respect to one of the slots 16; however, it will be understood that similar representations may be made with respect to the remainder of the slots 16. As illustrated by the flux plot, magnetic flux lines 27 extend between pole piece 17 and anode 8, passing through apertures 24. The significant aspect of the magnetic field configuration is that the flux lines, fringing out from the grooves 16 and the adjacent bosses 25 toward anode 8, are not perpendicular to the face of pole piece 17 in the vicinity of grooves 16 within which cathodes 6 are supported. Instead, the fringing flux lines on both sides of each groove 16 converge to provide a uniform flux density a short distance away from the pole face of pole piece 17. The nature of such a configuration is well known and it may be viewed simply as a characteristic of a magnetic field to align itself to provide a substantially uniform field. The important effect of the convergent fringing flux lines is that the electrons emitted from cathodes 6 with a velocity other than in a direction perpendicular to the bases of slots 16 encounter a force due to the magnetic field in which they are traveling. Such force, as is well known, is perpendicular to both the direction of the magnetic flux lines and the velocity components of the electrons perpendicular thereto, whereby the electrons possess helical trajectories as they progress along the flux lines to the anode. It is to be understood, of course, that the control electrode 7 or the anode 8 or both are maintained at positive potentials during the operation of electron discharge tube 1 to provide a relatively strong electrostatic field which accelerates electrons emanating from cathodes 6 toward anode 8. Thus, even those electrons whose initial velocities tend to carry them beyond the confines of grooves 16 and toward one of the non-magnetic members 23 of control electrode 7 are forced to follow the converging lines of flux and pass through apertures 24. Consequently, with a dispersive electron source which emits electrons having initial velocities of many directions, the electrons are compressed by the converging flux lines into a relatively narrow beam which passes through apertures 24 without striking any of the conductive members 23. Since the flux lines, after they have converged to form a substantially uniform field, remain essentially parallel until reaching bosses 26 of anode 8, the electrons are assured of following desired paths through apertures 24. The flux lines extending from bosses 25 of pole piece 17 and passing through non-magnetic members 23 have substantially no effect upon the electrons emanating from cathode 6 because the more proximate converging fringing flux constrains the electrons to follow in the direction of its lines.

It will now be seen that the present invention provides an efficient and useful means for the control of high currents without the collection of grid current. To increase the available electron current in the discharge tube 1 multiple cathodes 6 are provided; however, it will be understood that a single cathode along with appropriate modification of the remainder of the structure may be employed with efficacy if desired. High current densities are readily established by providing a relatively very large potential gradient between the cathode and control electrode, it being possible according to the invention to apply a large positive voltage to the grid without drawing control electrode current since substantially all of the electrons emitted by the cathode are focused by the magnetic field through apertures 24. The diameters of the helical paths of the emitted electrons may be controlled by the respective magnetic and electrostatic field intensities so that the pitch is large in proportion to the diameter. For example, in a device constructed in accordance with the principles of the invention and having a one-half centimeter spacing between the cathode and control electrode, a magnetic field having a flux density of the order of 1000 gauss and a 500 volt positive control electrode potential may be employed, whereby the total rotation of the electrons in their travel from the cathode through the corresponding aperture 24 is less than one radian. With such circuit parameters, the paths of the electrons, while actually being helical about the flux lines, may be considered as substantially following the flux lines with the circular orbit being relatively negligible.

It has been found that most effective operation of the apparatus of the invention is obtained by positioning the uppermost portion of the cathode emitting surface slightly below or coplanar with the surfaces of bosses 25. The cathodes may be positioned down further within grooves 16 but, in such event, the capacitance between control electrode 7 and pole piece 17 is likely to be increased to an objectionable value. As shown, pole piece 17 is insulated from cathodes 6, thereby permitting the operation of cathodes 6 at a slightly positive potential with respect to pole piece 17 in order that emitted electrons will be repelled from the surfaces of pole piece 17. If desired, cathodes 6 and pole piece 17 need not be insulated from one another and may be operated at the same potential. Both anode 8 and pole piece 17 may be of a high coercive force, permanently magnetized material and, in such circumstance, magnetic circuit 2 may be composed entirely of soft iron or may be eliminated. Anode 8 may also be composed of soft iron or highly permeable magnetic material even though pole piece 17 is composed of a permanently magnetized material. There need be no magnetic pole in the vicinity of anode 8 because, for tubes having very close interelectrode spacings, the ultimate divergence of the flux lines becomes of decreasingly less concern with distance from the pole face of pole piece 17.

While this invention has been described by reference to a particular embodiment thereof, alternative constructions will readily occur to those skilled in the art. I, therefore, aim in the appended claims to cover all such alternative embodiments as may be within the true spirit and scope of the foregoing description.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. An electron discharge device comprising a first magnetic pole piece having therein a groove from which a convergent fringing flux extends in a direction generally perpendicular to the base of said groove, a control electrode spaced from said first magnetic pole piece, said control electrode including a pair of elongated non-magnetic conductive members having longitudinal axes substantially parallel to the surface of said first magnetic pole piece into which said groove extends and being transversely spaced apart to provide an aperture aligned with said groove, an anode spaced from said control electrode including a second magnetic pole piece having a boss opposed to the aperture between said elongated conductive members and having a cross section substantially coextensive with the cross section of the aperture between said elongated conductive members whereby said convergent fringing flux extends between said first and second magnetic pole pieces through the aperture in said control electrode, and an elongated cathode disposed in said groove for producing electrons which are constrained to follow said convergent fringing flux through the aperture in said control electrode without striking the conductive members thereof.

2. An electron discharge device as defined by claim 1, in which said first magnetic pole piece is composed of permanently magnetized material.

3. An electron discharge device as defined by claim 1 in which both said first and second magnetic pole pieces are composed of permanently magnetized material.

4. An electron discharge device as defined by claim 1,

in which said groove and the aperture between said elongated conductive members are substantially coextensive in cross section.

5. An electron discharge device as defined by claim 1, including an evacuable envelope enclosing said anode, control electrode, cathode and first pole piece, and magnetic flux generating means located exteriorly of said envelope and coupled magnetically with said pole pieces for providing a desired magnetic flux in said pole pieces.

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