

April 12, 1938.

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2,114,035

ELECTRON DISCHARGE APPARATUS

Filed July 21, 1936

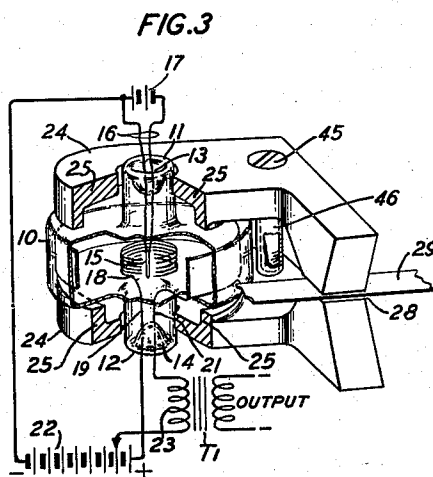
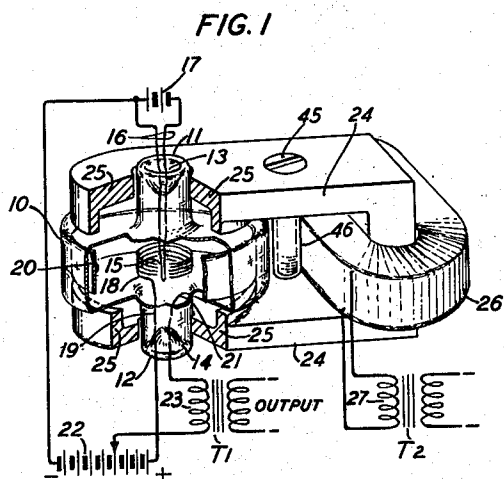
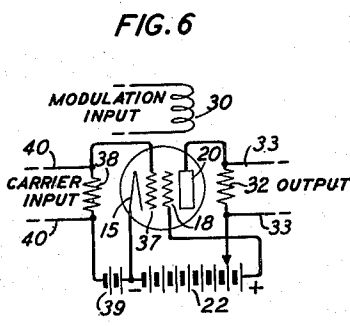
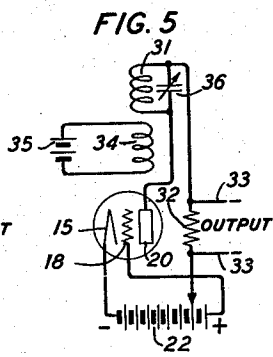
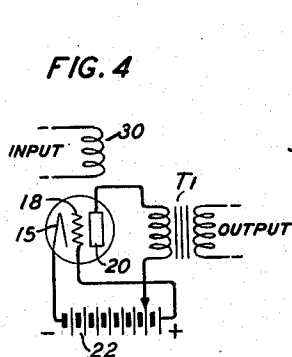
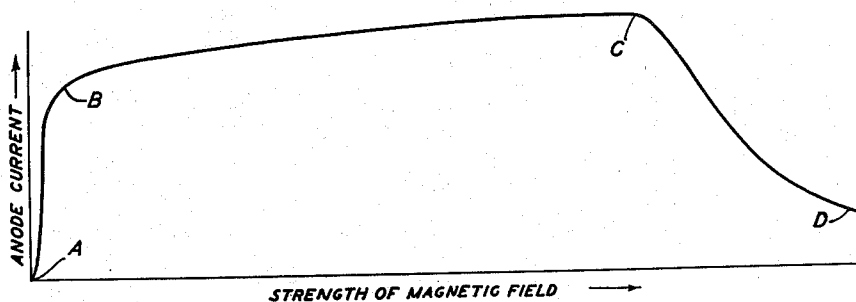


FIG. 2



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2,114,035

ELECTRON DISCHARGE APPARATUS

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Application July 21, 1936, Serial No. 91,652

13 Claims. (Cl. 250-27)

This invention relates to electron discharge apparatus and more particularly to such apparatus including an electron discharge device and wherein the space current of the device is controlled by a magnetic field.

As is known in the art, the flow of electrons between electrodes, for example between an incandescent cathode and an anode, of an electron discharge device may be controlled by magnetic fields which, for example may alter the paths traversed by the electrons or be of sufficient intensity to prevent electrons emanating from the cathode, from reaching the anode. Because of the high potential differences between the electrodes employed in general at the present time, magnetic control of the space current heretofore has necessitated the utilization of very intense magnetic fields and hence required the employment of expensive magnetic structures. Furthermore, because of the great energy of electrons emanating from a cathode under the influence of the high potential upon the anode, the sensitivity of the magnetic control of the space current has not been as great as is desired.

One object of this invention is to enable highly sensitive magnetic control of the space current in electron discharge devices.

Another object of this invention is to enable the control of large space currents in high voltage electron discharge devices by a relatively weak magnetic field.

A further object of this invention is to reduce the cost and to increase the efficiency of electron discharge apparatus including electron discharge devices wherein the space current is controlled by magnetic fields.

In one illustrative embodiment of this invention, electron discharge apparatus comprises an electron discharge device including an incandescent cathode, an anode and a third or grid electrode disposed between the cathode and anode, the surface of the anode directed toward the cathode preferably having a coating of a material, such as barium or caesium oxide, which is an efficient emitter of secondary electrons. The anode is maintained at a high positive potential with respect to the cathode and the third electrode or grid likewise is maintained at a high positive potential, greater than the anode potential, with respect to the cathode.

In the operation of the apparatus, because of the high potentials upon the anode and the grid, a large primary electron current will flow from the cathode to the anode. The electrons constituting this current will impinge upon the anode

at high velocities and, therefore, secondary electrons will be released from the anode. The greater portion of these secondary electrons will be attracted to the third electrode or grid because of the potential difference between this electrode and the anode. The current which will flow in an output or utilization circuit connected between the cathode and anode will be determined by the algebraic sum of the primary electrons reaching the anode from the cathode and the secondary electrons flowing from the anode to the third electrode or grid.

In accordance with one feature of this invention, the potentials upon the anode and the third electrode or grid are so adjusted that the resultant anode current is substantially zero or of a small fixed value and the anode current is then varied by a magnetic field of an intensity sufficient to affect appreciably only the secondary electrons released from the anode. More specifically, the potentials upon the anode and the third electrode or grid are so adjusted that for each primary electron reaching the anode from the cathode a secondary electron from the anode flows to the third electrode or grid. A variable magnetic field is then produced adjacent and substantially parallel to the surface of the anode directed toward the cathode. This field affects only the secondary electrons and alters the orbits thereof so that a portion of these electrons returns to the anode instead of flowing to the third electrode or grid. Consequently, the equilibrium between the primary and secondary electron currents is disturbed and a current will obtain in an output or utilization circuit connected to the cathode and the anode.

Inasmuch as the secondary electrons leave the anode with energies of but a fraction of a volt, only a weak magnetic field is necessary to affect them and cause their return to the anode. Hence, it will be apparent that such a weak field may be utilized to control a very large space current to the anode, that is, a current composed of primary electrons.

The invention and the various features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing in which:

Fig. 1 is a view partly in perspective and partly diagrammatic of electron discharge apparatus illustrative of one embodiment of this invention, portions of the apparatus being broken away to show the electron discharge device and the electrodes thereof more clearly;

Fig. 2 is a graph illustrating the relationship

between the output or anode current and the magnetic field in electron discharge apparatus constructed in accordance with this invention;

Fig. 3 is a view illustrative of another embodiment of this invention wherein the output current of an electron discharge device is varied in accordance with recordings on a magnetic tape;

Figs. 4 and 5 are schematic views of an amplifier and an oscillator, respectively, embodying this invention; and

Fig. 6 is another schematic view illustrating the utilization of this invention in a modulator.

Referring now to the drawing, the apparatus shown in Fig. 1 comprises an enclosing vessel having a cylindrical body or central portion 10 and reduced end portions 11 and 12 provided with inwardly extending stems 13 and 14 respectively. Disposed within the enclosing vessel, and preferably coaxial therewith, is an incandescent cathode 15, which may be of any of the types known in the art. In the specific form shown in Fig. 1, the cathode is a U-shaped filament supported from the stem 13 by leading-in conductors 16 through which the cathode heating current from a source, such as a battery 17, is supplied.

The cathode 15 is encompassed by a cylindrical grid 18, preferably coaxial with the cathode, which is provided with a leading-in conductor 19 sealed in the stem 14. The grid 18 in turn is encompassed by a cylindrical anode 20, preferably coaxial therewith, having a leading-in conductor 21 also sealed in the stem 14. Preferably the inner surface of the anode 20 is coated with a material which is an efficient emitter of secondary electrons. For example, this surface may be coated with a monatomic layer of barium or a layer of caesium oxide.

The leading-in conductors 19 and 21 for the grid 18 and anode 20, respectively, are connected to suitable positive terminals of a source, such as a battery 22, the negative terminal of which is connected to the cathode 15, the potential applied to the grid 18 being greater than that applied to the anode 20. The primary winding 23 of an output transformer T_1 may be connected between the battery 22 and the anode 20 as shown.

The electron discharge device may be mounted between the arms 24 of a magnetic yoke, the arms being provided with suitable apertures for receiving the end portions 11 and 12 of the enclosing vessel of the device. The magnetic yoke may be composed of separable halves, held together as by a screw 45 passing through a sleeve 46, to allow positioning of the electron discharge device with respect thereto. Preferably the opposed faces of the arms 24 are provided with annular protuberances 25 of substantially the same diameter as the anode 20 whereby concentrated magnetic fields are produced adjacent the inner surface of the anode and substantially parallel thereto.

A portion of the magnetic yoke is encompassed by a field coil 26 through the agency of which the intensity of the magnetic fields extant adjacent the anode may be varied. For example, the field coil 26 may be energized from a circuit including the secondary winding 27 of an input transformer T_2 .

With suitable potentials upon the anode 20 and grid 18, for example, potentials of several hundred volts, and the field coil 26 deenergized, electrons emanating from the cathode 15 will travel toward the grid and anode at high velocities. Because of these velocities and the open-work character of the grid, a large proportion of these pri-

mary electrons will reach and impinge upon the anode 20. These primary electrons upon striking the anode cause the release of secondary electrons from the anode, some of which will flow to the grid 18, because of its higher positive potential, and others of which will return to the anode 20. The net anode current, then, and hence the current flowing in the primary winding 23 of the output transformer T_1 will be the algebraic sum of the current due to the primary electrons reaching the anode and the reverse current due to those secondary electrons which flow from the anode to the grid. The magnitude of this net or resultant current will be dependent, of course, upon the difference of potential existing between the anode and the grid.

If the potentials upon the grid 18 and the anode 20 are properly adjusted, a state of equilibrium will be established between the primary and secondary electron currents so that the resultant current is substantially zero. That is to say, the anode and grid potentials may be so adjusted that for each primary electron reaching the anode from the cathode, one electron will be released from the anode and flow to the grid. This state of equilibrium may be disturbed by energizing the field coil 26 so that a magnetic field is established adjacent the inner surface of the anode 20 and parallel thereto. This field, which should be of such intensity that it does not affect appreciably the primary electron streams, will alter the orbits of a portion or all of the secondary electrons so that they will return to the anode and not pass to the grid. Hence, an increase in the anode current results, the magnitude of this increase being dependent upon the intensity of the magnetic field produced. By varying the intensity of this field, as by energizing the coil 26 by a variable current, corresponding variations in the output circuit will be obtained.

The relationship between the output current, which it may be noted is composed entirely of primary electrons, and the strength or intensity of the magnetic field is illustrated graphically in Fig. 2. As indicated in this figure, when the magnetic field is zero and the state of equilibrium between primary and secondary electrons heretofore mentioned obtains, the anode current is zero. When the magnetic field is produced, the anode current rises or increases rapidly as indicated by the portion AB of the curve. A further increase in the magnetic field produces but a slight and gradual increase in the anode current as indicated by the portion BC of the curve. If the magnetic field is increased still further, it becomes of sufficient intensity to affect the primary electrons and to prevent a portion of these electrons from reaching the anode, so that the anode current decreases as indicated by the portion CD of the curve.

It is desirable, of course, that during operation of the electron discharge apparatus, the variations in the energizing current for the field coil 26 correspond to the variations in the field intensity in turn corresponding to the portion AB of the curve in Fig. 2. Under such conditions, it will be apparent that relatively large changes in the anode current may be produced by comparatively small variations in the field intensity. Hence, the electron discharge apparatus constructed in accordance with this invention is highly sensitive and may be used advantageously for the translation of weak impulses.

It will be appreciated also that the invention enables the facile and economic control by elec-

tromagnetic means of relatively large currents; that is to say, high potentials may be utilized upon the anode 20 and grid 18 so that a large space current will flow and the cathode 15 may be operated at or near its saturation point. The secondary electrons emanating from the anode are released with energies of only a fraction of a volt so that they are readily susceptible to control by weak magnetic fields.

The foregoing feature may be utilized particularly advantageously in magnetic tape recorders, as illustrated for example in Fig. 3. As shown in this figure, the magnetic yoke is provided with an elongated opening or slot 28 through which a magnetic tape 29 may be passed. As the tape 29 is drawn through the opening or slot 28, the reluctance of the magnetic circuit is varied in accordance with variations in the thickness of the tape or variations in the magnetization thereof and, hence, corresponding variations in the anode or output current result.

The variations in the magnetic field may be produced directly by a coil encompassing the electron discharge device or disposed in proximity to the anode thereof. For example, in an amplifier such as illustrated in Fig. 4, a coil 30 connected to an input circuit may be disposed in proximity to the anode 20 to produce a variable magnetic field adjacent and substantially parallel to the inner surface of the anode 20. Current variations corresponding to variations in the input current to the coil 30 will thus be produced in the output transformer T₁.

The invention may be utilized also in an oscillator, such as illustrated, for example, in Fig. 5. As shown in this figure, an oscillating coil 31 is connected between the grid 18 and anode 20 and in series with a resistance 32 across which conductors 33 leading to an output or utilization circuit are connected. The coil 31 may encompass the enclosing vessel of the device or may be disposed substantially in alignment with the anode 20. In shunt with the coil 31 is a variable condenser 36 which may be adjusted to cause the generation of oscillations of a desired frequency.

The points upon the portion AB of the anode current-magnetic field characteristic at which the electron discharge device is to be operated may be determined by an auxiliary or biasing coil 34 disposed adjacent the oscillating coil 31 and energized by a constant current from a source such as a battery 35, or may be determined by utilizing a yoke similar to that shown in Figs. 1 and 2 and permanently magnetized to produce a constant magnetic field of the requisite intensity. Preferably the coils 31 and 34 are so wound and disposed that the magnetic fields produced thereby are in opposition.

The auxiliary or biasing magnetic field may be produced alternately by the anode 20 and the use of the auxiliary coil 34 thereby obviated. For example, the anode may be of a suitable iron-nickel-aluminum alloy and permanently magnetized to produce a permanent magnetic field adjacent and substantially parallel to the surface of the anode directed toward the cathode 15.

The invention may be utilized also in modulating apparatus as illustrated, for example, in Fig. 6, wherein there is shown an electron discharge device including in addition to the cathode 15, anode 20 and grid 18, a second grid 37 disposed between the cathode 15 and grid 18. The grid 37 may be biased negatively with respect to the cathode 15, as by a battery 39, through a connection including a series resistance 38 to the ends of

which conductors 40 are connected. A suitable current, for example of carrier frequency, may be supplied through the conductors 40, in accordance with which the grid 37 varies the primary electron anode current. A second current of modulating frequency is supplied to the coil 30 whereby corresponding variations in the anode current are produced by affecting the secondary electron current from the anode. The portion of the anode current-magnetic field characteristic upon which the device is to be operated may be determined, as heretofore described, by an auxiliary magnetic field produced by either an auxiliary coil, by the anode 20, or by a permanently magnetized yoke.

Although specific embodiments of the invention have been shown and described, it will be understood, of course, that these embodiments are but illustrative of the invention and that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims. For example, it may be desirable in some instances to utilize a permanently magnetized anode in the embodiments of the invention illustrated in Figs. 1, 3 and 4 as well as in those shown in Figs. 5 and 6.

What is claimed is:

1. The method of controlling space current in an electron discharge device having a cathode, an anode capable of emitting secondary electrons and a grid between the cathode and anode, which comprises applying such positive potentials to said anode and grid that the secondary electrons leaving said anode are substantially equal to the primary electrons flowing to said anode from said cathode, and producing a variable magnetic field adjacent said anode to disturb the equilibrium between said primary and secondary electrons, said field being of sufficient intensity to affect only said secondary electrons.

2. The method of controlling space current in an electron discharge device having a cathode, an anode adapted to emit secondary electrons and a grid between the cathode and anode, which comprises applying positive potentials to said anode and grid such that the primary electron current to said anode from said cathode and the secondary electron current from said anode to said grid are substantially equal, producing a constant magnetic field adjacent said anode to decrease said secondary electron current, and producing a variable magnetic field adjacent said anode to vary said secondary electron current.

3. The method of controlling the output current of an electron discharge device including a cathode, an anode and a grid, which comprises applying such positive potentials to the grid and anode that a primary electron current flows to said anode from said cathode and a secondary electron current flows to said grid from said anode, varying said primary current periodically to produce corresponding variations in the output current of said device, and simultaneously producing a variable magnetic field adjacent said anode of sufficient intensity to affect only said secondary electron current.

4. Electron discharge apparatus comprising a cathode, a cylindrical grid encompassing said cathode, a cylindrical anode encompassing said grid, the surface of said anode directed toward said grid being adapted to emit secondary electrons, means applying positive potentials to said anode and said grid with reference to said cathode, the potential on said grid being greater than that upon said anode and said potentials being

- such that the secondary electrons released from said surface and flowing to said grid are substantially equal to the primary electrons flowing to said anode from said cathode, and means for
- 5 producing a variable magnetic field adjacent and substantially parallel to said surface, said field being of sufficient intensity to affect only said secondary electrons.
5. Electron discharge apparatus comprising a
- 10 cathode, a grid surrounding said cathode, an anode surrounding said grid and having its inner surface coated with an electron emissive material, means maintaining said grid and anode at a positive potential with respect to said cathode
- 15 such that the secondary electrons flowing from said anode to said grid are substantially equal to the primary electrons flowing to said anode from said cathode, and means for producing a variable magnetic field immediately adjacent said
- 20 surface and substantially parallel thereto.
6. Electron discharge apparatus comprising an enclosing vessel housing a cathode, an anode, and a grid, means maintaining said grid and anode at positive potentials with respect to said
- 25 cathode, said potentials being such that the primary electron current to said anode and the secondary electron current from said anode are substantially in equilibrium, a magnetic member having arms overlying opposite edges of said
- 30 anode, and means for varying the magnetic field produced by said magnetic member.
7. Electron discharge apparatus comprising an enclosing vessel housing a cathode, a cylindrical anode encompassing said cathode and a cylindrical
- 35 grid between said cathode and said anode, the inner surface of said anode being adapted to emit secondary electrons, means for applying such positive potentials to said grid and said anode that the secondary electrons leaving said
- 40 anode and the primary electrons reaching said anode are substantially equal, means producing a concentrated magnetic field adjacent and substantially parallel to said surface including a magnetic yoke having arms overlying opposite
- 45 ends of said anode, and means for varying the intensity of said field, said fields being of sufficient intensity to affect appreciably only the secondary electrons emanating from said surface.
8. Electron discharge apparatus comprising a
- 50 cathode, an anode, a grid between said anode and cathode, and means for applying a positive potential to said anode with respect to said cathode and a higher positive potential to said grid, said anode being magnetized to produce a magnetic
- 55 field substantially parallel to the surface thereof toward said cathode.
9. Electron discharge apparatus comprising a cathode, an anode, and a grid between said cathode and said anode, the inner surface of said anode being capable of emitting secondary electrons and said anode being magnetized to produce
- 5 a magnetic field adjacent and substantially parallel to said surface, means applying a positive potential to said anode with respect to said cathode and for applying a higher positive potential to said grid, and means for producing a variable
- 10 magnetic field adjacent and substantially parallel to said surface.
10. Electron discharge apparatus comprising a cathode, an anode, a grid, means maintaining said grid and anode at such positive potentials with
- 15 respect to said cathode that the primary electron current to said anode is substantially equal to the secondary electron current from said anode, a coil for producing a substantially constant magnetic field adjacent said anode, and an oscillating
- 20 coil connected in circuit with said anode and said grid for producing a variable magnetic field adjacent said anode.
11. Electron discharge apparatus in accordance with claim 10 wherein said coils are so related
- 25 that the magnetic fields produced thereby are in opposition.
12. Electron discharge apparatus comprising a cathode, a grid, an anode, means for applying positive potentials to said grid and anode with
- 30 respect to said cathode whereby primary electrons flow to said anode from said cathode and secondary electrons flow from said anode to said grid, means for varying the primary electron current flowing to said anode, and means for producing a variable magnetic field adjacent said
- 35 anode to vary the secondary electron current flowing from said anode to said grid.
13. Electron discharge apparatus comprising a cathode, an anode, a grid between said cathode
- 40 and said anode, a second grid between said cathode and said first grid, means for applying positive potentials to said anode and said first grid whereby a primary electron current flows from
- 45 said cathode to said anode and a secondary electron current flows from said anode to said first grid, means for applying a variable potential between said cathode and said second grid to vary said primary current, and means for producing
- 50 a variable magnetic field adjacent said anode, said field being of an intensity sufficient to materially affect only said secondary electron current.