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ELECTRON DISCHARGE APPARATUS

Filed Sept. 27, 1939

FIG. 1

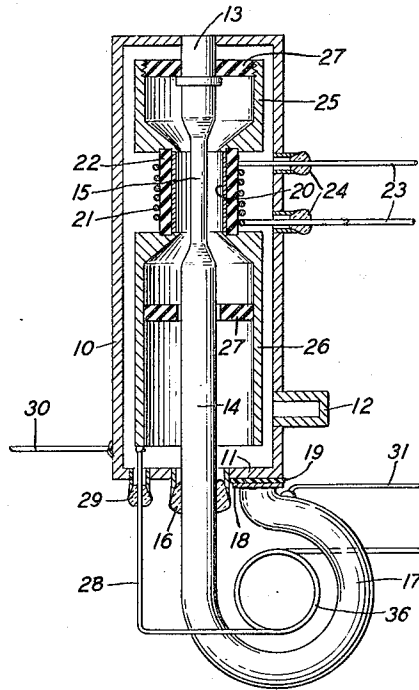


FIG. 2

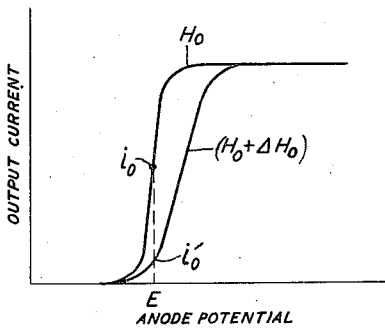


FIG. 3

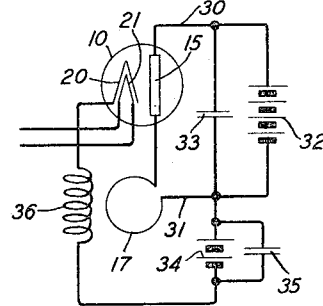
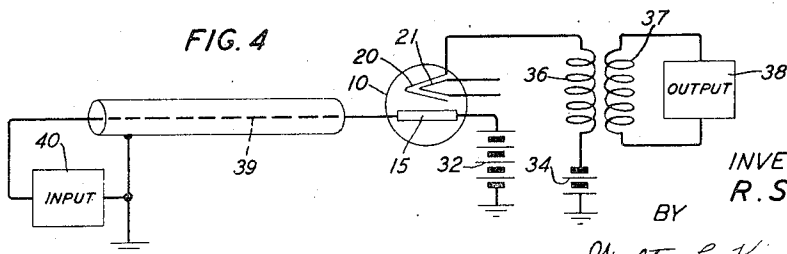


FIG. 4



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ELECTRON DISCHARGE APPARATUS

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5 Claims. (CL 250-27)

This invention relates to electron discharge apparatus and more particularly to electronic amplifiers and oscillators of the type wherein a magnetic field is utilized to control the space current.

One object of this invention is to improve the efficiency and operating characteristics of magnetically controlled electronic amplifiers and oscillators. More specifically, one object of this invention is to obtain a sharp cut-off characteristic in magnetically controlled electronic devices whereby a high degree of amplification is attained.

Another object of this invention is to simplify the structure of electronic oscillators and amplifiers and to reduce the number of elements therein requisite for efficient and satisfactory operation.

In one illustrative embodiment of this invention, electron discharge apparatus comprises an anode and a cathode encompassing and coaxial with the anode. The cathode may be of the indirectly heated equipotential type and comprise a cylindrical metallic member heated by a suitably energized resistance or induction coil encompassing the metallic member. An output circuit is connected between the cathode and the anode.

In accordance with one feature of this invention, means are provided for passing a direct current through the anode whereby a circular magnetic field is produced in the region between the cathode and anode, the field being of sufficient strength to so influence the electron trajectories at certain values of anode potential that substantially all electrons emanating from the cathode return to the cathode without impinging upon the anode.

In accordance with another feature of this invention, the anode is provided with an integral loop portion forming a single turn coil which may be coupled to the output circuit to produce feedback whereby oscillations may be generated.

The invention and the foregoing and other 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 an elevational view mainly in section of electron discharge apparatus illustrative of one embodiment of this invention;

Fig. 2 is a graph illustrating a typical anode current-anode voltage characteristic of electron discharge apparatus constructed in accordance with this invention; and

Figs. 3 and 4 are circuit diagrams illustrating operation of the apparatus shown in Fig. 1 as an oscillator and as an amplifier, respectively.

Referring now to the drawing, the apparatus shown in Fig. 1 comprises an evacuated cylindrical metallic enclosing vessel 10 having a base wall 11 and an exhaust tubulature 12. Disposed axially within the vessel 10 is an elongated, preferably circular, anode having end portions 13 and 14 and an intermediate reduced portion 15. The end portion 13 is conductively joined to the enclosing vessel 10 and the end portion 14 extends through the base wall 11 and is hermetically sealed thereto as by a vitreous seal 16. The anode may be provided with an integral loop portion 17, one end of which terminates in a plate 18 which is spaced from the base wall 11 by a dielectric member 19 and forms a condenser therewith.

Encompassing the intermediate reduced portion 15 of the anode and coaxial therewith is a cylindrical cathode 20 which may be of magnetic or non-magnetic material, the inner surface of the cathode being coated with thermionic materials, such as barium and strontium oxides. The cathode 20 may be heated indirectly by a resistance coil 21 encompassing and coaxial with the cathode and mounted on an insulating, preferably ceramic, sleeve 22, fitted about the cathode 20. The coil 21 may be energized by a suitable alternating or direct current source, not shown, connected to leading-in conductors 23 which extend outwardly from the side wall of the vessel 10 through hermetic seals 24.

Electrically integral with the cathode 20 are a pair of cylindrical metallic, preferably non-magnetic, members 25 and 26, which abut the cathode 20 and are grooved to receive the insulating sleeve 22. The metallic members 25 and 26 are spaced concentrically from the anode by insulating discs 27 and accurately center the cathode 20 about the anode 15.

Electrical connection to the cathode 20 may be established through a leading-in conductor 28 connected to the cylinder 26 and extending from the base wall 11 through a hermetic seal 29. Electrical connection to opposite ends of the anode may be established through leading-in conductors 30 and 31, one of which is connected to the enclosing vessel 10 and the other of which is connected to the end of the loop 17.

During operation of the device, as illustrated for example in Fig. 3, a direct current is passed through the anode 15 from a source, such as a battery 32, which is by-passed for alternating current by a condenser 33 formed by the base

11, the plate member 18 and the dielectric medium 19 therebetween. The anode 15 is maintained at a positive potential with respect to the cathode 20 by a source, such as a battery 34, which, as shown, may be by-passed by a condenser 35 and is in series with a multi-turn coil or winding 36 inductively coupled to the loop or single turn coil 17. As shown in Fig. 1, the coil 36 may be positioned within the coil or loop 17 and coaxial therewith.

The direct current flowing through the anode 15 by virtue of the potential applied across the anode by the battery 32 produces a magnetic field between the anode 15 and cathode 20, the lines of force of the field being circles about and coaxial with the anode 15. The strength of this field at any point outside of the surface of the anode may be expressed as:

$$H = \frac{2i}{R} \quad (1)$$

where H is the strength of the field, i the current through the anode, and R the distance from the longitudinal axis of the anode. From this relation it will be seen that the magnetic field varies inversely with the distance from the axis of the anode.

It is known that an electron moving in a magnetic field is deflected and caused to traverse a curved path, the radius of curvature of which is expressed by the relation

$$p = \frac{m \cdot v}{e \cdot H} \quad (2)$$

where p is the radius of curvature, m and e are respectively the mass and charge of an electron, v is the velocity of the electron, and H is the strength of the field.

The velocity of the electrons is related, of course, to the potential through which they fall and may be expressed mathematically by the relation

$$v = \sqrt{\frac{2Ve}{m}} = 5.95 \times 10^7 \sqrt{E} \text{ cm./sec.} \quad (3)$$

where V is the potential, in electrostatic units, acting upon the electrons, E is the anode potential in volts, and the remaining characters are as defined above.

From the above equations it will be seen that the magnetic field increases in strength from the cathode to the anode and that in a device wherein the distance an electron travels inwardly is large compared to the radius of the anode, the radius of curvature p of the path traversed by electrons emanating from the cathode 20 decreases as the electrons approach the anode 15. Although in an electron discharge device the velocity v generally is not constant, it will be noted from Equation 2 above that the velocity increases only in proportion to the square root of the voltage E so that the radius of curvature p decreases as the electrons approach the anode even in the presence of the electric field.

From the foregoing it will be seen that the magnetic field and anode potential may be so correlated that all electrons emanating from the cathode are so deflected that they do not reach the anode but return to the cathode and, therefore, a sharp cut-off characteristic may be obtained.

As will be apparent, the strength of the magnetic field is directly proportional to the current flowing through the anode. Changes in this current will result in changes in the magnetic field

and, hence, in changes in the space current to the anode. A typical operating characteristic for devices constructed in accordance with this invention is illustrated in Fig. 2. As shown in this figure, at an anode potential E and with a magnetic field H_0 , a space current i_0 will flow to the anode. If the current through the anode is varied so as to increase the magnetic field by the quantity ΔH_0 for the same anode potential E, the space current will be decreased greatly to a value i_0' because of the sharp cut-off characteristic. Conversely, if the current through the anode is varied to decrease the magnetic field by the quantity ΔH for the same anode potential E, the space current to the anode will be increased greatly. Thus, small variations in H_0 will result in relatively large changes in the space current to the anode whereby a high degree of amplification is obtained.

As will be apparent from Fig. 3, the coil 36 coupled to the loop or coil 17 produces feedback so that upon closing of the anode-cathode circuit oscillations will be produced.

When the device is operated as an amplifier, as illustrated for example in Fig. 4, the output winding 36 is coupled to a coil 37 connected to an output device 38 such as a receiver. The circuit through the anode 15 includes, in addition to the battery 32, the inner conductor 39 of a coaxial cable which terminates in a suitable input device 40. Signals impressed upon the cable by the input device 40 will vary the current through the anode 15 with consequent variations in the current supplied to the output device 38.

Although specific embodiments of this invention have been shown and described, it will be understood, of course, that they are but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. Electron discharge apparatus comprising a linear anode, a cathode encompassing said anode, an output circuit connected between said cathode and said anode, means for passing a current through said anode to produce a magnetic field between said cathode and said anode, the lines of force of said field being substantially circular and coaxial with said anode, and means for varying the strength of said field.

2. Electron discharge apparatus comprising an elongated linear anode, a hollow cathode encompassing said anode and uniformly spaced therefrom, an output circuit coupled to said cathode and said anode, means for passing a direct current longitudinally through said anode whereby a circular magnetic field coaxial with said anode is established between said cathode and said anode, and means for superimposing a variable current upon said direct current.

3. Electron discharge apparatus comprising a linear anode having a cylindrical electron receiving surface, a cathode encompassing said surface and having a cylindrical electron-emitting surface opposite and coaxial therewith, an output circuit coupled to said cathode and said anode, means for producing a circular magnetic field between said surfaces, coaxial therewith and decreasing in strength from said anode surface to said cathode surface, and means for varying said field.

4. Electron discharge apparatus comprising a linear anode, a cathode encompassing said anode, a circuit including a source for passing a direct current through said anode whereby a circular magnetic field coaxial with said anode is estab-

lished between said cathode and said anode, a circuit connected between said cathode and said anode, and means coupling said circuits to one another.

- 5 5. Electron discharge apparatus comprising an elongated anode having a linear portion and an integral loop portion, a cathode encompassing the linear portion of said anode, means for passing

a direct current through said anode to produce a circuit magnetic field coaxial with said linear portion, between said linear portion and said cathode, and an output circuit including a coil inductively coupled to said loop portion.

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