

Nov. 3 1925.

1,560,183

F. S. McCULLOUGH

VACUUM TUBE

Filed Dec. 11, 1922

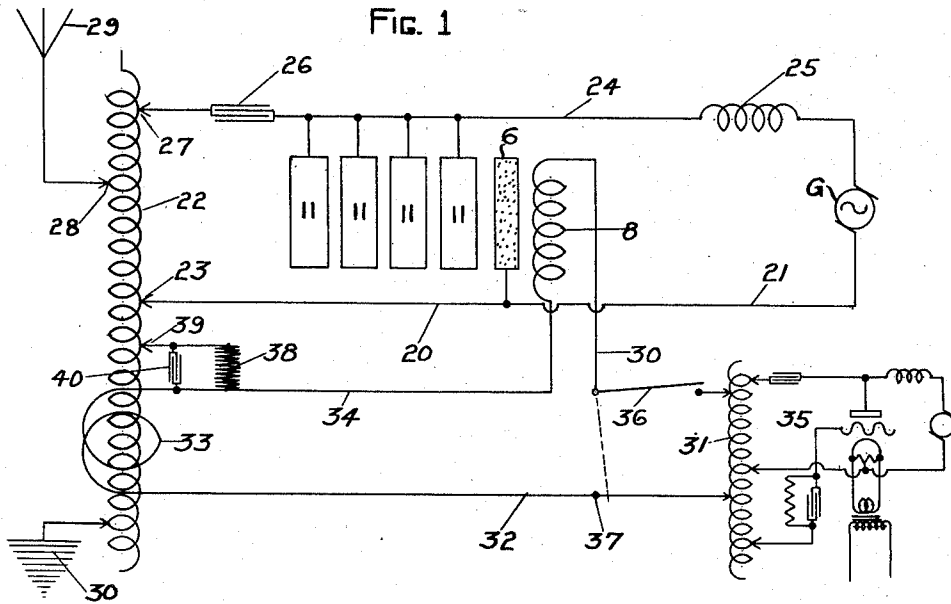


FIG. 2

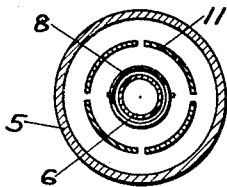


FIG. 4

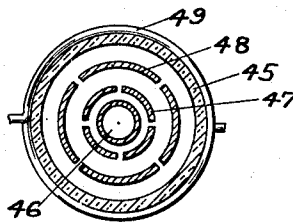
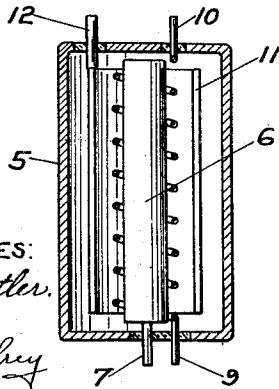


FIG. 3



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VACUUM TUBE.

Application filed December 11, 1922. Serial No. 606,345.

To all whom it may concern:

Be it known that I, FREDERICK S. McCULLOUGH, a citizen of the United States, and a resident of Wilksburg, in the county of Allegheny and State of Pennsylvania, have invented a new and useful Improvement in Vacuum Tubes, of which the following is a specification.

This invention is for a thermionic tube and a circuit for the use of the same.

The present invention relates to that type of electrical device in which a current-flow from an anode to a cathode is maintained by a flow of electrons emanating from the cathode toward the anode or plate, and it has, as a principal object, the utilization of radio-frequency oscillations generated in a circuit by the device itself for sustaining the thermionic radiation from the cathode.

Other important objects of the invention are to utilize a cathode of large surface area, whereby a greater surface is provided from which electrons may be driven, thereby increasing the power of the tube and incidentally lengthening the life of the cathode; and to heat such cathode by induction, preferably by current oscillating at radio frequency.

More specifically, the invention proposes to substitute a cathode, preferably of large surface area, in place of the incandescent filament generally utilized in devices of this nature, and to heat such cathode by means of induction. This is effected by means of a coil in proximity to the cathode in an oscillating circuit, and preferably a circuit in which the oscillations are at radio frequency, the lines of force from which induce eddy currents in and about the cathode, thereby heating the same. The radio-frequency current for heating the cathode may be generated in the circuit of which the valve is a part. The coil for inducing heating current in the cathode may have no other function in the circuit or may serve as another element of the tube, either as the grid or the plate.

The invention may be more readily understood by reference to the accompanying drawing, in which:

Fig. 1 is a diagrammatic view of an oscillating circuit such as may be employed in a radio transmitting station, showing diagrammatically a tube embodying my invention;

Fig. 2 is a transverse sectional view of a tube embodying my invention;

Fig. 3 is a vertical sectional view of the tube shown in Fig. 2; and

Fig. 4 is a view similar to Fig. 2 showing a modification.

In the drawing is shown a vessel 5 which may be of porcelain, glass, or metal, the latter material preferably being used because it may be more readily cooled than the other materials. Inside the vessel, from which most of the air has preferably been exhausted, is a cathode, preferably in the form of a cylindrical metal tube 6. The exterior of this tube may be coated with a substance, such as barium or strontium oxide, that will liberate electrons more freely and at a lower temperature than the metal of the cylinder itself.

A connection 7 on the exterior of the tube enables the cathode to be connected in a circuit.

Surrounding the cathode, or in proximity thereto, is a coil of wire 8 which may be connected, at its opposite ends, to the terminal connections 9 and 10. Surrounding the coil 8 is an anode or plate formed of several arcuate or segmental sections 11, electrically connected to each other and to a connection 12 extending through the wall of the vessel 5.

When an oscillating current is passed through the coil 8, a current oscillating at radio frequency being preferably employed, the lines of force generated about the coil induce currents in the cylinder 6, which currents are short circuited in the cylinder itself, in accordance with principles now recognized in electrical science, thereby heating the cylinder. Such heating of the cylinder liberates electrons from the surface thereof, or from the coating on the surface which is designed to radiate electrons at temperatures below incandescence.

If the plate and cathode are connected in a circuit, a current will flow, under proper conditions, from the plate to the cathode, which current-flow may be controlled by the potential of the coil 8, which constitutes the grid, the tube functioning then as a rectifier and oscillator, as an ordinary three-element vacuum tube. The plate is formed of sections to prevent induction of heating currents therein.

In Fig. 1, the tube is shown in a regenera-

tive circuit of a well known type, in place of the usual vacuum tube, the circuit shown being one which might be employed in a radio station: Instead of the tube being shown assembled, as in Figs. 2 and 3, the elements are shown in diagrammatic arrangement for purposes of illustration.

In Fig. 1, G represents a source of current, preferably a high-frequency alternating generator. One side of the generator connects, through a line 21 and an adjustable contact member 23, with a tuning coil 22. The other side of the generator connects, through a line 24, which includes a choke coil 25 and a condenser 26 and an adjustable contact device 27, with another part of the tuning coil 22. An adjustable contact member 28 leads from the tuning coil to an aerial 29. The coil 22 is grounded at 30.

The plate sections 11 of the tube are connected to the line 24 between the choke coil 25 and the condenser 26. The cathode 6 is connected to line 20. When the cathode is heated, a current will flow from the plates 11 across the intervening space to the cathode 6, and thence to the line 20.

In order to heat the cathode it is necessary to initially establish the coil 8 in an oscillating circuit. The coil 8 is inductively connected, through a wire 30, a tuning coil 31, a wire 32, a mutual inductance device 33 and a wire 34, to the coil 22. The inductance 33 serves to inductively couple the heating coil circuit, or grid circuit, to the tuning coil 22 of the aerial circuit. The coil 31 is included in an oscillating-tube circuit 35 of known arrangement. The vacuum-tube circuit 35 may be termed an exciter circuit.

Initially, the exciter circuit 35 is operated to pass a current, oscillating at radio frequency, through the coil 8 until the cathode 6 becomes heated. The tube, including the heating coil 8 which also operates as a grid, the cathode 6 and the plate sections 11, thereupon become a generator of high-frequency currents, upon a proper adjustment of the various inductances. A switch 36, which is initially employed to connect the wire 30 to the coil 31, is then swung around to contact 37 in the line 32, thus disconnecting the exciter circuit 35. Radio-frequency oscillations are then generated in the main circuit, by reason of the inductive coupling between the coils 22 and 33 and such oscillating currents will be sustained by the tube, cathode of which is heated by means of the radio-frequency currents generated thereby. The dotted-line position of switch 36 indicates substantially the normal position of this switch after the exciter circuit has been disconnected and the tube is maintaining its heating by oscillations sustained by its own action.

Once the tube begins to function as an oscillator, its principle of operation is substantially identical with that of a power tube of the usual type.

A grid leak 38 and a contact member 39, connecting one terminal of the coil 8 to the coil 22, may be provided in the customary way to relieve negative charges which accumulate on the grid or heating-coil circuit. The grid leak 38 is shunted by the customary grid condenser 40.

It will be appreciated that the circuit disclosed is merely illustrative of my invention, and that the invention is by no means confined to use in this circuit or in circuits for the same purpose.

In Fig. 4, I have shown a tube embodying the same principle of operation, but, in this device, the heating coil and the grid are separate elements of the tube. In the drawing, 45 designates a vessel, such, for instance, as a porcelain vessel, having a central cathode 46 therein which may be similar to that previously described. Surrounding the cathode is a segmental grid 47, outside of which is a divided or segmental plate 48. A heating coil 49 is disposed outside of the plate, and, as shown, it is also outside of the vessel 45. When the coil 49 is connected in a circuit oscillating at radio frequency, induced currents in the cylindrical cathode heat the same, to liberate electrons therefrom. The grid and the plate, being sectional, are less affected by the oscillating field about the coil, and, accordingly, do not heat to any great extent.

In operation, this device functions the same as that previously described except that, instead of the heating coil 49 acting as a grid, it acts solely as a means for producing an alternating field about the cathode, while a separate grid controls the action of the tube.

A great advantage of the utilization of currents oscillating at radio frequency to heat the cathode resides in a considerable saving of power, which is lost when alternating currents at audio frequency are utilized.

Various constructional changes may be made in the tube within the contemplation of my invention, the drawings merely illustrating diagrammatically different embodiments thereof, and the device may be used in various different circuits. I desire, therefore, that such changes and arrangements shall be considered as falling within the scope of the appended claims.

I claim as my invention:

1. A thermionic tube including an anode, and a cathode, means for inductively heating the cathode, and an external circuit utilizing said means as an electrode of the tube.

2. A thermionic tube including an anode

composed of a plurality of sections, a cathode, and means for inductively heating the cathode including a coil for connection in an alternating-current circuit the field of said coil extending to both said anode and said cathode.

3. A thermionic tube including an anode and a cathode, and means interposed between the anode and cathode for inductively heating the cathode.

4. A thermionic tube comprising an envelope enclosing an anode, a cathode, and a coil adapted for connection in an alternating-current circuit for inductively heating the cathode and means for so connecting said coil that it may be made to act as the control electrode for the space current.

5. In an electric circuit adapted for oscillation at high frequencies, a thermionic tube for generating high-frequency oscillations, said tube having an anode and a cathode, the latter of which must be heated, and means for heating the cathode by acting inductively thereon by the high-frequency currents generated by said tube.

6. In an electric circuit adapted for oscillation at a radio frequency, a thermionic tube for generating radio-frequency oscillations in the circuit, said tube including an anode and a cathode, and means for heating the cathode inductively, said means being so connected in said circuit that it serves as the grid for the tube.

7. In an electric circuit adapted for oscillation at a radio frequency, a tube in the circuit for generating radio-frequency oscillations in the circuit, said tube having electrodes so related to said circuit that they constitute, respectively an anode, a cathode, and a grid, said grid being arranged to inductively heat the cathode by means of radio-frequency currents passing there-through.

8. In a thermionic tube having an anode and a cathode, a grid in the tube for controlling the space current comprising a coil through which oscillating currents may be passed to inductively heat the cathode and means for supplying oscillating currents to said grid.

9. In a circuit, means including a tube for causing the circuit to oscillate, said tube including an anode, a cathode, and a grid in the form of a coil, said grid being electrically coupled to the circuit, whereby oscillating currents will also pass through the grid and thereby inductively heat the cathode.

10. A thermionic tube having a tubular cathode, an anode formed of a plurality of sections, and means for creating an oscillating electromagnetic field about said electrodes, whereby the cathode will be inductively heated to a greater degree than the anode.

11. In a space-discharge device, means for producing a high-frequency alternating field of magnetic flux, and a cathode and an anode disposed in said field, said cathode being of such nature as to be heated to operative temperature by electromagnetic induction, and said anode being of a structural nature to be materially less affected by said alternating field.

12. The combination with an in-coming circuit and an out-going circuit, at least one of said circuits being a high-frequency circuit, of a space-discharge device including a coil energized with high-frequency currents from said high-frequency circuit and a cathode adapted to be heated to operative temperature by electromagnetic induction from the field produced by said coil, at least one of said circuits being connected to said coil as an operative electrode of said space-discharge device.

13. The combination with an amplifier device comprising a space-discharge device having a cathode adapted to be operatively heated by electromagnetic induction, of oscillation-generator circuits associated therewith whereby said device operates as a generator of radio-frequency currents, a coil coupled to said circuits for producing an alternating field through the cathode for heating said cathode during the normal operation of the device, and a separate source of heating energy for initially heating said cathode to render the same operative.

14. In a radio-frequency power apparatus, the combination with a space-discharge device having a cathode and an anode, of radio-frequency flux-producing means producing a flux through said cathode for heating said cathode and for modulating the space-discharge.

In testimony whereof, I have hereunto subscribed my name this 7th day of December 1922.

FREDERICK S. McCULLOUGH.