Oct. 22, 1935.

H. M. FREEMAN ET AL

2,018,257

THERMIONIC VACUUM TUBE

Original Filed Jan. 8, 1923

2 Sheets-Sheet 1

Fig. 1.

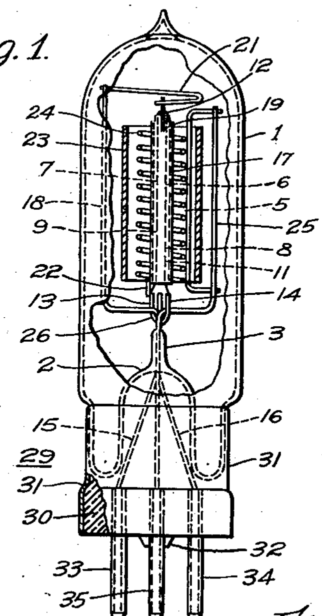

Fig. 2.

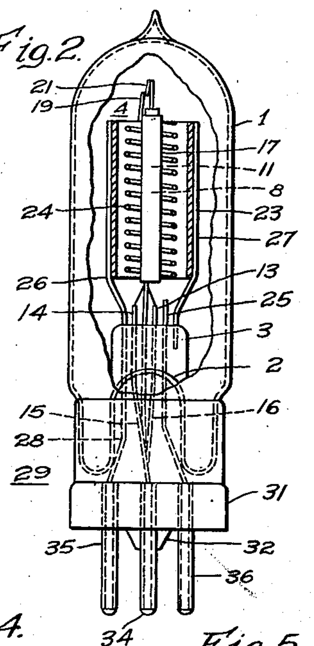

Fig. 3.

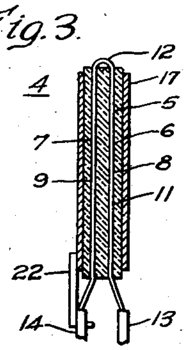

Fig. 4.

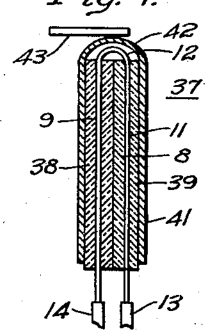

Fig. 5.

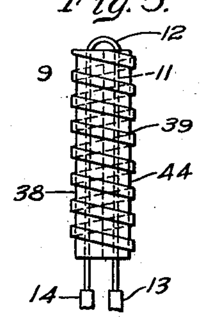

Fig. 6.

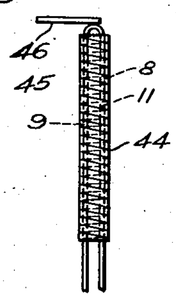

Fig. 7.

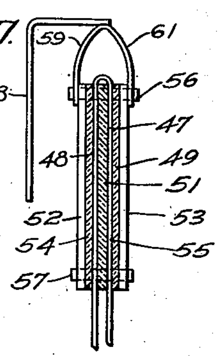

Fig. 8.

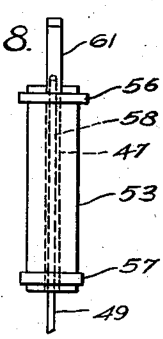

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Fig. 9.

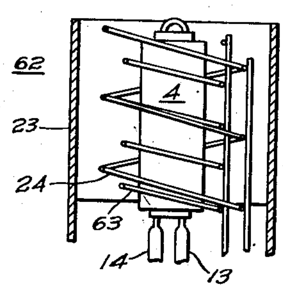


Fig. 10.

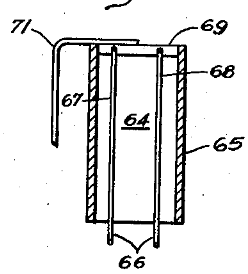


Fig. 11.

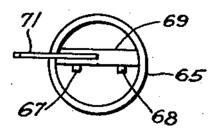


Fig. 12.

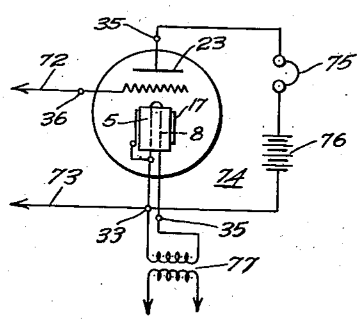


Fig. 13.

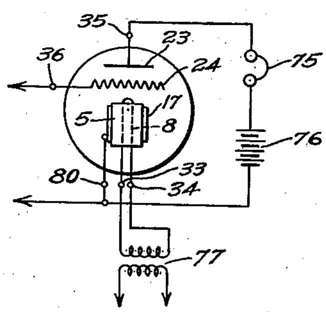
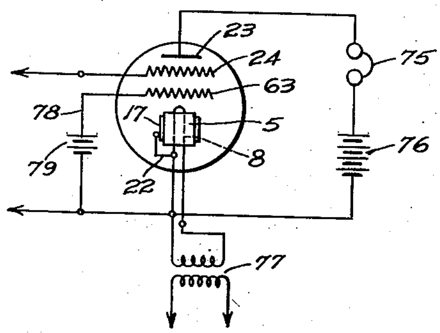


Fig. 14.



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Patented Oct. 22, 1935

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UNITED STATES PATENT OFFICE

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THERMIONIC VACUUM TUBE

Hubert M. Freeman, deceased, late of East Pittsburgh, Pa., by Max W. Reges, administrator, Bloomfield, N. J., and Wallace G. Wade, Philadelphia, Pa.; said Freeman and Wade assignors to Westinghouse Electric and Manufacturing Company, a corporation of Pennsylvania

Original application January 8, 1923, Serial No. 611,263, now Patent No. 1,909,051, May 16, 1933. Divided and this application August 13, 1932, Serial No. 628,696

13 Claims. (Cl. 250—27)

This application is a division of application Serial No. 611,263, filed January 8, 1923, Patent No. 1,909,051, May 16, 1933.

Our invention relates to space-current devices and more especially to the cathode structure of such devices.

The principal object of our invention is to provide a device of the character described which may be employed for detecting, amplifying or rectifying alternating currents and which embodies a cathode structure adapted for excitation from a source of low-voltage, commercial-frequency alternating-currents without the introduction of the alternating-current noises heretofore observed in the operation of such devices.

Another object of our invention is to provide a vacuum-tube structure having highly desirable operating characteristics, wherein a high voltage amplification factor may be obtained while simultaneously securing a comparatively low plate impedance.

A further object of our invention is to provide a vacuum-tube device of the class described embodying a construction which shall be adapted for quantity production methods of manufacture and which shall embody parts capable of manufacture in existing automatic machinery with minimum expenditures of time and of money.

Heretofore, it has not been practical to employ alternating currents for the excitation of the cathode or filament of a receiving or amplifying tube for the reason that such currents introduce variations in the plate current of the tube. Such variations are thought to be due to the following causes.

1. The variations in the intensity of the magnetic field established by the alternating currents traversing the filament, thereby resulting in a variable deflection of the electron stream emanating from the filament;

2. The variations in the electric field around the filament which are caused by the reversals in the potential-distribution along the filament;

3. The variations in the emissivity which are caused by the alternate heating and cooling of the filament.

We have found that the desirable results outlined hereinabove may be obtained by applying a cathode construction having an operating cathode surface which has no fall of potential along its surface, that is, a so-called "equipotential surface". Such cathode surface may be rendered thermionically active in a number of different ways, as by subjecting the same to heat or to an electron bombardment. In one form of embodiment of our invention, we provide a cathode construction comprising a central heater element and a cooperating equipotential cathode surface which is positioned immediately adjacent to the heater element. The thermal energy of the heater element may be transferred to the cathode surface either by conduction or by radiation.

With these and other objects and applications in view, our invention further consists in the combinations and details of construction and in the circuit arrangements hereinafter more fully set forth and claimed and illustrated in the accompanying drawings, wherein;

Figure 1 is a front elevational view of an evacuated electric device embodying our invention in a preferred form, a portion of the containing walls of the envelope being broken away and the grid and plate elements being shown in longitudinal section,

Fig. 2 is a side elevational view of the construction of Fig. 1.

Fig. 3 is an enlarged detailed longitudinal sectional view of the cathode construction of Figs. 1 and 2.

Fig. 4 is a view, similar to Fig. 3, showing a modification in the form of the member constituting the equipotential cathode surface and also showing a modification in the means for insulatingly supporting and separating the branch portions of the heater element.

Fig. 5 is a view, similar to Fig. 4, showing an alternative construction for the equipotential cathode surface,

Fig. 6 is a view similar to Fig. 5, but showing the member forming the operating cathode surface insulatingly carried by the heater element,

Figs. 7 and 8 are enlarged front and side detail elevational views of a further modified form of cathode construction embodying our invention,

Fig. 9 is a side elevational detail view illustrating our invention applied to a vacuum-tube construction employing a pair of controlling elements,

Figs. 10 and 11 are enlarged side elevational and top plan views of a cathode construction wherein the equipotential cathode surface is energized by thermal radiation rather than by thermal conduction, as in the preceding figures.

Fig. 12 is a diagrammatic view of circuits and apparatus embodying one form of our invention and illustrating a circuit arrangement wherein the equipotential cathode element is connected to the heater element within the inclosing envelope,

Fig. 13 is a view similar to Fig. 12 but showing a circuit arrangement wherein an additional lead for the equipotential cathode element is brought out from the tube permitting the usual vacuum-tube circuits to be electrically independent of the supply circuits for the heater element, and

Fig. 14 is a diagrammatic view of circuits and apparatus employing the vacuum-tube construction shown in Fig. 9.

In a preferred form of embodiment of our invention, as shown in Figs. 1, 2 and 3, we provide an elongated envelope 1 having a re-entrant portion 2 terminating in a supporting press 3. A cathode construction 4 comprises a mass of refractory material 5 in the form of a slender solid cylinder provided with a pair of adjacently positioned perforations 6 and 7 which extend between the ends of the cylinder 5. The perforations 6 and 7 are of such dimensions as to receive a filamentary heating element 8 which is threaded up through one perforation and down through the other, providing a filament of inverted U-shape having parallelly extending portions 9 and 11 and a top portion 12.

The distance between the parallel portions 9 and 11 of the filament 8 is so small that the magnetic field established by currents traversing one portion or section substantially neutralizes the magnetic field established by currents traversing the other section, thereby avoiding one of the causes for variations in the plate current of vacuum tubes when employing alternating currents for the energization of the cathode element. The filament 8 may be energized by connecting the same to filament supply conductors 13 and 14 which are supported in the press 3 and are provided with external extensions 15 and 16, respectively.

The cylindrical member 5 is preferably made of some insulating refractory material which, when heated to the temperature of the heater element 8, is free from chemical action therewith. In the course of much experimental work, we have found that zircon possesses such desirable characteristics.

A member 17, which forms the equipotential cathode surface, is shown in the form of a tube having its inner surface closely embracing the tubular insulating member 5. The outer surface of the member 17 may be coated with oxides of barium, strontium or other substance which is rendered thermionically active when subjected to heat.

The cathode construction 4 may be supported at its upper end by means of a carrier rod 18 extending from the press 3, as hereafter described. In practice, it has been found desirable to provide a spring connection between the cathode construction 4 and the supporting carrier rod 18 in order to provide for the expansion and contraction of the heating element 8. The desired result is obtained by welding a strip 19 to the upper end of the cathode construction, preferably to the tubular member 17, and connecting the strip 19 and the carrier rod 18 by means of a spring member 21. The equipotential cathode member 17 may be electrically connected externally of the tube 1 by connecting the same to one of the supply conductors, for example, conductor 13, by means of a conductor 22.

The cathode construction 4 may be surrounded by plate and grid elements 23 and 24 of conventional design. As a matter of illustration, the grid 24 is shown in the form of a helical member with its axis coinciding with the longitudinal axis of the heater element 8. The grid 24 is supported in position by means of a carrier rod 25 extending from the press 3 and welded to the several helices thereof to provide additional stiffness to the grid construction.

The plate 23 is a tubular member symmetrically positioned with respect to the previously mentioned elements and supported by carrier rods 26 and 27 which are mounted in the press 3. One of the carrier rods, say 27, may be extended through the press 3 to form an external circuit terminal 28.

The envelope 1 may be provided with a base 29, which comprises a solid circular insulating member 30 and a collar 31, opposite ends of the latter rigidly embracing the re-entrant tube portion 2 of the evacuated electric device and the insulating member 30, in any approved manner. The outer end of the insulating block 30 may be provided with a raised portion or base 32 and a plurality of hollow terminal pins 33, 34, 35 and 36. The several external connections are disposed in the hollow portions of the terminal pins such that pins 33 and 34 are connected to the terminals of the heater element and pins 35 and 36 are connected to the terminals of the plate and grid elements 23 and 24, respectively. The pin element 33 also serves as a terminal connection for the equipotential cathode member 17.

In Fig. 4 is shown an enlarged detail longitudinal sectional view of a cathode construction 37 which differs from that previously described in the following important respects. The adjacent sections 9 and 11 of the heater element 8 are insulating supported and spaced by means of separate tubular members 38 and 39, respectively. The tubular members 38 and 39 may be made of any refractory material having properties similar to those described for the tubular supporting member 5 shown in Fig. 3. The cathode construction herein shown has an equipotential electron-emitting element in the form of a cylindrical casing 41 having a cap portion 42 which is electrically connected to the bent portion 12 of the heater filament 8. The structure may be supported by means of a carrier rod 43 which is welded to the cap portion 42. The carrier rod 43 may be extended through the press 3 to serve also as an external terminal connection for the equipotential cathode member 41.

In Fig. 5 is shown a cathode construction which is differentiated from that of Fig. 4 in the form of the member constituting the equipotential cathode surface. In this construction, the cathode surface is formed by spirally winding an oxide-coated platinum strip 44 around the outer portions of the tubular spacing members 38 and 39.

The construction 45 shown in Fig. 6 is distinguishable over the preceding cathode constructions in that the oxide-coated platinum strip 44 forming the equipotential cathode surface is wound directly around the sections 9 and 11 of the heater element 8, the oxide coating on the platinum strip 44 serving to insulate the strip 44 from the heating element 8. If additional insulation is necessary, the heating element 8 itself may be covered by some insulating oxide, such, for example, as magnesium oxide. The structure may be supported by means of a carrier rod 46 which is welded to the bent portion 12 of the heater element and to the strip 44. The carrier rod 46 may also serve as a lead for the equipotential cathode member 44.

In Figs. 7 and 8, a cathode construction is shown which differs from the foregoing constructions in the following respects. A heater element 47, which may be in the form of a flat ribbon of tungsten or other suitable material, is doubled to form a pair of adjacently positioned sections 48 and 49, as in the preceding figures. The adjacent sections 48 and 49 are separated by a thin mica strip 51. Equipotential cathode members 52 and 53, in the form of oxide-coated strips of nickel, are positioned immediately adjacent to the filament sections 48 and 49, respectively, and are insulatingly spaced therefrom by mica strips 54 and 55. The structure is bound tightly together at the opposite ends thereof by collar members 56 and 57 and may be supported from the top by means of a carrier rod 58 having bail extensions 59 and 61 secured to the collar 56. The carrier rod 58 may be extended through the press to serve as an external terminal connection for the cathode members 52 and 53.

Fig. 9 is a greatly enlarged view of a vacuum-tube construction 62 which is differentiated over that of Figs. 1 and 2 in the provision of an additional controlling element 63, all as described more fully hereinafter.

The foregoing cathode constructions are all characterized by the fact that the equipotential cathode surface thereof is energized by means of thermal conduction, the insulating means separating the heater element and the equipotential cathode member serving as the heat conducting means between the two members.

Figs. 10 and 11 are greatly enlarged views of a construction 64 wherein an equipotential cathode member 65 is heated by thermal radiation rather than by thermal conduction. The construction there shown comprises a heater element 66 in the form of adjacently positioned parallelly extending filamentary sections 67 and 68, the sections being adjacently positioned to reduce the distorting effects of the varying magnetic fields established by the filament exciting currents as previously described. Adjacent ends of the filament sections are welded to a supporting member 69 of nickel or other suitable conducting material. The equipotential cathode member 65 is shown in the form of a cylindrical casing inclosing the parallelly extending sections of the heater element 66 and is rigidly secured to the supporting block 69. The construction may be supported by means of a carrier rod 71 having one end rigidly secured to the supporting block 69.

Fig. 12 is a diagrammatic view of the vacuum-tube construction shown in Figs. 1, 2 and 3 together with circuit connections whereby the tube may function as an amplifier of alternating currents. The grid 24 and the equipotential cathode 17 are connected by conductors 72 and 73, respectively, to a source of incoming signals (not shown). A plate-filament circuit 74, which extends from the plate 23 to the equipotential cathode element 17, includes a detecting device 75 and a source 76 of direct-current energy. A source of alternating-current energy (not shown) is operatively connected to the heater element 8 through a transformer 77. It is noted that, in this arrangement, the equipotential cathode member 17 is connected to the heater element 8 within the evacuated portions of the tube 1, thereby requiring only four terminal pins in the base 29.

The system shown in Fig. 13 is distinguishable over that of Fig. 12 in the provision of separate connections for the equipotential member 17 and for the heater element 8, thereby making the energizing circuits for the heater element 8 electrically independent of the usual vacuum-tube grid, filament and plate circuits. Such arrangement, however, necessitates the provision of an additional plug element in the base 29 of the tube as indicated at 80 in Fig. 13.

The system shown in Fig. 14 illustrates one application of the vacuum-tube construction 62 shown in Fig. 9. The additional grid element 63 is connected to the equipotential cathode member 17 by means of a conductor 78 including a source 79 of direct-current energy tending to make the grid 63 positive with respect to the equipotential surface. When such condition obtains, the grid 63 serves as an electrostatic screen tending to further decrease the tendency of the alternating exciting currents to vary the tube characteristics. When the grid 63 is made positive, as shown in the drawings, it forms, in effect, an artificial cathode, all as will be readily understood by those skilled in the art.

In practice, we have obtained remarkably high voltage amplification with vacuum tubes employing an indirectly heated cathode surface, as described in the foregoing portions of the specification. The low-resistance type of vacuum tube heretofore employed has a plate impedance of from 15,000 to 25,000 ohms, with amplification factors ranging from 5 to 7, whereas the operating characteristics of a vacuum-tube device embodying our invention are such that a tube may be designed having a plate impedance of 10,000 ohms and a voltage amplification factor of 10. Thus, it is seen that the figure of merit, which is the ratio of the amplification factor squared to the plate resistance, is, in a vacuum-tube construction embodying our invention, approximately four times greater than that of the ordinary tubes heretofore employed.

While we have shown a number of embodiments of our invention, for the purpose of describing the same and illustrating their principles of operation, it is apparent that various changes and modifications may be made in the nature and the mode of operation and in the details of construction without departing from the spirit of our invention. We desire, therefore, that only such limitations shall be imposed thereon as are indicated by the appended claims or demanded by the prior art.

We claim as our invention:

1. A thermionic tube having therein an anode and a cathode structure and having external anode and cathode-terminals and terminal provisions for a cathode-energizing circuit, said cathode-structure comprising resistance wire connected between said terminal provisions, each portion of such resistance wire being adjacent to but out of contact with another portion of such resistance wire, which exhibits at every instant an opposite electric polarity from the first-named portion, whenever said terminal provisions are connected in circuit with a source of alternating electric current, whereby external field effect of the cathode-heating current is neutralized.

2. A thermionic tube having therein a plate, a grid, and a cathode, said cathode comprising terminals and a filamentary structure connected between said terminals and comprising adjacent non-contiguous portions which exhibit opposite electric polarity when said terminals are connected in circuit with the ordinary alternating current lighting system.

3. A cathode structure comprising a plurality of parallel non-contiguous filaments each having terminals and supporting members connected thereto adapted to conduct energy to the said filaments, adjacent terminals of the said fila-

ments being connected to supporting members of opposite polarity.

4. A cathode assembly comprising a cylindrical casing, electron emitting material on said casing, a conductive member across one end of said cylindrical casing and connected thereto and a plurality of filaments attached to said conductive member.

5. A cathode assembly comprising a cylindrical casing, electron emitting material on said casing, a conductive member across one end of said cylindrical casing, heating means connected to said conductive member and a combined supporting means and cathode lead connected to said conductive member.

6. An indirectly heated equipotential cathode assembly comprising a hollow cylindrical casing, electron emitting material on the outer surface of said casing, a conductive member across one end of said cylindrical casing, a pair of filaments supported on said conductive member and extending parallel through said cylindrical casing and a combined supporting means and cathode lead connected to said conductive member.

7. An electrical discharge device comprising a uni-potential cathode having an alternating-current heater, an anode, a control electrode, and an electrostatic screening means positioned between the surface of said cathode and said anode.

8. An electrical discharge device comprising a unipotential cathode heated by alternating current, an anode, a source of substantially constant voltage supply connected between said cathode and said anode, and electrostatic screening means positioned between the surface of said cathode and said anode.

9. An electrical discharge device comprising an anode, a uni-potential cathode provided with an electrical heater so constructed that its magnetic field is substantially nil at all points between the surface of said cathode and said anode, a source of substantially constant voltage interconnecting said cathode and said anode, and an electrostatic screening means interposed between the surface of said cathode and said anode.

10. An electrical discharge device comprising a cathode having a surface of conducting material with a thermionically emissive coating at least partially enclosing an electrical heater for rendering said surface thermionically emissive, an electrode external to said cathode surface and spaced therefrom, and an electrostatic screen between said cathode surface and said electrode.

11. An electrical discharge device comprising a cathode having a surface of conducting material with a thermionically emissive coating at least partially enclosing an electrical heater for rendering said surface thermionically emissive, an electrode external to said cathode surface and spaced therefrom, a control electrode and an electrostatic screen between said cathode and the first-mentioned electrode.

12. An electrical discharge device comprising a cathode heated by alternating current, an anode, a source of substantially constant voltage supply connected between said cathode and said anode, and electrostatic screening means positioned between the surface of said cathode and said anode and connected to said cathode through a current path which does not include said source.

13. An electrical discharge device comprising a cathode heated by alternating current, an anode, a control electrode, leads for connecting said cathode and said control electrode to a source of varying voltage, a path for output currents responsive to said varying voltage connected between said cathode and said anode, and electrostatic screening means positioned between the surface of said cathode and said anode and connected to said cathode through a current path which does not include said first mentioned path.

MAX F. REGES.

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WALLACE G. WADE.