June 11, 1940. W. T. HARRIS 2,204,306

VACUUM TUBE

Original Filed Nov. 10, 1938 2 Sheets-Sheet 1

FIG. 1.

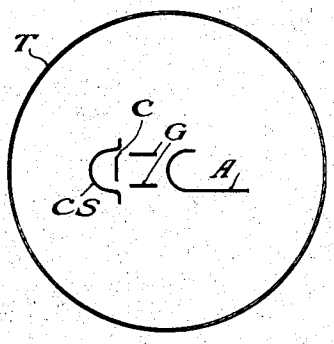


FIG. 2.

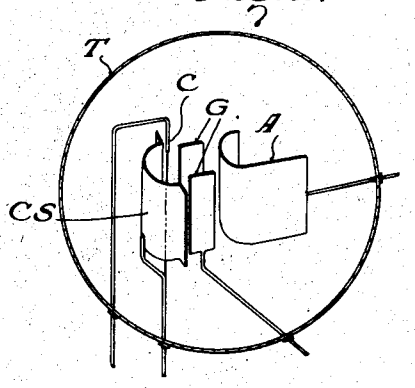


FIG. 3.

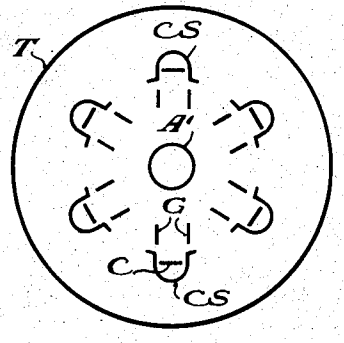


FIG. 4.

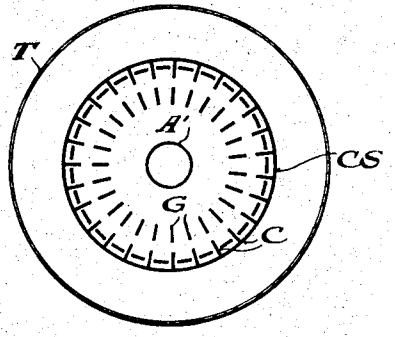
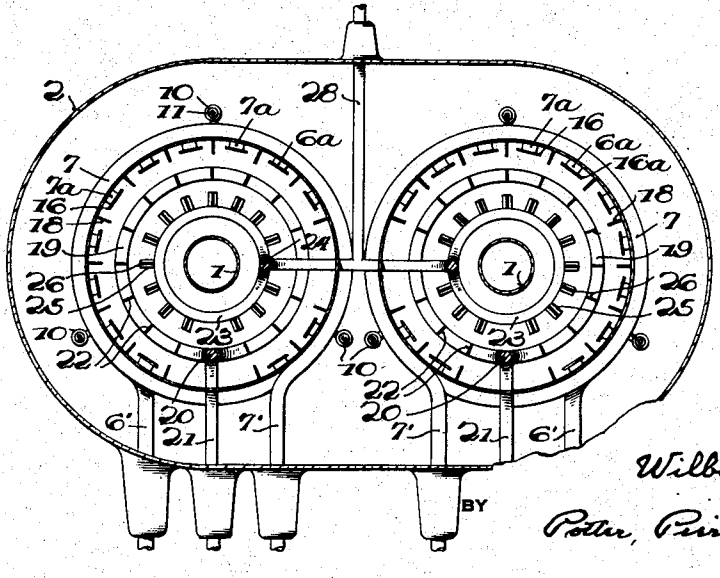


FIG. 5.



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FIG. 6.

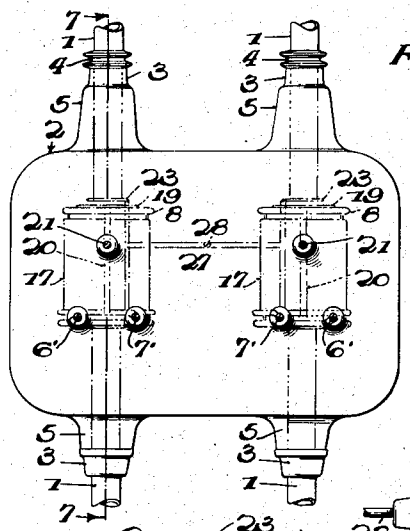


FIG. 7.

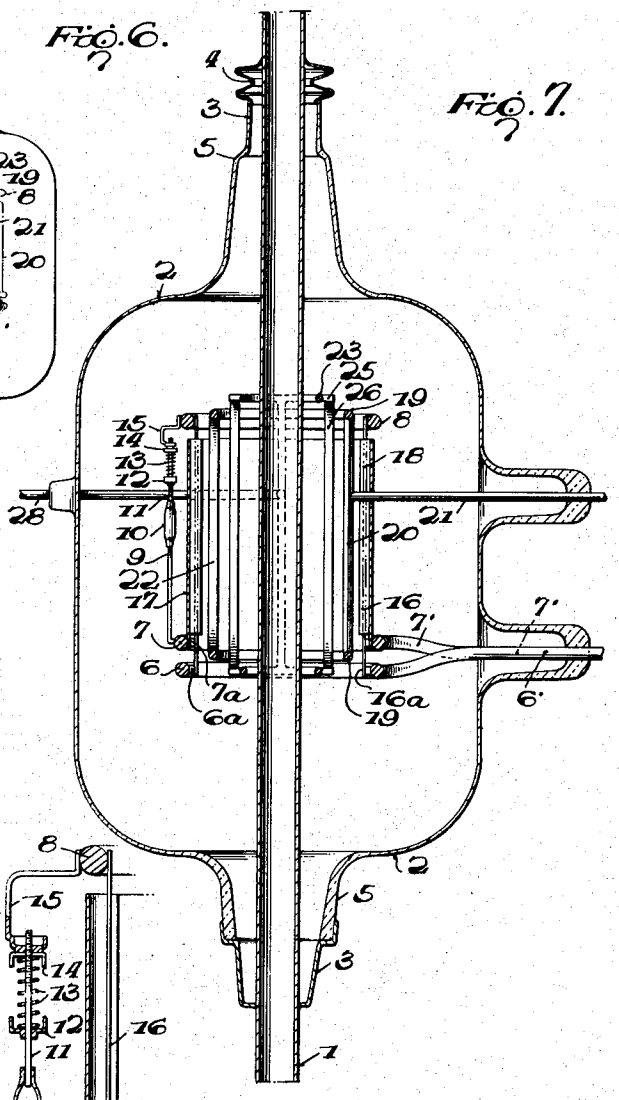


FIG. 8.

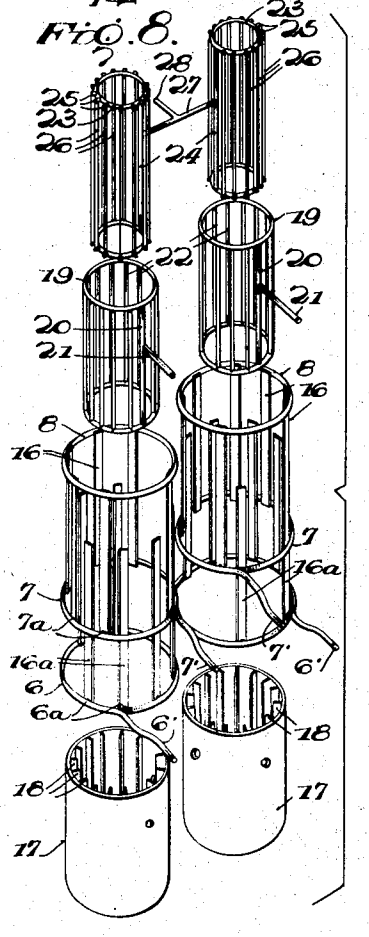
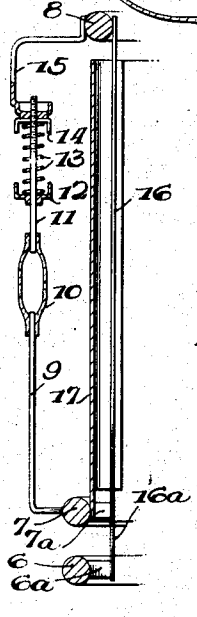


FIG. 9.



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UNITED STATES PATENT OFFICE

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VACUUM TUBE

Wilbur T. Harris, Trenton, N. J., assignor to Research Corporation, New York, N. Y., a corporation of New York

Original application November 10, 1938, Serial No. 239,885. Divided and this application December 27, 1938, Serial No. 247,933

16 Claims. (Cl. 250—27.5)

This invention relates to vacuum tubes and particularly to vacuum tubes having grid elements that draw substantially no current. The novel tubes are particularly adapted for use at ultra high frequencies but may be used to advantage at lower frequencies.

The tubes now used in ultra high frequency circuits are of clumsy shapes and have poorly arranged leads which are responsible for substantial inductance and high frequency resistance in ultra high frequency circuits that are built around the tubes. The output of the prior tubes has been limited by these faults and by the grid dissipation, i. e. grid currents due to electrons captured by the grid in their flow from cathode to plate. A recently produced ultra high frequency tube of the water cooled anode type exhibits a grid current of from one-fifth to one-half of the anode current when used as an oscillator. The output of this tube tends towards zero as the wave length is shortened to one meter.

Objects of the present invention are to provide vacuum tubes having grids of novel design that are not bombarded and therefore draw substantially no grid current. An object is to provide vacuum tubes having elements that may be directly incorporated into the oscillatory and the water cooling circuits of an amplifier or oscillator. An object is to provide vacuum tubes having one or more tubular anode elements that extend through the tube, and assemblies of cathode and grid elements in cylindrical symmetry about the anode tube or tubes. Further objects are to provide tubes of the type stated in which the grid elements are located at each side of the spaces, i. e. the paths of electron flow between the cathode elements and the centrally located hollow anode element.

These and other objects and advantages of the invention will be apparent from the following specification when taken with the accompanying drawings in which:

Fig. 1 is a schematic transverse section through a tube embodying the invention;

Fig. 2 is a perspective view of the same;

Figs. 3 and 4 are schematic diagrams of multiple element water-cooled tubes;

Fig. 5 is a transverse sectional view through a double screen grid tube;

Fig. 6 is a side elevation of the same;

Fig. 7 is a sectional view substantially on line 7—7 of Fig. 6;

Fig. 8 is an exploded view of the cathode and grid electrodes of the double tube; and

Fig. 9 is an enlarged detail view of the cathode and cathode shield elements.

Certain features of the invention as applied to tubes for use at ultra high frequencies may be incorporated in simpler tube constructions, as shown in Figs. 1 and 2, which may be operated at radio and lower frequencies with efficiencies not obtainable with prior tubes. The tube elements comprise an anode A having a semi-cylindrical section which merges into a flat heat-radiating flange, a filamentary cathode C, preferably a flat strip or ribbon extending parallel to the axis of the semi-cylindrical plate section, an approximately U-shaped cathode shield CS at the side of the filament opposite the anode and located outside of the space between the anode A and cathode C, and a grid G in the form of a pair of parallel ribbons extending along opposite sides of the space between the cathode and anode. The elements are supported within an evacuated envelope T in the usual manner by their leads, the control grid ribbon G having a common lead which supports the same and the cathode shield CS being connected to one of the cathode leads.

This electrode assembly has the general form, as viewed in cross-section, of an electron gun and the control grid lies outside of the electron stream and is not bombarded during use of the tube as an oscillator. Tubes of this design have been operated at ultra high frequencies with grid currents reduced to the order of one one-thousandth of the plate current, thus substantially eliminating overheating of the grid as a factor limiting efficiency and/or the highest frequency of operation. With an anode A of tantalum and a construction of substantially the dimensions of the patent drawings, the tubes of Figs. 1 and 2 have converted about 75 watts of power at ultra high frequencies. This is equivalent to the performance of prior small ultra high frequency tubes of more complex or expensive construction and operating without cooled anodes.

Tubes of higher power output may be constructed, as shown in Fig. 3, by a multiple assembly of a plurality of "electron gun" units about a central tubular anode A' through which water may flow to cool the anode. An assembly of six units, as shown in Fig. 3, has been operated with high efficiency at wave lengths of the order of one meter; the six filaments being of tungsten 0.050" wide, 0.001" thick and 1" long, with the filaments equally spaced to define a cylindrical surface of about 0.75" diameter. Amplification constants between 30 and 50 were obtained, and the tube exhibited very linear plate characteristics

that intersect the zero current axis smoothly, i. e., they exhibit sharp cut off characteristics. For operating conditions leading to maximum power output, the grid current remained vanishingly small; of the order of 1/1000 of plate current.

Increasing the cathode surface will give greater power converting capacities, and such increase in the cathode surface may be obtained through the use of more and/or of longer cathode ribbons. Exceedingly compact constructions may be obtained with the electrode geometry shown schematically, and on a larger scale, in Fig. 4. The cathode shield CS' takes the form of a cylinder having radial ribs that define compartments in which the cathode ribbons C are located, the grid G' being formed by ribbons or strips in radial alinement with the ribs of the cathode shield.

Screen grids may be desirable to simplify neutralization problems when modulating over an extended frequency band, as in television transmission, and the screen grid will comprise ribbons or strips in alinement with the control grid ribbons. The incorporation of two sets of electrode assemblies in one envelope is especially advantageous in screen grid tube constructions as this simplifies a connection of the two screen grids by a low impedance conductor. An appropriate design, as shown in Fig. 5, comprises two electrode assemblies that each include the elements shown in Fig. 4 and, in addition, an inner set of grid ribbons constituting a screen grid. The electrode assemblies may be in close proximity since each is within its cathode shield cylinder and the bar connecting the screen grids may therefore be quite short.

As shown in Figs. 5 to 9, the hollow anode of the vacuum tube is an oxygen free high conductivity copper tube 1 that extends centrally through a glass envelope 2 that is preferably of the type designated 707DG by the Corning Glass Company. The opposite ends of copper tube 1 extend through and are silver soldered to a rigid sleeve 3 and to a sylphon bellows 4 which, in turn, is soldered to a sleeve 3. These sleeves are "Kovar" (a glass sealing alloy) and they are connected to the main body 2 of the envelope by intermediate sections 5 of 704AJ glass manufactured by the Corning Glass Company. The different coefficients of expansion of the copper and glass necessitates the sylphon bellows or expansion joint at one anode seal.

The cathode ribbons are connected between rings 6, 7 at the bottom of the assembly and an upper ring 8 that is yieldingly supported from the ring 7 by telescoping connections that each comprise a wire 9 connected by a hollow glass bead 10 to a wire 11 having a cupped washer 12 secured thereto to carry a light tungsten spring 13 that bears against a washer 14, the wire 11 extending freely through washer 14 and the looped end of a wire 15 that is attached to the ring 8. The rings 6, 7 are preferably formed as loops in the ends of relatively long wires, thus leaving projecting ends 6', 7', respectively, that extend through the envelope 2 to serve as the cathode terminals and to support the cathode assembly. Alternate cathode elements 16, 16*a* extend between ring 8 and rings 6, 7, respectively, the ring 8 being of somewhat smaller diameter than rings 6 and 7, and short studs 6*a*, 7*a* being spot welded to rings 6, 7, respectively, to make connection to the lower ends of the cathode elements. The cathode screen comprises the cylinder 17 and radial ribs 18 which are carried by the ring 7 and terminate short of the upper cathode ring 8.

The control grid assembly comprises upper and lower rings 19 that are connected by a wire support 20 to which the grid lead 21 is attached. The grid elements 22 are secured to the rings 19 in radial alinement with the shield ribs 18. Similarly, the screen grid assembly includes upper and lower rings 23 that are spaced by a wire 24 and carry short studs 25 between which the screen grid ribbons 26 are connected. In a double assembly tube, the relatively rigid wires 24 of the screen grids are connected by a shorting bar 27 to which the terminal 28 is secured. The cathode shield cylinder 17 is apertured to pass the terminals 21 and 28 that support the control grid and screen grid, respectively.

This application is a division of my copending application Serial Number 239,885, filed November 10, 1938.

It is to be understood that the constructions herein shown and described are illustrative of the invention and that various modifications that may be developed by those skilled in the art fall within the spirit of my invention as set forth in the following claims.

I claim:

1. A vacuum tube comprising an evacuated envelope, an anode, a cathode assembly comprising an electron emitting member and a non-emitting member partially enclosing said emitting member at the side thereof opposite said anode and electrically connected to a point on the emitting member to assume the potential thereof, and means for controlling the intensity of the electron stream between said cathode assembly and said anode; said means comprising paired control grid members straddling the space occupied by the electron stream and having surfaces substantially parallel to the general direction of the electric field between said anode and the cathode assembly.

2. A vacuum tube as claimed in claim 1, wherein said electron emitting member is a flat strip in a plane normal to the path of the electron stream, and said non-emitting member is located outside of the space between said flat strip electron emitting member and said anode.

3. A vacuum tube as claimed in claim 1, wherein said non-emitting member is of approximately U-shape.

4. A vacum tube as claimed in claim 1, wherein said electron emitting element is a flat ribbon in a plane normal to the path of the electron stream, and said non-emitting member is of approximately U-shape and located substantially entirely at the side of said electron emitting member opposite said anode.

5. A vacuum tube comprising an evacuated envelope, an anode, a cathode assembly comprising an electron emitting filamentary member and a non-emitting shield member partially enclosing and spaced from the filamentary member, an electrical connection from said shield member to a point on said filamentary member, and grid means between said anode and cathode assembly to control the intensity of the electron stream; said grid means comprising a pair of members straddling the space occupied by the electron stream and having surfaces substantially parallel to the general direction of the electric field between said anode and the cathode assembly, and a common conductive support and lead for said pair of members.

6. A vacuum tube comprising an evacuated

envelope, a filamentary cathode element, an anode element opposed to said cathode element, a grid element comprising flat ribbons spaced apart by substantially the width of the anode element and extending along opposite sides of the space between said cathode and anode elements, an approximately U-shaped cathode shield at the side of said cathode element opposite said anode element and grid element, the edges of said cathode shield terminating substantially in a plane through the cathode element, and a connection within said envelope between said cathode shield and an end of said filamentary cathode.

7. A vacuum tube comprising an evacuated envelope, a flat ribbon cathode element, electron accelerating means consisting of a single anode element, a grid comprising flat ribbons extending along each side of the space between said cathode and anode elements, and an approximately U-shaped cathode shield at the face of said cathode opposite said grid and having side portions opposed to and in substantial alinement with the respective flat ribbons of the grid.

8. A vacuum tube comprising an evacuated envelope, an anode element extending through and to opposite sides of said envelope, a cathode comprising filamentary members in spaced relation lying in a cylindrical surface substantially coaxial with and surrounding said anode element, cathode shield means outside said cathode members and including ribs extending between adjacent cathode members, and grid means comprising flat ribbons radially disposed in alinement with the ribs of said cathode shield means and in the space between said anode and said cathode members.

9. A vacuum tube as claimed in claim 8, wherein said grid means comprises concentrically disposed control and screen grid sets of flat ribbons in radial alinement.

10. A vacuum tube comprising an evacuated envelope, a tubular anode extending through said envelope, a cathode surrounding said tubular anode, and grid means for controlling the intensity of the electron flow from said cathode to said anode; said cathode comprising a plurality of flat ribbons parallel to the axis of said anode and in a cylindrical surface coaxial with said anode, a pair of terminal rings surrounding said anode at one set of ends of said ribbons, said ribbons being connected in alternation to said rings, a ring adjacent the other set of ribbon ends and connected to all of said ribbons, and leads for said cathode extending through said envelope from said pair of rings.

11. A vacuum tube as claimed in claim 10, in combination with spring means maintaining said ribbons under tension.

12. A vacuum tube as claimed in claim 10, in combination with grid means comprising a plurality of radially disposed ribbon elements in the space between said cathode and said anode, said ribbon elements being in staggered relation to said cathode ribbons.

13. A vacuum tube as claimed in claim 10, in combination with a plurality of grids between said anode and said cathodes, each of said grids comprising a plurality of ribbon elements in the space between said cathode and said anode, the ribbon elements of the grids being in radial alinement with respect to said anode and staggered with respect to the ribbons of said cathode.

14. A vacuum tube as claimed in claim 10, in combination with a cathode shield comprising a cylinder secured to one of said rings and extending along and in spaced relation to said cathode ribbons, and ribs on said cylinder extending radially between adjacent pairs of the cathode ribbons.

15. A tube comprising an evacuated envelope, a pair of tubular anode members extending in parallel relation through said envelope, an assembly of circumferentially spaced filamentary cathode members arranged in cylindrical symmetry about each anode member, cathode shield means at the outer side of each cathode member and extending between adjacent cathode members, and radially disposed control grid members at opposite sides of the space between the respective cathode members and their associated anode members.

16. A tube as claimed in claim 15, in combination with screen grid members in radial alinement with the several control grid members, and means within the envelope electrically connecting the screen grid members associated with both anode members.

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