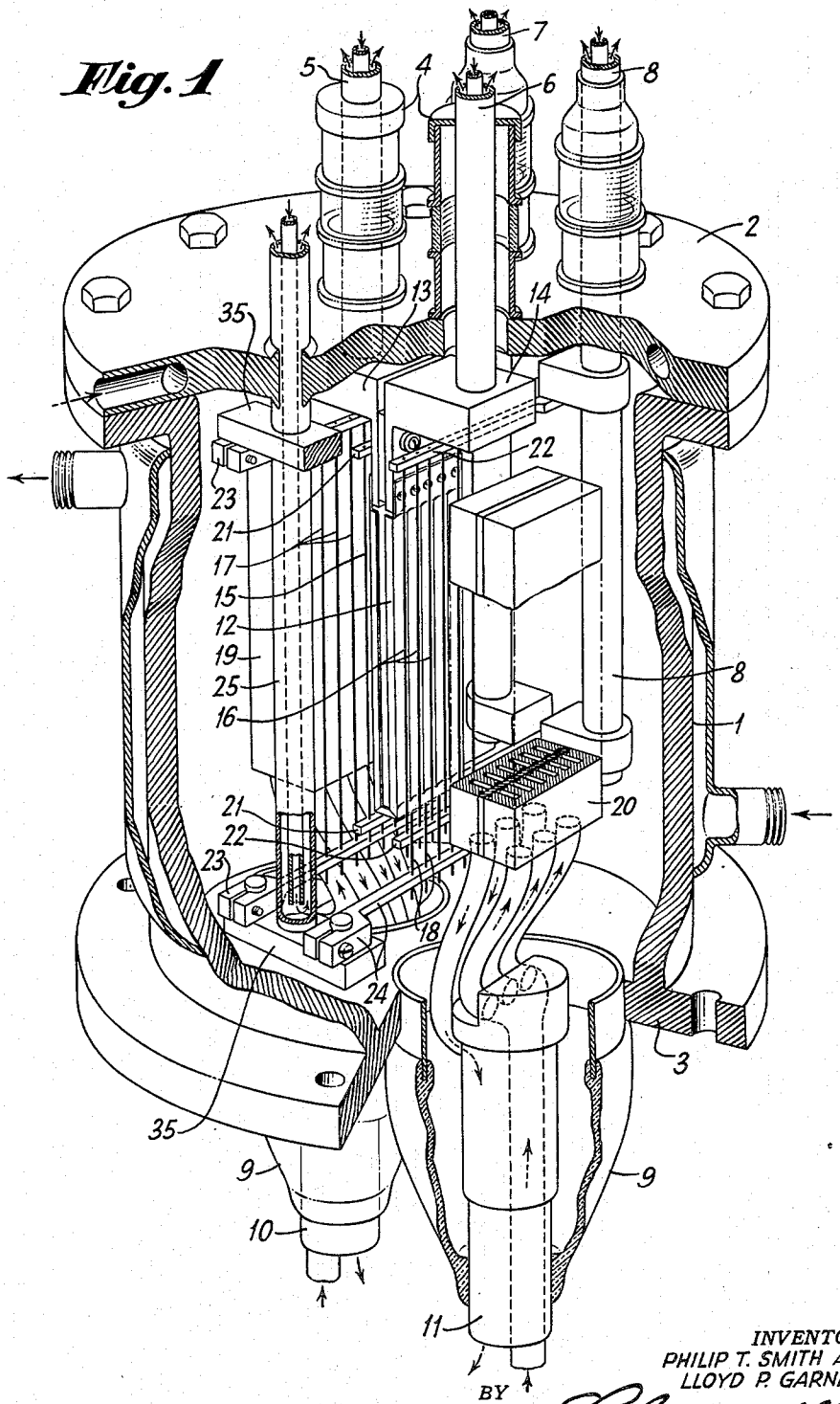
Dec. 31, 1940. P. T. SMITH ET AL 2,227,039

HIGH POWERED ELECTRON DISCHARGE DEVICE

Filed Feb. 28, 1939 3 Sheets-Sheet 1

Fig. 1



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Fig. 2

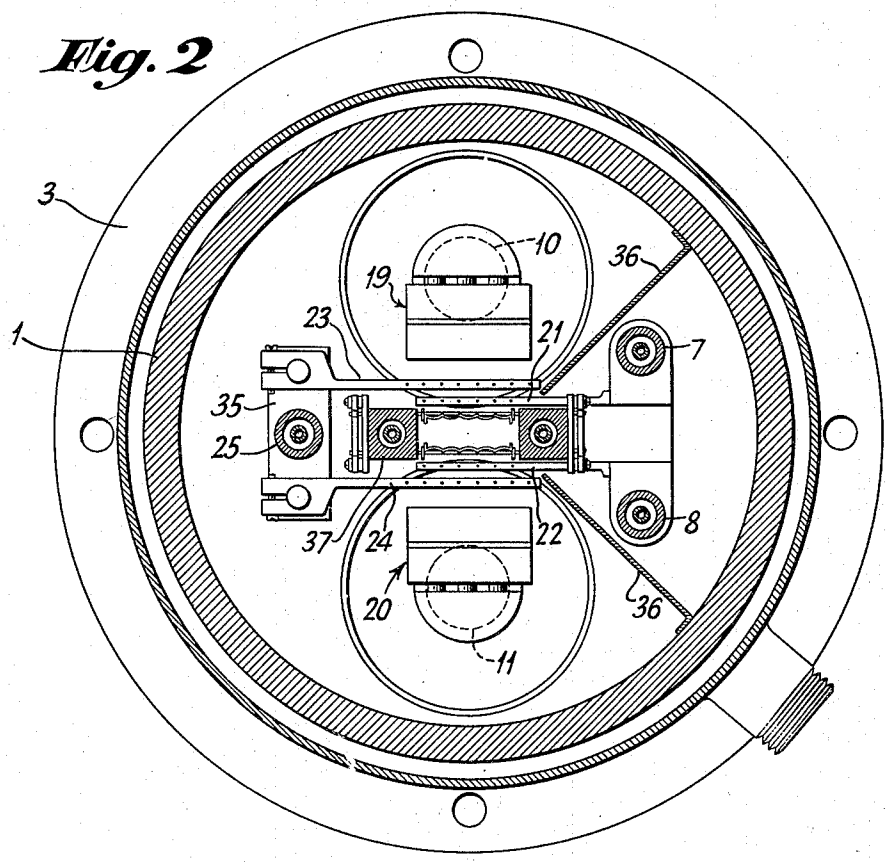


Fig. 7

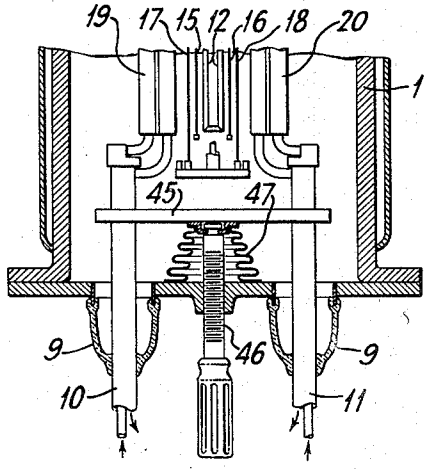
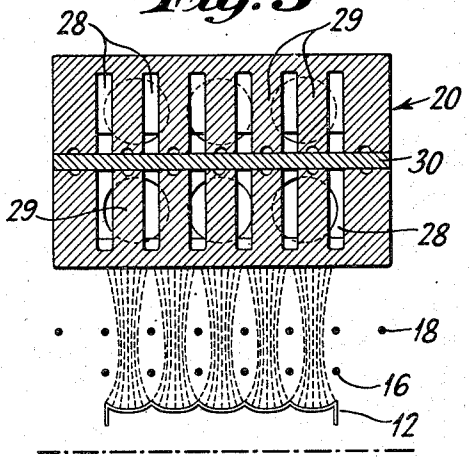


Fig. 3



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Fig. 4

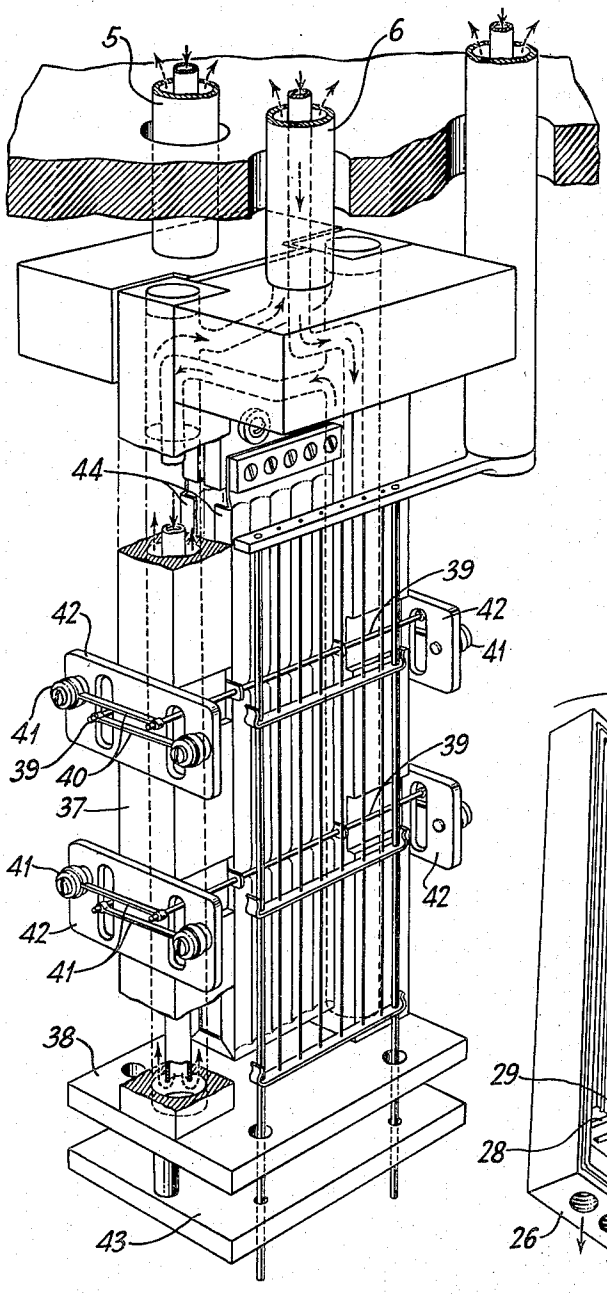


Fig. 5

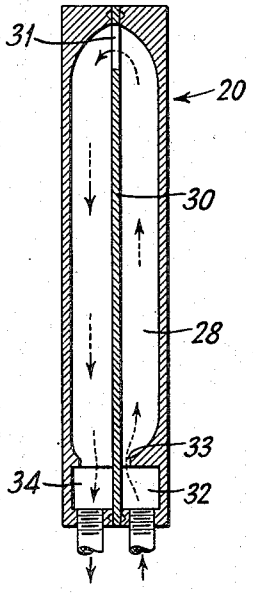
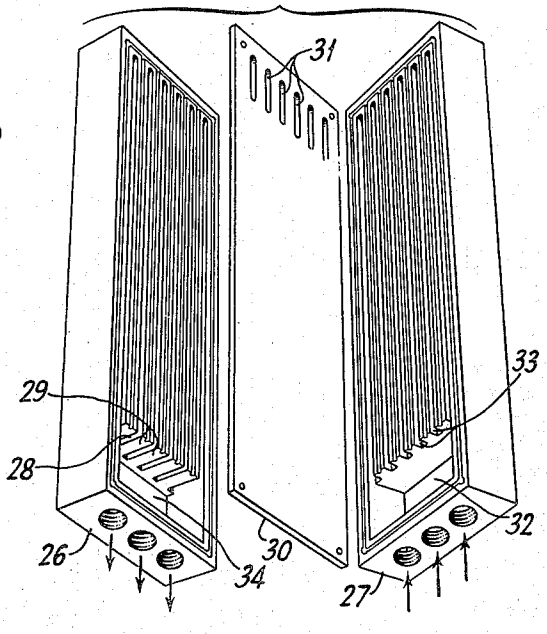


Fig. 6



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UNITED STATES PATENT OFFICE

2,227,039

HIGH POWERED ELECTRON DISCHARGE DEVICE

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Application February 28, 1939, Serial No. 258,868

13 Claims. (Cl. 250—27.5)

This invention relates to high frequency electron discharge devices, particularly devices for generating or amplifying ultra-short waves of considerable power.

To obtain ultra-high-frequency power for transmission purposes, it has been recognized that stable and efficient tube operation may be had only by properly isolating input and output circuits and electrodes. Neutralization of spurious oscillations in a triode by balancing condensers is impractical, and shielding an anode from a control grid in a tetrode with a screen grid becomes ineffective when the length of the screen structure becomes an appreciable percent of the operating wavelength since the screen cannot be held throughout its length at ground radio frequency potential. The ill effects of standing waves on the screen grid with attendant anode-to-control grid coupling becomes particularly bad when two tubes are set side by side for push-pull operation, since the two screen grids with their external connections become an oscillatory circuit and impose undesired resonant conditions on the tubes. Further, capacities between the electrode supporting structures of conventional transmitter tubes cannot because of their mass be held to reasonably low values.

Further the power output capacity of conventional tubes is limited. The maximum spacing between the cathode and anode is limited at ultra-high frequencies by the "transit time," or time of travel of electrons, as the operating frequency must be below the frequency at which the transit time becomes an appreciable percentage of the period of oscillation. The anode-cathode spacing then limits the size of the electrodes in tubes of conventional construction and limits the amount of power and heat that may be dissipated in the electrodes. Heretofore size limited electrodes and conventional cooling methods have prevented the use of tubes of the desired high power capacities and an even more serious limitation on the maximum power obtainable from ultra-shortwave transmitting tubes is the high grid temperatures.

It is an object of our invention to make an efficient electron discharge device adapted to deliver large amounts of ultra-shortwave power.

Another object of our invention is to construct a screen grid tube for ultra-shortwave operation in which the interaction between input and output circuits at ultra-high frequencies for practical purposes is absent or negligible.

A more specific object of our invention is a screen grid tube in which the screen grid may be held at zero radio frequency potential.

According to our invention two tetrode assemblies with planar electrodes are enclosed in one envelope with one emitter for both assemblies and with a single unitary screen grid structure for isolating the two control grids from the anodes. The screen grid struucture includes two planar screens comprising spaced parallel conductors attached to a common metal support to eliminate any potential difference between the two screens. Preferably the metal support is attached to and made electrically common with a metal enclosure or envelope for the electrode assemblies. The particular tube hereinafter described has an all-metal envelope to the inside wall of which is brazed a copper rod, upon which is clamped metal cross arms for carrying the wires of the two screens.

The emitter or cathode of our improved tube is of the filamentary U-shaped type comprising a relatively wide ribbon of refractory metal supported with the faces of the two sections of the ribbon parallel to planar grid and anode electrodes. The filament ribbon has a number of longitudinal grooves, channels or flutes, each groove being arcuate in cross section with the ridges between the grooves vertical and in alignment with the wires of the grids so that the curved faces of the grooves are in full view of the anode between the grid wires.

The characteristic features of this invention are specifically set forth in the appended claims and one embodiment of the invention is described in the following specification and the accompanying drawings in which Figure 1 is a perspective view, partly in section, of one tube embodying our invention, Figure 2 is a horizontal section of a tube constructed according to our invention and, except for the cathode support details, shows the elements of Figure 1, Figure 3 is an enlarged cross sectional view of the anode, grids and cathode of one tetrode section for beam forming, Figure 4 is a perspective detailed view, partly in section, of a cathode-control grid assembly constructed according to our invention, Figure 5 is a vertical section of the anode shown in Figure 1, Figure 6 is a view of the elements of the anode of Figure 1 expanded to show internal details of construction, and Figure 7 is a modified tube embodying our invention.

The envelope of the tube shown in Figures 1 and 2, constructed according to this invention, comprises a metal cylinder 1 flanged at each end and closed by metal plates or headers 2 and 3. Bushings 4 on the top plate electrically isolate and seal-in the cathode lead-in conductors 5 and 6, and control grid lead-in conductors 7 and 8 and relatively long glass bushings 9 at the bottom of the envelope seal-in and support the anode lead-in conductors 10 and 11. Depending centrally from the upper end of the envelope is the relatively wide ribbon-like filamentary cathode 12, the ribbon being bent into two parallel sections each section being formed with longitudinal vertical grooves, channels or flutes and joined at their

upper ends through metal terminal blocks 13 and 14 to the two cathode current supply electrodes 5 and 6. Opposite each outer face of the filamentary cathode and parallel therewith are control grids 15 and 16 and screen grids 17 and 18, and anodes 19 and 20. Each control grid comprises several parallel vertical wires arranged in a plane parallel to the plane of the filament ribbon and supported at either end upon metal arms 21 and 22 joined to the control grid lead-in conductors 7 and 8. Each screen grid comprises a number of parallel vertical wires arranged in a plane parallel to the control grid and joined at their ends to metal support arms 23 and 24 clamped to cross arms on the metal support rod 25 brazed at its upper end to the top plate 2 of the envelope. Each anode comprises a rectangular block of metal with internal fluid cooling ducts and is supported upon fluid cooling pipes communicating with the upper end of the anode lead-in conductors 10 and 11.

As best shown in Figure 3 the wires of the control grid and of the screen grid are lined up between the anode and cathode opposite the ridges of the cathode. In operation the field between the control grid wires and at the curved surfaces of the cathode flutes is such that the electrons leave normal to the surface of the cathode and form beams which pass between the spaced conductors of the control grids and of the screens and terminate on the anode. The number of electrons striking the grids is accordingly reduced to a minimum so that most of the heating of the grid wires is by radiation, and practically all of the energy of the space current is dissipated at the bombarded face of the anode.

Novel means is provided according to our invention to conduct away the heat generated at the face of the anode, it having been found that conventional methods of water cooling become ineffective where the energy dissipated per unit area is of the order of several hundred watts per square centimeter. In water-cooled anodes of the usual construction steam bubbles form in the water chamber opposite the bombarded face of the anode and effectively insulate the anode from the water. Hot spots may appear opposite the bubbles and holes are melted through. In some cases the bubbles accumulate, creating enough back pressure on the water pumps to impede the flow of water sufficiently to cause tube failure. The anode shown in Figures 3, 5 and 6 of the drawings substantially increases the area of contact between the anode and cooling medium, and has means for establishing uniform water flow against accumulations of bubbles. Our novel anode comprises a chamber fashioned from solid blocks of metal 26 and 27 chosen for good heat conductivity, such as copper. Conveniently, the two blocks of metal are milled throughout their length to make a number of parallel grooves, channels or fluid passages 28, each groove being defined by ribs 29 integral with the blocks. A metal separator 30 directs the fluid upward along one passage and downward in the registering passage in the opposite block as shown in Figure 5, the passages communicating through holes 31 in separator 30. The inlet pipes to the anode empty into a chamber 32 extending across the end of the anode. From this chamber the water flows through constrictions 33 into each of the channels and terminates in outlet chamber 34, each channel being considerably larger in cross section throughout its length than the construction at the inlet end. Any pressure which may be created by the generation of steam in the channel will thus be exhausted in the outlet pipes of the anode and because of the constriction will not prevent the in-flow of water to the inlet chamber. To most efficiently conduct the heat from the areas of the anode bombardment by the beams, it is preferred that the integral ribs be placed opposite the bombarded areas. Better heat conduction is thus insured from the face of the anode inwardly along the cooling ribs.

For a screen grid to effectively isolate an anode from a control grid it is necessary that the screen grid be held at zero RF potential and that standing or traveling waves be prevented on the screen grid. Any variation in potential of the screen grid caused by the anode is, through capacity coupling and through variation of space current, impressed upon the control grid and unstable and inefficient operation results. Tubes of conventional construction with lead-in conductors to the screen grids introduce the inherent lead-in inductance in the screen grid circuit and with the screen grid capacities make an oscillatory circuit which produces objectionable effects at high frequency. The screen grid constructed according to our invention has no lead-in conductor so that there can be no inductance between the two sections of the screen grid in the two tetrode assemblies. Each screen grid is clamped directly to the cross arms 35 of metal support rod 25, which is brazed or otherwise solidly connected to the enclosing metal envelope. The control grid proper is thus effectively shielded from the anode by the screen grid wires, and the control grid support members 7 and 8 are shielded from the anode preferably by metal partitions 36 extending the length of the envelope and, as best shown in Figure 2, are mounted on the metal wall of the envelope and extending radially inward with their inner edges in close juxtaposition with the edges of the screen grids.

For moderate power the cathode may comprise the unbraced ribbon shown in Figure 1. To brace the cathode against bulging or buckling caused by the magnetic field of the high filament current, a frame is placed around the edges of the filament as shown in Figure 4. The frame comprises two vertical water cooled metal columns 37 rigidly joined at their upper ends to block 14 and are held in fixed space relation at their lower ends by a transverse metal plate and heat shield 38. The cathode hangs freely between the two columns and is prevented from buckling outward by tie rods 39 fastened at their ends to pivoted arms 40 joined through insulating bushings 41 to cross plates 42 fixed to the columns. In this construction the lower end of the control grid may conveniently be guided in an insulating plate 43, such as a ceramic, parallel to and spaced below the cross plate. The cross plate, which effectively shields the insulator from heat and vaporized metal from the cathode, has enlarged holes to clear the side rods of the control grid which may slide freely in fitted holes in the ceramic. The cathode ribbon may be stiffened by forming inturned flanges 44 along its edges.

Our improved tube is particularly well adapted for connection in push-pull amplifier or oscillator circuits for ultra-high frequency currents of considerable power. The cathode of the two tetrode assemblies is common to the two assemblies and the distance between the two screen grids of the assemblies is a minimum which eliminates all inductance between the two screen grids and eliminates any possibility of

spurious oscillations and standing waves on the screen grids. Although the two tetrode assemblies are close together and their two cathodes common, interaction between the two assemblies is negligible. Stray radio frequency fields are grounded and output electrodes and control grids are isolated by the impervious shields brazed to the metal envelope. The two tetrode assemblies are accordingly shielded from each other and from all outside electrical disturbances.

According to a further feature of our invention the anode leads may be tuned to resonance at the desired frequency by a shorting bar placed across the leads, the transmission line extending outwardly from the shorting bar to a load circuit such as an antenna. In Figure 7 the shorting bar **45** is placed across the anode lead close to the anodes within the envelope. In the particular embodiment shown the bar is adjusted up and down on the anode leads by a threaded rod **46** extending through the lower plate of the envelope, a gas-tight seal being made by a conventional cup-shaped Sylphon bellows **47** joined gas-tight along its rim to the inner face of the header plate. The inner end of the threaded adjusting handle is joined to the bottom of the bellows cup through a journal which will move the bottom of the cup upwardly and downwardly with the adjusting rod. The shorting bar may be fastened in any desired way to the upper face of the bellows cup. The length of the oscillatory circuit and its resonant frequency is then determined by the lengths of the anodes, the shorting bar and the two conductors between the anodes and bar.

Good results have been obtained with a tube constructed according to our invention where the envelope is made of a copper cylinder about 7 inches in diameter and 8 inches long closed at each end with relatively heavy water-cooled copper header plates. The bombarded face of the anode is $1\frac{3}{16}$ inches by 5 inches and the cathode is a pure tantalum ribbon pressed from sheet stock .010 inch thick into the filamentary cathode shown with 5 longitudinal flutes. The cathode flutes are in cross section about .033 inch deep and .150 inch ridge-to-ridge, the bottom of the flutes being flattened and having a radius of curvature of .250 inch and merging at the sides into a curvature of .105 inch. The six wires of the control grid, preferably of tantalum or tungsten, are held in a plane parallel to the plane of the ribbon and spaced 0.112 inch from the ridges of the ribbon. Eight tungsten wires in the screen grid are aligned in a plane parallel with the control grid and are spaced from the control grid about 0.160 inch. All supporting members are of copper because of its good heat conducting properties. The anode is spaced from the screen grid about 0.250 inch. With two thousand volts on the plate and fifteen hundred volts on the screen grid, a current of 0.400 ampere per square centimeter may be drawn to the plate with tolerable grid bombardment. This current is about ten times greater than the current density tolerable in any existing conventional structure.

The high power capacity of our improved tube is due to a combination of features. The cathode flutes are so shaped in cross section that pronounced beam forming is obtained by the cathode alone. The beam formation is such that the control grid may be operated as high as 700 to 800 volts positive without exceeding the tolerable control grid current. The cathode flutes also have a much greater surface from which electron current can be drawn, as a consequence of which we obtain from two to five times as much current per unit area of grid as is available in existing conventional tubes with the same potentials on the elements. Furthermore, nearly all of this current arrives at the anode since the grid and screen absorption is so small, thus yielding a higher anode current per unit cathode emission. At 800 volts positive grid potential 1500 volts screen potential and 2000 volts anode potential, the grid current is between five and six percent of the space current and the screen current about ten percent, this is to be compared with some fifty or sixty percent grid current and a corresponding screen current in the conventional tubes. Few of the electrons in the beams, although strongly biased toward the edges of the beam because of the repulsive forces between the electrons, succeed in reaching the control or screen grid wires, since the anode is brought sufficiently close to the screen grid to exert a strong pull on the electrons and give them in effect less time to travel in a direction transverse to the beam and to the grid wires. Although the current densities in our improved tube are so high that for conventional electrode spacings and voltages the screen grid would be melted by its current, the entire stream of electrons in each beam reaches the anode face and is converted in the external circuits to useable power. Further, the closely spaced anode permits the complete entrainment of the beams to the anode without excessive anode voltages. In our improved tube, therefore, extremely dense space currents flow to the anode at relatively low velocities which contribute to the high electrical efficiency and ultimate power output of our improved tube.

An electron discharge device constructed according to our invention is simple in construction, easy to make and is adapted to deliver large amounts of ultra-shortwave power.

We claim:

1. An anode for an electron discharge device comprising a block of good heat conducting metal, a plurality of fluid channels extending through said block, an inlet chamber communicating through constricted orifices with the inlet end of said channels, and a second chamber communicating without constrictions with the outlet end of each channel for removing fluid from the channels.

2. An anode comprising a fabricated block of metal of good heat conducting material, a plurality of spaced fins in said block with channels through said block between said fins, an inlet chamber and an outlet chamber communicating respectively with the inlet and outlet ends of each of said channels, the passage between the inlet chamber and the channels being smaller than the passage between the outlet chamber and the channels.

3. An electron discharge device comprising a metal envelope, a planar cathode in said envelope, a planar anode on either side of said cathode, a planar control grid between said cathode and each of said anodes, and a planar screen grid between each of said anodes and each of said control grids, a metal rod along one edge of the cathode, said rod being joined at one end to said metal envelope, each screen grid being attached to said metal rod.

4. An electron discharge device comprising a

metal envelope, a cathode in said envelope, an anode on either side of said cathode and a separate control grid between said cathode and each of said anodes, and a screen grid between each of said anodes and each of said control grids, a metal rod, the sole support of each screen grid being said metal rod, said metal rod being supported on and electrically connected to said metal envelope.

5. A cathode assembly comprising two metal closely spaced terminals, a ribbon-like filamentary cathode folded with the two legs of the filament parallel and with the ends of the cathode connected to said terminals, a hollow metal column parallel with and in close spaced relation to each of the edges of said legs, said columns being mechanically supported by one of said terminal blocks, means for preventing distortion of said ribbon comprising a transverse rod pivotally attached to said columns through electrical insulating means.

6. An electron discharge device comprising a cathode assembly with two metal terminal blocks supported upon lead-in conductors, a planar cathode supported by said blocks, a mechanically strong column extending along each edge of said cathode and supported by said blocks, an insulating plate connected to the one end of said columns, a grid electrode parallel to the filament connected to and supported at one end by a lead-in conductor and slidably guided at its other end in holes in said insulator.

7. An electron discharge device comprising a metal envelope consisting of a metal cylinder closed gas-tight at each end with a metal plate, a filamentary cathode of the U-shaped type formed from a relatively wide ribbon of electron emissive metal, the filament being connected at its ends to lead-in conductors, a control grid opposite and parallel to each emitting face of the cathode and supported upon a separate lead-in conductor, a screen opposite each filament face, each screen being connected to a common metal support attached to one of said metal plates, an anode opposite each filament face supported upon lead-in conductors insulating sealed gas-tight through one of said metal plates, and a metal shield between each anode and the adjacent control grid lead-in conductor, each shield being supported by the metal envelope.

8. An electron discharge device comprising a plurality of side-by-side fluted emitting surfaces, a grid wire parallel to and spaced opposite each ridge between the flutes and an anode for collecting the electrons from said flutes comprising a block of metal with one surface parallel to said cathode and grid wires, and heat conducting ribs on the interior of said block integral with the electron collecting surface of said block and opposite said flutes.

9. An anode comprising a body of good heat conducting metal having an electron collecting surface, a plurality of passsages extending through the body to cool the body, a chamber communicating with the inlet end of each of the passages, a second chamber communicating with the outlet end of each of the passages, the inlet end of each passage being smaller than its outlet end.

10. An electron discharge device comprising a metal cylinder, a metal plate hermetically closing each end of the cylinder, two metal tubes extending through and insulatingly sealed gas-tight in one of said plates, a cathode having a plurality of side-by-side flutes, said cathode being supported at its ends on said tubes, a control grid having a wire spaced from and opposite each ridge between said flutes, a third metal tube insulatingly sealed into one of said plates and joined to the ends of the control grid wires, a screen grid having a wire spaced from and opposite each of said ridges and in alignment with a control grid wire and a cathode ridge, said screen grid being supported directly upon and electrically connected to one of said plates, a rectangular metal block in said cylinder with one side parallel to and facing upon the flutes of said cathode and having internal fluid cooling passages, a fourth tube insulatingly sealed into one of said plates, the interior of said third tube communicating with said passages.

11. An electron discharge device comprising a metal cylinder, a metal plate closing each end of said cylinder, a first and a second lead-in conductor insulatingly sealed into one plate, a U-shaped filamentary cathode having side-by-side flutes extending longitudinally of said cathode and supported at its ends on the inner ends of said conductors, a control grid on opposite sides of said cathode, each control grid having a wire parallel to and opposite each ridge between said flutes, a third and fourth lead-in conductor insulatingly sealed into one of said plates, the inner ends of the third and fourth conductors being joined to the ends of said control grid wires, a screen grid on opposite sides of said cathode, each screen grid having a wire parallel and in alignment with each of said ridges and corresponding control grid wires, a fifth conductor mechanically and electrically joined to one of said plates, each of said screen grids being supported upon the last mentioned conductor, a rectangular block of metal on each side of said cathode, each block having one side parallel to said cathode and having internal fluid cooling passages, two tubes insulatingly sealed into one of said plates, each tube supporting one of said blocks and communicating with said passages.

12. A cathode assembly comprising two metal terminal blocks electrically insulated from each other and fastened together, a relatively wide ribbon of electron emissive metal, said ribbon being folded into two parallel spaced planar portions, flat parallel portions of said blocks extending between the ends of said ribbon and the ribbon being connected across each end to one of said blocks, and parallel beam forming channels formed longitudinally of each of the planar portions of said ribbon, said grooves terminating at their ends adjacent the blocks.

13. A filamentary cathode comprising two spaced parallel side-by-side rectangular sheets of metal ribbon electron emissive on their outer surfaces at elevated temperatures, said sheets being electrically connected and mechancally joined across one end by a short section of the ribbon, said sheets being electrically insulated and mechanically joined at their other ends by support and current supply means comprising two rectangular blocks of metal insulatingly secured together inserted between and connected to said other ends of the sheets, said other ends of the sheets being held throughout their width in good electrical and mechanical contact with said blocks.

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