

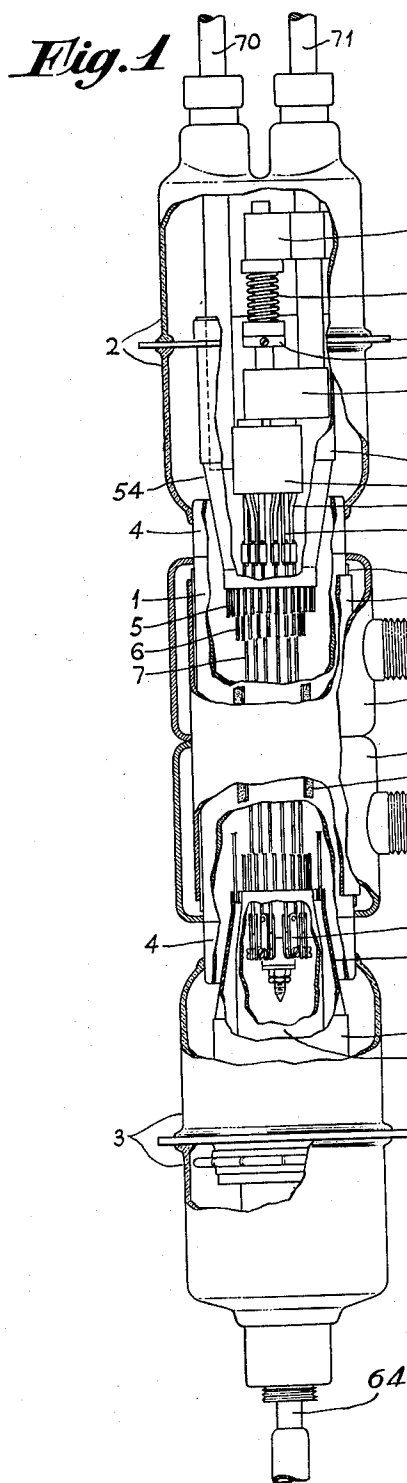
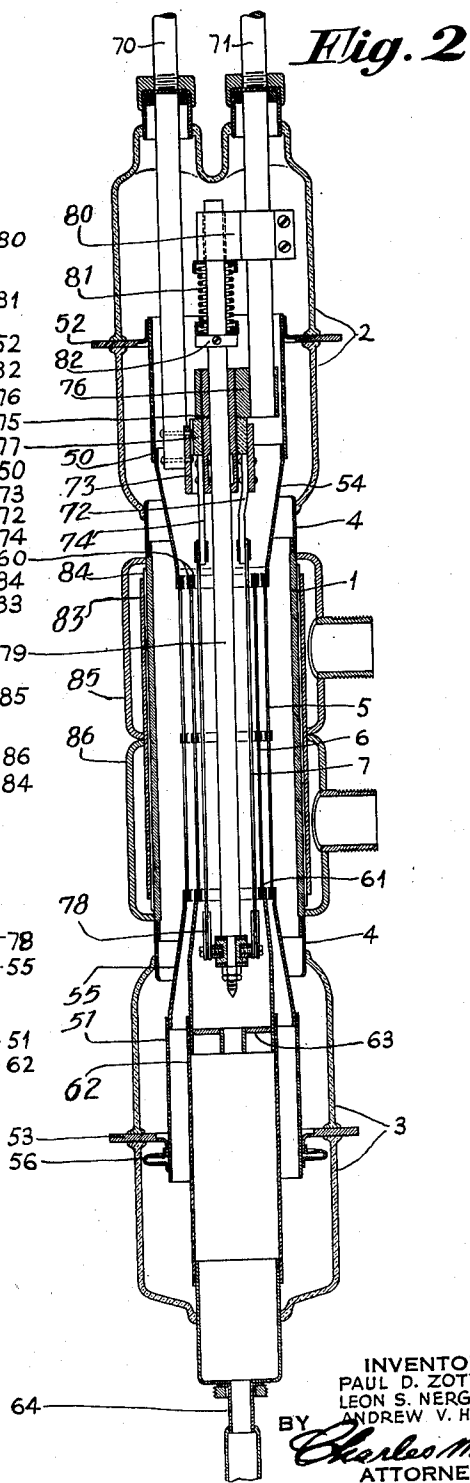
April 12, 1938.

P. D. ZOTTU ET AL
HIGH FREQUENCY POWER TUBE

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2 Sheets-Sheet 1



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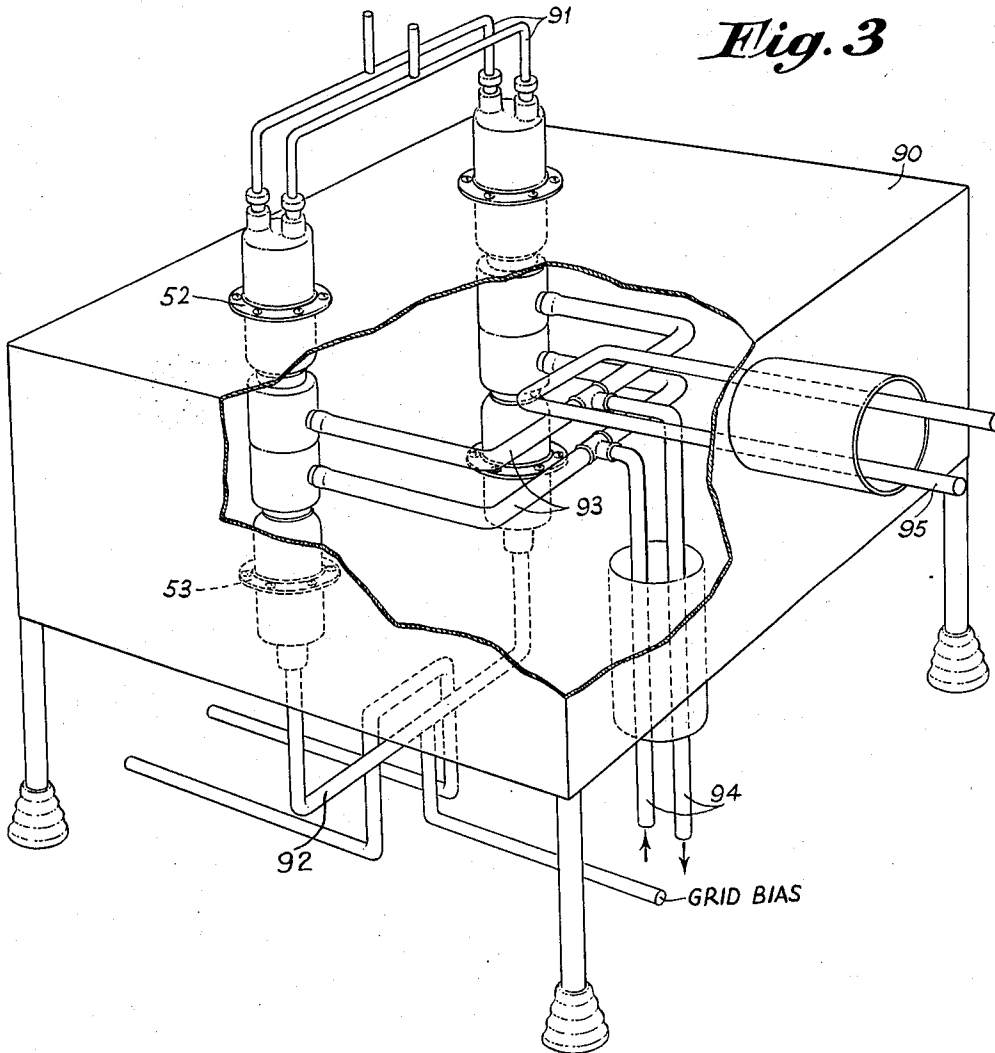
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Fig. 3



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HIGH FREQUENCY POWER TUBE

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7 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.

5 Since interelectrode capacities of electron discharge devices for use at ultra-high frequencies must be very small, and because these capacities increase with increase in dimensions of the electrodes, the electrodes of tubes of conventional construction for short-wave use are limited in size, which of course limits the permissible power dissipation. Further, 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.

20 Transmitters for ultra-high frequencies, such as generators of television signals where the bandwidth of the signal modulated carriers may be quite wide, require broadly tuned resonant circuits of low impedance. For efficient operation, the tubes connected to the tuned circuits must be of correspondingly low impedance with a highly emissive cathode as well as a short anode-cathode space to obtain high space current at low voltage. High cathode temperatures and high voltage space current produce considerable heat in the tube and aggravate the problem of power dissipation in the size-limited electrodes.

30 Because of the very close electrode spacing required in ultra-short wave tubes, effective isolation to electrostatic interaction of input and output electrodes is particularly important. The usual screen grid for neutralizing interelectrode capacities is impractical because the inductance and resistance of the electrode and its lead-in wire are sufficient at ultra-high frequency to generate troublesome screen grid voltage variations and standing waves. Further, conventional shields are inadequate to properly isolate the electromagnetic and electrostatic lines of force of the several tuned circuits of a high power ultra-short wave tube. For example, at these frequencies the coupling between even short lengths of lead-in wires in the wall of the envelope is sufficient to cause erratic and inefficient operation.

50 It is an object of this invention to make an efficient electron discharge device adapted to deliver large amounts of ultra-short wave power.

55 A further object of this invention is to construct a screen type of tube for ultra-short wave operation in which interaction between input and

output circuits is effectively reduced at ultra-high frequencies.

A still further object of our invention is to construct a tube which in combination with simple shielding means may completely isolate one electrode and its connected circuits from other electrodes and their connected circuits.

Ultra-short wave tubes capable of amplifying several kilowatts of power at a wave length of the order of two and one-half meters and constructed according to this invention comprise a cylindrical cathode with concentric control grid and anode so dimensioned as to give maximum output at the operating frequency with optimum low output impedance. To shield the control grid from the anode, a cylindrical screen grid is interposed in the annular space between these electrodes and is supported at each end by coaxial tubular members impervious to electrostatic fields attached at their ends to opposite ends of the screen grid structure. The rim of the outer ends of the screen grid supporting tubular members are attached to annular lead-in rings extending radially through and sealed gas-tight in insulating sections of the envelope with the outer edge of each ring concentric with and extending outward from the envelope. A control grid assembly and a cathode assembly are each held in spaced concentric relation inside the screen grid by the insulating sections at opposite ends of the envelope. By attaching conventional shields to the outer edges of the two screen grid lead-in rings, the shields may be extended outwardly to completely enclose and electrically isolate the individual circuits connected to the anode, to the control grid, and to the cathode. These shields may be easily grounded and, if desired, may be employed to mechanically support the tube. One characteristic feature of this invention is the impervious continuity of electrostatic and electromagnetic shielding means from the ends of the screen grid electrode to the circuit-isolating shields outside the tube.

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 in the accompanying drawings in which:—

Figure 1 is a view of an assembled tube embodying this invention with parts broken away to show details of construction;

Figure 2 is a longitudinal sectional view through the center of the tube shown in Figure 1; and

Figure 3 is a perspective view of one means

for mounting and electrically connecting circuits and tubes of this invention.

The envelope of the tube shown in Figures 1 and 2, constructed according to this invention, comprises a cylindrical metal anode 1 closed gas-tight at its ends by cylindrical glass end sections or bulbs 2 and 3 joined coaxial with the anode by sealing rings 4 of a metal which readily wets with glass and also welds or brazes with the metal of the anode. Within the anode are concentric screen grid 5, control grid 6, and cathode 7, the cathode comprising a plurality of straight parallel heater wires arranged in a cylindrical plane concentric with the anode and attached at their ends to means, hereinafter more fully described, for keeping the wires taut and in insulating spaced relation to the other electrodes in the tube. Supporting and tensioning means for the filament wires are carried by relatively heavy lead-in conductors 70 and 71 sealed gas-tight preferably through collars in the outer end of the upper glass bulb 2. The parallel wires of the control grid are cylindrically arranged and attached at their ends to round collars 60 and 61, the lower collar being welded to the end of a tubular support 62 sealed at its outer end in the lower glass bulb 3 to support the wire grid concentric with the circle of heater wires. Because of the successive heat dissipation in this tube it is preferred the grid wires and their adjacent supporting members be made of some refractory metal such as tantalum.

The usual screen grid between the anode and the control grid for electrostatically shielding the input and output electrodes of a tube operating at ultra-high frequencies has been found to have excessive impedance between the ends of the screen grid and in the lead-in wire to the screen grid, the inductance and resistance of the screen grid element and its leads being sufficient in some cases to cause voltage variation, standing waves, spurious oscillations, and highly inefficient operation. To minimize the impedance of the screen grid throughout its length, it is constructed according to this invention of straight wires longitudinal of and parallel with the axis of the anode and like the control grid and cathode are arranged in a cylindrical surface concentric with the other electrodes. To reduce the impedance of the lead-in conductors for the screen grid and to completely isolate the cathode and control grid lead-in conductors from the anode and its circuits screen grid supporting means constructed according to this invention and as shown in Figures 1 and 2 comprise tubular supporting members 50 and 51 attached at their inner ends to collars on the ends of the grid wires and supported at their outer ends in concentric spaced relation to the envelope by annular screen grid lead-in rings 52 and 53, each ring being sealed in the glass with its outer edge extending radially outward from the envelope. In the embodiment shown, the upper tubular supporting member 50 is attached preferably by welding to an up-turned flange on ring 52, the lower end tubular member 50 and the upper end of the screen grid being connected by a metal cone 54. Tubular supporting member 51 at the lower end of the tube is attached to the lower end of the screen grid through a conical piece 55 and is slidably journaled in the flange of lead-in ring 53 to permit longitudinal expansion of the screen grid. To permit the free longitudinal movement of the lower screen grid tubular support through the lead-in ring 75 and at the same time electrically bond the tubular

support throughout its periphery to the lead-in ring, an annular bellows type of connector 56 is attached by welding one end of its fold to the flange of the ring and the other end of its fold to the tubular screen grid support. The tubular support means between the ends of the screen grid and the lead-in rings 52 and 53 make the high frequency impedance between the screen grid and its external connectors practically negligible, and provide impervious continuity of electrostatic and electromagnetic shielding between the anode and the cathode and control grid electrodes and lead-in wires. The electromagnetic coupling between alternate cylinders of a series of coaxial cylinders is zero. Conventional shields attached to the outer edges of the two screen grid lead-in rings may be used, if desired, to completely enclose and electrically isolate the individual circuits connected to the anode, to the control grid, and to the cathode, these external shields being conveniently connected to a direct current screen grid biasing source. One means of shielding and supporting this novel tube will more fully be hereinafter described in connection with Figure 3.

Because of the low space impedance and high power dissipation required in this novel tube, the cathode is constructed according to this invention of a plurality of closely spaced parallel filament wires to form a substantially cylindrical surface of electron emitting material, all points of which are radially spaced an optimum distance from the anode. To minimize high frequency impedance between the ends of the heating circuit of the cathode and to keep the direct current heating voltage within the desirable limits, a plurality of parallel circuits are provided, six circuits being shown by way of example in the tube chosen for description, each circuit comprising a U-shaped heater wire joined at its ends to current supply supporting fingers and the transverse section or bight of the heater wires being insulatively held at the end of a central support rod for tensioning the filament wires. The means for tensioning and supporting the several filament wires is so constructed according to a further feature of this invention that it is easily assembled and mounted in the end of the screen grid supporting tubular member where it is effectively shielded from anode electrostatic influences.

One end of each of the U-shaped filaments is attached as by welding to evenly spaced inwardly curved fingers 72, the inner ends of which terminate in the cylindrical surface and the outer ends of which are secured to a cylindrical collar 73, which in turn is carried by rivets upon the inner end of lead-in conductor 70. The other end of each of the U-shaped filaments is connected to a second set of fingers 74 attached to tubular collar 75, which in turn is welded or brazed to bracket 76 carried on the inner end of the other lead-in conductor 71. Collars 73 and 75 are held in concentric spaced relation by an insulating refractory collar 77, preferably ceramic. The wires of the filament are held taut by pulley-like anchors 78 engaging the bights of the several filaments and insulatively secured to the lower end of relatively heavy central support rod 79 journaled at its upper end in tubular collar 75 and bracket 80 secured as by rivets to lead-in conductor 71, the collar and bracket being spaced apart to hold rod 79 centrally in the anode. The central support rod is biased downwardly to tension the filament wires by spring 81 bearing at one end against bracket 80 and at the other 75

against a collar 82 attached to the rod. The filament assembly constructed according to this invention is not only particularly adapted for mounting in this novel tube but is rugged in construction with the heavier parts of the supporting and tensioning means, including spring 81, removed from the source of heat of the filament.

The relatively large amount of heat generated in the size-limited anode of this ultra short-wave high powered tube is dissipated according to this invention by a novel fluid cooling system for the anode. It has been found that a relatively thin sheet of fast moving water will carry away from the anode more heat than a larger body of slow moving water. A thin sheet of cooling fluid is conveniently directed longitudinally of anode 1 between the wall of the anode and the inner surface of a cylindrical jacket 83 slightly larger in diameter than the anode and spaced therefrom by thin strips of metal 84 attached to the anode parallel to the axis of the tube. Cooling fluid, such as water, is admitted at a uniform pressure, for example at the upper end of the channels formed between the metal strips and the walls of the anode and cylinder from a chamber conveniently constructed by a housing 85 fitted over the end of the anode brazed at one end to the anode beyond the end of cylinder 83 and brazed at its other end to the wall of cylinder 83. A conjugate housing 86 is fastened by brazing to the other end of the anode and to the center section of the cylinder to receive the water exhausted from the lower end of the channels. Water inlet and outlet nipples are attached to the two housings for connection to any suitable cooling system.

Figure 3 shows by way of example one method of mounting and electrically connecting two tubes constructed according to this invention for push-pull operation as an ultra high frequency amplifier. The upper and the lower screen grid lead-in rings 52 and 53 are, respectively, clamped or bolted, preferably through flexible flanges, to the upper and lower plates of a box-like metal shield 90. Direct current filament supply leads 91, preferably about one-half a wave length long, are connected at their ends to the filament terminals of the tubes and connected at their center, the nodal point of standing waves, to the direct current filament supply. The grids, likewise, are tuned by a conductor 92 some value less than one-quarter of a space wave length, or a multiple thereof with the center of the conductor connected to a grid biasing source, the grid conductor being inductively coupled to any desired exciting potential by the loop of a Lecher wire. The inlet and outlet nipples on the water cooling jackets of the anodes are connected through tubular metal conductors 93 at the center of which are cooling fluid connections 94, which may extend downwardly through an opening in the shielding box. Direct current energizing potential for the anodes is preferably applied at the electrical center of conductors 93. A high frequency output circuit may conveniently comprise a conductor 95 coupled as shown to the anode coupling conductors 93 and extend outwardly through an opening in this side of the shield. While the weight of the tubes may be carried by flanges 52 and 53 in the shielding box it may be desirable to mechanically support the tubes by the water pipe connections to the anodes suitably attached to the nodal point on the anode conductors. The grid circuit may, alternatively, be tuned by an exterior extension

beyond the seal of the control grid supporting tubular member 62, Figures 1 and 2, the extension being of such a length that the grid circuit may be tuned by the long line or Lecher wire principle and its end connected to an exhaust pump to continually exhaust the tube during operation, the tube being of such a size that sudden evolutions of gas within the tube may be quickly drawn off to protect the electrodes from overheating. The supporting tubular members may be perforated to permit the free egress of gases from all parts of the envelope to the exhaust pump.

The tube described and shown in Figures 1 and 2 is particularly easy to assemble in manufacture. The anode with its water jackets in place is first sealed at its ends to collars 4 of a metal commercially known as "Fernico". Glass rings of the diameter of the bulb are sealed to each side of each of the annular screen grid lead-in rings and to collars 4. Each ring is then fused by fires to the glass rings on the anode. The pre-assembled screen grid assembly including the screen grid collars and their end cones 54, 55 and tubular members 50 and 51 are then inserted in the anode and an annular weld is made between 50 and the flange of ring 52 and annular expansion bellows 56 is welded to ring 53 and to tubular member 62. Next, the control grid with a glass cup comprising the lower half of the lower bulb sealed to tubular support 62 is inserted in the anode and the rim of the cup sealed to the ring of glass on screen grid lead-in ring 53, the free or upper end of the control grid being held in center by a jig. The control grid jig is then removed and the complete cathode assembly is inserted in the other end and its glass cup with its filament lead-in seals joined ring 52, the lower end of the filament assembly being engaged and centered by a tool inserted through an opening in the end of the control grid supporting tube and a centering collar 63 having a machined hole to accurately center said tool on the axis of the envelope. The opening in the lower end of the control grid tubular member may conveniently be closed by an exhaust nipple 64 for evacuating the envelope. Upon completion of the sealing of the filament assembly at the upper end, the tool may be removed and exhaust nipple 64 used for exhausting the tube. Around the exhausting tubulation may be secured a threaded collar upon which, after tip-off, a cup-shaped cap may be screwed to protect a glass tip and serve incidentally as a connector for the control grid.

With a tube constructed according to this invention with an anode about 15.5 centimeters long and 7.2 centimeters internal diameter and with the screen grid, the control grid and the cathode cylinders respectively about 4.2, 3.2 and 2.4 centimeters in diameter, and with the total filament current of 440 amperes through six parallel circuits at 16.4 volts, about 5. kilowatts of unmodulated carrier wave at about 2½ meters may be delivered. From tests it has been determined that the anode to screen grid capacity of this tube is about 33.7 m. m. f., that the anode to control grid capacity is about .31 m. m. f., that the current absorption of the control and screen grids are respectively about 6 amperes and 4.6 amperes, and that the plate current is about 20.5 amperes at a potential of about 9,000 volts.

Since many modifications may be made in the structural details of this novel tube and in the

method of mounting and applying it in service without departing from the scope of this invention it is desired that this invention be limited only by the prior art and the scope of the appended claims.

We claim:

1. An electron discharge device comprising a cylindrical anode, a glass bulb sealed gas-tight to each end of the anode, filament lead-in conductors sealed in one end of said bulb, a cathode, means on the inner end of said conductors for positioning and tensioning filamentary heater wires of said cathode concentrically inside said anode, a screen grid concentric with said cathode and supported at each end by tubular members joined along their rims at one end to the ends of said screen grid and at their other ends to metal rings extending radially through and sealed gas-tight in said bulbs, and a control grid concentric with tubular supporting means at its end sealed gas-tight in the end of said other bulb.
2. An electron discharge device comprising an anode sealed at one end with a bulb, filament lead-in conductors sealed in the end of said bulb removed from said anode, a plurality of parallel filament wires cylindrically arranged concentric with said anode, means on the inner end of said conductors for supporting and tensioning said filament wires, and means for electrically shielding said filament supporting and tensioning means from electrostatic fields of said anode comprising a metal ring extending radially through and sealed gas-tight in said bulb intermediate the ends of the bulb a substantial distance from the anode and the filament wires and a tubular member joined at one end to said ring and attached along its rim at its other end to a screen grid concentrically between said anode and said filament wires.
3. An electron discharge device comprising a cathode assembly with two parallel lead-in conductors, two coaxial metal collars attached to the ends of said conductors and held in insulating spaced relation by an insulating bushing between said collars, a plurality of U-shaped filaments, one end of each filament being attached and supported by one of said collars, the other end of each of said filaments being attached and supported by the other of said collars, means for tensioning said filaments comprising a support rod slidably journaled in the smaller of the coaxial collars, means for insulatingly supporting the transverse section of each of said filaments on the end of said rod, and spring means for biasing said rod longitudinally through said collar comprising a bracket on said one of said conductors, a compression spring attached at one end to said rod and bearing at its other end against said bracket.

4. A discharge device for amplifying several kilowatts of ultra high frequency power comprising a cylindrical cathode with concentric control grid, screen grid, and anode, cylindrical glass bulbs coaxial with and sealed gas-tight to opposite ends of said anode, metal tubular members, said cathode and said control grid being supported in opposite bulbs and the screen grid being supported by said metal tubular members attached at their ends to opposite ends of the screen grid and their outer ends attached to annular lead-in rings extending radially through and sealed gas-tight in the bulbs intermediate the ends of the bulbs.

5. An electron discharge device comprising a cylindrical anode, glass bulbular sections sealed gas-tight to opposite ends of said anode, two metal tubular members, two metal rings, a grid electrode concentric with said anode and supported at one end on the end of one of said metal tubular members, the other end of the metal member being peripherally attached to one of said metal rings extending radially through and sealed gas-tight in one of said bulbs, the other end of said electrode being supported on the end of a second of said metal tubular members the other end of said second member being slidably journaled in the second of said metal rings which extends radially through and is sealed gas-tight in the other of said bulbs.

6. An electron discharge device comprising a cylindrical anode with an insulating bulbular section sealed gas-tight to one end, a metal tubular member in said section, an annular lead-in ring, a cathode electrode and a control electrode concentric inside said anode, a screen grid between said electrodes and said anode attached at one end by one end of said metal tubular member, the other end of said tubular member engaging said annular lead-in ring which extends radially through and is sealed gas-tight in the wall of said bulb, and an exterior metal plate extending transversely of said tube and attached peripherally to the outer edge of the ring.

7. A cathode assembly comprising two parallel lead-in conductors, two coaxial metal collars attached to the ends of said conductors, a central support rod slidably journaled through said collars, a plurality of U-shaped filaments, the ends of said filaments being attached to said collars and the bight of said filament being insulatingly supported on the end of said rod, and spring means for biasing said rod longitudinally through said collars for tensioning said filaments.

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