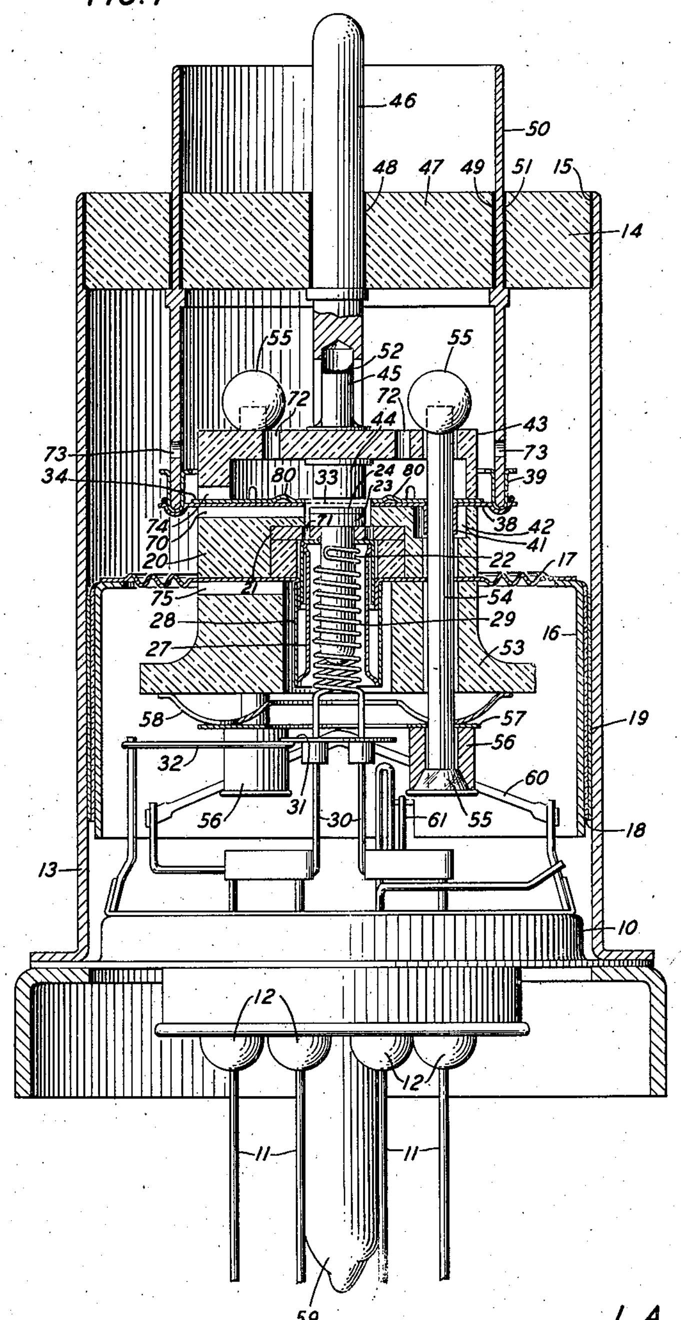
April 4, 1950 J. A. MORTON ET AL 2,502,530

ELECTRON DISCHARGE DEVICE FOR ULTRA HIGH FREQUENCIES

Filed Jan. 13, 1945 2 Sheets-Sheet 1

FIG. 1



INVENTORS: J. A. MORTON
R. L. VANCE
BY
Walter C. Kiesel
ATTORNEY

FIG. 2

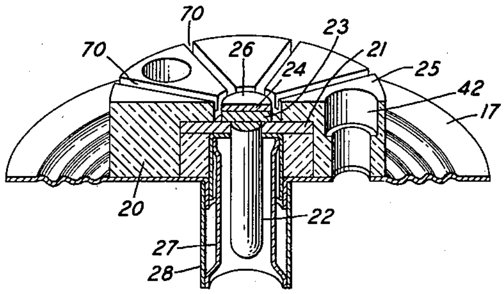


FIG. 3

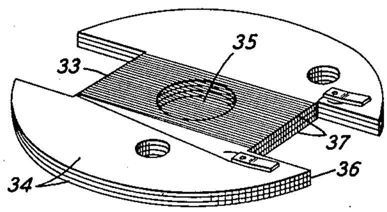


FIG. 4

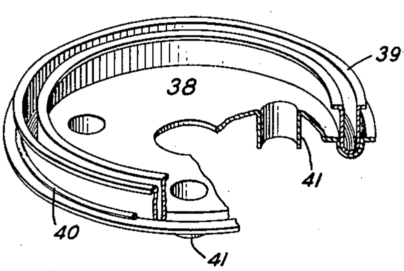


FIG. 7

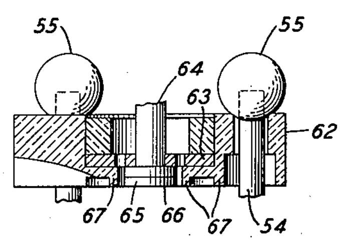
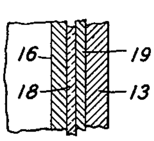


FIG. 6



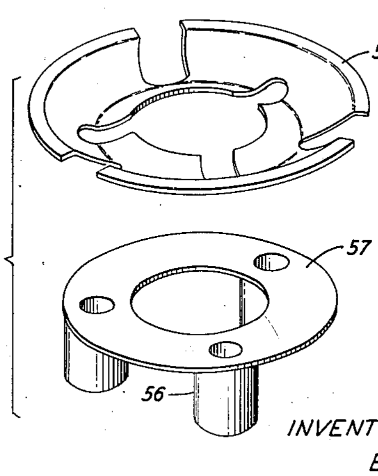


FIG. 5

INVENTORS: J. A. MORTON
R. L. VANCE
BY
Walter C. Kiesel
ATTORNEY

Patented Apr. 4, 1950 2,502,530

UNITED STATES PATENT OFFICE

2,502,530

ELECTRON DISCHARGE DEVICE FOR ULTRA HIGH FREQUENCIES

Jack A. Morton, Neshanic Station, and Robert L. Vance, Westfield, N. J., assignors to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application January 13, 1945, Serial No. 572,596

18 Claims. (Cl. 315—39)

1

This invention relates to electron discharge devices for ultra-high frequencies and more particularly to such devices including one or more grid electrodes between a cathode and an anode and especially suitable for operation at ultra-high frequencies, for example frequencies of the order of 3000 megacycles.

The performance of devices of the type noted above is dependent upon both the parameters of the elements defining the interelectrode regions and those of the coupling or transducer system between the interelectrode regions and the external circuit associated with the device. More particularly, the operating characteristics, such as gain, band width and signal-to-noise ratio and the upper limit of the operating frequency range are dependent largely upon the magnitude and uniformity of the cathode to grid and grid to anode spacings, the fineness and regularity of the grid, and the magnitude of the variations, due to temperature effects, in the electrode relationships during the operation of the device. Desiderata for the interelectrode regions from the standpoint of high gain, wide band width and large signal to noise ratio and a high limit for the frequency range over which these obtain, are small, accurate and uniform electrode spacings and the close maintenance of such spacings during operation of the device.

The coupling or transducer system between the interelectrode regions and the terminals of the device, that is, the external portions of the cathode, grid and anode leading in conductors to which the external circuits are connected, is of import from the standpoint of performance of the device in that it largely determines the conditions at these terminals for any particular conditions at the electrode regions. That is to say, it determines, in effect, to what extent the desirable electronic conditions at the electrode regions within the device are or may be available or utilizable at the terminals. This coupling or transducer system, therefore, should be such that the losses therein and effect upon band width thereof are small and, further, that good impedance transformation between the electrode regions and the external terminals is provided.

One general object of this invention is to obtain improved operating characteristics for electron discharge devices and particularly for ultra-high frequency devices of the type having a control grid interposed between a cathode and an anode.

More specifically, objects of this invention are to:

2

Realize high gain, wide band width and large signal-to-noise ratio in ultra-high frequency electron discharge devices;

Attain extremely small, highly accurate and very uniform spacings between the electrodes, specifically between the cathode and grid and grid and anode, in such devices;

Minimize the effects of temperature upon these spacings;

Facilitate the fabrication of electron discharge devices having closely spaced electrodes;

Enable substantially full utilization at the external terminals of an electron discharge device, of the desirable electronic characteristics at the interelectrode regions of the device; and

Minimize losses in and reactive transducer effects of a coupling system between the electron stream of an electron discharge device and an external circuit associated with the device.

In one illustrative embodiment of this invention, an electron discharge device comprises a cathode, control electrode or grid and anode, the effective surfaces of which are planar and parallel and of comparable over-all dimensions.

In accordance with one broad feature of this invention, the electrodes are constructed and arranged so that electronic conditions highly conducive to high gain, substantial band width and large signal-to-noise ratio are obtained at the interelectrode regions and the elements of the coupling or transducer system for associating the electrodes with external circuits are correlated to affect transformation without substantial degradation of the conditions mentioned to the external terminals of the device.

More specifically, in accordance with one feature of this invention, the effective electrode surfaces are constructed and mounted to provide extremely small and uniform spacings thereof which are maintained with high accuracy during the operation of the device, and the coupling system is constructed to provide a smooth geometrical and electrical transition from the electrode regions to the external circuit. In one particular construction, this system is constructed to define a double coaxial line terminating at one end in the electrode surfaces and characterized by low loss and parasitic capacitances, minimum reactive transducing effects and a very high surge impedance of the grid-anode region.

In accordance with another feature of this invention, the cathode or anode, or both, is mounted on a support member having a seating surface accurately coplanar with a face of the respective electrode, whereby each surface may be utilized as a reference for determining the spacing between a pair of electrodes. In a specific and illustrative construction, the support member is of a material, such as a low loss ceramic, having a low temperature coefficient, the electrode, i. e., anode or cathode, is fixed upon the support as by molding therein, and the electrode face and one face of the support member are lapped simultaneously to make them accurately coplanar, for example within the order of 0.2 of a mil.

In accordance with another feature of this invention, the grid assembly comprises a frame of prescribed thickness to one face of which a planar grid, formed of extremely fine wires, is affixed, and the aforenoted surface of the anode support is seated upon the other face of the frame whereby the thickness of the frame determines the spacing between the anode and the grid.

In accordance with a further feature of this invention, the grid frame is seated upon a spacer resting upon the lapped face of the cathode support, the spacer being of a thickness to provide the desired spacing between the grid and a flat thermionic coating upon the lapped face of the cathode.

In accordance with still another feature of this invention, the electrodes, the supports therefor and the spacer aforenoted are fabricated as a unitary assembly wherein the elements are in stacked relation and are locked together by rivets of a material, such as a low loss ceramic, having a low temperature coefficient.

In accordance with a still further feature of this invention, the unitary assembly above mentioned is provided with a cylindrical metallic member having a glaze or coating upon its outer face and adapted to fit slidably within a metallic cylindrical wall portion of the enclosing vessel of the device, the cylindrical member being connected electrically to the cathode and together with the glaze or coating and the cylindrical wall portion defining a by-pass condenser.

The invention and the above noted and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing in which:

Fig. 1 is an elevational view mainly in section of an electron discharge device illustrative of one embodiment of this invention;

Fig. 2 is a perspective view showing details of the cathode assembly included in the device shown in Fig. 1;

Fig. 3 is a perspective view illustrating the grid electrode construction and one method of fabricating this construction;

Fig. 4 is another perspective view showing the construction of the cathode to grid spacer member;

Fig. 5 is a detail view in perspective illustrating the retainer ring and associated resilient member forming a part of the electrode assembly in the device shown in Fig. 1;

Fig. 6 is an enlarged, fragmentary sectional view showing details of the by-pass condenser included in the device illustrated in Fig. 1; and

Fig. 7 is a detail view in section of a modification of the anode assembly.

Referring now to the drawing, the electron discharge device illustrated in Fig. 1 comprises a highly evacuated enclosing vessel including a base 10 through which there extend a plurality of leading-in conductors 11 which are sealed

hermetically to the base by vitreous beads 12. The vessel comprises also a flanged, metallic cylindrical portion 13, the flange on which is sealed to the base 10, as by welding or brazing, and the other end of which is closed in part by a dielectric, such as a glass or ceramic disc 14 hermetically sealed to the cylindrical portion 13 along the adjoining surfaces as at 15, by metallic or vitreous bonding material.

Mounted within the enclosing vessel is a unitary electrode assembly comprising a flanged, cylindrical metallic member 16 having an annular, concentrically corrugated, metallic diaphragm 17 affixed thereto, the diaphragm advantageously being of a material, such as "Invar," having a very small thermal expansion and conduction coefficient. The cylindrical member 16 has thereon a thin glaze or coating 18 of a ceramic, and the coating has thereon a thin metallic coating 19, for example of silver. The outer diameter of the coating 19 is such as to fit closely against the inner wall of the cylindrical portion 13 of the enclosing vessel. The cylindrical member 16, coating 18 and portion 13 constitute a cylindrical condenser the function of which will be pointed out hereinafter.

Seated against the diaphragm 17 is an insulating disc 20, advantageously of a ceramic, which mounts a cathode assembly comprising, as shown clearly in Fig. 2, a metallic disc 21, for example of platinum, a stem 22, for example of molybdenum, suitably secured to the disc 21, and having an enlarged head portion 23, and a disc 24, for example of nickel, welded to the head portion 23. In the fabrication of the cathode assembly, the disc 21 is molded in the disc 20, the surfaces 25 and 26 of the insulating and cathode discs 20 and 24 respectively are lapped simultaneously by a suitable abrasive, for example silicon carbide, to be essentially coplanar, for example within .0002 inch, and a thermionic material subsequently is applied to the lapped surface 26 to form a coating of prescribed and uniform thickness, e. g. of the order of ½ to 1 mil.

The cathode assembly includes also a cylindrical metallic heat shield assembly 27 which is joined to the disc 21 and to a cylindrical, metallic member 28 depending from the diaphragm 17. The cathode stem 22 is closely encompassed by a helical heater filament 29, such as a tungsten wire coated with an insulating material, the ends of the heater filament being joined to conductors 30 in turn joined to certain of the leading-in conductors 11. The conductors 30 mount a metallic heat reflecting shield 31, which is provided with oversize apertures through which these conductors extend and is mounted from the base 10 by a support 32.

Opposite the coated cathode surface 24 and parallel thereto is a grid 33 of substantially parallel coplanar wires which are affixed to a frame 34, e. g. of molybdenum, and extend across a central circular aperture 35 therein. As illustrated in Fig. 3, the grid 33 is fabricated by winding a fine wire, for example of .00033 inch tungsten, 1000 turns per inch, upon a pair of frames 34, for example of the order of 5 to 10 mils thick, separated by a suitable spacer 36. The grid wires after winding are affixed to the frames, as by gold brazing in an atmosphere of hydrogen, along the edges 37 of the frames and are severed adjacent these edges to form two grid-frame units. During the winding of the grid, the wire is maintained under a constant tension to facilitate the realization of uniformity of pitch and of conditions for securing the wires during the brazing operation. After the brazing, arcuate depressions, indicated at 80 in Fig. 1, are pressed in the frame 34 to stress the grid wire to of the order of 20 to 30 per cent of its breaking point. Thus, a uniform tension of the several grid wires and a constant and controlled tension are obtained. In the completed unit, the grid wires are continuously under tension and the desired parallel coplanar relation thereof is maintained despite the temperature variations in the wires during operation of the device in which the grid is included.

The frame 34 is seated upon an annular metallic spacer 38 with the aperture 35 in coaxial alignment with the cathode disc 24 and with the face of the frame on which the grid wires lie toward the cathode disc 24, whereby the cathode to grid spacing is determined by the difference between the thickness of the spacer 38 and the height of the thermionic coating above the lapped surface of the cathode support 20. The spacer 38 is provided with an annular corrugation in which a channeled metallic ring 39 is secured, as by a ring 40 of solder or brazing material, the inner surface of the ring 39 being tinned for a purpose which will appear presently. The spacer 38 is provided also with a plurality of depending sockets 41 which extend into apertures 42 in the ceramic disc 20, only one of which apertures is shown in the drawing. These sockets function to prevent the leakage of high-frequency energy through the holes in the grid frame from the output region to the input region.

Seated upon the grid frame 34 is a cup-shaped anode support 43 of an insulating, e. g. ceramic, material in which the anode 44, e. g. of stainless steel or copper is fixedly mounted. The lower surface of the anode, in Fig. 1, and the rim face of the support 43 are lapped simultaneously by a suitable abrasive, such as silicon carbide, to be essentially coplanar, whereby, as will be apparent, the anode to grid spacing is determined by the thickness of the grid frame 34. The anode is provided with an extension 45 which fits into a recess in the split inner end of a leading-in conductor 46 internally tinned as indicated at 52. The conductor 46 is sealed to an insulating, e. g. ceramic or glass member 47, along the adjoining surfaces at 48, and the member 47 in turn is sealed along the adjoining surfaces at 49, to a cylindrical leading-in conductor 50 coaxial with the conductor 46 and sealed to the glass or ceramic disc 14 along the adjoining surfaces at 51.

The cathode, anode and grid are constructed as a unitary assembly, including also an insulating, e. g. ceramic, body 53, wherein the parts are clamped together in stacked, coaxial relation by a plurality, for example three, of ceramic posts 54 having vitreous beads 55 fused to the ends thereof and extending through the several parts. The beads 55 at one end of the assembly are seated upon the anode support 43; the beads 55 at the other end of the assembly are fused into sockets 56 upon a metallic retaining ring 57, shown clearly in Fig. 5, which bears against a dished metallic spring 58 bearing in turn against the body 53.

In the manufacture of the device, the cylinder 13, the conductors 46 and 50 and the glass or ceramic discs 14 and 47 are fabricated as a unitary assembly. The unitary electrode assembly described hereinabove and including the cylinder 16 and coatings 18 and 19 thereon is inserted into the cylinder 13 so that the conductor 50 is

seated in the channeled ring 39 and the anode extension 45 extends into the conductor 46. By appropriate heating, the conductor 50 is soldered to the channeled ring 39, the inner surface of which was tinned as noted heretofore, and the extension 45 is soldered to the conductor 46. A third assembly, comprising the base 10, the heat reflecting shield 31 and the heater filament 29 is then inserted into the cylinder 13 and the flange on the cylinder 13 is sealed to the base 10 by welding or brazing.

The enclosing vessel may be evacuated by way of an exhaust tubulation 59 extending from the base 10. A getter carried by a wire 60 connected between two of the leading-in conductors 11 may be provided and flashed during the evacuation treatment of the device. To enable outgassing of inner parts of the electrode assembly, radially extending grooves 70, 74 and 75 are provided in the cathode support 20, the anode support 43, and the base insulator 53 respectively, and apertures 71 and 72 are provided in the disc 21 and anode support 43, respectively. Apertures 73 may be provided also in the grid conductor 50.

Electrically, the anode and grid constitute parallel plane electrode faces at the ends of the coaxial line constituted by the conductors 46 and 50. The effective cathode surface is parallel to the anode and grid and is connected conductively to the cylinder 16 in turn connected to one of the leading-in conductors 11 by a tie wire 61. For alternating currents, the cathode is connected to the cylinder 13, which is coaxial with the conductors 46 and 50, by the condenser defined by the cylinders 13 and 16 and dielectric coating 18. Thus, coaxial input and output systems terminating in parallel plane electrode surfaces are provided.

Because of the construction and association of the electrodes as described heretofore, it will be appreciated that extremely accurate parallel plane relationship of the effective electrode surfaces is attained and that this relationship is maintained during the operation of the device. Further, extremely small electrode spacings, for example of the order of ½ to 1 mil between cathode and grid and of the order of 5 to 10 mils between grid and anode, are achieved whereby electron transit times are minimized and high transconductance and good signal-to-noise ratio and band width are obtained.

As has been pointed out heretofore, the coupling between the electron stream and the external circuit is of major importance in determining the performance of the device. In the device disclosed, the parameters of the elements constituting this coupling are correlated to produce optimum performance over the operating range, specifically at frequencies in the microwave region. It will be noted that because of the coaxial relation of the cylinder 13 and conductors 46 and 50, the parallel plane relation of the electrode surfaces and the form and relation of the connections between the electrodes and the conductors, a geometrically and electrically smooth transition between the interelectrode spaces and an external double coaxial line coupled to the coaxial conductors 13, 46 and 50 is obtained. Further, inasmuch as the diameter of the conductor 46 associated with the anode is small in comparison to that of the conductor 50 associated with the grid, the surge impedance of the grid-anode region is very high. Also, because of the form and substantially equal diameters of the electrodes and the mounting thereof, parasitic capacitances are extremely small. Additionally, the members 14 and 47 may be positioned substantially an anti-nodes in the cathode-grid and grid-anode systems whereby losses and reactive transducing effects are minimized in certain specified frequency ranges.

Another anode assembly suitable for inclusion in the device shown in Fig. 1 is illustrated in Fig. 7 and comprises a support 62 of ceramic in which a disc 63 is embedded as by moulding. The disc mounts a stem 64 to which an anode disc 65, for example of zirconium is affixed. The surfaces 66 and 67 of the anode disc 65 and support 62, respectively, are lapped to make them accurately coplanar.

Although a specific embodiment of the invention has been shown and described, it will be understood that it is but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. An electron discharge device comprising a first support member having a plane seating surface, a cathode mounted by said support member and having a face coplanar with said surface, a second support member having a plane seating surface, an anode mounted by said second support member and having a face coplanar with said seating surface thereof, a plane grid, means spacing said cathode face, anode face and grid in aligned parallel relation comprising spacer means between said grid and the seating surfaces of said first and second support members, and means separate from said first and second support members locking said support members against said spacer means.

2. An electron discharge device in accordance with claim 1 wherein said spacer means comprises a plane frame mounting said grid and seated against said seating surface of said second support member.

3. An electron discharge device in accordance with claim 1 comprising a plane frame mounting said grid and wherein said spacer means comprises a plane spacer member between and engaged by one face of said frame and said seating surface of said first support member.

4. An electron discharge device comprising a plane frame, a grid extending across one face of said frame and substantially coplanar therewith, a cathode assembly comprising a disc having a plane seating surface and a cathode member mounted by said disc and having a face coplanar with said surface and opposite said grid, electron emissive material on said face of said cathode member, a plane disc between said face of said frame and said seating surface and determining the spacing therebetween, and an anode opposite said grid.

5. An electron discharge device comprising a first electrode assembly including a member having a plane seating surface and an electrode mounted by said member and substantially coplanar with said surface, a second electrode assembly comprising a second member having a plane seating surface and an electrode mounted by said second member and having a face coplanar with said seating surface thereof, said electrodes being in juxtaposition, planar spacer means between said seating surfaces, and means clamping said first and second members against opposite faces of said spacer means.

6. An electron discharge device comprising an insulating disc having a plane seating surface, an electrode member embedded in said disc and having one face coplanar with said seating surface, a support having a plane seating surface, an electrode mounted by said support and substantially coplanar with said seating surface thereof, said electrode and electrode member being in juxtaposed relation, and planar spacer means between said seating surfaces.

7. An electron discharge device comprising a first insulating disc having a plane seating surface, a cathode member mounted by said disc and having a face coplanar with said seating surface, a plane spacer member seated on said surface, a plane frame member seated on said spacer member, a grid mounted by said frame and substantially coplanar with one face thereof, a second insulating disc having a plane surface seated on said frame, and an anode mounted by said second disc and having a plane face coplanar with said plane surface thereof, said cathode member, grid and anode being in alignment.

8. An electron discharge device comprising a unitary assembly including a first insulating disc having a plane surface, a cathode mounted by said disc and having a face substantially coplanar with said surface, a plane frame seated on said surface, a grid mounted by said frame, substantially coplanar with one face thereof and in alignment with said cathode, a second insulating disc having a plane surface seated on said frame, an anode mounted by said second disc and having a face coplanar with said surface thereof and in alignment with said grid, and means clamping said first and second discs and said frame together comprising rivets of ceramic material extending therethrough, a disc spring member interposed between one end of said rivets and the insulating disc opposite said one end and a retainer member bearing against said spring member and locked to said one end of said rivets.

9. A cathode assembly for electron discharge devices comprising a ceramic member having an aperture therein and having also a plane face, a metallic disc embedded in said insulating member and extending across said aperture, a metallic stem extending through said disc and affixed thereto, a cathode disc joined to one end of said stem and having a face coplanar with said plane face, and a heater filament encompassing said stem.

10. An electron discharge device comprising an enclosing vessel having a cylindrical inner wall, a unitary electrode assembly within said vessel, and means separate from said vessel mounting said assembly comprising a cylindrical member coupled to said assembly and coaxial with and slidably fitted within said cylindrical wall.

11. An electron discharge device comprising an enclosing vessel having a cylindrical, metallic inner wall, a unitary electrode assembly within said vessel including a pair of cooperative electrodes, and means mounting said electrode assembly within said vessel including a cylindrical metallic member connected electrically to one of said electrodes and having a coating of dielectric material upon the outer surface thereof, said coating being immediately adjacent said cylindrical wall and defining a condenser therewith and with said cylindrical member.

12. An electron discharge device comprising an enclosing vessel having a cylindrical, metallic inner wall, a unitary electrode assembly within

said vessel including a pair of cooperative electrodes, and means mounting said electrodes within said vessel including a cylindrical metallic member connected electrically to one of said electrodes, a cylindrical layer of dielectric material upon the outer surface of said cylindrical member, and a cylindrical coating of electrically conductive material upon said layer of dielectric material and being of an outer diameter to fit within said cylindrical wall.

13. An electron discharge device comprising an enclosing vessel having an end portion, a leading-in conductor extending through said end portion, said conductor having a recess in the inner end thereof, a cylindrical leading-in conductor encompassing said first leading-in conductor and extending through said end portion, a unitary electrode assembly within said vessel and including a pair of electrodes, a conductive pin connected to one of said electrodes and fitted in said recess, and a conductive member connected to the other of said electrodes and having an annular portion engaging the inner end of said cylindrical leading-in conductor.

14. An electron discharge device comprising an evacuated enclosing vessel, a pair of coaxial leading-in conductors extending through one end of said vessel and sealed hermetically thereto, a unitary electrode assembly within said vessel including a cathode, grid and anode, electrical extensions of said grid and anode forming a part of said assembly and each engaging a respective one of said coaxial leading-in conductors, and means separate from said conductors mounting said assembly within said vessel.

15. An electron discharge device in accordance with claim 14 wherein said mounting means comprises a metallic member connected electrically to said cathode, a dielectric coating on the outer surface of said metallic member and an electrically conductive coating on the outer surface of said dielectric coating and adjoining an inner wall of said enclosing vessel.

16. An electron discharge device comprising an enclosing vessel having a cylindrical metallic portion, insulating means extending across one end of said portion, a leading-in conductor coaxial with said portion and extending through said insulating means, said conductor having a recess in the inner end thereof, a cylindrical leading-in conductor coaxial with said first conductor and extending through said insulating means, a unitary assembly within said vessel and including a cathode and a pair of electrodes in cooperative relation therewith, an electrical extension of one of said electrodes fitted in said recess, an annular, channeled metallic member electrically integral with the other of said electrodes, the inner end of said cylindrical conductor fitting within said channeled member, a cylindrical metallic member coaxial and adjacent said cylindrical portion and connected electrically to said cathode, and a dielectric material between said cylindrical metallic member and said cylindrical portion.

17. An electron discharge device comprising a cathode having a plane emissive surface, an anode having a plane surface parallel to and in alignment with said emissive surface, a plane control electrode between, parallel to and in alignment with said anode and cathode surfaces, an enclosing vessel having a cylindrical conductive portion encompassing said cathode, anode and control electrode and axially aligned therewith, means including a substantially plane metallic member extending parallel to said emissive surface, electrically coupling said anode to said cylindrical portion, a cylindrical conductor extending within said portion and coaxial therewith, means including a substantially plane conductive member parallel to said plane metallic member coupling said control electrode to said cylindrical conductor, and a cylindrical conductor connected to said anode and coaxial with said cylindrical portion.

18. An electron discharge device comprising an enclosing vessel having a cylindrical conductive portion, dielectric disc means extending transversely of said portion and sealed thereto, a cylindrical rod coaxial with said portion extending through said disc means and sealed thereto, a cylindrical conductor coaxial with and encompassing said rod, extending through said disc means and sealed thereto, an anode joined to the inner end of said rod and having its effective surface plane and substantially normal to the axis of said rod, a cathode having a plane emissive face opposite and parallel to said surface of said anode, means including a metallic disc coupling said cathode to said cylindrical portion, a substantially plane grid in cooperative relation with said cathode and anode and parallel to said emissive face, and means including a metallic disc parallel to said first disc connecting said grid to said cylindrical conductor.

JACK A. MORTON.
ROBERT L. VANCE.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,128,236	Dallenbach	Aug. 30, 1938
2,270,638	Llewellyn	Jan. 20, 1942
2,289,846	Litton	July 14, 1942
2,353,742	McArthur	July 18, 1944
2,402,601	Chevigny et al.	June 25, 1946
2,407,974	Clifford et al.	Sept. 24, 1946
2,408,927	Gurewitsch	Oct. 8, 1946
2,414,785	Harrison et al.	Jan. 21, 1947