Dec. 12, 1972 G. V. MIRAM ET AL 3,706,002

ELECTRON GUN

Filed Nov. 16, 1970 3 Sheets-Sheet 1

FIG. 1

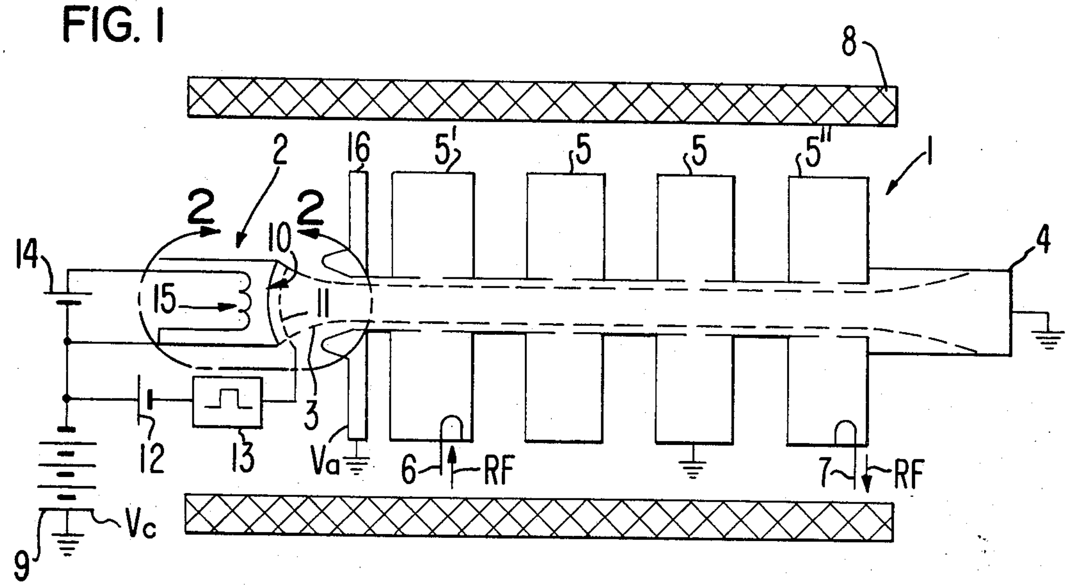

FIG. 2

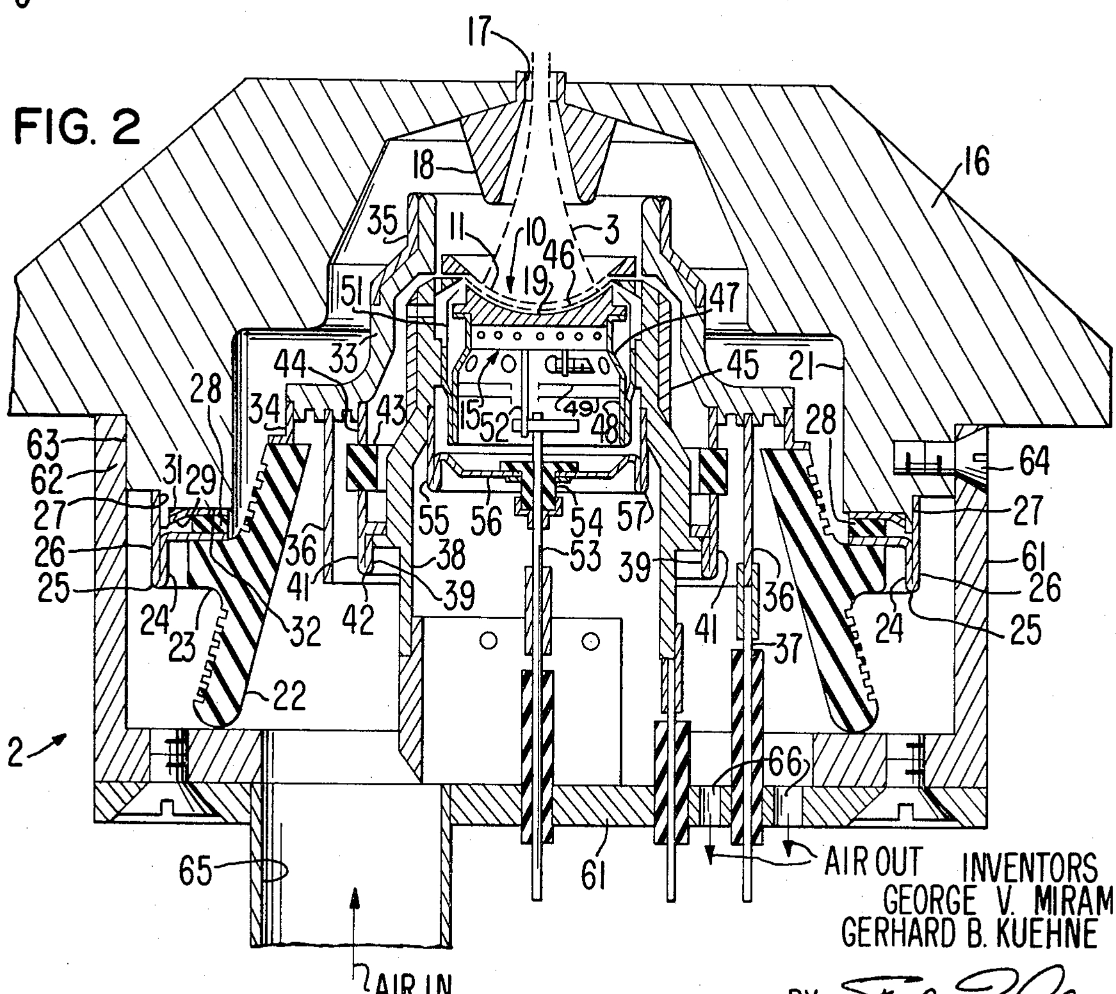

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FIG. 3

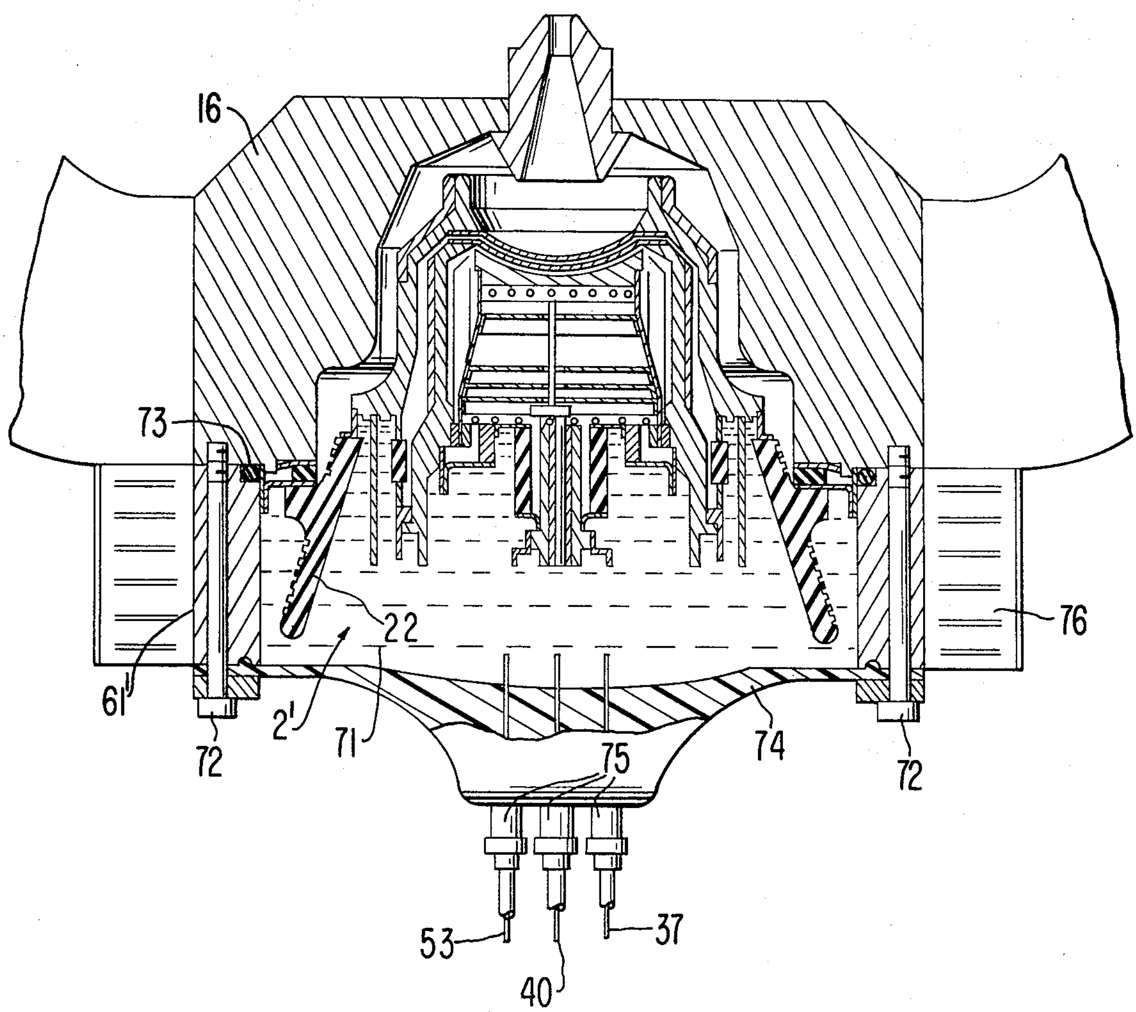

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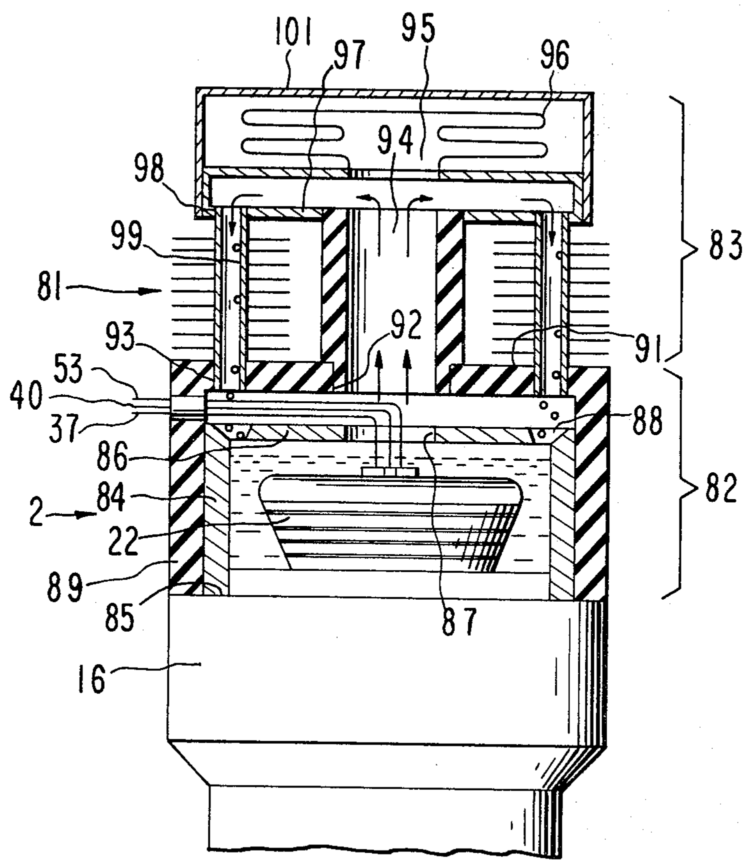
FIG. 4



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ELECTRON GUN

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Continuation-in-part of application Ser. No. 50,685, June 29, 1970. This application Nov. 16, 1970, Ser. No. 89,972
Int. Cl. H01j 25/10
U.S. Cl. 315—5.39 14 Claims

ABSTRACT OF THE DISCLOSURE

A high power microwave beam tube is disclosed employing an improved electron gun. The electron gun includes an outwardly flared high voltage electrical insulator for insulating the anode relative to the cathode. The outwardly flared insulator includes an external shoulder portion encircling the flared member, such shoulder being disposed intermediate the length of the flared member and being joined to a portion of the envelope of the gun to be operated at a potential positive with respect to the cathode potential. A fluid enclosure encloses the wide end of the flared insulator for containing a fluid coolant in heat exchanging relation with portions of the vacuum envelope of the gun for cooling the gun in use.

RELATED CASES

This application is a continuation in part application of parent application U.S. Ser. No. 50,685, filed June 29, 1970 now abandoned and assigned to the same assignee as the present application.

DESCRIPTION OF THE PRIOR ART

Heretofore, electron guns for high power microwave tubes have included a generally cylindrical high voltage insulator for insulating the cathode of the gun from the anode. The anode structure was generally affixed to one end of the cylindrical insulator member and the cathode was affixed to or near the opposite end of the cylindrical insulator structure. When relatively high anode to cathode voltages were employed, as of voltages in excess of 10 kv., the resultant gun structure became relatively long due to the relatively long length of the required insulator body. As a result the overall length of the tube body including the insulator structure was excessively long for some applications and cooling of the gun was difficult in use. A typical electron gun of the prior art including the cylindrical anode to cathode insulator structure is disclosed in U.S. application Ser. No. 29,963, filed Apr. 20, 1970, and assigned to the same assignee as the present invention.

SUMMARY OF THE PRESENT INVENTION

The principal object of the present invention is the provision of an improved electron gun and tubes using same.

One feature of the present invention is the provision, in an electron gun, of a hollow generally outwardly flared insulator member having an external shoulder portion encircling the flared member, such shoulder being disposed intermediate the length of the flared member for joining the insulator member to a portion of the gun structure operating at a potential positive with respect to the potential to be applied to the cathode, whereby the narrow end portion of the insulator body may extend reentrantly into the anode structure for shortening the overall length of the anode to cathode insulator structure.

Another feature of the present invention is the same as the preceding feature wherein the hollow outwardly flared insulator member is generally frusto-conically shaped.

Another feature of the present invention is the same as any one or more of the preceding features including a fluid enclosure enclosing the wide end of the flared insulator member for containing fluid coolant in heat exchanging relation with a portion of the evacuated envelope of the gun disposed within the flared electrical insulator member for cooling portions of the gun structure.

Another feature of the present invention is the provision of a fluid coolant enclosure for an electron gun wherein the fluid coolant is a liquid and the fluid enclosure includes a boiler portion for containing the liquid coolant in heat exchanging relation with the electron gun and a condenser portion for condensing vaporized coolant and returning same to the boiler portion.

Another feature of the present invention is the same as either one of the immediately two preceding features wherein the fluid enclosure includes a flexible wall portion to permit expansion of fluid coolant trapped within the fluid coolant enclosure.

Another feature of the present invention is the same as any one or more of the preceding features wherein a hollow outwardly flared control electrode structure is affixed to the narrow end of the high voltage insulator member, such control electrode structure being insulated from the anode and cathode to permit an independent operating potential to be applied thereto for controlling the beam current.

Other features and advantages of the present invention will become apparent upon a perusal of the following specification taken in connection with the accompanying drawings wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic line diagram of a linear beam microwave tube incorporating features of the present invention,

FIG. 2 is an enlarged section view of a portion of the structure of FIG. 1 delineated by line 2—2,

FIG. 3 is a view similar to that of FIG. 2 depicting an alternative embodiment of the present invention, and

FIG. 4 is a view similar to that of FIG. 3 depicting an alternative embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, there is shown a microwave klystron tube **1** incorporating features of the present invention. The kylstron tube **1** includes an electron gun assembly **2** for forming and projecting a beam of electrons **3** over an elongated beam path to a beam collector structure **4** disposed at the terminal end of the elongated linear beam **3**. A plurality of cavity resonators **5** are successively disposed along the beam path for successive electromagnetic interaction with the electron beam passable therethrough.

Microwave energy to be amplified is applied to the upstream cavity **5'** via an input coupling means, such as input coupling loop **6**. The microwave energy in the input cavity **5'** velocity modulates the beam. The velocity modulated beam excites successive floating cavities **5** disposed along the beam path to produce current density modulation of the beam at the gap of the output resonator **5''**. The current density modulated beam at the output gap excites the output resonator **5''** and output microwave energy is extracted from the output resonator **5''** via suitable output coupling means, such as output coupling loop **7**, which couples the energy to a suitable load, such as an antenna, not shown.

A solenoid 8 or permanent magnet structure schematically represented by solenoid 8 is disposed around the tube 1 for producing an axially directed beam focusing magnetic field throughout the length of the beam path from the gun to the collector 4 for focusing the beam 3 through the structures disposed along the beam path.

In the electron gun 2, a negative potential C_c, as of −15 kv., is applied to a cathode emitter 10 from a beam power supply 9. A control grid 11 overlays the cathode emitter 10 for controlling the beam current. The control grid 11 is biased negative relative to the cathode 10 by a relatively small DC bias voltage, as of a new hundred volts, supplied by a potential supply 12. The control grid 11 is pulsed positive relative to the cathode 10 for turning on the beam via pulse power supply 13, thereby pulsing the beam current. A relatively small power supply 14, as of 7 volts, is connected across the heater leads of a heating element 15 for heating the cathode 10 to thermionic emission temperature.

Referring now to FIG. 2, there is shown an electron gun assembly 2 incorporating features of the present invention. The electron gun 2 includes a centrally apertured anode electrode structure 16, as of iron. The central aperture 17 in the anode 16 includes a copper insert 18 to define an outwardly flared beam passageway 17 through the anode 16. The thermionic cathode emitter 10 having a spherically concave cathode emitting surface 19 is disposed in axial alignment with the beam passageway 17 for emitting the beam of electrons 3 through the beam passageway 17. The cathode emitter 10 is disposed well within a reentrant bore 21 in the anode structure 16. The magnetic anode structure 16, which surrounds cathode emitter 10, serves to shape the beam focus magnetic field in the region of the cathode 10 for magnetically focusing the convergent electron stream 3 through the beam passageway 17.

A hollow outwardly flared high voltage electrical insulator member 22 and generally frusto-conical shape, as of alumina, or beryllia ceramic, serves to support the cathode emitter 10, from the anode 16 in insulative relationship thereto. More particularly, the frusto-conical insulator 22 includes an external shoulder portion 23 which encircles the insulator 22 at a position intermediate the length of the insulator member 22. The shoulder 23 is metallized and brazed to a metallic sealing flange 24 which is sealed in a gas-tight manner, as by Heliarc welding, at 25 to a metallic cylindrical flange 26, which in turn is brazed to the anode structure 16 at 27.

A ceramic backup ring 28 is brazed to the sealing flange 24 opposite the shoulder 23 for dividing the thermal stresses on seals to the sealing flange 24. A metallic positioning ring 29 is brazed to the opposite side of backup ring 28. Positioning ring 29 bears, at its outer periphery, on the inside wall of a circular bore 31 in the anode 16 for aligning the cathode emitter structure within the anode 16. Positioning ring 29 also bears against the transverse shoulder 32 of bore 21 in the anode 16 for transmitting axial loads through the backup member 28 to the shoulder 23 of the conical insulator 22.

A hollow outwardly flared beam control electrode structure 33, as of molybdenum, is joined in a gas-tight manner to the narrow inner end of conical insulator member 22 by means of a metallic sealing flange 34 brazed to the metallized inner end of the insulator 22 and to the outwardly flared end of control electrode 33. A magnetic jacket 35, as of soft iron, is disposed around the narrow end portion of control electrode 33 to facilitate convergence and shaping of the magnetic beam focus field in the region of the cathode emitter 10. The control grid 11 has a generally spherical concave shape conforming to the concave shape of the emitting surface 19 of the cathode 10 and is disposed overlaying the emitting face 19 for controlling the electron current drawn from the cathode 10 in accordance with the operating potential applied to the control electrode 33 relative to the potential applied to the cathode emitter 10. A cylindrical metallic cooling fin 36, as of copper, depends from the flared end of control electrode 33 to facilitate cooling of the control electrode structure. In addition, cooling fin 36 forms an electrical lead for application of the control grid potential to the control electrode, such potential being derived from an insulated lead 37 which is connected to the cooling fin 36.

A cylindrical focus electrode 38, as of molybdenum, is joined to the control electrode structure 33 via the intermediary of mating metallic flanges 39 and 41 hermetically sealed together at 42 via a Heliarc weld running around the mating ends of flanges 39 and 41. An insulative ring 43, as of alumina or beryllia ceramic, is hermetically sealed between flange 41 and a similar flange 44 carried from control electrode 33 for insulatively supporting the cathode focus electrode 38 relative to the control electrode 33. A magnetic jacket 45, as of soft iron, surrounds the inner end of focus electrode 38 for shaping the magnetic field in the region of the cathode emitter 10. A focus grid 46 having its apertures in alignment with the apertures in the control grid 11 and operated at cathode potential is physically supported at its periphery from the inner end of focus electrode 38.

The cathode emitter 10, as of barium impregnated tungsten or an oxide coated cathode, is affixed to the end of a tubular support 47, as of molybdenum or molybdenum-rhenium alloy. Support member 47 is carried from the inside wall of the focus electrode 38 via the intermediary of a tubular support 48, as of molybdenum, which is welded to support 47 and in turn welded at its other end to the focus electrode 38.

Heating element 15, as of molybdenum or tungsten, is potted within a thermally conductive insulative structure, as of alumina ceramic, and positioned adjacent the back side of the cathode emitter member 10 for heating the emitter to thermionic emission temperature. A plurality of disc shaped heat shields 49, as of molybdenum or nickel 0.005" thick, are positioned within the cathode emitter support 47 to form a thermal barrier to prevent radiation of heat from the heater element 15 to the surrounds. In addition, a thin walled tubular metallic heat shield 51, as of molybenum, surrounds the heater and cathode emitter to minimize the loss of heat from the heater and emitter to the surrounding focus electrode 38. One lead 52 for the heater element 15 is electrically connected to a heater input lead 53 which passes through a hermetically sealed feed-through insulator 54 sealed across the inside of focus electrode 38 via metallic sealing flanges 55 and 56. Flanges 55 and 56 are carried from the focus electrode 38 and feed through insulator 54, respectively, and are sealed together at their mating edges via a circular Heliarc welded joint 57.

A cup-shaped insulative fluid coolant enclosure 61, as of alumina, is carried at its lip 62 from a shoulder 63 of the anode structure 16 via a plurality of screws 64 passing radially through the periphery of the lip. A fluid coolant duct 65 passes through the lower wall of the cup 61 for directing a stream of fluid coolant, as of air, into and through the fluid enclosure 61 in heat exchanging relation with that portion of the vacuum tight envelope enclosed by the housing 61 for cooling the electron gun structure in use. The heated fluid coolant exhausts from the housing 61 via exhaust ports 66 disposed in the bottom wall of the cup 61 for exhausting and dissipating the heat removed from the electron gun 2.

The advantage of the re-entrant frusto-conical insulator member 22 is that it readily facilitates access, due to its outwardly flared opening, to the various joints in the gun 2, whereby welded joints may be readily made. In addition, the outwardly flared insulative member greatly shortens the overall length of the electron gun 2 by providing a substantial length of the insulator inside of the anode bore 21. The electrical leakage path across the surface of the insulator 22 which is exposed to the vacuum can be made substantially shorter than that portion of its leakage path exposed to the atmosphere or coolant fluid for the same current leakage thereacross. The conical shape with the re-entrant portion of the insulator allows the shorter leakage path to be disposed inside the vacuum and provides a relatively long leakage path around the outside of the insulator body which is exposed to the atmosphere. The outside surface of the insulator body **22** is preferably provided with transverse corrugations encircling the body **22** to increase the leakage path thereacross.

Also, the conical shape of the anode to cathode high voltage insulator **22** allows the control electrode to cathode insulator **43** to be positioned in a place which is hidden or shielded from deposition of cathode emitting material, which otherwise might be deposited on the insulator, thereby causing leakage of current thereacross. The short length of the focus and control electrode supports and the provision of fluid coolant in heat exchanging relation with respect to such supports greatly reduces the length of such supports that experience a thermal gradient thereacross. Thus, relative movements therebetween due to thermal expansion is kept to a minimum.

Referring now to FIG. 3, there is shown an alternative electron gun **2'** incorporating features of the present invention. The electron gun **2'** of FIG. 3 is essentially the same as that of FIG. 2 with the exception that the cup-shaped fluid coolant enclosure **61'** traps a liquid coolant **71**, such as a perfluorinated liquid coolant, examples of which include 3M brand FC–75 or FC–77. Such perfluorinated liquid coolants have a relatively high dielectric strength, as of 55 and 45 kv. per 0.1 inch at 77° F., and have a relatively low boiling point, as of 216 and 207° F., respectively. Such coolant fluids have relatively high thermal capacity and relatively high thermal conductivity for conducting heat from the contacted envelope portions of the gun to the sidewalls of the cup-shaped enclosure **61'**.

The sidewalls of the cup **61** are preferably made of a thermally conductive metal, such as copper or iron, and are secured to the anode structure via a plurality of screws **72** passing axially of the cup into the anode structure **16**. An O-ring hermetically seals cup member **61'** and the anode **16**. The bottom wall **74** of the cup-shaped fluid enclosure **61'** is made of a flexible wall material, such as silastic rubber, to permit expansion of the fluid coolant **71** upon heating thereof within the housing **61'**. Heater, cathode and control grid leads **53, 40** and **37**, respectively, pass through the flexible wall **74** via feedthrough insulator assembly **75**. An array of cooling fins **76**, as of copper, are affixed in heat exchanging relation around the outside of the sidewall of fluid enclosure **61'** for dissipating heat conducted thereto, via the coolant liquid **71**, to the surrounds.

Referring now to FIG. 4, there is shown an alternative embodiment of the present invention. In this embodiment, the microwave tube **1** is disposed with the electron gun **2** elevated above the collector **4**. The inverted conical insulator **22**, with its internal elements, is enclosed by a fluid coolant enclosure **81** comprised of a liquid boiler chamber portion **82** disposed below a vapor condenser portion **83**. The boiler **82** is filled with liquid coolant, such as one of the aforementioned perfluorinated liquids.

A cylindrical magnetic shield **84**, as of soft iron, surrounds the gun **2** and is attached at its bottom lip **85** to the cathode pole piece **16** of the beam focus magnet. The upper end of the shield **84** is closed off by an apertured end wall **86**. The apertured end wall **86** includes a central aperture **87** and a plurality of smaller drain holes **88** disposed about the periphery of the circular end wall **86**.

The boiler portion **82** of the coolant enclosure **81** includes a lower cylindrical enclosure portion **89** made of an electrically and thermally insulative material, as of alumina ceramic, which surrounds the magnetic shield **84** and is sealed thereto in a fluid tight manner. The upper end of the boiler portion **82** is closed off by a transverse apertured end wall **91**. The end wall **91** includes a central aperture **92** and a plurality of smaller apertures **93** disposed about the perimeter of the end wall **91**.

A flue **94** is connected to the central aperture **92** for conducting vaporized coolant into an upper expansion chamber **95** of the condenser **83**. The expansion chamber **95** has a portion of its upper end wall defined by an expansible bellows **96**, as of stainless steel. The lower wall **97** of the expansion chamber **95** is provided at its periphery with smaller holes **98**. Finned condenser tubes **99** interconnect the expansion chamber **95** with the boiler **82** for condensing and returning the liquid coolant to the boiler **82**. A protective cover **101** is disposed over the expansion chamber. The heater, cathode, and control grid leads **53, 40** and **37** are fed through the side of the boiler **82**.

The boiler and condenser coolant enclosure serves to maintain the gun **2** at a constant temperature, namely, the coolant boiling temperature, and has the advantage of much greater thermal capacity as contrasted with the fluid coolant enclosure of FIG. 3. The constant temperature of the gun eliminates changes in critical dimensions usually associated with temperature changes.

Although the microwave tube **1** has been disclosed as a klystron tube, the features of the present invention are applicable in general to electron guns useful in all type of electron tubes such as traveling wave tubes, klystrons, magnetrons, etc.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. In an electron tube, thermionic cathode emitter means for emitting electrons, anode means spaced from said cathode emitter means and having a beam passageway therein for accelerating the emitted electrons through the beam passageway in said anode, evacuated envelope means for containing said cathode and anode means, electrical insulator means for insulating said anode means relative to said cathode means for a preponderance of the operating potential to be applied to said anode and cathode means in use, the improvement wherein, said insulator means comprises a hollow generally outwardly flared insulative member defining a narrow end and a wide end and having an external shoulder portion encircling said flared member, said insulative member having a portion thereof which forms a portion of the wall of said evacuated envelope means, said shoulder portion being disposed intermediate the length of said flared member, and said insulator means being joined at said shoulder portion to a portion of said envelope means to be operated at a potential positive with respect to the operating potential to be applied to said cathode means.

2. The apparatus of claim **1** wherein said flared insulator means is joined substantially at the narrow end thereof to another portion of said envelope means to be operated at a potential negative with respect to the operating potential to be applied to said anode means.

3. The apparatus of claim **1** wherein said flared insulator member has a generally frusto-conical shape.

4. The apparatus of claim **2** wherein said flared insulator member has a generally frusto-conical shape.

5. The apparatus of claim **1** including hollow electrode structure having a generally outwardly flared shape defining a narrow and a wide end, said hollow electrode structure being joined at the wide end thereof to the narrow end of said flared insulator means.

6. The apparatus of claim **5** including second electrical insulator means connected between said cathode emitter means and said hollow electrode structure to permit an operating potential to be applied to said hollow electrode structure relative to the potential to be applied to said anode and cathode emitter means.

7. The apparatus of claim 5 wherein said cathode emitter means includes a concave emitting surface facing the electron beam passageway in said anode means, and wherein said hollow electrode structure includes a concave grid portion disposed overlaying said concave emitting surface of said cathode emitter means for controlling the beam current drawn from said cathode emitter through said beam passageway in said anode means.

8. The apparatus of claim 1 including, fluid enclosure means enclosing the wide end of said flared insulator means for containing fluid coolant in heat exchanging relation with a portion of said evacuated envelope disposed within said flared electrical insulator means.

9. The apparatus of claim 8 including means for directing a stream of fluid coolant through said fluid enclosure means for cooling a portion of said evacuated envelope.

10. The apparatus of claim 8 including, fluid coolant means trapped within said fluid enclosure, and wherein said fluid enclosure means includes a flexible wall portion to permit expansion of said fluid coolant means trapped within said fluid coolant enclosure means.

11. The apparatus of claim 10 wherein said fluid coolant means is a perfluorinated electrically insulative liquid.

12. The apparatus of claim 1 including, electrical circuit means for interaction with the electron beam to produce an output wave energy and means for extracting the output energy from said circuit means.

13. The apparatus of claim 8 wherein said fluid enclosure means includes, a boiler chamber portion for containing liquid fluid coolant in heat exchanging relation with said evacuated envelope, such liquid coolant being vaporized by the exchange of heat from said envelope to the liquid coolant, said fluid enclosure including a condenser chamber portion for condensing vaporized fluid coolant, and means for returning the condensed coolant to said boiler chamber.

14. In an electron tube, thermionic cathode emitter means for emitting electrons, anode means spaced from said cathode emitter means and having a beam passageway therein for accelerating the emitted electrons through the beam passageway in said anode, evacuated envelope means for containing said cathode and anode means, electrical insulator means for insulating said anode means relative to said cathode means for a preponderance of the operating potenital to be applied to said anode and cathode means in use, the improvement comprising, said insulator means having a portion thereof forming a portion of the wall of said evacuated envelope means, fluid enclosure means enclosing the end of said electrical anode to cathode insulator means and containing fluid coolant in heat exchanging relation with a portion of said evacuated envelope disposed within said anode-to-cathode electrical insulator means, said fluid enclosure including a boiler chamber portion and a condenser chamber portion, said boiler chamber containing liquid coolant in heat exchanging relation with said evacuated envelope, such liquid coolant being vaporized by the exchange of heat from said envelope to the liquid coolant, said condenser chamber portion serving to condense the vaporized fluid coolant, and means for returning the condensed coolant to said boiler chamber.

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U.S. Cl. X.R.

313—12, 82