Feb. 25, 1947. P. L. HARTMAN 2,416,315

ELECTRON DISCHARGE DEVICE

Filed June 4, 1942

FIG. 1

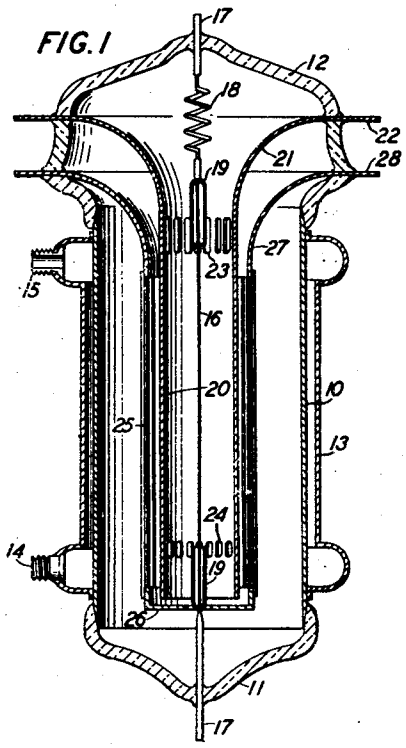


FIG. 2

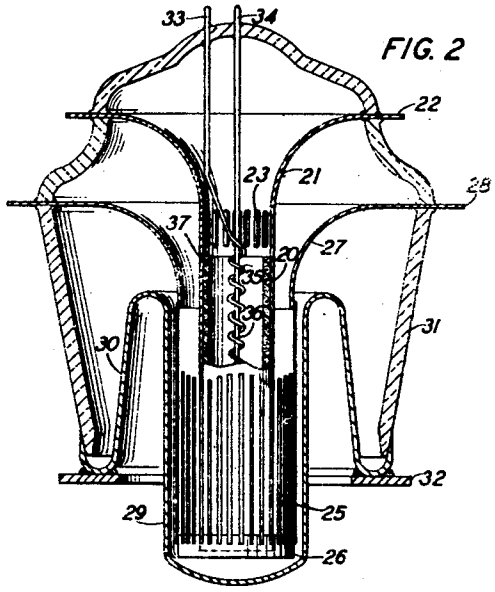


FIG. 3

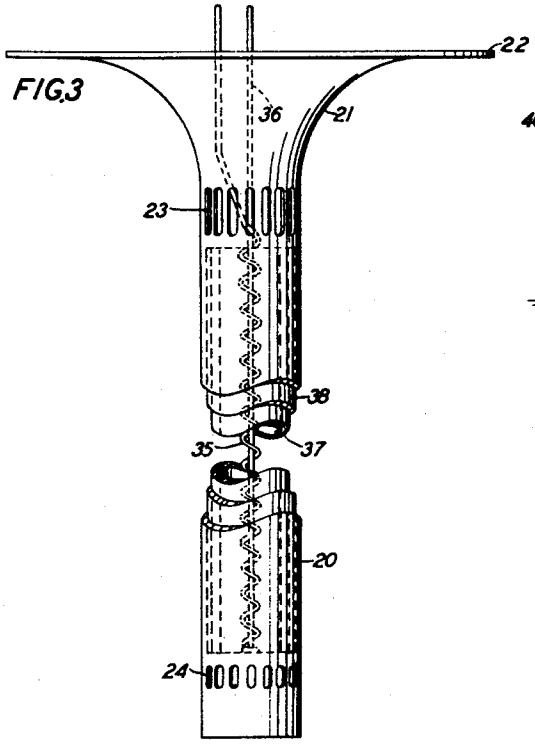
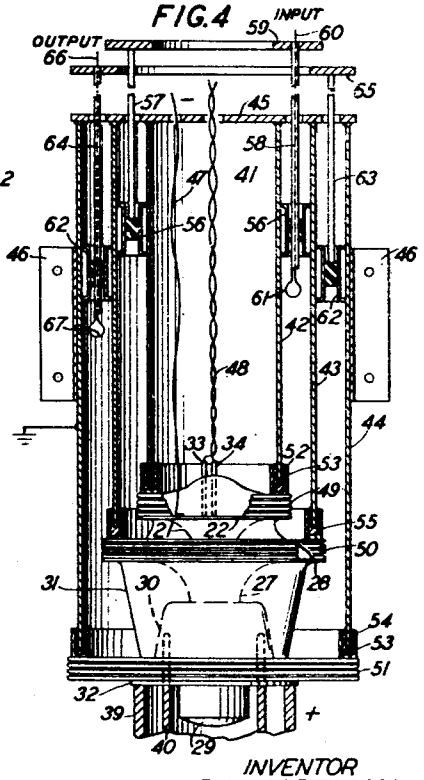


FIG. 4



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ELECTRON DISCHARGE DEVICE

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8 Claims. (Cl. 250—27.5)

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This invention relates to electron discharge devices and more particularly to such devices capable of generating a high power output in ultra-high frequency systems.

In the usual high power discharge device, such as employed in transmitters for broadcasting and allied purposes, the power output is limited by space charge which is determined by cathode emission which in itself is governed by the heating current. Any attempt to increase the heating current to obtain higher emission necessarily accentuates the electrical and mechanical difficulties in the device, such as electric and magnetic fields which complicate the electron trajectories and a greater cathode area and a more involved heating source must be provided. Furthermore, the potential distribution of the heating source tends to lower the transconductance of the device. Some advantage in increased emission may be attained by employing a cathode of large area indirectly heated by conduction and radiation but such emission radiation is dependent on the heating radiator being large and operating at a temperature higher than the cathode emitter. This necessarily requires high current in the heating radiator.

These difficulties are overcome in accordance with this invention by heating the emission source or cathode by electron bombardment so that the heating source is of moderate current consuming character and interaction between the source and emitter is substantially eliminated.

An object of this invention is to attain a high emission of electrons whereby higher output may be achieved in ultra-high frequency devices.

Another object of the invention is to eliminate end cooling effect in the electron emitting cathode.

A further object of the invention relates to the matching of the characteristic impedances of the device with a cooperating continuous coaxial circuit having constant value over the whole length thereof.

These objects are attained, in accordance with this invention, in a high power electron discharge device operating in the ultra-high frequency range, said device having an external anode which forms part of the enclosing vessel, and the cooperating electrodes, such as a control electrode and an emission source, being mounted therein. The control electrode and emission source or cathode are concentrically arranged within the anode of the device and provided with integral flare ring portions which are sealed in the enclosing vessel and constitute coaxial conductors for applying suitable potentials to these electrodes.

A feature of this construction relates to the fabrication of the device wherein the cathode is provided with portions at opposite ends, of high

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thermal resistance, to reduce end cooling effect whereby uniform thermal conditions are maintained to increase the emissivity of the cathode.

A further feature relates to the provision of a primary emitting source within the cathode structure to directly heat the cathode by electron bombardment to maintain the cathode at a high temperature for the copious emission of electrons in the discharge space of the device, the temperature of the primary emitter and the cathode being so chosen that excessive interaction between them is avoided.

Another feature relates to the construction of the cathode assembly to insure an efficient emitter of composite layers intended to be self-activating whereby loss of activating material by normal diffusion during operation is renewed or replaced by adjacent environmental substances of the composite cathode. In this arrangement the cathode is formed of concentric layers or cylinders of carbon, thorium and tungsten or tantalum with a central spiral heater element within the composite structure. The intermediate thorium layer replenishes the thorium diffused from the outer cathode cylinder which supplies the electron emission to the discharge space and the inner carbon cylinder reactivates the heater element within the assembly. Furthermore, the carbon cylinder maintains the cathode at a high emission temperature due to the bombardment thereof by the central heater.

Another feature of the invention relates to the utilization of the concentric disposition of the anode, cathode and control electrode rim conductors to directly connect a coaxial line thereto to form a unitary resonating amplifier or oscillator circuit having matched impedance and other electrical characteristics for efficient operation in ultra-high frequency transmission systems.

In view of the high temperature involved in this power generating system, another feature of this construction is the provision of yieldable or expansion coupling members between the concentric conductors of the coaxial line and the related conductors of the electrodes of the device. A metallic bellows-type ring coupling member is connected through a capacitance to the adjacent termination of the coaxial line conductor and the electrode conductor to form an expansion joint to compensate for thermal differences between these elements in the assembly and also to isolate the cathode and anode from the control electrode in the resonator structure.

These and other features and advantages of the invention will be more clearly set forth in the following detailed specification and will be more apparent when considered with the accompanying drawing.

Fig. 1 shows in cross section one form of the

invention in which the primary emitter is brought out through opposite ends of the device.

Fig. 2 illustrates another form of the invention, in cross section, in which all the connections project from one end of the device.

Fig. 3 is an enlarged view, partly broken away, of the composite cathode assembly which may be utilized in the structure of Figs. 1 and 2; and,

Fig. 4 shows a unitary assembly, partly in cross section, of the device of Fig. 2, coupled to a concentric line to form an efficient amplifier circuit for high power ultra-high frequency communicating systems.

Referring to the drawing, one embodiment of the invention is shown in Fig. 1 in which the high power discharge device is formed of a cylindrical metallic anode portion 10, preferably of copper, having the opposite ends closed by vitreous cap portions 11 and 12, of borosilicate glass, and the anode is surrounded by an integral water jacket 13 provided with inlet and outlet ports 14 and 15, respectively, for the circulation of a cooling fluid therein to dissipate the heat energy generated in the external anode 10 of the device. A filamentary emitter 16, of tungsten or thoriated tungsten is centrally mounted along the axis of the device by leading-in conductors 17 sealed through the glass portions at opposite ends of the vessel, the filamentary emitter 16 being tensioned by a spring 18 at one end of the vessel adjacent the glass cap portion 12. The filamentary emitter adjacent the lower conductor 17 and the spring 18 at the opposite end is provided with elongated cup-shaped members 19 to form end shields so that the portions of the filamentary emitter within the cup shields are maintained at a uniform temperature by radiation from the inner surface of the shield so that end cooling effect is eliminated and the emitter is held at a uniform temperature throughout its length.

The filamentary emitter 16 is surrounded coaxially by a cathode cylinder 20, preferably of tungsten with a thoria coating applied thereto or thorium metal admixed in the cylindrical body portion thereof, the cathode cylinder being provided with an aperture adjacent the glass cap 11 to permit passage of the filament 16 and cup 19 while the opposite end is provided with a tapered outwardly extending wall 21, which is sealed through the glass cap 12 to form an external ring conductor 22 extending radially from the glass cap portion 12 in a plane perpendicular to the axis of the device. The cathode shell 20 is also provided with guard ring portions in the form of elongated slots 23 and 24 at opposite ends of the shell to form restricted or attenuated peripheral high resistance paths to reduce end cooling effect of the cathode shell, thereby maintaining the area of the cathode shell between the guard rings at a uniform temperature.

A control electrode 25 formed of a plurality of longitudinal wires surrounds the cathode shell 20, the wires being attached at one end to a cup-shaped disc 26 having a central aperture which clears the cup shield 19 of the primary emitter filament 16 and the wires at the other end being attached to a metallic flared ring 27 having the rim 28 sealed through the glass cap 12 in a plane parallel to the ring 22 and spaced therefrom to form an external ring conductor for the control electrode 25. This construction provides coaxial ring conductors for the cathode and control electrodes of the device and facilitates the production of a high power output in the anode 10 by the relation of the primary emitter 16 and the

cylindrical cathode 20, whereby the cathode 20 is heated to the required emission temperature, for the copious supply of electrons to the discharge space between the cathode and the anode by electron bombardment from the primary emitter 16. This arrangement permits high temperature emission from the cylindrical cathode shell 20 by a heating source of moderate current consuming character, whereby maximum emissivity is attained in the cathode without expending enormous current in the heating radiator to obtain this result.

It is desirable to keep the ratio of the cathode cylinder diameter to primary emitter diameter from being too high, since if the filament becomes too small, then for even moderate voltages between it and the cathode cylinder, high fields are produced at its surface so that it operates as a temperature limited electron source and tends to be unstable when the two temperatures approach each other. This effect is produced by radiation from the primary emitter thereby raising the temperature of the cathode cylinder which then raises the temperature of the primary emitter and in turn more electrons are supplied with the result that the cathode temperature is raised and this cycle continues until the primary emitter becomes space charge limited. This effect may be overcome by operating the primary emitter at a much higher temperature than the cathode sleeve to prevent excessive interaction between them. Accordingly, if the primary emitter is formed of pure tungsten operating at approximately 2500° K. and the cathode sleeve is formed of thoriated tungsten or tantalum operating at a much lower temperature, interaction between them is easily controlled and reciprocal heating effect is avoided. In the event that tantalum is employed as the cathode sleeve, the flare portion 21 may be formed of copper or tungsten which will seal in the glass cap portion 12 of the device.

A modification of the invention is shown in Fig. 2 in which the external anode is formed of a tubular metallic portion 29 which is closed at one end and which merges at the other end into a reversely turned or spun portion 30. The turned edge of the latter portion is sealed to a glass cap portion 31, which in combination with the anode forms a vacuum-tight container or vessel. The peripheral rim of the anode portion 30 is rigidly attached to a metallic ring member 32 to form a supporting surface for a water jacket to encase the anode of the device. The cathode cylinder 20 and the control electrode shown herein are substantially the same as described in connection with Fig. 1 except that these elements extend into the tubular portion 29 of the external anode while the flare portions 21 and 27, respectively, are sealed radially through the wall of the glass cap portion 31. Since the external anode 29 is closed at the lower end, the primary emitter conductors 33 and 34 may be sealed through the top of the glass cap portion 31 so that all the connections to the device are closely related at one end of the vessel. The primary emitter in this form of the invention consists of a spiral conductor 35 supported by a central standard 36 which extends along the axis of the cathode 20 and the terminations thereof form the external conductors 33 and 34 of the primary emitter. The cathode sleeve 20 is also provided with a carbon sleeve liner 37 to increase the temperature distribution in the cathode by the bombarding electrons striking it and also constitutes

a source of carbonaceous vapor to reactivate the primary emitter **35** in which the active material is depleted by diffusion.

The cathode assembly shown in Fig. 3 is similar to the structure in Fig. 2 and may be substituted therefor or employed also in the device shown in Fig. 1. This view shows a composite assembly in which an intermediate layer **38**, of conducting or semi-conducting material containing a thermionically active emitting substance, such as thorium or thorium and thorium oxide, is interposed between the carbon liner **37** and the cathode sleeve **20** to form a reservoir to replenish active material diffused from the surface of the cathode **20**, the carbon liner, reservoir layer and cathode sleeve lying in stratified relation in an outward direction from the internal heater or primary emitter **35**. This construction forms a substantially rigid and efficient composite assembly capable of emitting a copious supply of electrons in the discharge device of this invention over a considerable period of operation.

The power discharge device of this invention, particularly including the annular coaxial conductors of the main electrodes in the vessel, is especially suitable for continuous coaxial transmission systems operating in the ultra-high frequency range, since the device can be directly matched with a resonating circuit employed as an amplifier or oscillator in the system and the characteristic impedances of the line may be maintained at a substantially constant value over its entire length by simulating the impedances of the amplifier or oscillator circuit to coincide with the device. This is accomplished in accordance with this invention by the unitary assembly of the structure, as shown in Fig. 4, which represents a grounded grid amplifier having a coaxial resonator chamber integrally associated with the discharge device. As shown the anode **29** of the device of Fig. 2 is enclosed in and supported by a water jacket container **39** having an inner partition **40** which extends partly within the boundary of the device as defined by the reversely turned wall **30** of the anode. The water jacket is electrically and mechanically connected to the ring **32** of the anode and a positive high voltage is applied to the jacket to maintain the anode at a high positive potential. A closed resonating chamber **41** formed of three concentric tubular members **42**, **43** and **44** of conductive material, such as copper or brass, of increasing diameter and increasing length, respectively, from the inner tubular member **42** to the outer tubular member **44** is associated with the discharge device to form a unitary coaxial transmission system operating in the ultra-high frequency range. These tubular members are rigidly affixed to a flat metallic disc or plate **45** at the top end with the tubular members equally spaced from each other and extending downwardly therefrom. The resonating chamber is of considerable mass so that it is necessary to support it in relation to the discharge device from a wall or standard by brackets **46**, the complete chamber being grounded to maintain the grid or control electrode at grounded potential. The cathode **20** is maintained at a negative potential with respect to the anode **29** by connecting a conductor **47** to the rim conductor **22** of the device and the central terminals **33** and **34** of the primary emitter are connected to twisted insulated wires **48** to apply a suitable heating current to the primary emitter, the conductor **47** and wires **48** extending through apertures in the closure plate **45** of the resonator.

Since the resonator **41** and the discharge device are separately and rigidly affixed to permanent supports, it is desirable to interconnect the coaxial tubular members of the resonator to the electrodes of the device through flexible joints in the form of yieldable bellows type rings **49**, **50** and **51** attached to the rim conductors **22** and **28** of the cathode and control electrode and the flange **32** of the anode, respectively. This arrangement compensates for expansion and contraction of the separate units and materially reduces rupture strains on the coacting metallic parts of the resonator and discharge device.

In order to couple the tubular members of the resonating chamber to the various electrodes of the discharge device and at the same time maintain the cathode and anode at their respective negative and positive potentials, in relation to the control electrode, it is preferable to interpose the necessary blocking condensers between the tubular members **42** and **44** and the respective electrodes. This type of blocking condenser may take the form of a channelled ring **52** soldered or sweated to an inwardly extending flange of the bellows ring, such as **49**, so that the end of the tubular member **42** extends within the channel opening but is insulated therefrom by a suitable dielectric material **53** which is sealed in the channel opening and rigidly affixes the end of the tubular member **42** therein. A similar annular channelled ring **54** is attached to the bellows expansion joint **51** of the anode to encase the free end of the outer tubular member **44** of the resonating chamber, said end being suitably embedded in a dielectric material in the channel ring to insulate the anode from the resonator housing. The intermediate tubular member **43** is electrically and mechanically secured to the bellows ring **50** of the control electrode by soldering the end of the tubular member **43** within the confines of a channel ring **55** so that the control electrode is at ground potential through the conductive path provided by the metallic resonating chamber.

Since the spaces bounded by the walls of the tubular members form fields of resonance between the cathode and control electrode and the control electrode and the anode for ultra-high frequency currents, these volumes can be utilized for impressing and taking out energy generated by the electron discharge device. Furthermore, the close coupling of these volumes to the discharge device eliminates inherent losses due to resistance and capacity which reduce the efficiency of the transfer of energy particularly in the ultra-high frequency range. It is possible to construct the resonant chambers of such characteristic impedances to match the characteristic impedances of the internal electrodes in the discharge device.

Tuning of the input and output circuits to resonance is accomplished by providing a plurality of slidable contacts such as **56** in the space between the inner tubular member **42** and the intermediate member **43** and to adjust the relation of the contacts in a vertical direction so as to make the electrical distance from the contacts to the extreme ends of the cathode and grid one quarter wave-length, or stated differently, to make the impedance between the grid and cathode a maximum. The contacts are adjusted by rigid push rods **57** and **58** which are affixed to a ring **59** exterior to the resonator **41**. The rod **58** is hollow to provide a coaxial channel for a central input conductor **60** which

terminates in a loop 61 below one of the contacts 56 to inductively couple the input circuit of the amplifier to the input resonating chamber of the assembly, the loop 61 being attached to the end of the hollow rod 58 to form a coaxial termination.

Similarly the space between the intermediate tubular member 43 and the outer coaxial member 44 may be tuned to the resonant frequency of the input by slidable contacts 62 attached to rods 63 and 64 connected exterior to the chamber by a ring support 65. The rod 64 is hollow and provided with a central output conductor 66 which terminates in a loop 67 inductively coupled to the resonating space and attached to the end of the hollow rod 64.

While the invention in its various aspects has been described in relation to an external anode discharge device, it is, of course, understood that the concepts of the invention may be employed in other types of discharge devices wherein high power output is not a predominating factor. Furthermore, various modifications in the relation of the electrodes and their constituent parts and also in the elimination or addition of one or more of the electrodes may be practiced in accordance with this invention without departing from the scope of the invention as defined in the appended claims.

What is claimed is:

1. A cathode assembly comprising a tubular shell, an emitting source therein for heating said shell by electron bombardment, a carbon sleeve between said source and shell, and a thermionically active metal layer between said sleeve and shell, said sleeve layer and shell being in stratiform relation.

2. A cathode assembly comprising a central helical filament, a carbonaceous member surrounding said filament, a layer of thorium containing material in contact with said member, and a refractory metallic shell enclosing said layer and member.

3. A cathode assembly comprising a central helical filament, a carbonaceous member surrounding said filament, a layer of thorium containing material in contact with said member, and a refractory metallic shell enclosing said layer and member, said shell having a flare portion at one end and an attenuated guard ring portion between said member and said flare portion.

4. A high frequency unit comprising, an electron discharge device having a plurality of cooperating electrodes concentrically mounted in said device, said cooperating electrodes having coaxial ring conductors extending from said device, a coaxial line unit of matched characteristic impedance comparable to that of said device including concentric conducting cylinders, said cylinders being coupled to said cooperating electrodes through said conductors, and capacitance elements interposed between said cylinders and said conductors, each of said capacitive elements being coupled between its respective cylinder and conductor.

5. A high frequency unit comprising an external anode discharge device having a plurality of cooperating electrodes concentrically mounted within said anode, said cooperating electrodes and anode having coaxial ring conductors extending from said device, a coaxial line unit of matched characteristic impedance comparable to that of said device including concentric conductive cylinders, said cylinders being coupled

to said anode and said cooperating electrodes, and yieldable connections between said cylinders and said anode and cooperating electrodes.

6. A high frequency unit comprising an external anode discharge device having a plurality of cooperating electrodes concentrically mounted within said anode, said cooperating electrodes and anode having coaxial ring conductors extending from said device, a coaxial line unit of matched characteristic impedance comparable to that of said device including concentric conductive cylinders, yieldable connections between said cylinders and said electrodes, and capacitive elements interposed between certain of said cylinders and the respective yieldable connections.

7. A high frequency unit comprising an electron discharge device having an external anode and a glass portion sealed thereto, a plurality of coaxial electrodes within said anode having annular portions sealed through the side walls of said glass portion, a plurality of concentric tubular metallic members coupled to said annular portions and said anode, and external input and output ring connectors having extensions slidably extending within and between adjacent members coupled to said electrodes and said anode, respectively.

8. An ultra-high frequency power generating unit comprising an external anode discharge device having concentric cathode and control electrodes in coaxial relation within said anode and rim conductors extending from said electrodes and mounted in parallel planes, a coaxial line resonator of matched characteristic impedance directly coupled to said device including three concentric cylinders of varying length, the inner and outer cylinders being capacitatively coupled to said rim conductors of said cathode and anode respectively and the intermediate cylinder being conductively connected to the rim conductor of said control electrode, a cover plate joined to and closing said resonator remote from said device, tuning elements adjustably movable in the spaces between said inner and intermediate cylinders and said intermediate and outer cylinders respectively, and coaxial input and output loops inductively coupled to said control electrode and anode respectively and movable with said tuning elements.

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