June 10, 1952 A. W. HULL 2,600,246

CAESIUM ELECTRIC DISCHARGE DEVICE

Filed April 19, 1951

Fig.1.

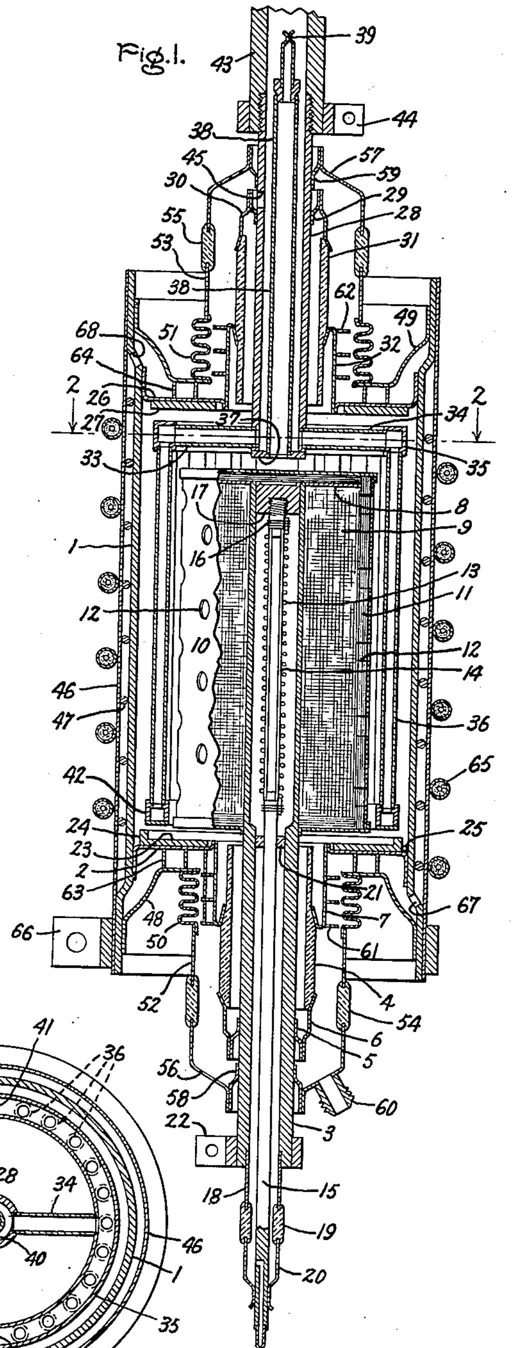
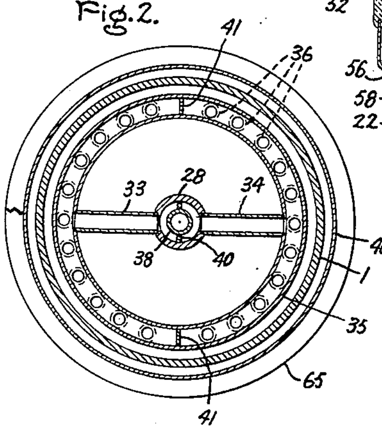


Fig.2.



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CAESIUM ELECTRIC DISCHARGE DEVICE

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6 Claims. (Cl. 313—227)

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My invention relates to electric discharge devices of the type generally known as thyratrons which utilize an ionizable medium and a control grid, and, more particularly, to such devices employing caesium, rubidium or alloys thereof, as the ionizable medium.

The construction and use of a successful caesium vapor electric discharge device has long been a goal of the discharge device art, since it is known that caesium vapor possesses the lowest ionization potential, i. e., 3.9 volts, available and, therefore, that a caesium vapor device operates at a low arc drop resulting in very high efficiencies. Further, it has been found that in a caesium vapor device having a small reservoir of liquid caesium, no oxide coating or other special electron emitting surface must be applied to the cathode, since a monatomic layer of caesium is condensed from the caesium vapor upon the hot cathode and serves as an efficient source of emitted electrons. Moreover, the emitting surface made up of a monatomic layer of condensed caesium has a very long life and high current capacity, since the monatomic layer of caesium is maintained on the cathode, even under severe operating conditions, by an equilibrium process of condensation on and evaporation of caesium from the cathode surface. Thus, a successful caesium vapor electric discharge device possesses the desirable characteristics of high efficiency, long life, high current capacity, small size, and ruggedness.

However, the employment of caesium as an ionizable medium in an electric discharge device presents several serious obstacles which must be overcome before the device may be considered successful and practical. The problems relating to the construction of uncontrolled caesium discharge devices are specifically described in U. S. Patent 2,489,891, issued to me November 29, 1949, and assigned to the same assignee as that of the present invention.

In general, caesium is a chemically active element which attacks many materials, particularly glass insulators, employed in making a hermetically sealed envelope and insulating various electrodes from one another. To maintain sealed tightness of the envelope, caesium resistant ceramic, instead of glass, insulators and caesium resistant seals are used. However, caesium resistant ceramics, while excellent insulators in air and at room temperature, behave quite differently in the presence of caesium vapor at elevated temperatures. It has been found that appreciable condensation of caesium on the surfaces of ceramic insulators considerably reduces their insulation properties producing a relatively low resistance surface leakage path and, therefore, that it is necessary to maintain the ceramic insulators at a higher temperature than the liquid reservoir of caesium in order that condensation does not occur in appreciable amounts on the insulators. The essential problem, then, is to maintain some portion of a caesium discharge device at the proper temperature for the desired vapor pressure of caesium and to maintain the insulators, as well as electrodes, at higher temperatures in order that caesium is not condensed in appreciable amounts thereon. The present invention is concerned with additional problems encountered in the construction of a grid controlled caesium discharge device and constitutes over the said patent an improvement which provides a successful and practical grid controlled caesium vapor discharge device.

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In the construction of a successful grid controlled caesium vapor discharge device even greater problems are encountered, since two ceramic insulators are required between the three electrodes and since the control grid itself must be maintained above the lowest temperature in the device. The temperature of the control grid, as well as that of the anode, must be prevented from reaching the emission temperature of a caesium-coated surface or grid emission and anode emission will occur. Grid emission results in loss of grid control, while anode emission may initiate arc-back. Consequently, for almost every part of the device, the temperature must be neither too high nor too low, being thus restricted to a relatively narrow temperature range.

It is an object of my invention to provide a new and improved grid controlled electric discharge device of the type employing caesium as an ionizable medium.

It is a further object of my invention to provide a necessary temperature controlling system for a grid controlled caesium vapor electric discharge device.

It is a still further object of my invention to provide a grid controlled electric discharge device of the caesium type requiring less critical temperature control through the use of a caesium-alkali metal alloy.

In carrying out my invention in one form thereof, I provide an electric discharge device having a cylindrical shell, with suitable end closures, forming the greater part of a hermetically sealed envelope and serving also as an anode. A cathode structure and heating means therefor is supported within and extending from the bottom end of the anode shell by means of a caesium resistant ceramic insulator bonded between the cathode structure and the shell, at the same time forming a part of the sealed envelope. A control grid structure is similarly supported within the anode shell, interspaced between the shell and the cathode and extending from the top end of the shell, by means of a second ceramic insulator bonded between the control grid structure and the anode shell and forming a part of the sealed envelope. An outer jacket and headers are provided around the sealed envelope to define a path for cooling fluid between the anode and the jacket; and the control grid is made up of tubular members supported between headers to define a path for cooling fluid through the control grid. A small amount of caesium is present in the sealed envelope, lying in liquid form in a small trough near the bottom end of the anode shell, or in some other portion so located with respect to the circulation path of the cooling fluid that its temperature is lower than that of any other part of the enclosure.

In operation, the tube is heated sufficiently, by cathode heating means or external means, so that a portion of the caesium vaporizes to the proper vapor pressure. The cathode is also heated and emits electrons which are collected by the anode held at positive potential with respect to the cathode. In order that the various parts of the device are kept at the proper temperatures in accordance with the aforementioned requirements, cooling fluid is circulated serially through the outer jacket passing by the first ceramic insulator, the caesium reservoir, the anode shell, and the second ceramic insulator in that order, and thence through the tubular control grid. The liquid caesium is thus kept cooler than any part in the tube, since the fluid passes near it first. The first insulator is kept warmer than the liquid caesium, even though the fluid passes it early in the flow cycle, since it is positioned to receive radiated heat from the heated cathode stem. The cooling fluid cools the anode and absorbs heat from the anode so that by the time the fluid passes the second insulator it is warmer than the liquid caesium and thus keeps the second insulator higher in temperature than the liquid caesium. The grid is next cooled by fluid flow but only to a temperature somewhat above the temperature of the liquid caesium. Therefore, by this arrangement, any appreciable condensation of caesium vapor occurs only at the coolest point, i. e., back into the liquid caesium, and not on the anode, control grid, or insulators. An appreciable condensation is one considerably in excess of a monatomic layer producing a lowered surface leakage resistance.

The novel features of my invention are pointed out with particularity in the appended claims. However, for a better understanding of the invention, together with further objects and advantages thereof, reference should be had to the following description, taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is an elevational view in section of an electric discharge device illustrating one embodiment of my invention; and Fig. 2 is a cross-sectional view taken along the line 2—2 of Fig. 1.

Referring now to Figs. 1 and 2, I have shown an electric discharge device comprising a hermetically sealed envelope including a cylindrical shell **1**, the inner surface of which serves, in this preferred form, as the anode of the device. To close the lower end of shell **1**, an annular header **2** is provided through which a cathode metal support cylinder **3** extends. In order to support cylinder **3** and the cathode structure from header **2**, and insulate the cathode from electrical connection with the anode, means including an insulating seal are provided, in this instance a cylindrical insulator **4** made of a material not attacked by caesium, such as ceramics of the alumina or of the magnesium silicate groups. As shown in the drawing, a metal collar **5** is bonded at one end thereof to support cylinder **3** and at the other end thereof to a metal connecting sleeve **6** which, in turn, is joined to insulator **4**. A preferable method of effecting a reliable seal between metal sleeve **6** and ceramic insulator **4** is one such as the titanium hydride method disclosed and claimed in the copending application of Bondley, Serial No. 36,244, filed January 30, 1948, and assigned to the same assignee as that of the present application. A second metal connecting sleeve **7** is bonded, in a manner similar to that for sleeve **6**, to the outer surface of insulator **4**, well spaced from the inner end of insulator **4**, and welded to the header **2**, as shown, to complete the lower portion of the sealed envelope.

The cathode structure includes a plurality of vanes **8** which extend radially from cylinder **3** and which may be covered with screen mesh **9** to increase the effective area and emission capacity of the cathode. Cylinder **3**, vanes **8**, and mesh **9** are preferably made of clean nickel, no special emitting surface being required in this caesium vapor device as explained hereinbefore. A heat conserving shield **10** is supported from cylinder **3** to surround vanes **8**, being as shown a generally closed cylindrical metallic covering having a plurality of layers **11** of thin metal or metal foil and provided with openings **12** in the side walls through which electrical discharge may take place between the anode and the cathode. The interior of support cylinder **3** serves as an hermetically sealed chamber containing a heating element **13**, preferably tungsten. Heating element **13** is wound upon a ceramic sleeve **14** which surrounds the inner end of a metallic support and electrical lead-in member **15**, to which one end of element **13** is welded. The other end of element **13** is welded to a stud **16** extending inwardly from a cap or closure member **17** which closes the innermost end of the chamber. Support and lead-in member **15** extends through an insulating seal to the exterior of the chamber, such a seal being formed by a connecting cylinder **18** welded at one end therof to the inner surface of cylinder **3** and sealed at the outer end to a glass cylinder **19**. A closing collar **20** is sealed to cylinder **19** and, in turn, welded to member **15**. Member **15** may be spaced from cylinder **3** by a heat-resistant insulation ring **21**, as shown, if it is necessary or desirable. Heating current is supplied to member **15** and a terminal **22** which, being attached to cylinder **3**, serves as the cathode terminal.

On the inner surface of header **2** there is located a stiffening ring **23** having an inwardly extending flange **24**. Ring **23** serves to strengthen the relatively thin header **2** in supporting the cathode structure, while flange **24** provides an annular reservoir between itself and shell **1** to hold a small amount of liquid metal **25**, which may be caesium, rubidium, or certain alloys thereof giving an ionizable medium having the desired features of caesium described hereinbefore.

The upper end of shell 1 is closed by a second annular header 26, also having a stiffening ring 27, through which a metal support cylinder 28 extends to support the control grid structure. The sealed envelope is completed by a collar 29 bonded at one end thereof to cylinder 28 and at the other end thereof to a metal connecting sleeve 30. Sleeve 30, in turn, is sealed to a cylindrical insulator 31, similar to insulator 4, by a process such as the process given by the aforementioned copending application. As shown in the drawing, another metal connecting sleeve 32 is also sealed to insulator 31 and also bonded to header 26 to complete the upper portion of the sealed envelope.

In order to provide for cooling of the control grid, a unique structure, preferably made of iron, is supported from cylinder 28, and comprising a pair of ducts 33 and 34 welded into cylinder 28 and communicating with a ring header 35 into which the upper ends of a plurality of grid-forming tubes 36 are fastened. Supported within cylinder 28 by an annular disk 37 is a tube 38, the inner end of which communicates with the interior of the sealed envelope and on the upper end of which there is provided a seal-off tubulation 39 for reducing the pressure in the envelope and making the final seal. Annular disk 37 also closes the lower end of the annular space between cylinder 28 and tube 38 which is a part of the cooling fluid flow path, as will be explained hereinafter. As shown more clearly by Fig. 2, the annular space between cylinder 28 and tube 38 is divided by a diametral partition 40 and ring header 35 is divided by a similar diametral partition 41, providing a cooling passageway, in order that cooling fluid may flow downwardly in half of grid-forming tubes 36 and upwardly in the other half of tubes 36, the bottom of ends of tubes 36 being fastened into another ring header 42, as shown in Fig. 1. Attached to the upper end of cylinder 28 is a fitting 43 to conduct the flow of cooling fluid, as will be explained hereinafter, and around fitting 43 a control grid terminal 44 may be conveniently located. For control grid cooling purposes, a small opening 45 is made through cylinder 28, as shown.

To provide an outer jacket for the device and define a path for cooling fluid which gives the proper temperatures at the various parts, I have welded an outer cylinder 46 around anode shell 1 and separated them with a spiral baffle 47, as shown in Fig. 1. Headers 2 and 26 are also enclosed by the jacket, since closure members 48 and 49 are bonded to the inner surface of shell 1 at its opposite ends. To the inner edges of closure members 48 and 49, bellows 50 and 51 are bonded, as shown, in order that expansion or undue pressure will not cause a leak in the jacket and, at the same time, providing a path for fluid flow past insulators 4 and 31. The jacket is completed by sleeves 52 and 53, bonded to bellows 50 and 51, and sealed into glass insulators 54 and 55; and by other sleeves 56 and 57 sealed into insulators 54 and 55 and bonded to collars 58 and 59, which, in turn, are bonded to cylinders 3 and 28. An entrance 60 to the cooling jacket is formed on sleeve 56, the ultimate exit being formed by fitting 43. In order to define spiral paths of fluid flow past insulators 4 and 31 and to thus obtain good heat exchange relation therewith, baffles 61 and 62 are mounted respectively on sleeves 7 and 32; and similarly spiral fluid flow paths past headers 2 and 26 are defined by baffles 63 and 64, mounted on closure members 48 and 49.

Since the device is intended to operate with the coolest portion of the tube, i. e., the caesium reservoir defined by flange 24, at around 150° C. so that the caesium vapor pressure is approximately 10 microns, it is preferable to provide an external sheathed heating element 65 around cylinder 46 to bring the device up to temperature before commencing operation and to hold it there during standby periods. Of course, the cathode heating element 13 may be used for this purpose, but its action is slower and, therefore, less convenient. Once the device is in operation, the heat generated therein is more than sufficient to maintain the desired temperatures and the cooling jacket and circulating cooling fluid acts to maintain each part of the device at the proper temperature. It will be apparent that the cooling fluid to be used must be one which is electrically non-conductive and which is unaffected by the relatively high temperatures involved. Water, of course, is not satisfactory but certain oils such as the silicone oils have been employed with success as cooling fluids for the device illustrated.

In operation, current is conducted by electric discharge from anode to cathode through an anode terminal 66 and cathode terminal 22. However, as in well known thyratron type discharge devices, such discharge can only be initiated when the control grid is at or above a predetermined potential, applied to terminal 44, for the particular voltage difference between the anode and the cathode. Electron emission, as previously mentioned, occurs from a monatomic equilibrium layer of caesium on the hot cathode, heated by heating element 13 to approximately 750° C. Electrons striking the control grid and the anode produce a certain amount of heat which must be removed in order to maintain the various parts of the device at the proper temperatures mentioned hereinbefore, and this is accomplished by the device illustrated in Fig. 1 by cooling fluid circulated in the following path: Relatively cool fluid enters the device through entrance 60, passes insulator 4, goes through baffles 61 and 63, and thence through an opening 67 in shell 1 and into the space between shell 1 and cylinder 46. The liquid caesium 25 held by shell 1, header 2, and flange 24 lies near the early part of the cooling fluid flow cycle and is, therefore, maintained as the coolest part of the device. Even though insulator 4 is surrounded by cooling fluid in an earlier part of the flow cycle, its inner surface is maintained at a temperature from 10° C. to 50° C. above the temperature of the liquid caesium by heat radiated directly from cylinder 3 which is relatively hot due to heat received from element 13. After entering the space between shell 1 and cylinder 46, the cooling fluid flows in the spiral path around shell 1, cooling the anode and being warmed as a result. The fluid next flows through a second opening 68 in shell 1, past header 26 in a spiral path defined by baffle 64 and upwardly past insulator 31 in a spiral path defined by baffle 62. The fluid, after passing anode shell 1, is warmer than when it passed liquid caesium 25 and, therefore, insulator 41 is maintained above the lowest temperature in the device and there is little likelihood of caesium vapor condensing on the surface of insulator 31. Also, it will be noted that the inner surfaces, i. e., the surfaces exposed to caesium vapor, of insulators 4 and 31 between sleeves 6 and 4 and sleeves 30 and 32 are made great in length by the particular construction illustrated so that leakage due to surface conductance of condensed caesium thereon, if any, will be minimized. After passing insulator 31, the cooling fluid enters the flow path provided in the grid structure, i. e., enters the annular space between cylinder 28 and tube 38 through opening 45, thence passing downwardly through the left half of the annular space, into duct 33, through the left half of ring header 35 and downwardly through the left half of grid tubes 30. Entering ring header 42, the cooling fluid flows thence upwardly through the right half of grid tubes 30, through duct 34, upwardly between cylinder 28 and tube 38, and out of the cooling jacket through fitting 43. The grid structure is, therefore, also cooled by the circulation of cooling fluid and the danger of it becoming an emitter, as the cathode is, is remote. However, the grid structure, by this method, is maintained appreciably hotter than the coolest portion in the device, and the danger of caesium condensing on the grid structure in appreciable amounts is also remote.

The caesium discharge device shown by Figs. 1 and 2 is, therefore, one which successfully meets the problems encountered in the construction of a controlled caesium vapor device. The various parts of the device are maintained at the proper temperatures for successful operation by the unique sequential series flow path for cooling fluid.

The ionizable medium employed in the device of my invention may be caesium or rubidium. However, I have discovered that an alloy of caesium or rubidium with some other alkali metal such as potassium or sodium may be used to further advantage, and, therefore, I prefer in some cases to use a caesium-sodium alloy, for example, for the ionizable medium. The benefit of an alloy such as this is believed to result from a lower caesium vapor pressure over the liquid alloy than over pure caesium, with the consequence that caesium vapor tends to condense more easily back into the liquid pool and less easily on to the ceramic insulators, anode, or control grid. Therefore, the temperature differentials between the various parts of the device are not so critical. More specifically, an alloy of caesium (or rubidium) with some other alkali metal is known to follow Raoult's law, which may be stated in this case as follows:

$$\frac{\text{Vapor pres. of Cs above alloy}}{\text{Vapor pres. of Cs above Cs}}=\frac{\text{Atomic per cent of Cs in alloy}}{1.00}$$

From the above expression it will be seen that a 50-50 atomic percent alloy of caesium with another alkali metal, say potassium, will result in only one-half the caesium vapor pressure over the liquid metal for a given temperature than that resulting from the use of pure caesium. Hence, the use of such an alloy gives the caesium vapor more tendency to condense back into the liquid metal instead of onto the insulators and electrodes, with the result that the temperature differential between the liquid metal and the various other parts of the tube is not such a critical factor to the successful operation of a discharge device of this type. In certain cases, however, it is desirable to use pure caesium or rubidium as the ionizable medium, while in other cases alloys of these metals with other alkali metals may be used with advantage.

While the present invention has been described by reference to particular embodiments thereof, it will be understood that numerous modifications may be made by those skilled in the art without actually departing from the invention. I, therefore, aim in the appended claims to cover all such equivalent variations as come within the true spirit and scope of the foregoing disclosure.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A grid controlled electric discharge device comprising an hermetically sealed envelope with an anode therein; a quantity of liquid metal selected from the group consisting of caesium, rubidium, alkali metal alloys of caesium, and alkali metal alloys of rubidium in a portion of said envelope; a cathode structure; means supporting said cathode structure within said envelope in insulated relation with respect thereto including a first ceramic insulator forming part of the envelope wall and positioned to receive heat from said cathode structure during the operation of said device; a control grid structure; means supporting said control grid structure within said envelope in insulated relation with respect thereto including a second ceramic insulator forming part of the envelope wall; and means defining cooling paths in heat exchange relation with said portion of said envelope, one electrode of said device, and said second insulator in series so that during operation of said device cooling fluid may be circulated through said paths in the order named to maintain said second insulator at a temperature above the temperature of said liquid metal.

2. An electric discharge device of the thyratron type comprising an hermetically sealed envelope; a quantity of liquid metal selected from the group consisting of caesium, rubidium, alkali metal alloys of caesium, and alkali metal alloys of rubidium within said envelope; a cathode structure; means supporting said cathode structure within said envelope in insulated relation thereto including a first ceramic insulator forming part of the envelope wall; a control grid structure including a pair of headers and a plurality of tubular members connected between said headers defining a cooling path therethrough; means supporting said control grid structure within said envelope in insulated relation with respect thereto including a second ceramic insulator; said first ceramic insulator being positioned to receive heat from said cathode structure; and means defining a cooling fluid flow path around said second insulator in series with said control grid cooling path.

3. A grid controlled electric discharge device comprising an hermetically sealed envelope including a metal portion forming an anode for said device; a quantity of liquid metal selected from the group consisting of caesium, rubidium, alkali metal alloys of caesium, and alkali metal alloys of rubidium within said envelope; a cathode structure; means supporting said cathode structure within said envelope in insulated relation with respect thereto including a first ceramic insulator forming part of the envelope wall and positioned to receive heat from said cathode structure during operation of said device; a control grid structure; means supporting said control grid structure within said envelope in spaced relation between said cathode structure and said envelope

and in insulated relation with respect to said envelope including a second ceramic insulator forming part of the envelope wall; means defining cooling paths in heat exchange relation with the region containing said liquid metal, said anode portion of said envelope, said second insulator, and said control grid structure so that during operation of said device cooling fluid may be circulated serially through said paths in the order named to maintain said liquid metal at a first predetermined temperature, to maintain said anode portion and said control grid structure below a second predetermined temperature but above said first predetermined temperature, and to maintain said second insulator above said first predetermined temperature.

4. An electric discharge device of the thyratron type comprising an hermetically sealed metal envelope forming an anode for said device, a reservoir defined in one end of said envelope, a quantity of liquid caesium in said reservoir, a cathode structure, a first ceramic insulator supporting said cathode structure from said one end of said envelope and positioned to receive heat from said cathode structure during operation of said device, a control grid structure including a plurality of tubular members supported in spaced relation between headers defining a cooling path therethrough, a second ceramic insulator supporting said control grid structure from the opposite end of said envelope, and jacket means around said envelope and said second insulator defining cooling paths in heat exchange relation therewith,

said jacket means and control grid structure being arranged so that cooling fluid may be circulated past said envelope and said second insulator and through said control grid structure in series.

5. An electric discharge device as set forth in claim 4 which contains a quantity of a caesium-sodium alloy in place of the liquid caesium.

6. An electric discharge device of the thyratron type comprising an hermetically sealed envelope having a metal portion forming an anode for said device, a quantity of liquid caesium in one end of said envelope, a cathode structure, a first ceramic insulator supporting said cathode structure from said one end of said envelope and positioned to receive heat from said cathode structure during the operation of said device, a control grid structure, a second ceramic insulator supporting said control grid structure from the opposite end of said envelope, and jacket means defining a cooling path around said anode and said second insulator in the order named so that during the operation of said device cooling fluid may be circulated through said jacket means to maintain said liquid caesium at a first predetermined temperature, to maintain said anode below a second predetermined temperature but above said first predetermined temperature, and to maintain said second insulator above said first predetermined temperature.

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No references cited.