

United States Patent

Pickering

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[54] ELECTRON DISCHARGE TUBES

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[51] Int. Cl.H01j 23/04

[58] Field of Search.....313/12, 30, 32, 34

[56] References Cited

UNITED STATES PATENTS

2,197,760 4/1940 Freedman313/12

2,080,628	5/1937	Mulder.....	313/34
2,600,390	6/1952	Boyer.....	313/34
2,637,827	5/1953	Boyer et al.	313/30
1,894,593	1/1933	Lamm.....	313/30
3,405,299	10/1968	Hall et al.....	313/12

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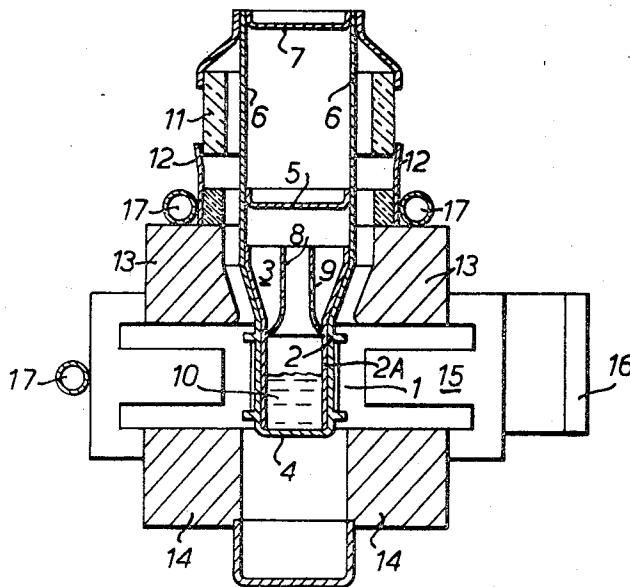
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[57] ABSTRACT

An electron discharge tube has its cathode carried by a supporting structure constituted by a closed hollow container which is in good heat exchanging relation with the cathode. In the container is a quantity of sodium, potassium, caesium, rubidium, lithium or an alloy of two or more of these metals having a boiling point equal to the desired cathode operating temperature. In operation the container acts as a boiler and condenser for the material.

19 Claims, 6 Drawing Figures



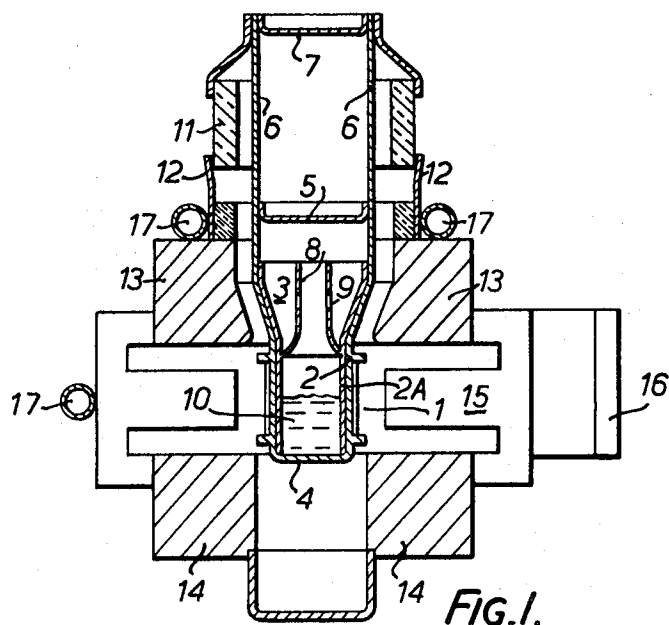


FIG. 1.

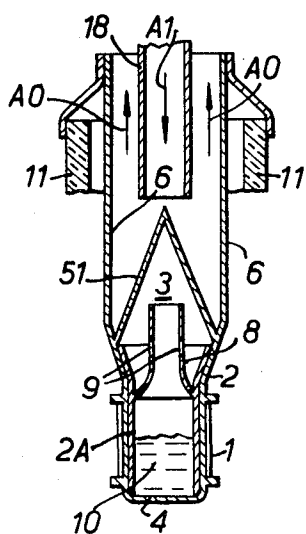


FIG. 2.

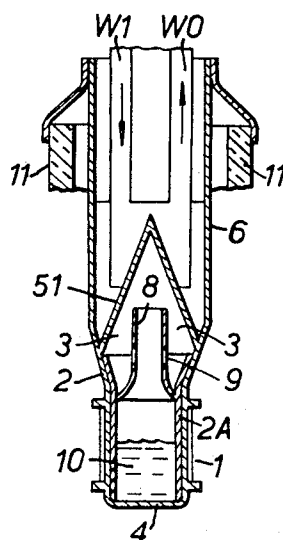


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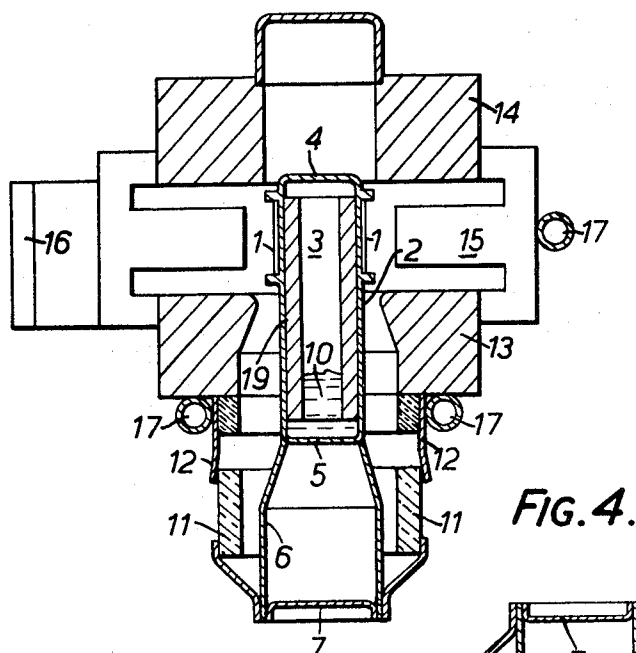


FIG. 4.

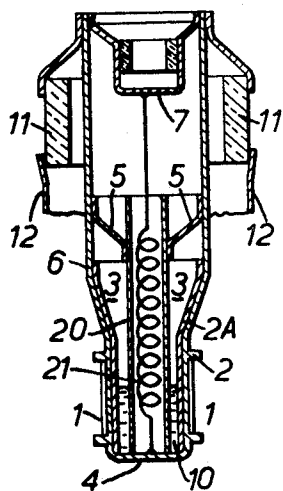


FIG. 5.

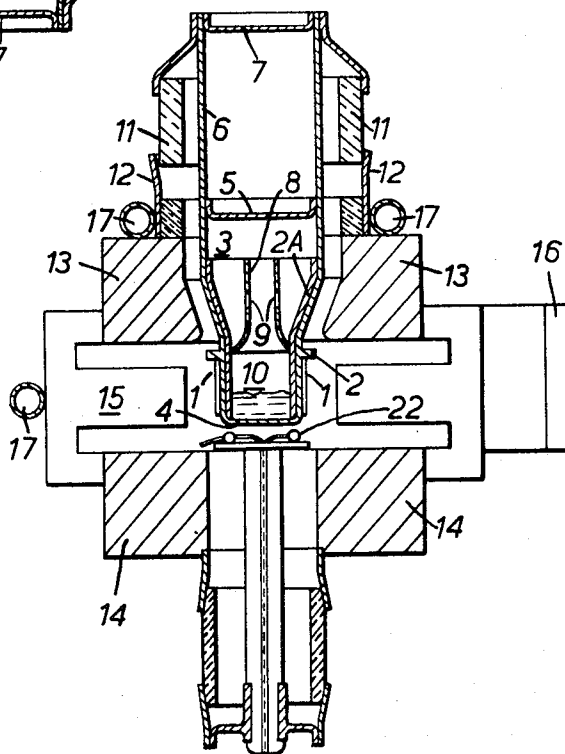


FIG. 6.

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ELECTRON DISCHARGE TUBES

This invention relates to electron discharge tubes and more specifically to electron discharge tubes of the kind having a cathode which, when the tube is in normal operation, is maintained in the required emissive condition either wholly or partly as the result of bombardment by electrons from the discharges in the tube. So-called cross field microwave tubes, i.e. tubes with operate under the influence of crossed magnetic and electric fields are tubes of this kind. Magnetrons provide a very well known example of tubes of the kind referred to but there are other examples, such as the cross field amplifiers known as "amplitrons."

In electron discharge tubes of the kind referred to the total cathode emission may be provided entirely by secondary emission or by a combination of secondary and thermionic emission. If sufficient electrons can be supplied by secondary emission, heating effects on the cathode are purely incidental and the maximum power which the tube can handle is set by what the cathode can stand before it suffers melting, decomposition or other damage. In some tubes of the kind referred to, however, secondary emission alone is not sufficient to supply all the electrons required from the cathode and is augmented by thermionic emission. In such tubes the cathode temperature must be maintained within fairly close predetermined limits (dependent on the thermionic emissive material employed) and there is provided a cathode heater which, on starting, when the tube is brought into operation, raises the cathode to near the required operating temperature but the power to which is reduced as electronic bombardment commences and increases its contribution to the total emission by secondary emission effect. In such a tube a limit to the power the tube can handle is usually set by the power at which electron bombardment maintains the cathode at the correct operation temperature with no auxiliary heating.

In known tubes of the kind referred to the permissible heat dissipation per unit of cathode area and therefore the power handling capacity of the tube is severely and undesirably limited. In such known tubes heat generated at the cathode is removed by a combination of radiation and conduction to other more or less massive parts of the tube. These parts may be cooled by radiation to atmosphere of force-cooled by circulated air, liquid, or steam. In practice the cathode area is determined largely by considerations of electronic design and because of the limitations on the removal of heat from the cathode the permissible heat dissipation per unit area of cathode surface is limited and the power handling capacity of the tube is correspondingly limited. Moreover, since electron bombardment of the cathode increases with load on the tube the requirements that a predetermined cathode operating temperature shall be maintained and that the cathode shall not be overheated to the point of damage under conditions of heavy loading, are difficult to satisfy and also set limits to power handling capacity.

The present invention seeks to provide improved electron discharge tubes of the kind referred to which shall be such as to permit the adoption of a substantially higher permissible cathode heat dissipation per unit area than is the case with known comparable tubes and which shall also be such that a desired predeter-

mined operating temperature can be obtained and maintained with a good degree of independence, over a wide range of loading, of the load on the tube. In other words the invention seeks to provide improved electron discharge tubes of the kind referred to which shall be able, safely and satisfactorily, to handle considerably larger powers than known comparable tubes.

According to this invention an electron discharge tube has a cathode carried by a supporting structure constituted by a closed hollow container which is in good heat-exchanging relation with said cathode and in which is a quantity of a material having a boiling point at least approximately equal to the desired intended cathode operating temperature, said container being adapted to act when the tube is in operation, as a boiler and condenser for said material.

Choice may be made of any of a variety of suitable materials for putting in the container — for example sodium, potassium, caesium, rubidium, lithium and alloys of two or more of these metals. For example, in the case of a cathode with an intended operating temperature of about 850° C, an alloy of sodium and potassium, with a boiling point of about this temperature, is very suitable.

In the form of construction a chimney within the container separates a first portion adapted to act as a boiler from a second portion adapted to act as a condenser, said chimney extending from the inner wall of said first portion into the interior of said second portion and having holes for returning condensate from said second portion to said first portion, the cathode being carried externally on the wall of said first portion. The container may be tubular with the said second portion tapered and of increasing cross section in a direction away from the said first portion.

The inner wall of at least the boiler portion of the container may be grooved longitudinally and/or circumferentially, or fitted with wire mesh or tubes joined to its surface, or otherwise formed to assist in splashing movement of boiling material and prevent the formation and retention of vapor layers and bubbles on said inner wall. If desired walls providing return paths for condensate may be similarly treated.

Where the invention is applied to electron discharge tubes intended to be used in any of a variety of different positions (i.e. in a vertical position either way up, or in a horizontal position, or in some intermediate position) the interior of the container is preferably tubular and continuous (as distinct from being separated into two physically distinct portions as by an internal chimney) the cathode is carried externally on a portion of the length of the tubular wall, and a wick is provided extending over at least most of the length of the tubular inner wall of the container. Such a wick may be, for example, of asbestos or of ceramic material or of stainless steel wires.

Heat may be taken from the container by radiation or by forced-cooling by air, water or steam or by a combination of two or more of these methods. Radiation cooling may be effected for example by mounting said container with at least part of its external wall adjacent to but spaced from a radiated heat receiving body which may itself be force-cooled by air, steam or water. In the case of a magnetron such a body may conveniently be constituted by part of the normally pro-

vided magnet system and/or the normally provided anode system of the magnetron. Forced cooling of the container may be effected by extending the wall thereof to form a tubular extension beyond said container and having its wall in good heat exchanging relation with said container, and force-cooling the extension by circulating air, water or steam.

The invention is applicable alike to cathodes which are heated to operating temperature and so maintained solely by electron bombardment; or are brought to operating temperature and so maintained by an electrical heater supplemented (when in operating condition) by electronic bombardment; or are brought near operation temperature by an electrical heater and maintained at operating temperature solely by electronic bombardment. Furthermore the invention is equally applicable to tubes in which the cathode carried by a supporting structure constituted by the container provides all the cathodic emission and to tubes in which an electrically heated cathode (hereinafter termed an auxiliary thermionic cathode) is also provided either to act as a "starting" cathode or, in addition, to provide some of the total cathodic emission when the tube is in operation condition. In one form of construction in which an electrical heater is employed the interior space of the container is external of a central axial tube member providing the inner boundary wall of said container and a heater filament is mounted inside said tube member. In another form of construction an electrical heater, which may also act as an auxiliary thermionic cathode, is mounted near one end of the container adjacent the cathode thereon.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional view showing one form of the invention;

FIG. 2 is a sectional view through a portion of a tube showing a modified form of the invention employing forced air cooling;

FIG. 3 is a view similar to FIG. 2 but showing forced cooling by water circulation;

FIG. 4 is a view similar to FIG. 1 but showing a modification adapted for use in any attitude;

FIG. 5 is a section through a portion of a modified form of the invention employing pre-heating means; and

FIG. 6 is a view similar to FIG. 1 but showing a still further modification of the invention.

DETAILED DESCRIPTION OF THE INVENTION

The invention is illustrated in the accompanying drawings which are diagrammatic sectional elevations of a number of embodiments. The drawings illustrate the application of the invention to magnetrons but, although this is a very important practical application of the invention, it can be applied to other tubes of the kind referred to. In the drawings only those parts necessary to an understanding of the invention are shown. Parts of the magnetrons not shown are, it is to be understood, as known per se.

Referring to FIG. 1, a secondary emission cathode 1 of cylindrical form is deposited on a portion of the tubular outer wall 2 of a closed container which, as will be seen later, acts as a boiler and a condenser of a quantity of vaporable material contained therein. The

container is indicated by the general reference 3 and its outer wall 2 is tapered with an increasingly large diameter as the distance from the cathode 1 increases. In the particular embodiment now being described, the cathode 1 is cylindrical and the cross section of the wall 2 is annular but other cross-sectional shapes, e.g. polygonal, can be adopted. The container 3 is closed at one end by a wall 4 which is integral with the wall 2 and, at the other, larger, end the container is closed by a disc closure member 5.

The wall 2 is extended as a tubular extension beyond the disc 5. This extension is, of course, of metal but is thin enough to have, when the tube is in operation, a large temperature drop along its length. The disc 5 closes the container 3 in at least a vapor-tight manner. The end of the tubular extension is closed in a vacuum-tight manner by a further disc 7.

Central and upright in the chamber 3 is a chimney 8 which is joined to the wall 2 near the upper end (upper in FIG. 1) of the cathode and extends well into the portion of the container above the cathode, in effect separating the space below the chimney from the space above and round it. The chimney has a row of holes 9 but there may be more than one ring of holes and the said holes may be of any number and arrangement. The portion of the container 3 below the chimney 9 acts as a boiler, and will hereinafter be referred to as such and the other portion acts as a condenser and will hereinafter be referred to as such.

In the boiler is a quantity of vaporable material indicated by the reference 10. This material may be, for example, an alloy of sodium and potassium.

The cathode connection (not shown) is made to the upper end of the illustrated structure, e.g. to the disc 7 and the cathode structure is supported by means of an insulating sleeve 11 and a ring 12 from one of the normally provided pole pieces 13 of the magnetron. The other pole piece is indicated at 14, 15 represents the normally provided magnetron anode system and 16 a radio frequency coupler to a waveguide output — all in accordance with known magnetron practice. Water cooling pipes 17 circulate cooling water for cooling the pole piece and anode structures. Part of the outer surface of the container wall is close to, though spaced from the inner wall of the pole piece 13. Heat from the container can radiate to the pole piece 13 and magnetron anode system. If desired, grooving, which may be vertical as indicated at 2A and/or circumferential, and/or wire mesh, may be provided on the inside of the container wall 2, or tubes joined to the inner surface of the container wall may be provided in the same position in order to assist with splashing movement of the boiling liquid or prevent vapor layers or bubbles forming on and sticking to the inside of the container wall.

In operation, when the tube is switched on, the material 10 first melts and then, as the temperature increases and cathode emission builds up, said material boils and the resultant vapor in the boiler passes up through the chimney 8 into the condenser where it is condensed and returns through the holes 9 to the boiler. With this arrangement a very considerably higher heat dissipation per unit of cathode area is permissible than in the case of a comparable known tube and the final operating temperature overwide limits of tube loading, will be to a high degree independent of

the power input to the tube for it is determined by the boiling point of the material 10 — in the example given about 850° C.

In FIG. 1 heat is taken from the cathode structure by radiation. FIG. 2 shows, so far as is necessary to an understanding thereof, a modification in which forced cooling by air is used. In FIGS. 1 and 2 (as in the other figures) like references denote like parts. In FIG. 2 the upper closure, here referenced 51, of the container 3 is made vacuum tight and is conically shaped. Cooling air is forced in through an air inlet tube 18 as indicated by the arrow AI, impinging on the closure member 51 and is fed back into the air circulating system (not otherwise shown) past the wall of the extension 6 as indicated by the arrow AO. The vacuum-tight closure member 7 of FIG. 1 is, of course, omitted from the structure of FIG. 2.

FIG. 3 shows a further modification which is very like that of FIG. 2 except that forced cooling by circulating water instead of by air is employed. It is thought that, in view of the description of FIG. 2 already given, FIG. 3 will be found practically self-explanatory. The arrow WI represents circulating water inlet and the arrow WO water outlet.

The construction of FIGS. 1 to 3 are designed for use in an upright position, i.e. as shown in these figures. FIG. 4 shows a modification which can be used in other positions. In FIG. 4 the container 3 is cylindrical and the boiler and condenser continuous with one another, i.e. not physically separated by a chimney. A tubular wick 19, which can be of asbestos, ceramic or stainless steel material, is fitted inside the wall 2 of the container and serves to ensure the return of fluid from the condenser by capillary action.

FIG. 5 shows a modification for use in a tube which is so designed that it will not start "from cold." Here an electrical heater is provided for starting purposes to raise the cathode structure to a temperature at which a discharge will start. The heater, referenced 21, is so arranged as not to heat the material 10 to any substantial extent. In FIG. 5 the said heater 21 is within and spaced from a central tube 20 which constitutes the inner wall of the container 3, the cross-section of which is annular in this construction.

FIG. 6 shows a further embodiment, again suitable for use in a tube not designed to start "from cold." The construction of FIG. 6 is generally similar to that of FIG. 1 but differs therefrom by the provision of an auxiliary thermionic cathode 22 for starting. This auxiliary cathode is constituted by a loop filament 22 mounted close to and beneath the end wall 4 of the container 3. This filament is switched on when the tube is to be put into use and is switched off at the end of an initial "warming up" time.

The material 10 to be boiled into vapor may be any material which boils at the required cathode operating temperature; is compatible chemically with the materials with which it will be in contact; and has a sufficiently low viscosity at the temperature at which it returns to the boiler from the condenser. It is of advantage to choose a material with as low a freezing point as possible and as high a latent heat of vaporization as possible.

Throughout the drawings the material 10 is shown in what may be termed its "reservoir" position, i.e. the

position to which it should return when it is all condensed. With some force-cooled arrangements such as are illustrated by FIGS. 2 and 3 it may be necessary, when the tube is to be switched off, first to switch off the cooling air or water in order that the condensed material may have time to flow back to its reservoir position before it freezes. If it is inconvenient, for some reason, the arrange for this to be done and it is required to switch off the tube and the circulation of coolant simultaneously, an auxiliary heater (not shown) positioned to apply temporary heat to the container may be provided and switched on temporarily when the tube is switched off, this auxiliary heater applying heat long enough for the material 10 to flow back to its reservoir position.

There is reason to believe that tubes with cathode arrangements in accordance with this invention will be able to be designed to dissipate as much as five times more heat per unit cathode area than is permissible with a comparable tube of the kind referred to.

I claim:

1. A cross field microwave tube having a cathode carried by a supporting structure constituted by a closed hollow container which is in good heat-exchanging relation with said cathode and in which is a quantity of a material having a boiling point at least approximately equal to the desired intended cathode operating temperature, said container being adapted to act when the tube is in operation as a boiler and condenser for said material.

2. A tube as claimed in claim 1 wherein said material is sodium, potassium, caesium, rubidium, lithium or an alloy of two or more of these metals.

3. A tube as claimed in claim 2 wherein said container comprises a first portion adapted to act as a boiler and a second portion adapted to act as a condenser, said first and second portions having between them a chimney which extends from the inner wall of said first portion into the interior of said second portion and which has holes therein for returning condensate from said second portion to said first portion, the cathode being carried externally on the wall of said first portion.

4. A tube as claimed in claim 3 wherein the container is tubular with the said second portion tapered and of increasing cross section in a direction away from the said first portion.

5. A tube as claimed in claim 4 wherein the inner wall of at least the boiler portion of the container is formed to assist in splashing movement of boiling material and prevent the formation and retention of vapor layers and bubbles on said inner wall.

6. A tube as claimed in claim 5 wherein the inner wall of at least the boiler portion of the container is grooved longitudinally and/or circumferentially.

7. A tube as claimed in claim 5 wherein the inner wall of at least the boiler portion of the container is fitted with wire mesh or tubes joined to its surface.

8. A tube as claimed in claim 2 and intended to be used in any of a variety of different positions wherein the interior of the container is tubular and continuous, the cathode is carried externally on a portion of the length of the tubular wall, and a wick is provided extending over at least most of the length of the tubular inner wall of the container.

9. A tube as claimed in claim 8 wherein heat is taken from the container by radiation by mounting said container with at least part of its external wall adjacent to but spaced from a radiated heat receiving body.

10. A magnetron in accordance with claim 9 wherein said body is constituted by part of the normally provided magnet system and/or the normally provided anode system of the magnetron.

11. A tube as claimed in claim 8 wherein forced cooling of the container is effected by extending the wall thereof to form a tubular extension beyond said container and having its wall in good heat exchanging relation with said container, and force-cooling the extension.

12. A tube as claimed in claim 1 wherein the interior space of the container is external of a central axial tube member providing the inner boundary wall of said container and a heater filament is mounted inside said tube member.

13. A tube as claimed in claim 1 wherein an electrical heater is mounted near one end of the container adjacent the cathode thereon.

14. In a cross field microwave tube including a tubular cathode adapted to operate at a selected temperature and an anode disposed in outwardly spaced relation to said cathode, said cathode being of selected length, the combination of:

an elongate hollow container having one end portion surrounded by said cathode in heat-exchange relation thereto, said container being of a length substantially greater than said selected length of the cathode to present a body portion of said container which projects beyond said cathode, said container including wall means for providing a closure at said one end of the container and closure means remote from said one end to define a closed space within said container providing a boiler region encompassed by said cathode and a condensation region within said body portion;

a body of material within said container which is a liquid at the operating temperature of said condensation region and vaporizes at the operating temperature of said boiler region, said material having a boiling point temperature and a latent heat of vaporization sufficient to prevent overheating of

said cathode; and means for recycling condensate from said condensation region to said boiler region.

15. In a cross field microwave tube as defined in claim 14 wherein said means for recycling comprises a chimney within said container and joined thereto adjacent the juncture between said boiler and condensation regions, said chimney projecting into said condensation region and having openings therein for draining condensate into said boiler region.

16. In a cross field microwave tube as defined in claim 15 including an auxiliary thermionic cathode disposed close to said one end of the container but externally thereof.

17. In a cross field microwave tube as defined in claim 16 including means connected to the opposite end of said container for supporting the container and locating said tubular cathode with respect to said anode.

18. In cross field microwave tube as defined in claim 14 including means connected to the opposite end of said container for supporting the container and locating said tubular cathode with respect to said anode.

19. A cross field microwave tube comprising, in combination:

a tubular cathode and an anode disposed in spaced, surrounding relation to said cathode; and means for supporting and cooling said cathode, said means comprising an elongate, hollow container having one end portion surrounded by said cathode in heat-exchange engagement therewith and having an opposite end portion projecting axially away from said cathode, support means connected to said opposite end of said container and fixed relative to said anode to position and support said cathode with respect to the anode as aforesaid, and a quantity of material within said container which is a vapor at the operating temperature of that region of the container surrounded by said cathode and is a liquid at the operating temperature of that region of the container axially beyond said cathode, whereby the container not only supports and positions the cathode with respect to said anode but also functions as a boiler-condenser to cool said cathode.

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