# United States Patent [19]

**Manyafov et al.**

[11] **3,784,866**

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[54] **ELECTRON TUBE HAVING CHAMBER ANODE STRUCTURE**


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[51] **Int. Cl.** ..... **H01j 21/14**

[58] **Field of Search** ..... 313/265, 299, 300, 313/306, 330, 348, 356



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[57] **ABSTRACT**

An electron tube is disclosed having at least one grid positioned between the cathode and the chamber anode with the chambers thereof formed by fins arranged parallel to one another and perpendicularly to the anode surface opposite the cathode. Each chamber is of a width given by the following formula:

$$b = 2\sqrt{\frac{\Delta U_{min}}{U_a}}\,(U_a)^{3/4} \cdot \frac{1}{\sqrt{j\left[1 - \frac{1}{ch\left(1.58\frac{a}{b}\right)}\right]}},$$

where

$b$ = width of the chamber,

$U_a$ = anode voltage other than zero,

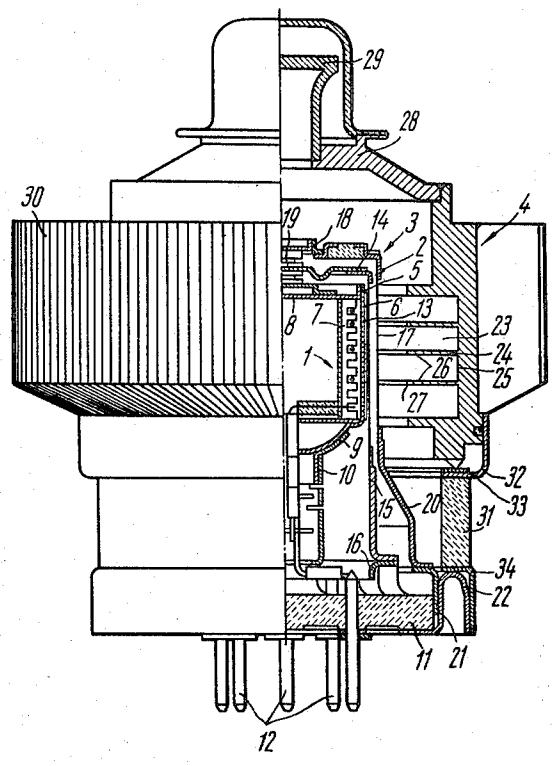
$\Delta U_{min}$ = a difference between anode voltage $U_a$ and the minimum chamber potential, i.e., a potential drop in the chamber,

$j$ = average density of the maximum anode current which flows via a surface passing through the centre of the chamber perpendicularly to its lateral inserts,

$ch$ = hyperbolic cosine,

$a$ = depth of the chamber.

**1 Claim, 3 Drawing Figures**

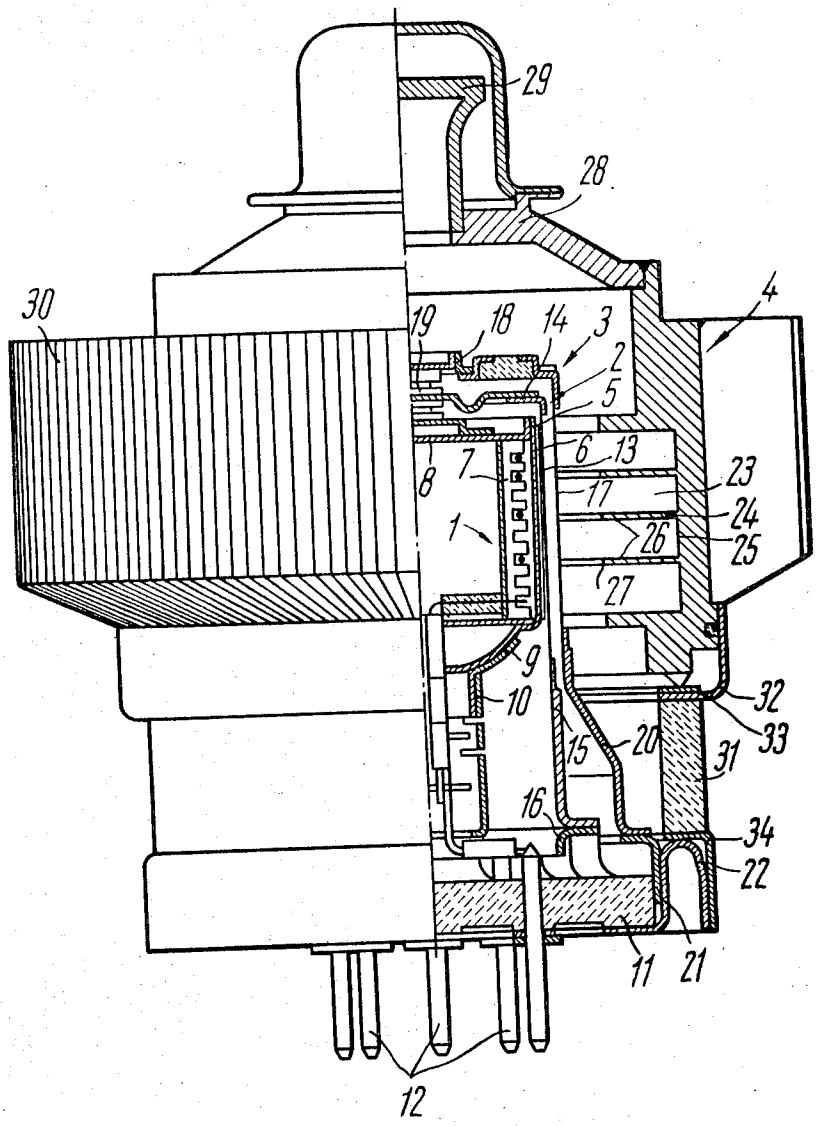

29
28
30
19
18
14
3
4
2
5
6
13
8
7
17
23
24
1
26
25
27
9
10
32
33
15
20
31
16
34
22
11
21
12

FIG.1

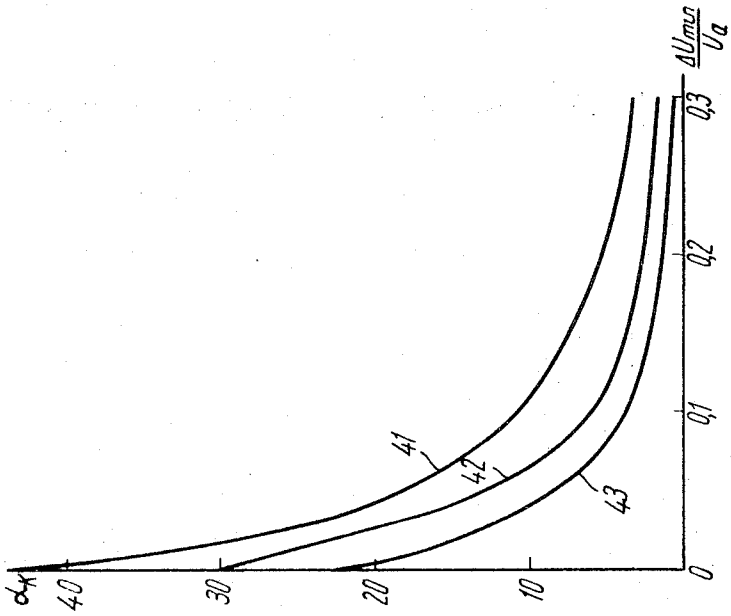

ΔUmin/Ua
0,3
0,2
0,1
0
41
42
43
40
30
20
10
α°

FIG. 3

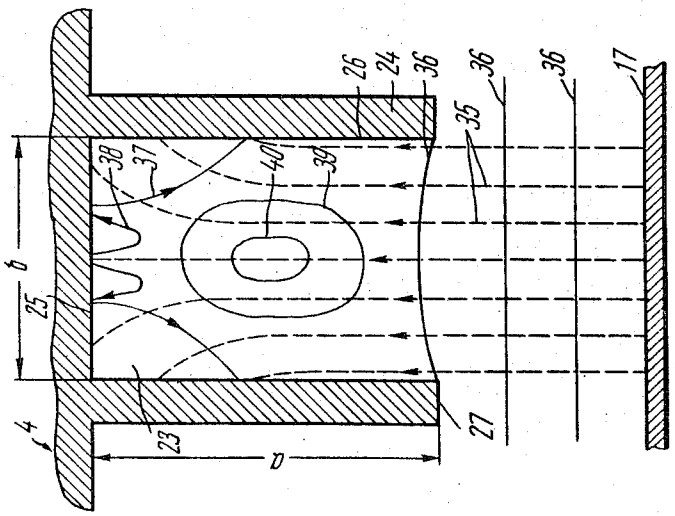

26
24
36
36
36
17
35
38
37
40
39
b
25
4
23
D
27

FIG. 2

# ELECTRON TUBE HAVING CHAMBER ANODE STRUCTURE

## BACKGROUND OF THE INVENTION

The present invention relates to electron devices, and, more particularly, to electron tubes. The invention can be used in electron devices where a high degree of suppressing secondary anode emission is required, in particular, in oscillator and modulator tubes.

Prior art electron tubes comprise a cathode, a chamber anode divided into a plurality of chambers by parallel fin members arranged perpendicularly to the anode surface facing toward the cathode, and at least one grid located between the cathode and the chamber anode.

In these known tubes a distance between the longitudinal fins dividing the anode into a plurality of chambers, i.e., the width of each chamber, is selected so that electric-field intensity inside the chambers is low and does not practically affect the paths of secondary electrons. Consequently, the anode chambers may be considered as mechanical traps of the secondary electrons since the anode fins forming the chamber walls restrict the flow of the secondary electrons out of the chamber space.

However, such absorption of secondary electrons by the anode chamber walls is not effective, because by virtue of cosine distribution over the emission angles, a large number of secondary electrons passes out of the anode chambers impairing thereby current distribution in the tube.

This disadvantage does not allow a considerable increment in the anode-voltage characteristic curve to be obtained, in other words, residual anode voltage ($U_a$) cannot be kept to a low level.

## SUMMARY OF THE INVENTION

It is an object of the present invention to provide an electron tube with a chamber anode construction which reduces to the maximum extent the emission of secondary electrons at the anode.

These objects and others are achieved according to the present invention by providing an electron tube with a cathode, a chamber anode divided into chambers by fins disposed parallel to one an other and perpendicularly to the anode surface facing toward the cathode, and at least one grid arranged between the cathode and the chamber anode, in which each chamber of the chamber anode is of a width determined by the formula:

$$b = 2\sqrt{\frac{\Delta U_{min}}{U_a}}\,(U_a)^{3/4} \cdot \frac{1}{\sqrt{j\left[1 - \frac{1}{ch\left(1.58\frac{a}{b}\right)}\right]}},$$

where:

$b$ = width of the chamber,

$U_a$ = anode voltage other than zero,

$\Delta U_{min}$ = the difference between anode voltage $U_a$ and the minimum chamber potential, i.e., the potential drop in the chamber,

$j$ = average density of the maximum anode current which flows via a surface passing through the centre of the chamber perpendicularly to its lateral inserts,



$ch$ = hyperbolic cosine,

$a$ = depth of the chamber.

The proposed electron tube provides an appreciable decrease in the secondary-emission current at the anode which makes it possible to obtain high anode currents at a low residual anode voltage thereby to raise the efficiency of the anode circuit.

## BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood from the following description taken in connection with the accompanying drawings, wherein:

FIG. 1 is a partial side sectional view of an electron tube embodying the present invention;

FIG. 2 is a side sectional view of one of the anode chambers of an electron tube embodying the present invention showing the distribution of the equipotential lines of the electric field in the chamber and in the screen grid-anode space;

FIG. 3 is a graph showing the secondary-emission suppression coefficient in slot-type chambers versus the ratio of a potential drop in the chamber to the anode voltage.

## DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT OF THE INVENTION

An electron tube embodying the present invention comprises a cathode assembly **1** (FIG. 1), a control grid **2**, a screen grid **3**, and a chamber anode **4** positioned coaxially with respect to each other at a preset distance.

The cathode assembly **1** includes a cylindrical cathode **5** coated with an emission layer forming an emitting surface **6** of the cathode **5**, a heater **7** disposed inside the cathode **5**, a plate **8** joining the upper terminal members of the cathode **5** and the heater **7**, supports **9** and **10** by means of which the cathode assembly **1** is joined to a mount **11** and electrically connected via jumpers (not shown in the drawing) to appropriate cathode terminals of one of pins **12**.

The cylindrically-shaped control grid **2** is composed of wires **13** disposed along the generatrices of the cylinder. The upper ends of the grid wires **13** are fixed in a cap **14** provided with a centre hole, while the lower ends are fastened in a support **15** which joins the control grid **2** to a ring **16** of a mount **11** and connects it through a jumper (not shown in the drawing) to an appropriate control grid terminal of one of the pins **12**.

A cylindrically-shaped screen grid **3** is composed of wires **17** arranged along the generatrices of the cylinder and aligned with the wires **13** of the control grid **2**. The wires **17** of the screen grid **3** are held together by a screen **18** in the centre of which there is provided a hole for a centering ceramic unit **19** joining the upper terminal members of the cathode assembly **1**, control grid **2** and screen grid **3**. The lower ends of the grid wires **17** are attached to a support **20**. The screen grid **3** is fixed to the mount **11** through a metal ring **21** soldered to a seal **22**.

On the surface of the chamber anode **4** facing the cathode **5** there are disposed chambers **23** formed by fins **24**. The fins **24** are arranged parallel to one another and perpendicularly to the surface of the chamber anode **4** facing the cathode **5**, so as to form slot-type chambers. A portion of the inner surface of each chamber **23** of the chamber anode **4** located between the fins

24 forms a bottom 25 of the chamber 23 and serves as an active surface of the chamber anode 4.

The side surfaces of the fins 24 facing toward the chamber 23 are lateral walls 26 of the chambers 23. The narrow part of each insert 24 facing toward the cathode 5 forms an end face 27 of the fin 24.

The distance between the end face 27 (FIG.2) of the fin 24 and the bottom 25 of the chamber 23 is the depth of the chamber 23 designated $a$.

The distance between the lateral walls 26 of the chamber 23 is the width of the chamber 23 designated $b$.

The width $b$ of the chamber 23 is found from the formula:

$$b=2\sqrt{\frac{\Delta U_{min}}{U_a}}(U_a)^{3/4}\cdot\frac{1}{\sqrt{j\left[1-\frac{1}{ch\left(1.58\frac{a}{b}\right)}\right]}},$$

where:

$b$ = width of the chamber, 23;

$U_a$ = voltage other than zero at the anode 4;

$\Delta U_{min}$ = the difference between anode voltage $U_a$ and the minimum potential in the chamber 23, i.e., the potential drop in the chamber 23;

$j$ = average density of the maximum anode current which flows via a surface passing through the centre of the chamber 23 perpendicularly to its lateral inserts 24;

$ch$ = hyperbolic cosine;

$a$ = depth of the chamber 23.

$a$ must be expressed in mm, $j$ in mA/sq cm, $U_a$ and $\Delta U_{min}$ in V, then $b$ will be obtained in mm.

The ratio $a/b$ is selected larger than unity, in particular, $a/b = 2$.

The voltage $U_a$ of the chamber anode 4 required for calculating $b$ according to the above formula is the minimum attainable voltage at the chamber anode 4 (residual anode voltage). For the present embodiment of the invention (a tetrode), this voltage is within the following limits:

$$0.2U_{g_2}<U_a\leq U_{g_2},$$

where $U_{g_2}$ is the voltage across the screen grid 3.

The value of the ratio $\Delta U_{min}/U_a$ is dictated by the necessity for suppressing the dynatron effect of the chamber anode 4 which is made clear by further explanation. The value $j$ is the average density of the maximum anode current which flows through a surface passing through the centre of the chamber 23 perpendicular to its longitudinal fins 24.

In this embodiment of the invention wherein

$(\Delta U_{min}/U_a) = 0.28$, $a/b = 2$, $U_a = 100$ V, $j = 100$ mA/sq cm,

$b$ is equal to 3.5 mm.

The envelope of the proposed electron tube (FIG. 1) is formed by the cup-shaped chamber anode 4 in the top member 28 which is provided with an exhaust tube 29 intended for evacuation of the electron tube, while its outer surface has soldered heat-radiating wings 30 for cooling the chamber anode 4, and by a ceramic ring 31 connected to the chamber anode 4 through rings 32 and 33 and to a seal 22 of the mount 11 through a seal 34 which serves as a lead of the screen grid 3.

The operating principle of the proposed electron tube is as follows.

Electrons emitted by the cathode 5 (FIG. 1) which is heated by the heater 7, pass through the wires 13 of the control grid 2 and the wires 17 of the screen grid 3 and fly off into the space between the screen grid 3 and the chamber anode 4.

Paths 35 of the primary electrons (FIG.2) are shown by dashed lines (in the figure, the wire 17 of the screen grid 3, cross-section of the chamber 23 and paths 35 of primary electrons are given in one plane for the purpose of illustration).

While passing through the above spaces with the potential distribution thereof characterized by equipotential lines 36, the primary electrons enter the chamber 23 and bombard its bottom 25 and side walls 26 dislodging other electrons which "leave" these surfaces and go into the surrounding space. These secondary electrons travel in the direction shown by lines 37 and 38 due to the fact that as soon as they leave any point of the surfaces of the chamber 23 shown above, they are acted upon by a high-intensity electric field having closed equipotential lines 39 and 40 formed inside the chamber 23 on account of an appropriately selected width of the chamber in accordance with the invention, the electric potential of the field at any point of the chamber 23 being below the voltage $U_a$ of the chamber anode 4.

If a high-intensity electric field is set up inside the chamber 23, the chamber 23 operates not only as a mechanical trap, but substantially as an electric trap of secondary electrons. The minimum potential in the chamber 23 is provided at the point located approximately in the centre of the chamber 23. In a high-intensity field inside the chamber 23, the secondary electrons are slowed down, deflected toward the bottom 25 and side walls 26 and absorbed by the chamber 23. As a result, the current at the screen grid 3 remains unaltered under the effect of secondary electrons which considerably improves current distribution in the tube.

The voltage drop appearing in the chamber 23 at a constant density of current flowing into the chamber 23, constant anode voltage, and a preset ratio of the depth a of the chamber 23 to its width $b$, is a function of the width $b$ of the chamber 23. The difference between the anode voltage and the minimum potential in the chamber 23 must be sufficient to suppress secondary emission.

The effect of suppressing secondary electrons by the chambers 23 depends on the ratio of potential drop $\Delta U_{min}$ in the chamber 23 to voltage $U_a$ at the chamber anode 4 and its measure is a secondary-emission suppression coefficient $\alpha_k$ which is the ratio of the number of secondary electrons that have passed out of the chamber 23, to the total number of dislodged secondary electrons.

FIG.3 pictures the secondary-emission suppression coefficient $\alpha_k$ (the ordinate gives the values of $\alpha_k$ in percent) versus the ratio $\Delta U_{min}/U_a$ (the abcissa) for different ratios of the depth $a$ of the chamber 23 to its width $b$

($(a/b) = 1$ /curve **41**/, $(a/b) = 1.5$ /curve **42**, $(a/b) = 2$ /curve **43**/).

FIG.3 represents an optimum embodiment of the invention when the entire electron flow is directed to the bottom **25** of the chambers **23**. Curves **41, 42** and **43** relate to the chamber anode **4** made of copper, the shapes of the curves being similar for other anode materials.

In order to ensure more effective suppression of secondary emission from the chamber anode **4** in a broad range of anode voltages, it is advisable to select the ratio $(\Delta U_{min}/U_a)$ within 0.1 – 0.4. As was shown above, the ratio $(\Delta U_{min}/U_a)$ for this embodiment of the invention is taken equal to 0.28.

If the proposed electron tube operates in conditions when voltage at the chamber anode **4** is below the voltage at the screen grid **3**, a rise of voltage at the anode **4** causes the ratio $(\Delta U_{min}/U_a)$ to decrease both due to an increase of voltage across the anode **4** and to diminution of $\Delta U_{min}$ resulting from the reduction of the volume charge of the primary electron current in the chamber **23**. Then, the ratio $(\Delta U_{min}/U_a)$ may drop below 0.1 and the effect of the suppression of secondary emission will be greatly reduced, as can be seen from FIG.3.

The dynatron effect of the anode **4** is particularly pronounced in the anode voltage range $0 < U_a 4 U_{g2}$, or, taking into account physically attainable residual voltages at the anode **4**, in the range $0.2\ U_{g_2} < U_a \leq U_{g_2}$. If voltage at the anode **4** varies in this manner, it is advantageous to operate the chamber **23** in conditions corresponding to the gently sloping portions of curves **41, 42** and **43**.

In this case, by virtue of the monotonic and weak nature of the relationship $\alpha_k = f(\Delta U_{min}/U_a)$, $\Delta_k$ will remain practically unchanged with $U_a$ varying within the specified limits and, consequently, secondary electrons produced at the chamber anode **4** will be effectively reduced.

It is clear from FIG.3 that in the absence of the minimum potential in the chambers **23**, the secondary-emission suppression coefficient for slot-type chambers with $(a/b) = 2$ is 23 percent, while with $(\Delta U_{min}/U_a) = 0.3$ and $(a/b) = 2$, $\alpha_k = 0.5$ percent which is indicative of an almost complete suppression of secondary emission from the anode **4**. In practice, values $\alpha_k = 0.5 - 5$ percent can be attained.

The above operating mechanism of the chambers **23** may be called electromechanical. The effect of reducing secondary electrons in chambers using the electromechanical trapping pirnciple is 20 to 40 times as great as the effect of secondary emission suppression in chambers which depend for their operation on the mechanical trapping only. This engineering solution allows the reduction of the residual anode voltage in the proposed embodiment of the invention by about 5 times and appreciably raises the efficiency of the proposed electron tube.

The proposed solution yields the greatest effect when used for oscillator tubes of the given type employed in radio equipment operating with a broad-band (low-resistance) load, in particular, in distributed amplifiers. The efficiency of such devices can be increased almost two-fold (from 30 to 50 percent), while their weight, size and cost are amenable to a large reduction through cutting down the number of tubes in a stage.

An electron tube with a flat electrode assembly can also be realized, with the anode chamber being of a width specified in the present invention.

While we have shown and described a particular embodiment of the invention, it will be obvious to those skilled in the art that other changes and modifications may be made without departing from the invention in its broader aspects. We therefore claim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

**1.** An electron tube, comprising: an envelope; a cathode arranged in said envelope and emitting a flow of electrons; at least one grid also disposed in said envelope behind said cathode in the direction of said flow of electrons; a chamber anode positioned in said envelope behind said grid in said flow of electrons and receiving said flow of electrons; fins of said chamber anode arranged perpendicular to the surface of said cathode to form chambers of said chamber anode, said chambers being of a width given by the following formula:

$$b = 2\sqrt{\frac{\Delta U_{\min}}{U_a}}\,(U_a)^{3/4} \cdot \frac{1}{\sqrt{j\left[1 - \frac{1}{ch\left(1.58\frac{a}{b}\right)}\right]}},$$

where:

$b$ = the width of the chamber;

$U_a$ = the anode voltage, other than zero;

$U$ = the difference between the anode voltage $U_a$ and the minimum chamber potential, i.e., a potential drop in the chamber;

$j$ = the average density of the maximum anode current which flows via a surface passing through the center of the chamber perpendicular to its fins;

$ch$ = hyperbolic cosine, and

$a$ = the depth of the chamber,

the ratio $a/b$ lying within the range of from 1 to 2, and the ratio $(\Delta U_{min}/U_a)$ being within the range of 0.1 to 0.4.

* * * * *