Sept. 13, 1938. M. KNOLL 2,130,281

ELECTRON DISCHARGE TUBE

Filed July 11, 1935 2 Sheets-Sheet 1

Fig. 1

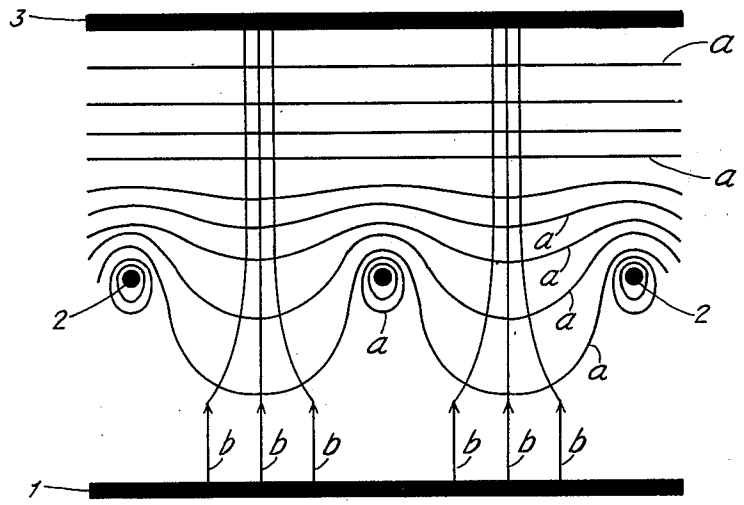
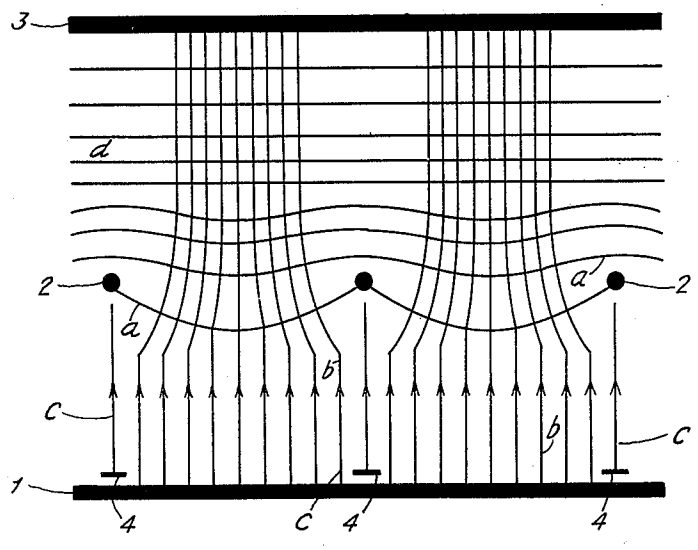


Fig. 2



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Filed July 11, 1935 2 Sheets-Sheet 2

Fig. 3

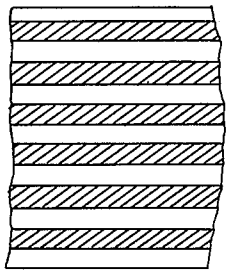


Fig. 4

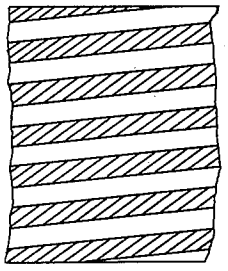


Fig. 5

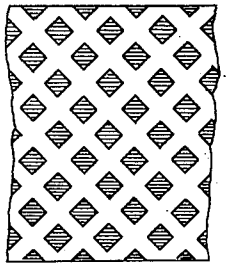


Fig. 6

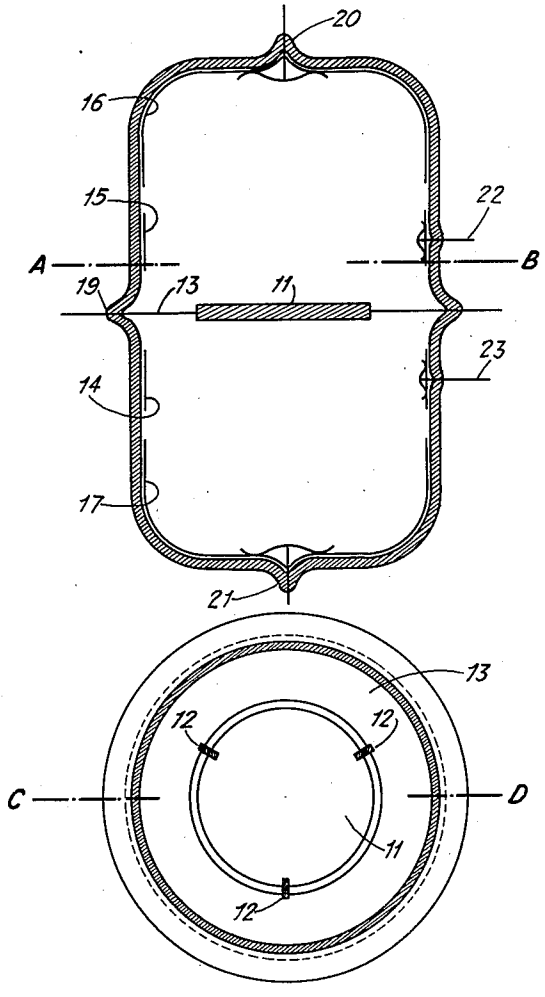
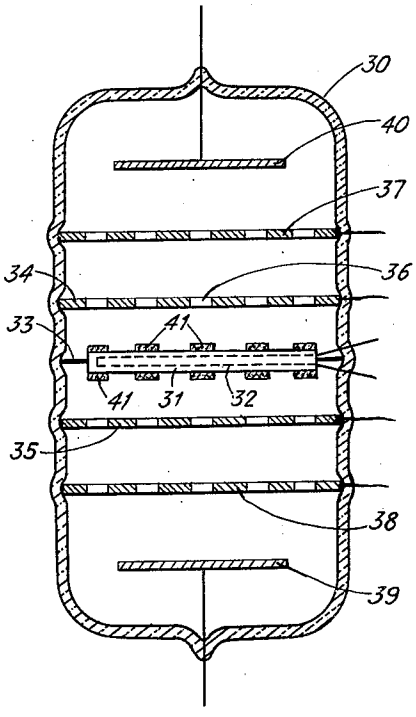


Fig. 7



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Patented Sept. 13, 1938 2,130,281

UNITED STATES PATENT OFFICE

2,130,281

ELECTRON DISCHARGE TUBE

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Application July 11, 1935, Serial No. 30,830
In Germany February 2, 1934

10 Claims. (Cl. 250—27.5)

The invention relates to an electron discharge tube and particularly to methods and means for decreasing grid current.

It is known that the permissible power obtainable from an electron discharge tube, and especially from one using an oxide coated cathode, is usually limited, not by the emissivity of the cathode, but by the setting in of positive control grid current.

The invention has for its object a displacement of the point of setting in of the grid current toward positive values of control grid bias.

The novel characteristics of the invention are pointed out with particularity in the appended claims, but the invention itself will best be understood in connection with the following description taken with the accompanying drawings in which Figures 1 and 2 are diagrams of the lines of force of the field in a triode, the grid being biased negative in Figure 1 and positive in Figure 2; Figures 3 to 5 are plan views of portions of the surface of cathodes constructed in accordance with my invention; Figure 6 is a longitudinal section along the line C—D and a cross section along the line A—B of a double triode embodying one form of my invention; and Figure 7 is a longitudinal section of a flat electrode screen grid tube embodying another form of my invention.

The invention is based upon experimental proof that in electron discharge tubes of the usual construction the mutual repulsion of the electrons is so small that the electron stream represents not a continuous flowing medium, but is split up in accordance with the laws of geometrical electron optics into single, separated beams or rays corresponding to the openings in the control electrode.

As long as the potential of the control grid of a three electrode tube or triode is negative, the electrons as a whole go to the anode; with positive control grid bias, a part of the electrons land on the surface of the grid. Without anything more this is evident from the diagrams of the field of force shown in Figures 1 and 2. These figures show schematically a flat three-electrode system with a cathode surface 1, a control grid 2, and an anode 3. The equipotential lines of force are designated by the letter *a*, while the electron paths are distinguished by the letter *b*. Figure 1 shows the conditions with the grid 2 biased negatively. It will be noted that only such electron beams or rays as pass from the cathode to the anode are present and that the portions of the cathode surface in register with the grid conductors 2 and intermediate the groups of electron paths *b* emit substantially no electrons. From Figure 2 may be seen the changes which occur when the grid bias assumes positive values. To the beams previously present are added new beams of which a part, indicated by the letter *c*, start from the cathode surface and end on the grid wire.

With an increase of the positive grid bias the new self constituted electron beams which furnish the positive grid currents arise at first, not on the entire cathode surface, but only on certain limited parts of that surface. These parts are very small at low positive grid bias, but increase more and more with increase of the positive grid bias until they finally, when the grid voltage has reached approximately the anode voltage, are practically identical with the entire cathode surface, consequently always there is available only a part of the emitting surface of the cathode for the supplied anode current power.

In accordance with the invention the cathode is so made that electrons are not emitted by those portions of the cathode surface in the regions indicated by 4 in Figure 2, which are in register with the grid conductors 2 and in which the lines of force leading to the control grid at low positive grid bias terminate. In this way the cathode surface has emissive portions in register with the spaces between the individual conductors or wires 2 of the grid and non-emissive portions in register with the grid conductors, and it is possible without loss of mutual conductance to control the grid as far in the direction of positive grid bias as the electron emissivity of the cathode permits.

The prevention of electron emission at undesired places can be accomplished in various ways with the usual constructions of electrode systems; for example, by providing that the emitting substance upon the cathode surface is not uniformly distributed, but is applied only to those places lying opposite the openings in the grid, so that, for instance, with a grid consisting of parallel rods the pattern which appears upon the cathode surface is of composite rectangles, (Figure 3); with a helical grid is spiral shaped, (Figure 4); and with a mesh grid is rhomboid shaped, (Figure 5). This treatment of the surface can be applied to indirectly heated cathodes and also to directly heated cathodes.

Another way of limiting the emission capacity of a cathode to definite parts of the surface comprises a special procedure in the formation process of the cathode. In general, the activation of oxide coated cathodes is so conducted that the cathode surface is covered with a suitable oxide,

for example, barium oxide, and from it is liberated metallic barium on the presence of which the electron emissivity is dependent. During the formation process the grid is connected to the anode, and a voltage of about 50 to 100 volts is applied to the anode whereby the entire cathode surface is uniformly treated. In accordance with the invention the cathode formation takes place in such a way that the anode is brought to a comparatively high positive potential, for example, 500 volts, while the grid is connected with the hot cathode or is brought to a negative potential. In this way only those parts of the cathode surface will be activated, that is, transformed into metallic barium, which do not lie in the shadow of the grid wires; the remainder of the oxide between the activated parts has no emissivity.

Likewise, upon a uniformly activated cathode surface every place at which the emissivity is to be suppressed can be covered with non-emitting material having a high work function, such as zirconium oxide.

However, the inventive idea furthermore leads to entirely new forms of cathodes and of control electrodes which differ in principle from the prior usual forms. For instance, the requirement that electron emission shall take place only at the places lying opposite the openings of the grid can also be met by providing that at these places the cathode temperature is maintained high and on the contrary is kept low at the places where electron emission is undesired.

The same effect can also be obtained by providing that every part of the cathode surface which is not intended to contribute to the discharge current be depressed or deepened. In this way hollow spaces or recesses (the so-called space charge nests) are obtained in which electron space charge accumulates and hinders the escape of further electrons at these places.

In the Figures 6 and 7 electron tubes are shown as examples in which the idea of the invention is embodied in various ways.

Figure 6 shows two sectional views of a double triode. In these views **11** designates an indirectly heated flat cathode mounted by supports **12** on an auxiliary cathode **13** having the shape of an annular disc. **14** and **15** are control electrodes, and **16** and **17** are hollow cylindrical anodes. The so-called auxiliary cathode is an unheated or low temperature metal disc and thus without electron emissivity, which, for producing an undistorted field distribution suitable for the purpose in view, is maintained at cathode potential. The cylindrical control electrodes and anodes are directly placed on the inner wall of the glass bulb **18** in this embodiment, and can accordingly be formed of a thin current conducting deposit (for instance of silver or graphite). Obviously it is also possible to make the electrodes **15**, **16**, and **17** as hollow cylinders of sheet metal, or as perforated discs, and to mount them, for instance, on the auxiliary cathode **13**. The auxiliary cathode **13** is joined to the glass wall by means of a sealed-in lead **19** and the leading-in wires for the cathode **11** and for the control electrodes **14** and **15** can be brought out through the said glass wall. **20** and **21** are leading-in wires for the two anodes **16** and **17**. Since the cold auxiliary cathode **13** constitutes those parts of the cathode surface directly adjacent the grids, a grid current first appears at relatively high positive values of the grid voltages. Contrary to the known arrangements, this type of structure is furthermore especially insensitive against strong mechanical vibrations.

Besides triodes, obviously screen grid tubes, space charge grid tubes, or pentodes, etc., can also be constructed in accordance with the example shown in Figure 6. Such tubes have the advantage over those of the prior customary construction in that not only the control electrode in the region of small voltages, but also all other positive electrodes (space charge grid, screen grid) with the exception of the anode, do not receive any electron current from the cathode, so that a lower load and thus also a reduction in the cost of the current sources will be obtained.

Obviously the object of the invention can also be attained for instance by means of a disc-shaped control electrode having several openings, if opposite each opening an incandescent cathode is disposed, and the interspace in the common plane of the cathodes is filled in by a cold auxiliary cathode. One embodiment of this arrangement is shown schematically in Figure 7 in longitudinal section.

Figure 7 shows a symmetrically constructed screen grid tube having flat electrodes. The two electrode systems may either be connected in parallel by connecting the equivalent electrodes to each other, or else they may operate in push-pull. In this embodiment an evacuated glass bulb **30** encloses the electrodes. An indirectly heated cathode **31** capable of emission at both sides and having a heater **32**, is fixed in position by means of an annular metal disc or auxiliary cathode **33**. The two control electrodes **34** and **35** are disposed on opposite sides of the cathode, and each has apertures **36**. Behind the control grids are mounted the two screen grids **37** and **38**, which are of exactly the same construction as the control grids and so mounted that the apertures of each control grid and of the screen grid behind it are in registry with each other. The outermost electrodes or anodes **39** and **40** are disc-shaped. By a suitable surface treatment only those places **41** on the cathode which are situated directly in line with the apertures of the grid electrodes have been activated. Obviously a suitable distribution of the emissivity of the cathode can also be obtained by placing an individual cathode below each aperture of the control electrode. The individual cathodes can be joined together by means of a suitably formed auxiliary cathode, thereby forming a complete cathode unit of the assembly. Obviously, the individual cathodes or emitting surfaces are conductingly connected to each other. The heating elements for the individual cathodes may as desired be connected in series or in parallel.

In summary, it may also be pointed out that the advantages attained by the invention on the one hand reside in an increase with equal heater power of the obtainable anode current power, and furthermore that the working point is moved toward a steeper portion of the characteristic. Furthermore, the negative grid bias and the means necessary for its production (voltage divider, battery, etc.) can be omitted. The increase in the anode power at unchanged consumption of heating current is of particular importance in power tubes for power amplifiers and in transmitters, while the suppression of the grid current and the simplification of the circuit affords an advantage also in smaller tubes for the purposes of reception and of amplification.

What I claim as new is:—

1. An electron discharge tube comprising a

perforated control electrode having a plurality of apertures, a cold electrode on one side of said control electrode, and a thermionic cathode on the other side of said control electrode and having on its surface discrete electron emitting places no larger than the apertures in said control electrode and each in registry with one of said apertures.

2. An electron discharge tube comprising a perforated control electrode having a plurality of apertures, a thermionic cathode on one side of said control electrode and having a surface with electron emitting portions no larger than the apertures in said control electrode and in registry with said apertures, and another perforated electrode similar to said control electrode and mounted on the other side of said control electrode with its apertures in registry with the apertures in said control electrode and with said emitting portions of said cathode.

3. An electron discharge tube comprising a cold work electrode, an oxide coated thermionic cathode having a surface with alternate coated and uncoated portions, and a grid electrode between said work electrode and said cathode comprising conductors in registry with only the uncoated portions of said cathode and spaced to provide openings of the same size as and in registry with the coated portions of said cathode.

4. An electron discharge device comprising an evacuated vessel enclosing an oxide coated cathode comprising a metal member having on its surface an oxide coated place and an uncoated place contiguous to said coated place, a control electrode comprising a conductor in registry with the uncoated place on said cathode only and having in registry with the coated place an aperture larger than said place, and a cold work electrode in registry with the aperture in said control electrode.

5. An electron discharge tube comprising an anode, a thermionic oxide coated cathode having separated active portions of high electronic emissivity and intermediate inactive portions of low electron emissivity, and a pair of grid electrodes interposed between said cathode and said anode to be passed successively by the discharge from said cathode to said anode, said grid electrodes comprising conductors aligned with said inactive portions only and spaced to leave openings in registry with said active portions only of said cathode.

6. An electron discharge device comprising a thermionic cathode having inactive portions of low emission and active portions of high emission separated by an inactive portion, a cold anode for collecting the discharge from said cathode, and a pair of grid electrodes interposed between said cathode and said anode to be passed in succession by the discharge in said cathode to said anode, each of said grid electrodes comprising spaced conductors and the conductors of both said grids being aligned with said inactive portions only of said cathode with the openings between said conductors of each grid being aligned and in registry with only said active portions of said cathode.

7. An electron discharge tube comprising a cold anode, a grid electrode adjacent said anode and comprising conductors spaced to provide apertures in said electrode, and a thermionic cathode adjacent said grid electrode and having electron emitting places on its surface in registry with and no larger than the apertures in said grid electrode coated with material of high electron emissivity and non-emitting uncoated places on its surface in registry with said spaced conductors and depressed below the coated surface of said cathode.

8. An electron discharge tube comprising a perforated control electrode having a plurality of apertures, a cold anode on one side of said control electrode and a thermionic cathode on the other side of said control electrode having in registry with each aperture in said control electrode an electron emitting portion no larger than said aperture, said electron emitting portions of said cathode being conductively connected to be at the same potential.

9. An electron discharge tube comprising a perforated grid electrode having a plurality of apertures, an anode on one side of said grid electrode and a thermionic cathode on the other side of said grid electrode comprising a metal sheet parallel to said grid electrode and coated with material of high electron emissivity at elevated temperatures, and a heater in good thermal relation with a plurality of electron emitting places on said sheet no larger than and in registry with the apertures in said grid electrode and in poor thermal relation with non-emitting places contiguous to said emitting places to maintain during operation said non-emitting places at temperatures below the electron emission temperature of said material.

10. An electron discharge tube having an oxide coated thermionic cathode, a cold anode and a grid electrode interposed between said cathode and said anode and comprising spaced conductors, said cathode having on its surface in registry with the spaces between said conductors electron emitting places no larger than said spaces and activated to have high electron emissivity, and non-activated places of substantially no emissivity in registry with said conductors.

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