Aug. 25, 1942. E. W. HEROLD 2,294,298

LOW DISTORTION ELECTRON DISCHARGE TUBE

Filed Aug. 2, 1940

Fig. 1

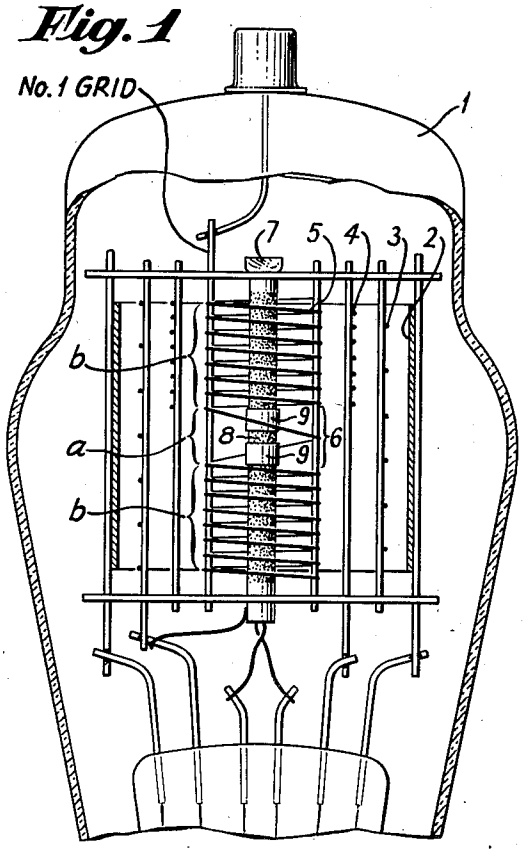


Fig. 5

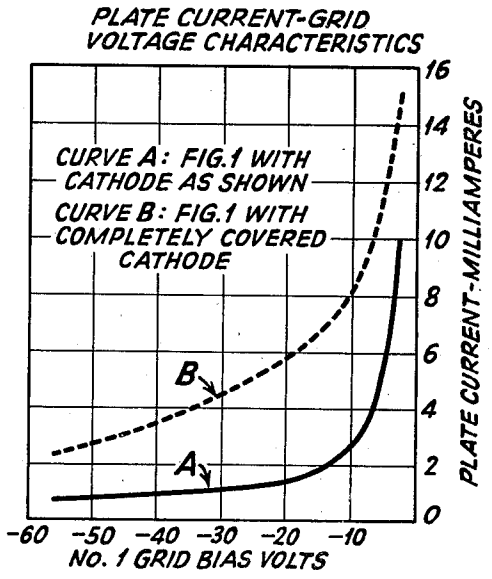


Fig. 6

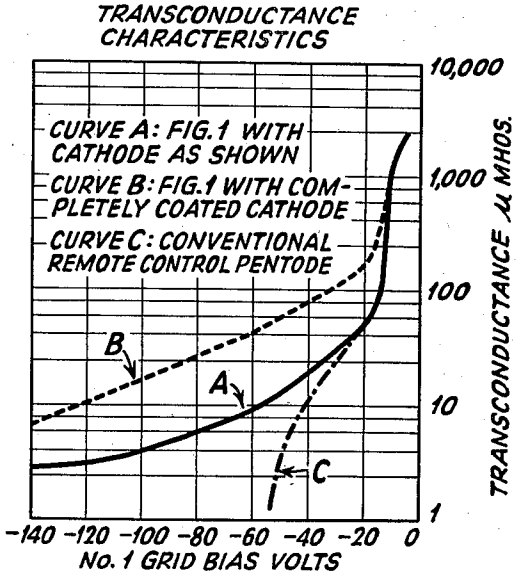
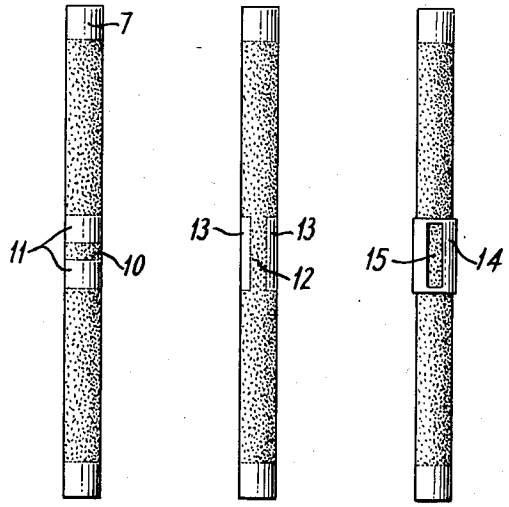


Fig. 2 Fig. 3 Fig. 4



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LOW DISTORTION ELECTRON DISCHARGE TUBE

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10 Claims. (Cl. 250—27.5)

My invention relates to electron discharge tubes, such as radio frequency amplifier tubes, of the kind known as variable-mu or remote control tubes and in which the grid closest to the cathode is non-uniform in pitch.

The conventional variable-mu or remote cut-off tubes have a gap or a coarse pitch section in the control grid in order to reduce distortion effects at highly negative grid bias values. These tubes have transconductance characteristics such that, when the usual automatic-volume-control increases the grid bias, in order to reduce the amplification or gain in response to strong signals, distortion of the envelope of a modulated wave is not objectionable until the grid bias approaches the cut-off value of about 50 volts negative. The trend of broadcasting stations toward an increase in power has resulted in such an increase in signal strength however that the gain must be adjusted to very low values. Under these conditions the automatic-volume-control impresses such a high negative bias on the control grid that, in receiving sets using conventional variable-mu tubes, the radio-frequency envelope distortion problem becomes serious and reception of a strong local station is accompanied by harmonic distortion. This difficulty can be remedied by using a larger gap in the control grid of the variable-mu tube in order to make the cut-off very remote, but it has been found that a larger grid gap causes such a great increase in plate current as to make the tube impracticable. In addition, the increase in the grid bias voltage necessary to reduce the gain of such a tube to the very low value required on very strong signals, is so great that the conventional automatic volume control systems are not always able to supply the necessary grid bias voltage without overloading some of the tubes.

The principal object of my invention is to provide a very remote cut-off tube with a very wide gap in the control grid in which the above disadvantages are reduced without any sacrifice in ability to handle signal voltages substantially higher than permissible with conventional remote control tubes. Another object of my invention is to provide a variable-mu tube having both a very remote cut-off and a low plate current.

In the conventional variable-mu tube, it is found that a large part of the plate current at normal bias comes from that section of the cathode opposite the widest gap in the control grid. In accordance with my invention a tube is so constructed that the maximum plate current per unit of grid area at the wide-gap portion of the control grid is considerably less than the maximum plate current per unit of grid area at other portions of the grid. The preferred method for attaining this result is to reduce the effective cathode area only opposite the more open parts of the control grid by coating only a part of the cathode, or by covering part of a completely coated cathode with non-emitting shields. The part of the plate current which comes from the reduced cathode area can thus be limited to a reasonable value no matter how large the control grid gap may be.

In a vacuum tube with uniformly-spaced grid apertures the cathode current which flows for a given effective electrode potential is proportional to a constant known as the perveance. The perveance is a measure of the emitting cathode area, of the spacings of the tube electrodes and of the electrode configurations, insofar as these factors affect the cathode current. In any variable-mu tube the effect of the variable pitch along the length of the control grid is to give rise to a varying effective electrode potential. The current through any given part of the control grid then depends on the perveance at this particular part and the effective electrode potential of this part. In the usual variable-mu tube the perveance at all parts of the control grid is approximately the same and, as a result, those parts with high effective potentials pass large amounts of current. According to my invention, the perveance is also made variable along different parts of the tube so as to prevent the cathode current from reaching excessive values at those parts exposed to a high effective electrode potential.

My invention will best be understood in connection with the accompanying drawing in which Figure 1 is a somewhat schematic longitudinal section of the electrode assembly of an electron discharge tube constructed in accordance with my invention; Figures 2, 3, and 4 show modifications of a cathode suitable for use in such an assembly; Fig. 5 is a curve sheet showing plate current-grid voltage characteristics of a tube embodying my invention and of a similar tube with conventional cathode; and Figure 6 is a curve sheet showing transconductance characteristics of the two tubes of Figure 5 and also of a conventional remote control or variable-mu pentode.

Merely for purposes of illustration, Figure 1 in the accompanying drawing shows a pentode with the usual electrode assembly comprising an anode 2, suppressor grid 3, screen grid 4, and a variable mu control grid 5 of non-uniform pitch. In accordance with my invention, the grid 5 has near the middle a gap 6, which may be two or three times the width of the corresponding gap generally used in remote control pentodes. The grid 5 surrounds a cathode 7, preferably of the usual indirectly heated type consisting of a conventional heater surrounded by a conventional tubular metal sleeve coated with a material having high thermionic electron emissivity, such as the conventional mixture of barium and strontium oxides. In accordance with my invention the middle portion of the cathode opposite the gap 6 in the grid 5 is so made that the cathode

current from this middle portion is considerably less than the cathode current from a cathode portion of equal length opposite the uniformly wound portion of the control grid. In the cathode shown in Figure 1 the reduction in cathode current is obtained by restricting the cathode area to a zone 8 considerably smaller than the surface of the portion or length of the cathode sleeve opposite the gap 6 of the grid 5. The cathode area is limited to the zone 8 by two thin tight-fitting non-emitting shields or bands 9 which surround the central portion of the completely coated cathode sleeve and are spaced to expose a narrow annular electron emitting zone 8 of the cathode coating. The length of the shielded portion of the cathode, as measured by the distance between the outer or remote edges of the bands 9, is substantially equal to the width of the more open portion or gap 6 of the grid. The shields or bands 9 have negligible electron emission at normal cathode temperature, hence the flow of space current through the gap 6 in the control grid comes only from the limited cathode area of the zone 8 and is very much less at normal grid bias than it would be were the cathode completely coated and the middle portion or length had the same effective cathode area as an equal portion or length of the remainder. As a result, the gap 6 may be made wide enough to obtain a very remote cut-off, without at the same time obtaining an undesirably high plate current at normal grid bias.

The electrode assembly shown in Figure 1 is substantially the same as that of a conventional pentode, such as the commercial 6K7, with a wider gap in the control grid and the cathode modified in accordance with my invention. The helically wound control grid, about 18 mm. long, has two end portions *b* of substantially uniform pitch, with 3 mil grid wires spaced apart 9 mils per half turn. The more open portion *a* of the grid, such as the gap 6, about 2½ mm. wide, is at the middle of the grid, in accordance with usual practice, although it may be at any other place on the grid if desired. It is understood, of course, that intermediate portions of the grid having other values of pitch are usually included in practice, although not shown in the figure because of their irrelevance to this invention. The shields 9 are bands of nickel, about 2 mils thick and each about 1 mm. wide, fitted snugly over the coated cathode. The adjacent edges of the shields 9 are spaced about ½ mm. to provide an annular emitting zone 8 about ½ mm. wide and opposite the middle of the gap 6. The width of the gap 6 and of the zone 8 is not critical, as I have obtained good results with such tubes in which the width of the zone 8 is only ¼ of a mm., or even less.

The limited coated area opposite the gap in the grid may be obtained in other ways. As shown in Figure 2, the limited cathode area may be a coating in the form of a narrow band or emitting zone 10 opposite the center of the widest gap in the grid, with wider uncoated zones 11 on either side of the emitting zone. As a result, the cathode current from the central portion of the cathode opposite the wide gap in the grid is only a fraction of what it would be were all of the central portion coated in the same way as the remainder of the cathode. A convenient way to obtain the uncoated zones 11 is to scrape the coating off the completely coated cathode on each side of the coated zone 10. When the cathode is coated by spraying, another method of obtaining the uncoated zones 11 is to shield these portions during the spraying by removable barriers.

Figures 3 and 4 show other ways in which the cathode current from a completely coated cathode may be cut down opposite the wide gap in the grid. In Figure 3 a coated strip 12 narrower than the cathode and with uncoated portions 13 on each side extends lengthwise of the cathode. In Figure 4 the central portion of the completely coated cathode is covered with a non-emitting shield 14 having a window 15 of considerably less area than the coated middle portion of the cathode so that the cathode current from the middle portion of the cathode comes only from that portion of the cathode which is exposed through the window. Other shapes of emitting and non-emitting portions can, of course, be used to the same end as these shown in the figures.

Figure 5 is a curve sheet of the plate current grid voltage characteristic curve for a radio frequency pentode made as shown in Figure 1 with a No. 1 grid having a large gap about 2½ mm. wide at the middle. In this figure curve A is the plate current grid voltage characteristic curve of a tube constructed in accordance with my invention as shown in Figure 1 where the emission current from that portion of the cathode opposite the gap in the grid is obtained from a narrow coated zone opposite the center of the gap. As shown by curve A the tube has at the normal bias of about 3 volts negative on the No. 1 grid a plate current of about 10 milliamperes which is about the same as that of the conventional radio frequency pentode of the type known as the 6K7. Curve B is the plate current-grid voltage characteristic of a tube of the same structure and with the same No. 1 grid as the tube of Figure 1, but with the conventional completely coated cathode instead of the cathode according to my invention. The tube in which the cathode is completely coated has about twice as much plate current at normal grid bias as the tube having the cathode constructed in accordance with my invention.

Figure 6 is a curve sheet showing the transconductance characteristics plotted in the usual way of the two tubes from which the characteristic curves of Figure 5 were obtained. At normal grid bias there is substantially no difference in the transconductance of the two tubes so that both have the same maximum value of amplification and both tubes have the long trailing out characteristic at highly negative grid bias voltage necessary to achieve low radio frequency distortion. The difference is made clear in Figure 6 by comparison of transconductance curves A and B with the similar transconductance curve C of a conventional remote control pentode, such as the 6K7.

Since radio frequency distortion is roughly proportional to the slope of the transconductance-grid bias curve as usually plotted on semi-logarithmic paper, the tube embodying my invention and from which curve A was obtained is not inferior for radio frequency distortion to the tube from which curve B was obtained except in a small region where the grid bias is about 20 volts negative. The tube from which curve A was obtained is equal to the conventional remote control tube in performance at all points down to about 40 micromhos transconductance and at points below this is far superior in signal handling capability. At transconductance below 10 micromhos the signal handling capacity of the tube embodying my invention and from which

curve A was obtained becomes about 20 times as high as that of the conventional remote cut-off radio frequency tube. At the same time, the plate current of the tube embodying my invention is not increased over that of the usual tube.

In the application of my invention I have found it desirable in some cases and in accordance with known practice in the art to apply automatic-volume-control voltage to both the normal control grid and to the third grid. By this means the value of control voltage necessary for the reception of large signals is reduced while, at the same time, all the advantages of the low distortion are retained.

I claim:

1. An electron discharge tube comprising a cathode, anode, and a grid between said cathode and said anode and having unequally spaced conductors, the length of said cathode opposite and coextensive with the more open portion of said grid having an electron emitting area with its middle opposite the middle of said more open portion of said grid and smaller than the electron emitting area of an equal length of said cathode opposite an equal length of the remainder of said grid.

2. An electron discharge tube comprising a cathode, anode, and a grid between said cathode and said anode having non-uniformly spaced conductors, a non-electron emitting shield covering part of the electron emitting surface of a length of said cathode opposite and coextensive with the more open portion of said grid with the middle of the uncovered part of said surface opposite the middle of said more open portion of said grid and exposing to said anode through said more open portion of said grid an electron emitting surface smaller than the electron emitting surface of another equal length of cathode and opposite the less open portion of said grid.

3. An electron discharge tube including a rectilinear cylindrical thermionic cathode of substantially uniform diameter throughout its length, an anode coaxial with said cathode, a grid between, and coaxial with, said cathode and anode and comprising conductors unequally spaced, said grid having a portion more open than the remainder thereof for exercising a lesser rate of control of the electron stream between said cathode and said anode than the remainder of said grid, and spaced non-electron-emissive shields on a length of said cathode opposite and coextensive with said more open portion of said grid for exposing to said grid an electron emitting area which is smaller than the electron emitting area exposed by an adjacent equal length of said cathode.

4. An electron discharge tube including a rectilinear cylindrical thermionic cathode of substantially uniform diameter throughout its length, an anode coaxial with said cathode, and a grid between and coaxial with said cathode and anode and comprising unequally spaced conductors, said grid having an intermediate portion more open than the other portions thereof and opposite an intermediate length of said cathode coextensive with said more open portion of said grid, said intermediate length of said cathode having an electron emitting area with its middle opposite the middle of said more open portion of said grid and smaller than the electron emitting area of an equal length of said cathode opposite other portions of said grid.

5. An electron discharge device including a rectilinear oxide coated cathode having between two uncoated strips of bare metal on an intermediate length of said cathode a coated strip narrower than the coated surface of adjoining equal lengths of said cathode, an anode, and a grid of non-uniformly spaced conductors interposed between said cathode and said anode and having a gap more open than the remainder of said grid opposite said coated strip and of a width substantially equal to the distance between the outer edges of said uncoated strips, said coated strip being midway between the edges of said gap.

6. An electron discharge device including a rectilinear oxide coated cathode, a pair of shields of uncoated metal covering part of said cathode along an intermediate length of said cathode and spaced to expose between their adjacent edges a strip of coated cathode surface narrower than the coated surface of an adjoining equal length of said cathode, an anode, and a grid having non-uniformly spaced conductors with the middle of its more open portion opposite the middle of said strip.

7. An electron discharge device comprising a tubular anode, a grid of non-uniformly spaced conductors coaxial with said anode, a rectilinear oxide coated cathode substantially coextensixe with and coaxial with said grid, and a pair of uncoated metal bands extending transversely of the longitudinal axis of said cathode and fitted on and covering a part of the coated surface of said cathode opposite the more open portion of said grid and being spaced lengthwise of said cathode and exposing between their adjacent edges a narrow zone of coated cathode surface opposite the middle of the widest aperture of said grid.

8. An electron discharge tube comprising a rectilinear oxide coated cathode having an intermediate shielded length comprising a pair of transverse uncoated metal bands spaced along said cathode and providing midway of said shielded length a narrow electron emitting zone between the adjacent edges of said bands, a grid of non-uniform pitch coaxial with and surrounding said cathode and having grid conductors spaced along an intermediate length of said grid coextensive with said shielded length of said cathode with greater spacing between conductors than along the end lengths of said grid, and a tubular anode coaxial with and surrounding said grid.

9. An electron discharge tube comprising a rectilinear thermionic cathode, an anode coaxial with said cathode, a helical control grid interposed between and coaxial with said cathode and anode and having lengths of different pitch, said cathode having adjacent and opposite the coarser pitch length of said grid an electron emitting surface of equal length with the middle of said emitting surface opposite the middle of said grid length of coarser pitch and having average electron emission less than that of an equal length of said cathode covered by the finer pitch length of said grid.

10. An electron discharge tube comprising an oxide coated cathode, an anode, and a grid between said cathode and said anode having unequally spaced conductors providing a gap, the length of said cathode opposite said gap in said grid having an electron emitting coating on only a fraction of the surface of said length of said cathode and with the middle of said coating opposite the middle of said gap in said grid.

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