Sept. 19, 1944. H. C. THOMPSON 2,358.542

CURRENTLESS GRID TUBE

Filed July 26, 1940

Fig. 1

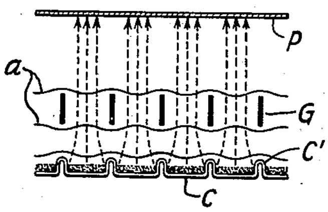


Fig. 2

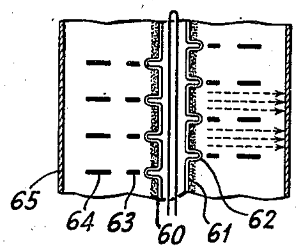
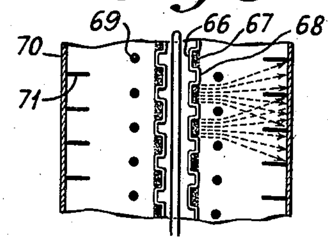


Fig. 3



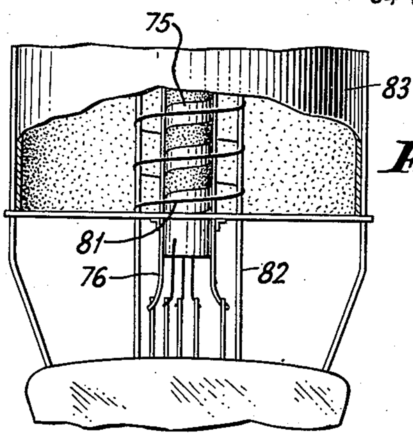


Fig. 5

Fig. 4

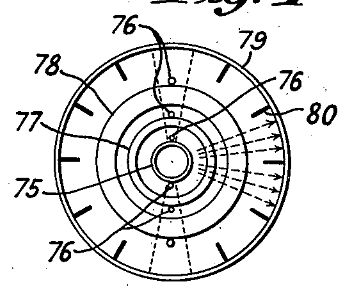


Fig. 6

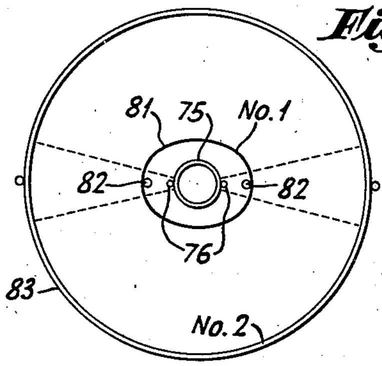


Fig. 7

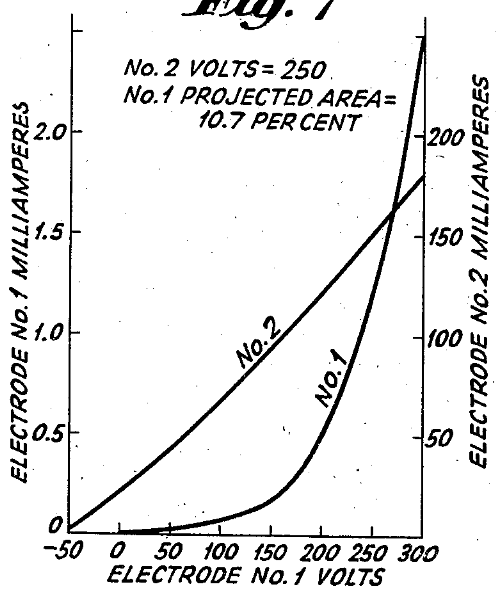
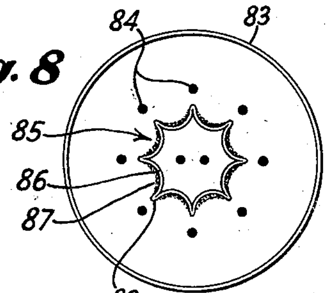


Fig. 8



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UNITED STATES PATENT OFFICE

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CURRENTLESS GRID TUBE

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Application July 26, 1940, Serial No. 347,649

12 Claims. (Cl. 250—27.5)

My invention relates to electron devices having thermionic cathodes and cooperating cold electrodes, and more particularly to devices of this type which utilize an electron discharge concentrated into more or less well defined beams of electrons and which will operate at the comparatively low voltages generally used in the conventional receiving tubes.

This application is a continuation in part of my application Serial No. 29,808, filed July 5, 1935, now Patent No. 2,254,095, issued August 26, 1941, for Electron beam discharge devices, and assigned to the same assignee.

One object of my invention is to provide electron discharge devices of the beam type which are efficient and in which the total discharge from the cathode is formed into a plurality of more or less well defined beams which are utilized in novel and effective ways to obtain improved tubes having advantages unobtainable with the conventional types of tube structure.

Another object of my invention is to provide improved electron discharge devices which are of much the same dimensions and are operated at much the same voltages as the conventional receiving tubes and in which various desirable characteristics are obtained by segregating the space current into an electron beam or beams and utilizing the properties of the beam to advantage.

A further object is to provide an electron discharge device having a control grid or similar electrode which may be operated over a positive range of potential with reference to the cathode and receive a current so radically reduced from that commonly obtained that the positive grid is substantially currentless during operation of the tube.

In accordance with my invention, tubes with grids which take practically no current from the electron stream can be made by segregating the space current into electron beams slightly narrower than the openings in a control or other grid and directing these beams through the control grid opening, whereby the total electron flow may be influenced by the grid, with comparatively small loss of current to the grid even when it is positive.

The novel characteristics of my invention are pointed out with greater particularity in the appended claims, but the invention itself will best be understood from the following specification taken in connection with the accompanying drawing in which:

Figure 1 is a diagram illustrating some principles of beam formation in a plane parallel three electrode structure having a cathode with non-emitting portions;

Figure 2 is a diagrammatic longitudinal section of a cylindrical screen grid tube utilizing a beam forming cathode with non-emitting portions;

Figure 3 is a diagrammatic longitudinal section of a cylindrical type of tube embodying some of the principles illustrated in Figure 1, and particularly suitable for use with high positive grid potentials;

Figure 4 is a diagrammatic cross section of a screen grid tube with grids such as shown in Figure 2 and a cathode such as shown in Figure 3;

Figure 5 is a view in perspective of a three electrode assembly with the cathode broken away near the middle and a portion of the anode broken away to show the interior; Figure 6 a cross section, Figure 7 current curves of a tube which has a beam forming cathode with a non-emitting strip helically disposed on the surface and a helical grid in registry with the non-emitting strip, and Figure 8 a cross section of a tube having a modified form of cathode.

In accordance with my invention I may provide electron discharge devices employing beam forming structures for segregating space current into one or more beams and having control electrodes which control the magnitude of the space current and operate over a potential range which includes a positive potential, the control electrodes or grids having their elements so placed with reference to the electron beams as to avoid receiving electrons from the cathode. I have found experimentally that in a variety of widely different structures it is possible by systematic employment of electron beams to make the ratio of the percentage of space current received by a positive electrode situated between the cathode and the utimate anode to the percentage projected area of that positive electrode very much smaller than in the usual construction where there is no systematic segregation of space current into beams and no displacement of the control electrode elements out of the paths of the beams. By suitably positioning the elements of the grids with reference to the beams, it is feasible to provide tubes in which grids positive with reference to the cathode are substantially currentless.

I have observed in plane parallel three electrode devices having a plane cathode, a plane grid and a plane anode coated with willemite that in some cases when the grid is at zero or negative potential there may appear on the anode not only parallel intense beam traces of streaks of light in alignment with the openings between the grid wires, but also a system of faint or minor beam traces beside and in addition to the major or intense beam trace system. Making the grid slightly positive causes this minor trace system to disappear. Probably the minor beam trace arises from a virtual electron source formed under each grid element and between it and the cathode, and these small virtual sources furnish the extra beam pattern represented by the minor beam trace system. It is desirable to eliminate these minor beam systems where the beam forming properties of grids are utilized for the production of currentless positive electrodes and particularly where such electrodes must have high impedance and low electron currents. For eliminating these minor beam systems originating from virtual cathode sources the beam forming electrode may be combined with the cathode in such a way that the beam forming grid is very close to and in effect rests on the cathode, so that no virtual electron sources under the grid elements can exist, or the parts of the cathode structure under the elements of the control grid may be made non-emitting. In this way suppression of the minor beams and increased transconductance of the control electrode may be obtained, as the control electrode can be placed nearer the cathode and the shielding of the cathode from the control grid by the beam forming electrode is reduced to a minimum.

Figure 1 is a diagram illustrating some of the principles in connection with the use of such a cathode. In this diagram the plane cathode C has ridges or elevations C′ between which the cathode surface is coated with electron emitting oxides, such as barium or strontium oxides. The edges of the ridges project above the electron emitting coating and are uncoated and therefore non-emitting and have the effect of and constitute a virtual beam forming grid close to the cathode and at zero potential. A positive grid electrode G adjacent this cathode with its elements in registry with the ridges or non-emitting portions of the cathode will deform the field approximately as indicated by the equipotential lines of force in the diagram, and the space current from the cathode to a plate P will be formed into beams, as indicated by the arrows. The positive grid electrode has an effect as regards beam formation and the field near the openings of such a grid has a tendency to diverge the beams. It is important that such diverging tendencies near a positive electrode are less effective upon the beam than the converging tendencies of the lower voltage field near the beam forming elements, as the electrons in the field near the beam forming grid are moving slowly and are influenced by its converging tendency for a longer time than they are by the field of the positive grid after having been accelerated. The beam forming properties of a cathode having alternate emitting and non-emitting portions may therefore be utilized to cause the electron streams from the emitting portions to avoid a positive grid electrode, such as a control electrode or screening electrode.

Tubes which are capable of operating with a grid at positive potential and with negligible current to the grid have desirable properties and overcome some serious disadvantages of the conventional types of tubes. For example, in the so-called class B and class C modes of amplifier operation the control grid potential is in a positive range during part of the oscillation cycle and in hitherto existing devices certain troubles and limitations have arisen from this fact. In the positive range of operation control grids of the conventional kind, particularly in power devices, receive a considerable percentage of the space current and such operation requires a relatively large and entirely wasteful input of modulation power, an undesired heating of the control grid, distortion of the amplifier output and an array of subsidiary troubles. In amplifiers employing oxide cathodes these subsidiary troubles include excessive thermionic and secondary emission from such grids because of the deposition thereon of material from such cathodes. These troubles arise directly and indirectly from the bombardment of the grid by electrons and all are consequently very much mitigated by the radial reduction of such bombardment by the means here disclosed.

Figure 2 shows a screen grid type of tube constructed in accordance with the principles illustrated in Figure 1, and having substantially currentless grids. The cylindrical cathode **60** has its surface coated with electron emitting material **61** between the turns of a non-emitting helical ridge **62**. An edgewise wound helical ribbon No. 1 electrode or control grid **63** of the same pitch as the cathode ridge and a similar No. 2 electrode or screen grid **64** are mounted coaxial with the cathode with the turns of both grids in registry with each other and with the cathode ridge. A No. 3 electrode or anode **65** surrounds and is coaxial with the grids. The No. 2 or screen electrode is interposed between No. 1 and No. 3 in such a way as to electrostatically screen No. 1 from No. 3, but with its openings in registry with the openings of No. 1 and the emitting areas on the cathode, so as to minimize the current to itself. In this figure I have illustrated the grids as made of edgewise wound metal ribbon or strips, although grids made of wire can be used if desired. The edgewise wound grids may in some cases be advantageous in giving somewhat higher transconductance. It is usually desirable to minimize the secondary electron emission from the anode as much as possible as, for example, by coating the inner surface of the anode with lamp black or with other finely divided conductors such as electrolytically deposited nickel.

Figure 3 shows a triode utilizing a similar type of cylindrical cathode **66** with the electron emitting material **67** on its surface disposed in a helical groove formed in the cathode to leave a non-emitting helical strip **68** between the turns of the groove. The groove is filled to the surface of the cathode, so that the emitting and non-emitting portions of the cathode are in the same cylindrical surface. A helical grid **69** is mounted coaxial with the cathode and with its turns in registry with the non-emitting helical strip on the surface of the cathode. A tubular anode **70** surrounds the grid, and may to advantage be provided on its inner surface with pockets or recesses in definite relation to the grid. For example, the anode may have pockets between a plurality of inwardly extending vanes or ribs **71** on the anode. The proper relation of these ribs and the pockets between them to the other elements of the tube is dependent upon conditions under which the tube is used. The beams should be directed so far as feasible to impinge upon the anode in the pockets between the inwardly extending ribs. Where the positive potential of the grid 69 in operation is usually no greater than the potential of the anode, the ribs 71 should be in alignment with the grid turns and with the non-emitting portion of the cathode. Where the grid during operation usually attains positive potentials higher than the anode potential, the ribs 71 should be, as shown in Figure 3, in alignment with the spaces between the grid turns, and the major concentration of the beams and the major beam trace on the anode will be in the pockets and in alignment with the grid wires.

Figure 4 is a diagrammatic cross section of a screen grid tube much like Figure 2. The cathode 75 is of the same construction as the cathode 66 in Figure 3, but has in addition two longitudinal non-emitting strips formed by two uncoated wires or rods 76 lying alongside the cathode and at zero potential. The side rods 76 of the grids 77 and 78, which are like the grids 63 and 64 of Figure 2, are in alignment with and in the electron shadows of the cathode rods 76, as indicated by broken lines. Secondary electron emission from the tubular anode 79 is reduced by any suitable means, such as inwardly projecting longitudinal ribs on its inner surface. The cathode rods 76 may be replaced by non-emitting uncoated strips or regions which are uncoated or rendered non-emitting in any suitable way. By this construction, in which all of the corresponding parts of the grids are in registry, the electron flow in the plane of the grid rods is negligible, and practically all of the space current flows through the openings of the grids.

Figure 5 is a perspective view with a part of the anode and some parts of the cathode broken away, of the electrode assembly of one three electrode tube which I have made embodying my invention, and Figure 6 is a cross section of this tube. In this particular tube the cathode 75 has a cathode sleeve like that of Figure 3 with a helical groove or recess filled with the electron emitting coating, the surface between the turns of the groove being left uncoated, and therefore non-emitting. The non-emitting and emitting areas are about equal in extent, and constitute a common cylindrical cathode surface. The grid 81 is 0.005 inch molybdenum wire wound into a helix of ten turns per inch and supported by two grid side rods 82 of 0.020 inch nickel wire. The grid is coaxial with and surrounds the cathode, with the turns of the grid in registry with the non-emitting portion of the cathode, which is helical and of the same pitch as the grid. This particular grid is elliptical, with a major diameter of 0.22 inch and a minor diameter of 0.19 inch, and is carbonized or blackened to reduce back emission. The parts of the cathode in alignment with the grid side rods are rendered non-emitting in any suitable way, preferably by the longitudinal cathode rods 76 of 0.015 inch nickel wire extending lengthwise of and electrically connected with the cathode sleeve, and in registry with the support rods 82 of the grid. One convenient way of positioning these cathode rods is, as shown in Figure 5, to secure them to supports in the press and in direct contact with the uncoated non-emitting portion of the cathode. The tubular anode 83 coaxial with and surrounding the grid is about 1 inch long and 0.75 inch innner diameter, and has on its inner surface a coating of lamp black to substantially eliminate secondary electron emission. The helical groove in the cathode is filled with a thin wet spray of the usual electron emitting oxides, such as barium oxide and strontium oxide, so as to be substantially flush with the remainder of the cathode. The electrodes may be held in proper relation to one another in various ways, preferably by mica spacers at the ends of the electrode assembly, which is carried on the usual press of the bulb (not shown).

Figure 7 shows some volt ampere characteristics obtained at an anode voltage of 250 volts from the tube shown in Figure 5, in which the projected area of the grid is about 11%. The current to No. 2 electrode or anode 83 is shown as a function of the No. 1 electrode or grid 81 voltage, which includes a positive range up to 300 volts, that is, 50 volts higher than the steady potential of the No. 2 electrode. At this highest positive potential of the grid the current to it is a maximum, and is equal to about 2 milliamperes, whereas No. 2 current is equal to about 200 milliamperes. The maximum space current flowing to the No. 1 electrode or control grid is not more than about 1.5% of the space current to the anode even when the grid is at a considerably higher potential than the anode. As is well known, the loss of electrons from a grid is negligible when the grid is at higher positive potential than the anode, hence the observed low percentage of current to the grid is not due to secondary emission from the grid, but is due entirely to the position of the grid out of the paths of the beams.

Figure 8 is a cross section of a modified form of tube embodying my invention. In this form the cathode has arcuate electron emitting surfaces extending lengthwise of the cathode, and contiguous to and separated by non-emitting portions which are parallel to the emitting surfaces and are in alignment with the conductors of a rod type grid adjacent the cathode. In such a cathode two or more concave electron emitters side by side are separated at the edges by a non-emitting region between the edges of each pair of emitters, and the discharge from each emitter tends to concentrate into an electron beam which passes between the grid conductors, as indicated in Figure 1. By thus rendering parts of the beam forming cathode structure under the conductors of the grid non-emitting, the formation of virtual cathodes under the grid conductors and therefore the formation of the minor beam traces is prevented. In this modification the tubular anode 83 surrounds and is coaxial with a tubular rod type grid 84 having spaced parallel grid conductors or rods extending lengthwise of the anode. The grid is coaxial with the cathode 86, which is shown as an indirectly heated cathode with arcuate grooves or concave channels 85 parallel to the longitudinal axis of the cathode. The curved surfaces of these grooves, which constitute arcuate electron emitters, are made electron emitting, preferably by coating a portion of the curved surface near the bottom of the groove with a coating 87 of high thermionic electron emissivity, such as the mixture of barium and strontium oxides commonly used for oxide coated cathodes. The metal edges 88 of the grooves project above the coated surfaces and are made non-electron emitting, preferably by leaving the cathode metal at the edges of the grooves uncoated. The non-emitting areas of the shown shape and registration conductivity connected to the cathode or made integral with the cathode act as beam forming means which offer the advantage of increased transconductance of the control electrode, as the control electrode can be placed nearer the cathode and the electrostatic effect of the beam forming elements is reduced to a minimum.

The electron emitting areas are usually, as shown in the drawing, no larger than the grid apertures with which those areas are in register, in order that full advantage may be taken of the beam forming properties of the cathode and the current to the grid made a minimum.

It is obvious that the elongated concave electron emitters 87 need not be parts of an indirectly heated cathode, but may be in the form of concave metal strips connected in parallel and directly heated to electron emitting temperature by the low heating current through them, provided there are non-emitting regions between the edges of the emitters and in alignment with the grid conductors. Those non-emitting regions should be of metal, as in the embodiments utilizing indirectly heated cathodes, if pronounced beam forming is desired.

While I have indicated the preferred embodiment of my invention of which I am now aware and have also indicated only one specific application for which my invention may be employed, it will be apparent that my invention is by no means limited to the exact forms illustrated or the use indicated, but that many variations may be made in the particular structure used and the purpose for which it is employed without departing from the scope of my invention as set forth in the appended claims.

I claim:

1. An electron discharge device comprising an electron emitting cathode having contiguous emitting and non-emitting areas, each non-emitting area consisting of metal electrically connected to said cathode and projecting above the surface of the contiguous emitting areas, a work electrode adjacent said cathode, and a grid electrode interposed between said cathode and said work electrode comprising a conductor in registry with said non-emitting areas of said cathode and disposed to leave openings in registry with said emitting areas.

2. An electron discharge device comprising an anode, a thermionic cathode having extended arcuate electron emitting areas separated by strips of bare non-emitting metal projecting above the level of the surface of said emitting areas, and a perforated electrode between said cathode and said anode with its perforations in registry with said emitting areas and its solid portions in registry with said non-emitting areas of said cathode.

3. An electron discharge device comprising a cylindrical cathode with an electron emitting oxide coated metal core having a non-emitting strip in the form of a helix of uncoated bare metal projecting above its surface and with only its surface between the turns of said helix coated to a level below the top of said uncoated helix with oxides of high electron emissivity, a grid electrode coaxial with said cathode and comprising a conductor wound into a helix of the same pitch as and in registry with said non-emitting strip and with an opening in registry with the coated surface of said cathode, and an anode surrounding and coaxial with said grid electrode.

4. An electron discharge device comprising an electron emitting cathode having continuous emitting and non-emitting areas, each non-emitting area consisting of metal electrically connected to said cathode and projecting above the surface of the continuous emitting areas, a grid electrode adjacent said cathode comprising a conductor in register with said non-emitting areas of said cathode, said grid having openings in register with said emitting areas, and a work electrode further from said cathode than said grid electrode having pockets as large as the openings in said grid electrode and facing and opposite said openings so that electron beams through said openings impinge on the bottoms only of said pockets.

5. An electron discharge device comprising a cylindrical cathode with an electron emitting oxide coated metal core having a non-emitting strip in the form of a helix of uncoated bare metal projecting above its surface and with only its surface between the turns of said helix coated to a level below the top of said uncoated helix with oxides of high electron emissivity, a metal rod extending lengthwise of said cathode and across the coated surface, a grid electrode coaxial with said cathode and comprising a longitudinal side rod parallel to and in alignment with said metal rod on said cathode, and a conductor wound over said side rod into a helix of the same pitch as and in register with said non-emitting strip and with an opening in register with the coated surface of said cathode, and an anode surrounding and coaxial with said grid electrode.

6. An electron discharge device comprising a rectilinear thermionic cathode having a plurality of longitudinally extending electron emitting areas separated by longitudinally extending areas of non-electron emitting metal, an anode adjacent said cathode, and a grid electrode between said cathode and said anode having a plurality of conductors, each in alignment with a non-emitting area and spaced to correspond to the spacing of said areas.

7. An electron discharge device comprising an anode, a rectilinear thermionic cathode having alternate electron emitting and non-emitting portions extending lengthwise of said cathode, and a grid electrode between said anode and said cathode comprising conductors in alignment with said non-emitting portions and spaced to provide openings no smaller than and in register with said emitting areas.

8. An electron discharge device comprising an anode, a rectilinear thermionic cathode having alternate narrow elongated electron emitting surfaces and non-emitting metal strips extending lengthwise of said cathode, and a grid electrode between said anode and said cathode comprising conductors aligned with and spaced to correspond to said non-emitting strips.

9. An electron discharge device comprising an anode, a rectilinear indirectly heated cathode having in its surface a plurality of longitudinal depressions, an electron emitting coating in said depressions only with strips of cathode metal between said depressions uncoated and substantially non-emitting, and a grid electrode between said anode and said cathode with conductors in alignment with said uncoated strips and spaced to provide openings corresponding to said coated depressions.

10. 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.

11. 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.

12. 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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