

Feb. 8, 1938.

O. H. SCHADE

2,107,520

ELECTRON DISCHARGE DEVICE

Filed Feb. 26, 1936

2 Sheets-Sheet 1

Fig. 1

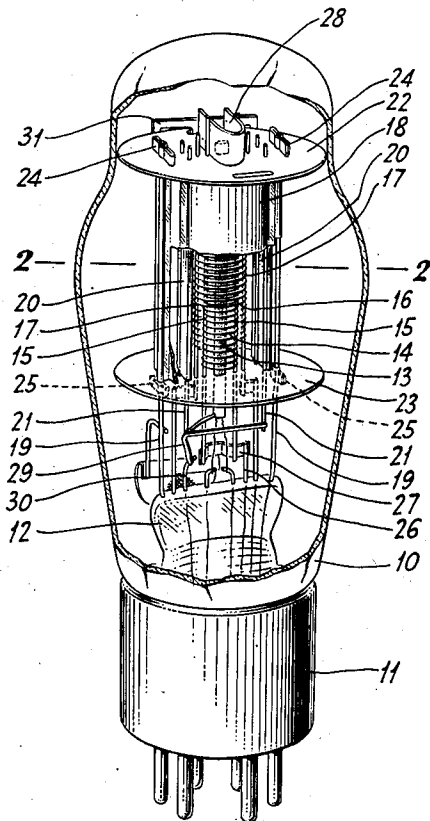


Fig. 2

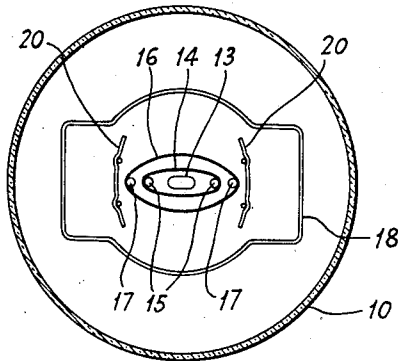


Fig. 3

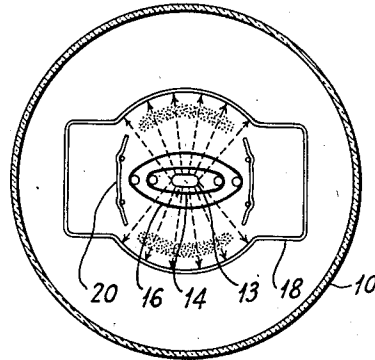
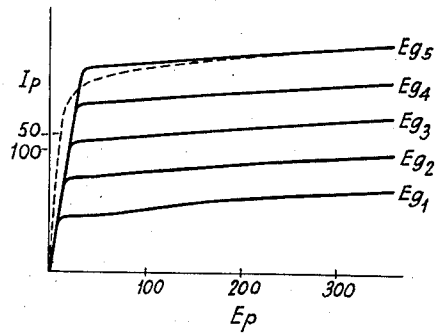


Fig. 4



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2 Sheets-Sheet 2

Fig. 5

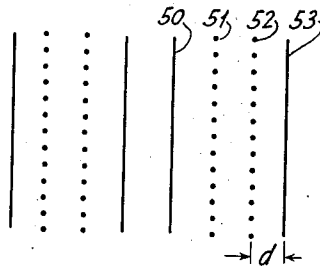


Fig. 6

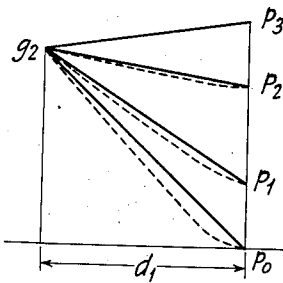


Fig. 7

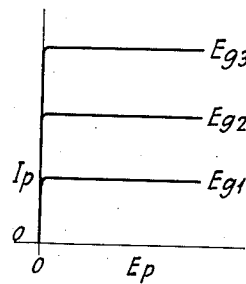


Fig. 8

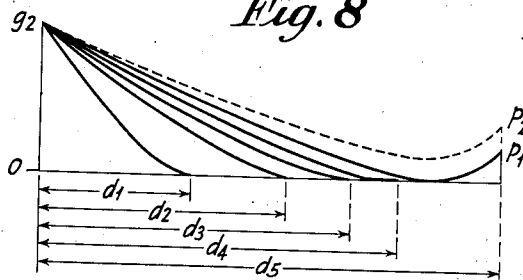
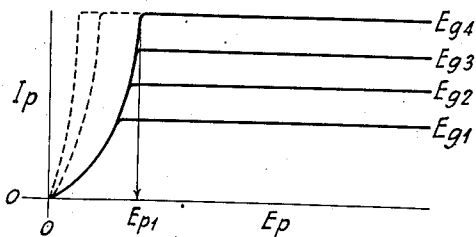


Fig. 9



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UNITED STATES PATENT OFFICE

2,107,520

ELECTRON DISCHARGE DEVICE

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 mesne assignments, to Radio Corporation of
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 Delaware

Application February 26, 1936, Serial No. 65,745

3 Claims. (Cl. 250—27.5)

My invention relates to electron discharge devices, particularly to improvements in such devices intended for power output purposes.

In the conventional screen grid tube having a thermionic cathode, a control grid, screen grid and anode or plate, secondary emission from the plate to the screen becomes serious and results in distortion in the output of the tube, particularly at high power outputs, when the plate voltage falls below the screen voltage. For this reason the plate voltage during operation of the tube is usually no lower than the screen voltage, hence the useful output of the tube is limited and the efficiency of the tube is reduced, because the plate voltage cannot swing below the screen voltage. While difficulties from secondary emission are lessened in the suppressor grid or pentode type of tube by a third or suppressor grid between the screen grid and the plate, a tube of this type does not have as good plate-voltage plate-current characteristics as might be desired at low plate voltages, here also the plate-voltage swing is limited for power operation by the distortion introduced by swinging the plate-voltage down into the region of low plate voltage where the characteristics are not satisfactory.

An object of my invention is to provide an electron discharge tube capable of a large power output at high efficiency, of high power sensitivity, and with low distortion. Another object of my invention is to provide a screen grid tube of this type having high impedance and in which the plate voltage may swing considerably below the screen grid voltage without introducing distortion whereby the usefulness of the tube is increased.

In general the preferred embodiment of my invention comprises a flat thermionic cathode surrounded by coaxial elliptical control and screen grids of the usual helical type with side rods, a plate having curved surfaces, and a pair of shields, preferably connected to the cathode, a shield being mounted adjacent each screen grid side rod between the screen grid and the plate. The shape of the electrodes and the spacing between them are important in obtaining the desired characteristics.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims, but the invention itself will best be understood by reference to the following description taken in connection with the accompanying drawings in which: Figure 1 is a perspective view with parts broken away to show details of construction of an electron discharge device embodying my invention; Figure 2

is a horizontal cross section taken along the line 2—2 of Figure 1; Figure 3 indicates diagrammatically certain operating conditions in the tube; Figure 4 shows the plate-current plate-voltage characteristics of a tube embodying my invention, with superimposed similar characteristics for a pentode under the same operating conditions; Figure 5 is a vertical cross section of an electrode system of a theoretically perfect electron discharge device illustrating the principles of my invention; Figure 6 is a graphical representation of the field potential between the screen and anode electrodes of an electrode system such as shown in Figure 5; Figure 7 is a graph showing the plate-current plate-voltage characteristics of the tube shown in Figure 5; Figure 8 is a graphical representation of the field potential between the screen and plate as the plate is moved away from the screen; and Figure 9 is a plate-current plate-voltage characteristic of an electrode system such as shown in Figure 5 with the anode electrode at a given distance from the screen grid.

Figures 1 and 2 show one embodiment of my invention of an electron discharge device with an evacuated envelope 10, a conventional base 11 and a press 12 on which the electrode mount assembly is supported. In accordance with my invention the electrode mount assembly comprises an indirectly heated cathode 13 having oppositely disposed flat sides and surrounded by a control grid 14 having side rods 15 and a screen grid 16 having side rods 17. The grids are mounted coaxial with the cathode with the corresponding side rods of the two grids in alignment. For best results both grids should be lenticular, preferably of the general shape of a cylindrical convex lens. The grids are surrounded by a coaxial tubular anode or plate 18 having curved or arcuate shaped active surfaces opposite the flattened sides of the cathode. The anode has side rods 19, and may be carbon coated to reduce secondary emission and to radiate heat more effectively. A pair of shields or electron beam confining plates 20, preferably of metal, are positioned between the anode and the screen grid side rods 17, close to the screen grid side rods and perpendicularly to the plane of the grid side rods, which pass longitudinally through the longer transverse axis of the cathode since this plane passes through the cathode parallel to the sides of the cathode. The various electrodes are supported between, and their side rods extend through a pair of upper and lower insulating spacers 22, 23, preferably of mica, which are held in position on the anode side rods 19 by metal clips or straps 24 and 25 welded to the side rods.

- The bottom ends of the control grid side rods 15 are electrically connected to the grid lead 26 by a strap 27 which also acts as a heat radiator. The upper ends of the control grid side rods also have a heat radiator 28 for maintaining the grid side rods cool. The cathode 13 and shields 20 are electrically connected at their lower ends by a conductor or strap 29 to the cathode lead 30, so that the shields produce an electrostatic field.
- The upper end of the electrode assembly is resiliently supported from the upper end or dome of the envelope by mica springs 31, only one of which is shown in Figure 1, secured to the edge of the upper mica spacer 22.
- The plate-current (I_p) plate-voltage (E_p) characteristics of a tube made in accordance with my invention are shown in full lines in Figure 4. This graph was made from photographs of the plate characteristics as shown on the screen of an oscillograph of a pentode and of a tube made in accordance with my invention. The characteristic curves of a tube made according to my invention for several control grid bias voltages (E_g), differing by 7 volt steps, have very sharp knees at comparatively low plate voltages, hence the tube may be operated with large swings of plate voltage and therefore at high efficiency, without introducing undesirable distortion in the output of the tube. The slope of the almost flat topped curves from the knee in a positive direction of plate voltage is very small, is substantially constant, and is the same for each grid bias. I have been successful in practice in obtaining a sharp knee at as low as 35 volts on the plate and 200 milliamperes of current, with 250 volts on the screen grid, this low plate voltage and high current being considerably below that possible in the conventional screen grid tubes. With a proper load the power sensitivity of the tube is high, as a small change in grid voltage causes a large change in power output, while at the same time undesirable tube distortion is low.
- The dotted line on Figure 4 represents the plate-voltage plate-current characteristics of a suppressor grid tube or pentode operating under the same conditions of plate-voltage and grid bias as a tube made according to my invention. The difference in the curves is readily apparent. The pentode curve has a long rounded knee and steeper slope in the operating range than the characteristic curve of the tube made in accordance with my invention. It will also be noted that the amount of plate-current and hence the power output of a tube made according to my invention is more than twice that for a pentode under the same conditions of plate-voltage and grid bias. It will thus be apparent that not only is a tube made according to my invention a much more efficient tube, permitting greater voltage swings, but is capable of handling greater power outputs without distortion. Because of the flatter curves which are obtained with a tube made according to my invention, the mutual conductance as well as the impedance remain more nearly constant over a wide range of plate voltages. When operated with a negative 7 volt bias on the grid, the plate voltage of my tube may be swung below 35 volts without introducing undesirable distortion in the tube.
- A better understanding of the principles involved and of the superior results produced by a tube embodying my invention may be had by considering Figures 5 to 9 inclusive. Figure 5 is a longitudinal section of a theoretical screen grid tube with four concentric cylindrical elec-

trodes, a thermionic cathode 50, control grid 51, screen grid 52 and plate 53. It is assumed that the electrodes have no side rods, that the control grid 51 has a negative bias, that the screen grid 52 is at some positive potential and that the plate voltage is varied. The distance between the screen grid and the plate is represented by the letter d .

The potential distribution or electrical voltage effect at all points between the screen grid 52 and the plate 53 for a fixed screen voltage and for different plate voltages with the plate at a short distance d_1 from the screen grid is graphically shown in Figure 6. With a fixed positive voltage represented by g_2 on the screen grid, the cathode cold and not emitting electrons, and with no electrons flowing between the screen grid and anode, the potential distribution is represented by the straight solid lines g_2p_0 , g_2p_1 , g_2p_2 , and g_2p_3 for the anode voltages p_0 , p_1 , p_2 and p_3 . However, when the cathode 50 is heated to emit electrons and electrons move from the cathode through the control grid 51 and positively biased screen grid 52 to the plate 53, the potential distribution, that is the electrical voltage effect of the field between the screen grid and plate, becomes somewhat changed and is lowered by the presence of the negatively charged electrons in the space between the screen grid and the plate as indicated by the dotted lines just under each of the straight lines representing the potential distribution when no electrons are in the space between screen and anode. In considering what takes place when electrons move from the cathode to the anode it is assumed for the purposes of this discussion that all electrons passing through the screen grid have uniform velocity and path length, that is move perpendicularly to the surface of the electrodes, and that there are no secondary electrons generated by electrons from the cathode impinging in the plate. The electrons drawn from the cathode by the positive screen grid will attain such velocity that most of them will pass through the screen grid between the grid wires and will tend to move toward the plate. When the plate is at a lower potential than the screen the electrons approaching the plate are decelerated due to the decreasing field potential. If the plate is just slightly negative there will be no plate current, as the electrons will stop just short of the plate and return to the screen. If the plate is slightly positive, the electrons are decelerated in the space between the screen grid and the plate, but nevertheless all of the electrons will reach the plate because the velocity of the electrons through the screen brings the electrons close to the plate, and the positive voltage on the plate pulls the electrons into the plate. Making the plate more positive by increasing the plate voltage (E_p) does not increase the plate current (I_p) because all of the electrons passing through the screen grid reach the plate for all positive plate voltages. This is illustrated in Figure 7 by the plate-current (I_p) and plate-voltage (E_p) characteristics plotted for different control grid voltages. The control grid is usually biased negatively with respect to the cathode and increasing the control grid voltage in the positive direction, that is from E_{g1} to E_{g2} , increases the plate current (I_p). The characteristic curves are flat and parallel, and such characteristics would be ideal for a power tube.

Figure 8 shows graphically the change in potential distribution between the screen and plate

with increasing distance between the plate and the screen grid, with electrons in the inter-grid-plate space, and with a fixed positive screen voltage g_2 . With no voltage on the plate and the plate at any distance less than distance d_3 from the screen grid, the potential distribution will be very similar to that shown in Figure 6, except that the change in the potential distribution curve will not be so rapid under the conditions where the field reaches zero potential at the plate. For different anode voltages and different control grid voltages much the same plate current-plate voltage curves will be obtained as shown in Figure 7. As the plate is moved slightly further away from the screen grid, say to a distance d_4 , the field will have a zero potential at a point somewhere in front of the plate instead of exactly at the plate as is the case when the plate is at any of the distances d_1 , d_2 or d_3 . If the plate is moved still further away from the screen to a distance d_5 , and a certain positive potential p_1 is applied to the plate, then the curve of potential distribution will, as shown, reach the zero voltage axis and have a zero slope, that is, will be neither increasing nor decreasing at some point in front of the plate. A probable explanation of this phenomenon is as follows: As the plate is moved further and further away from the screen, the electrons passing through the screen will be decelerated to a stop before reaching the plate. The electrons which have come to a full stop have only a slight tendency to return to the screen, but their return is hindered by other electrons moving toward the plate. The result is that eventually a cloud of electrons, commonly referred to as space charge, is formed in the space in front of the plate and the negative charges on the electrons cause the field potential to be depressed at that point.

This condition in space is effectively the same as would exist if a real cathode were substituted for the electron cloud, which forms a virtual cathode.

With no voltage on the plate the electrons from this cloud have no tendency to move to the plate. If a small positive voltage is applied to the plate some electrons on the outer fringe of the cloud will of course be attracted to the plate and there will be a small plate current. As the plate voltage is increased, more and more electrons are drawn to the plate and the space charge at the virtual cathode becomes less dense and has less and less effect in keeping the electrons moving from the screen from reaching the plate. Up to the point where a voltage, such as p_1 , is applied to the plate the space charge is effective in limiting the number of electrons and hence the amount of current reaching the plate. When the voltage p_1 is applied to the plate the electrons are drawn out of the virtual cathode as fast as they arrive, but nevertheless there is a region between the screen and the plate where the potential is a minimum. The tube may theoretically be considered as a diode comprising the virtual cathode and the plate. If now with the plate still at this distance d_5 , a slightly greater plate voltage p_2 is applied, there is still a region of minimum potential between the screen grid and the plate as shown by the dotted line g_2p_2 and all of the electrons still reach the plate. This is true for all positive plate voltages greater than p_1 up to voltages greater than that applied to the screen grid. The plate-current plate-voltage characteristics for different control grid

voltages when the plate is at this distance d_5 from the screen grid is represented by the solid lines in Figure 9, the portion of the curve between O and E_{p1} being due to the formation of the cloud of electrons or virtual cathode in front of the plate. Since at plate voltages greater than E_{p1} as many electrons go to the plate from the virtual cathode as arrive from the screen, no further increase in the plate current will take place with increase in plate voltage above E_{p1} if the bias E_g on the control grid is not changed. With the plate at this distance d_5 the value of plate voltages E_{p1} depends on the control grid bias.

When the plate is moved toward the screen from d_5 to d_3 , the portion of the curve OE_{p1} , representing the space charge limited curve, moves toward the zero voltage axis as shown by the dotted in curves. In other words under these conditions the "virtual diode" is closer spaced and will saturate at a lower plate voltage. With the plate at the critical distance d_3 both the plate and the virtual cathode occupy the same position, and the plate current permitted by the bias on the control grid reaches its maximum at an extremely small positive plate potential, regardless of the control grid bias. A tube having these characteristics, in which a slight positive plate potential will produce the maximum plate current possible with each particular control grid bias voltage, would be an ideal tube inasmuch as maximum current and plate voltage swings would be permitted and the tube could be operated at a maximum efficiency. These conditions would be present in a tube in which there is perfect field homogeneity, uniform electron velocity and a total absence of secondary electrons.

However, secondary electrons are produced under all operating conditions in practice and so long as the voltage increases from the plate to the screen these secondary electrons will return to the screen and cause not only higher screen current but also distortion in the output of the tube. It is, therefore, desirable to suppress secondary emission effects by preventing these secondary electrons from moving to the screen from the plate. It has been found that if a field potential of minus 10 to 15 volts with respect to the plate is produced in a region between the plate and the screen the secondary electrons emitted from the plate will be unable to move through this region to the screen. The so-called suppressor grid maintained at a zero potential and positioned between the screen and the plate produces an approximation to such a region of potential lower than plate potential. However, the presence of this suppressor electrode distorts the uniformity of the field between the screen and the plate and thus deviates many electrons from a short straight path and prevents them from reaching the plate due to loss of velocity, so that a plate-current plate-voltage characteristic with a sharp knee can not be obtained. In other words the potential distribution is different for different cross sections of the tube, so that some portions of the anode receive more electrons than others. Hence, no one definite plate voltage will cause all the electrons to reach the plate and produce maximum plate current, consequently the knee of the characteristic becomes very rounded. With a rounded knee the permissible minimum voltage to which the plate voltage can swing would be shifted to the right on the plate-cur-

rent plate-voltage curve, thus increasing the minimum plate voltage and decreasing the efficiency of the tube. It would, therefore, be desirable to establish a field between the screen grid and the plate which would have a region of minimum potential of at least 10 or 15 volts lower than that of the plate by means which would not distort the field.

As shown in Figure 7, I have obtained such a condition in the field by placing the plate a distance greater than the critical distance d_3 from the screen grid. If the plate is moved a distance, for example, d_5 from the screen as shown in Figure 7 and if at this distance a voltage on the anode will produce a field distribution such that there is a region of 10 or 15 volts lower potential between the plate and screen grid, then for all positive voltages on the plate a barrier will be formed in front of the plate which will prevent the secondary electrons from flying to the screen grid inasmuch as the secondary electrons cannot move through a field in which the voltage is 10 or 15 volts less than that at the point at which they are generated.

In a screen grid tube of the type described substantially perfect characteristics could, in accordance with my invention, be obtained by properly spacing the anode from the screen grid. In practice the grids are usually supported upon grid side rods, which produce what are known as electron shadows or areas between the cathode and the plate through which movement of the electrons directly from the cathode to the anode is prevented. They may even produce portions on the anode where no primary electrons reach the anode from the cathode. According to my invention I place specially shaped shields close to the screen grid side rods between the grid side rods and the anode, as shown in Figures 1 and 2. Probably these shields prevent secondaries from returning to the screen through the space between the screen and the anode, as I have obtained indications that no space charge or cloud of electrons forms between the anode and the grid electrode at that section of the tube whose side rods are positioned so that secondaries can return to the screen in this area thus adversely affecting the tube characteristics. The side rods also cause non-uniform field distribution between the screen and anode. These shields are also necessary and must be properly shaped to restore a uniform field between the screen grid and the plate, so that all electrons leaving the cathode and passing through the screen will travel along uniform paths from the cathode to the plate and produce a space charge of uniform density and distance from the plate.

Referring to Figure 3, the path of the electrons is represented by the dotted lines, and the cloud of electrons or the space charge, which forms between the anode and the cathode, by the dots. This space charge and the shields 20 form a field of minimum potential between the screen grid 16 and the plate 18. The cathode is made oblong or roughly elliptical in cross section, with substantially flat sides to obtain an evenly spaced effective surface with respect to the control grid for supplying electrons, so that the current density will not be decreased at the edges to an undesirable extent by thinning the density of the electron beam on the sides as would be the case, for example, if a small round cathode were used. Flat wide cathodes make it unnecessary to open the mesh of the control grid more than desirable to obtain a sufficient electron density. As a re-

sult the flat wide cathode produces less distortion and better power sensitivity. The grids 14 and 16 have the general shape of cylindrical convex lenses with surfaces of a curvature defined by arcs, the radii of which decrease toward the plate, that is the radius of the arc defining the curvature of the surface of the control grid 16 is greater than that of the screen grid 16. The shield plates 20 compensate for variations in the potential distribution due to the grid side rods and help to confine the electrons in two well defined beams as illustrated in Figure 3, and thus insure uniform conditions for all electrons moving from the screen to the anode.

In one specific form of my invention the transverse sectional dimensions of the electrode assembly are as follows: cathode .095 inch along its major axis, and .040 inch along its minor axis; control grid .220 inch between the centers of the side rods and a radius of curvature of .285 inch for the grid wires which are tangent to the side rods; screen grid .320 inch between the centers of the side rods and a radius of curvature of .220 inch for the grid wires which are tangent to the side rods, the radius of the curved or cylindrical portions of the plate being .281 inch. The grid side rods should have a diameter less than the distance between the flat sides of the cathode or less than .040 inch. The shield side rods lie in a plane spaced .045 inch from the screen grid side rods and are .280 inch in width. For best results the ratio of the distance from the flat surface of the cathode to the screen grid along its minor axis to the distance between the cathode surface and the anode should be about 1 to 3 and preferably not less than 1 to 2. The control grid is placed close to the cathode, the spacing between the grid wires being greater than the distance between grid and cathode. I have found that good results are obtained when the spacings have a ratio of 3 to 2. This spacing determines to a large extent the grid voltage-plate current characteristic of the tube. For best results the grids should be aligned to reduce the screen grid current. A power tetrode of high power sensitivity requires comparatively close grid wire spacing, for example, of the order of 30 to 35 turns per inch. With 30 to 35 turns per inch of 4.1 to 3.3 mil. diameter grid wire the spacing between the control grid and screen grid should not be greater than 1.6 times the grid wire spacing. The radii of the arcs defining the curvature of the surfaces of the grids with side rods should decrease in going from the cathode to the plate. This is for the purpose of obtaining a uniform potential distribution in conjunction with the beam confining plates.

The space charge suppression of secondary emission effects from the plate in a tube embodying my invention by means of a low potential region between the screen and the plate requires a current density of approximately 12.5 milliamperes per square centimeter or more at the plate for electrons passing through a screen with a velocity of 200 volts. If the electron density is lower small differences in density along the beam cross section will manifest themselves in producing a non-uniform potential gradient in front of the plate, thus causing a more rounded knee in the plate-current plate-voltage characteristic. At high current density these differences appear to be somewhat smoothed out.

While the shape and ratio of the dimensions of the various electrodes may vary to some extent, I have found that for best operation with maxi-

5 mum power sensitivity that the ratios given are most suitable. For example, with a given current density if the plate diameter is decreased too much, that is if the plate is brought too close to the screen, secondary emission effects will result because the suppression of secondary electrons will not be effective. If the diameter of the plate is increased too much, that is if the plate-screen grid spacing is increased too much, indications are that with the control grid voltages increased in a positive direction with respect to the cathode, the plate voltage-plate current curve seems to reverse. A tube having such a characteristic might well cause undesirable results during operation in its associated circuit.

10 A tube made in accordance with my invention has a grid voltage-plate current characteristic which varies as the square of the current rather than according to the usual three halves characteristic. The result is a tube in which the third harmonic of the fundamental voltage applied to the control grid, and the harmonic which causes the most undesirable distortion, is practically eliminated. While there is some second harmonic distortion this is not objectionable because it can be easily eliminated by using a preamplifier, the second harmonic of which is out of phase with and hence neutralizes at least a portion of the second harmonic in the tube or by using a pair of tubes made according to my invention in push pull which will completely cancel out the second harmonics and thus produce a distortion-free output.

15 It will thus be seen that by my invention I have equalized the differences in potential distortion between the screen grid and plate by forming and spacing the electrodes in a predetermined manner. Because of the resulting uniform potential distortion I am able to provide a tube having the desirable characteristics pointed out above.

20 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 having a straight thermionic cathode oblong in cross section with a long and a short transverse axis, an anode having curved surfaces surrounding said cathode and coaxial therewith, a pair of concentric lenticular grids coaxial with said cathode and positioned between said cathode and said anode, each of said grids being provided with a pair of oppositely disposed side rods lying in a plane passing through the longer transverse axes of said lenticular grids, the longer axes of said cathode and said grids coinciding, the radius of the arc defining the curved surface of the outer grid being less than the radius of the arc defining the curved surface of inner grid, and shields between the anode and the grid side rods, the curved surfaces of the anode lying opposite the curved surfaces of the grids.

2. An electron discharge device having a straight thermionic cathode with flattened surfaces and a long and a short transverse axis, and an anode surrounding said cathode and coaxial

therewith, a pair of concentric lenticular grids coaxial with said cathode and positioned between said cathode and said anode, each of said grids being provided with a pair of oppositely disposed side rods lying in a plane passing through the longer transverse axes of the lenticular grids, the long axis of said cathode and the longer transverse axes of said grids coinciding, the radius of the arc defining the curved surface of the outer grid being less than the radius of the arc defining the curved surface of the inner grid, the ratio of the distance between the flattened cathode surface and the outer of said two grids and the distance between the flattened surface of the cathode and said anode being of the order of 1 to 3.

3. An electron discharge device having a straight thermionic cathode with flattened surfaces and a long and a short transverse axis, and an anode having curved surfaces and surrounding said cathode and coaxial therewith, a lenticularly shaped grid surrounding and coaxial with said cathode, a second lenticularly shaped grid coaxial with said cathode and surrounding said first grid, said grids being positioned between said cathode and said anode, each of said grids being provided with a pair of oppositely disposed side rods lying in a plane passing through the longer transverse axes of said lenticularly shaped grids, the long axis of the cathode and the longer transverse axes of said grids coinciding, the radius of the arc defining the curved surfaces of the outer grid being less than the radius of the arc defining the curved surfaces of the inner grid, and shields between the anode and second grid side rods, said shields being connected to the cathode.

4. An electron discharge device having a flattened straight thermionic cathode having a long and a short transverse axis, and an anode having curved surfaces opposite the flattened sides of the cathode and surrounding said cathode and coaxial therewith, a pair of concentric lenticularly shaped grids coaxial with said cathode and positioned between said cathode and said anode, each of said grids being provided with a pair of oppositely disposed side rods lying in a plane passing through the longer transverse axis of said lenticularly shaped grids, the longer transverse axis of said lenticularly shaped grids coinciding with the long transverse axis of the cathode, the ratio of the distance between the flattened sides of the cathode surface and the outer of said pair of lenticularly shaped grids and the distance between the flattened sides of the cathode and the anode being of the order of 1 to 3 and shields between the anode and the grid side rods, the longitudinal edges of said shields terminating near the curved surfaces of the anode.

5. An electron discharge device having a thermionic cathode provided with oppositely disposed substantially flat parallel sides, an anode having curved surfaces opposite the substantially flat sides of the cathode and coaxial with said cathode, a grid between said cathode and said anode and coaxial with said cathode and having a lenticularly shaped transverse cross section, a second grid around said first grid and coaxial with said cathode and having a lenticularly shaped transverse cross section, each of said grids having a pair of oppositely disposed side rods lying in a plane through the longer transverse axis of said lenticularly shaped grids, the minor transverse axes of said grids being perpendicular to the flat sides of said cathode, the

radii of said first grid and said anode being substantially the same, and the ratio of the distance between the cathode surface and said second grid and the distance between the surface of said cathode and said anode being about 1 to 3.2, and shields between the anode and the grid side rods.

5 6. An electron discharge device having a straight thermionic cathode and an anode surrounding said cathode and coaxial therewith, a
10 pair of lenticularly shaped grids coaxial with said cathode and positioned between said cathode and said anode, each of said grids being provided with a pair of oppositely disposed side rods, said side rods lying in a plane passing through
15 the longer transverse axis of said lenticularly shaped grids, the ratio of the distance between the cathode surface and the outer of said two grids and the distance between the surface of said cathode and said anode being not less than
20 1 to 2 and shields between the anode and the grid side rods.

7. An electron discharge device having a straight thermionic cathode and an anode surrounding said cathode and coaxial therewith, a
25 pair of concentric lenticularly shaped grids coaxial with said cathode and positioned between

said cathode and said anode, each of said grids being provided with a pair of oppositely disposed rods lying in a plane passing through the longer transverse axis of the lenticularly shaped grids, and a shield adjacent each side rod of the outer of the two concentric grids and positioned only
5 between the anode and the side rods of the outer of the two concentric lenticularly shaped grids.

8. An electron discharge device having a straight thermionic cathode for supplying electrons, and an anode for receiving electrons from
10 said cathode and surrounding said cathode and coaxial therewith, a pair of concentric lenticularly shaped grids coaxial with said cathode and positioned between said cathode and said anode,
15 each of said grids being provided with a pair of oppositely disposed rods lying in a plane passing through the longer transverse axis of the lenticularly shaped grids, said rods forming oppositely disposed beams of electrons directed from
20 said cathode to said anode, and a shield adjacent each side rod of the outer of the pair of concentric lenticularly shaped grids and between the outer grid and anode, said shields lying outside the path of said beams.
25

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