April 23, 1940. C. S. BULL 2,198,330

THERMIONIC VALVE

Filed May 27, 1938 2 Sheets-Sheet 1

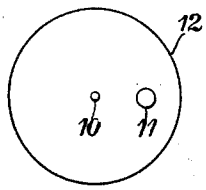


Fig. 1.

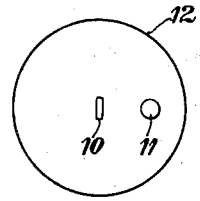


Fig. 2.

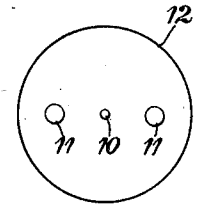


Fig. 3.

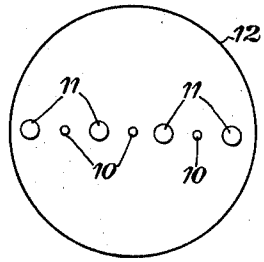


Fig. 4.

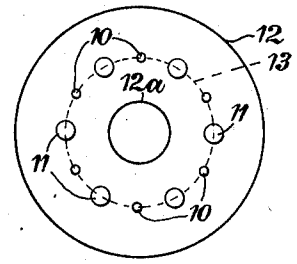


Fig. 5.

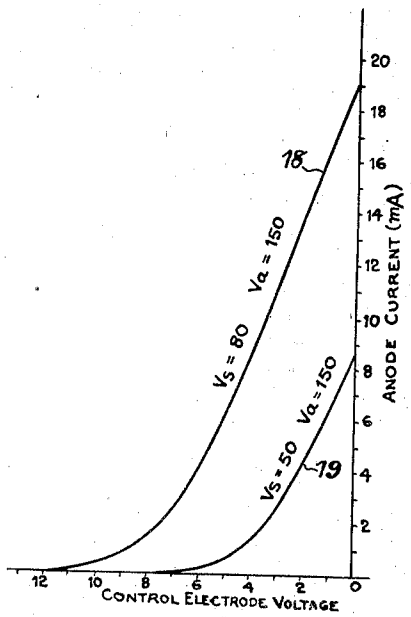


Fig. 7.

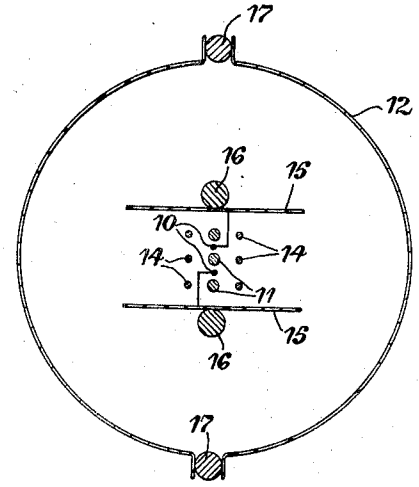


Fig. 6.

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THERMIONIC VALVE

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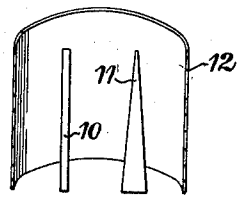


Fig. 8.

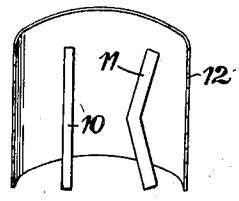


Fig. 9.

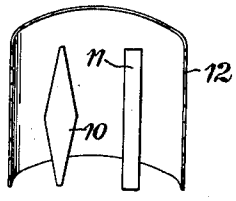


Fig. 10.

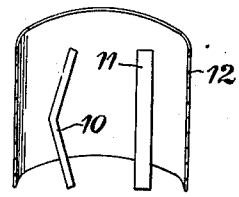


Fig. 11.

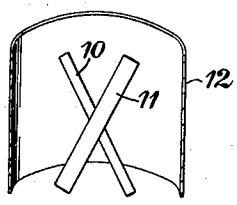


Fig. 12.

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UNITED STATES PATENT OFFICE

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THERMIONIC VALVE

Cabot Seaton Bull, Hillingdon, England, assignor to Electric & Musical Industries Limited, Hayes, Middlesex, England, a company of Great Britain

Application May 27, 1938, Serial No. 210,302
In Great Britain June 1, 1937

9 Claims. (Cl. 250—27.5)

This invention relates to thermionic valves of the type in which a space charge limited current is adapted to flow between cathode and anode. The invention is therefore distinguished from certain other types of valves in which the current from the cathode is controlled not by space charge limitation but by deflection of the electron beam.

The chief object of the present invention is to provide an improved thermionic valve in which the disadvantages of wound grids are avoided and to provide a valve of simplified manufacture which may easily be made to have a variable mu characteristic or to have a sharp cutoff so that the slope of the grid voltage anode current characteristic changes only slightly as the grid bias approaches the value at which anode current becomes zero.

Previously proposed valves in which the cathode is in the form of a straight rod and the control electrode is also in the form of a rod or rods are easy to manufacture but require a large grid bias to reduce the anode current to zero, that is to say, the valve has a large amount of "tail." This disadvantage, it has been found, arises from the fact that when the control electrode is disposed close to the cathode the control exercised on the cathode is not uniform around the surface of the cathode and, consequently, a large bias is required on the control electrode before the control electrode can exercise a sufficient control around the whole area of the cathode to reduce the anode current to zero.

According to the invention the control electrode is placed at a sufficient distance from the cathode for the control exercised on the electrons on leaving the cathode to be substantially uniform around the area of the cathode. In one embodiment of the invention a thermionic valve comprising at least a cathode, a control electrode and an anode wherein the cathode is rectilinear or rod-like, has a control electrode also like a rod in a common plane with the cathode and so positioned that the minimum distance between the cathode and control electrode is substantially constant along the length of said electrodes, the interelectrode spacing being such that the distance of the control electrode from the cathode is sufficiently large compared with the cross section of the cathode and the spacing of the anode or of any other positive electrode from the cathode is sufficiently great to make the strength of the field which causes electrons to leave the cathode to be substantially independent for a given anode current of the relative values of the electrode potentials producing said field under normal operating conditions.

For the purpose of this specification "normal operating conditions" means the condition in which a space charge limited current flows and in which the range of anode currents and voltages is in the ratio of from 5 to 10:1. For example, with a triode output valve the anode voltage may vary between 50 volts and 350 volts whilst the anode current may vary from 100 *m*/A. to 10 *m*/A.

The cathode either of the directly or indirectly heated type is preferably linear and of a constant cross section along its length, the cross section being either circular or rectangular. In the case of a cathode of circular cross section the current leaving each unit area of the cathode is substantially constant around the whole surface of the cathode even when the relative values of grid and anode voltages are changed, in such a manner that the same current leaves the cathode. Where a cathode is employed of a rectangular cross section the current leaving each unit area of the cathode may not be uniform from point to point but the distribution will be again independent of the relative values of control electrode and anode potentials causing the current to leave the cathode. The distance of the control electrode from the cathode should be at least two-and-a-half times the cathode diameter when the latter is of circular cross section and two-and-a-half times the longest dimension of the cathode cross section when the latter is of rectangular form no matter which way the cathode is orientated with respect to the control electrode.

The invention may also be applied to tetrode, pentode and other muti-electrode valves, the additional electrodes being of any suitable form according to known practice and arranged at suitable distances from the cathode to perform their required functions.

The position of the anode, which is preferably cylindrical, or of the screening electrode is relatively unimportant providing that no point of the positive electrode (anode or screening electrode) is closer to the cathode than the distance of the control electrode from the cathode. For practical purposes the control electrode will seldom be of smaller cross section than the cathode. Preferably the control rod is a substantially larger cross section than the cathode and may to advantage be of a diameter 5 to 10 times that of the cathode.

The invention is particularly suitable for valves which are designed for the generation of oscillations of very high frequencies, such as those encountered in television systems, and higher, since the capacity between the cathode and the control electrode can be made very small and the time of flight of the electrons very short. By employing a valve in accordance with the invention which can be readily constructed with a low amplification factor larger currents can be drawn by the anode and because of the larger current flowing the time of flight of the electrons is reduced so that very high frequencies can be obtained.

If desired, the control electrode may comprise a plurality of rods and two or more cathodes may be provided, each cathode being between adjacent control rods, the cathodes and the rods of the control electrode being in the same plane. Alternatively, the cathodes and the rods of the control electrode may be on the circumference of an imaginary cylinder.

Since in the preferred form of the invention both cathode and control electrode are in the form of straight rods they can be manufactured with very little variation of their dimensions throughout their length, enabling them to be easily mounted in the same plane and parallel to one another. The fact that the control electrode may consist of a thick wire, and is not of the usual wound construction, enables it to be disposed sufficiently close to the filament to permit of a high mutual conductance to be obtained without increased microphonic or mechanical difficulties and enabling the time of the flight of the electrons to be reduced and to permit of the production of valves having low amplification factors which are eminently suitable both for the detection and generation of oscillations of very high frequencies.

In order that the invention may be clearly understood and readily carried into effect the same will now be more fully described with reference to the accompanying drawings in which:

Figure 1 is a diagrammatic cross sectional view of a triode valve constructed in accordance with the invention,

Figure 2 is a view similar to Figure 1 but illustrating a modification,

Figure 3 illustrates a modification of the invention in which the control electrode comprises a pair of rods,

Figure 4 illustrates a modification in which the control electrode comprises a plurality of rods and a plurality of cathodes also provided.

Figure 5 illustrates a further form of the invention,

Figure 6 illustrates yet another form of the invention as applied to a tetrode valve,

Figure 7 illustrates two characteristic curves of the valve shown in Figure 6, and

Figure 8 of the drawings illustrates one form of variable-mu valve constructed in accordance with the invention and

Figures 9, 10, 11 and 12 illustrate further forms of variable-mu valves.

As shown in Figure 1, the valve comprises a cathode **10**, a control electrode **11** and a cylindrical anode **12**. The cathode **10** is circular in cross section and is a straight rod. The cathode may be indirectly heated or directly heated and mounted in the conventional way. The control electrode **11** comprises a straight rod of circular cross section arranged parallel to the cathode **10**, the spacing of the cathode and control electrode being at least two-and-a-half times the diameter of the cathode **10**. The electrodes of the valve will of course be mounted in a highly evacuated envelope. The anode **12** shown as a cylinder but optionally of other shapes, such as a flat plate, is disposed at a distance from the cathode, not less than the distance between the cathode **10** and the control electrode **11**.

In Figure 2 the cathode **10** is of the indirectly heated type and comprises an outer casing of rectangular form and coated with a suitable electron-emitting substance, and is provided internally with a heater, not shown. The control electrode **11** comprises a rod mounted parallel to the cathode **10** and the distance between the cathode and the control electrode is at least two-and-a-half times the longest dimension of the cathode cross section.

The construction of valves shown in Figures 1 and 2 are eminently suitable where low amplification factors are required, but where high amplification factors are necessary the control electrode may comprise two or more rods.

Figure 3 of the drawings illustrates such an arrangement in which two control rods **11** are mounted on each side of the cathode **10**. In this arrangement the exact centering of the cathode in the plane containing the axes of the rods **11** is not critical but care should be taken to ensure that slight deviation of the cathode occurs in a direction at right angles to the said plane.

Figure 4 illustrates a somewhat similar construction in which the control electrode comprises four rods **11** and a plurality of cathodes **10** is provided, a cathode **10** being disposed between adjacent rods **11**, as shown.

Figure 5 illustrates a modification of the arrangement shown in Figure 4, in which the control electrode comprises six rods **11** arranged on the circumference of an imaginary cylinder indicated by the dotted line **13** and six cathodes **10** are provided each cathode being disposed between adjacent rods **11** and also arranged on the circumference of the imaginary cylinder **13**. In this arrangement an additional anode **12***a* is provided arranged concentrically with the imaginary cylinder **13**. In some cases the anode **12** may be omitted and the inner anode **12***a* alone employed. With constructions employing up to three rods constituting the control electrode, it is preferable to employ cylindrical anodes and where additional electrodes are employed these should also be of cylindrical form since some reduction in the control electrode input capacity can be thus obtained.

In a valve manufactured in accordance with the invention and employing two filaments, each 1 mm. apart and 20 mms. long and of a diameter equal to 0.05 mm. together with a control electrode comprising three rod-like elements of 0.25 mm. diameter and 1 mm. apart, together with an anode in the form of a cylinder 4 mms. in diameter, the control electrode/anode capacity was found to be 1 to 2 cms. the amplification factor 3 and the mutual conductance 2.2 m/A. per volt. In a comparable valve having a filament 40 mms. long and 0.03 mm. diameter bent into a V-shape with a wound elliptical grid with a minor axis of 1 mm. and supported on two rods each 1 mm. in diameter and wound with molybdenum wire of a diameter of 0.1 mm. the mutual conductance was found to be 1.5 m/A. per volt and the grid/anode capacity 5 to 6 cms. and the amplification factor 15. Such a valve could not be manufac-

tured with an amplification factor as low as 3 without considerable difficulty.

Although it is possible to employ screening electrodes in a valve in accordance with the invention, which screening electrodes may comprise wire wound helices or meshes or a single rod it is preferable to employ as the screening electrode one consisting of rods similar to and parallel to the rods constituting the control electrode and aligned therewith, since in this case, so-called screened grid and other types of valves can be constructed having a screen current as low as 1/70 or less of the cathode current. A valve constructed in this manner is shown in Figure 6 with two cathodes 10 and three rods 11 constituting the control electrode. On each side of the control electrode three rods 14 are provided arranged in planes parallel to the plane containing the control electrodes and cathodes, the rods 14 being parallel to one another and aligned with the rods 11. Additional screening plates 15 are provided, preferably connected directly to the cathode, carried by support bars 16, the electrodes so far described being surrounded by a cylindrical anode 12 supported by support bars 17. The cathodes 10 may be 0.05 mm. diameter and the rods 11 may be 0.5 mm. in diameter and the distance between the centres of adjacent rods 11 may be 1 mm. The rods 14 may be 0.25 mm. in diameter, and the centres of the rods 14 may be spaced from the centres of the rods 11 a distance of 1 mm. The anode 12 may have a diameter of 15 mms. whilst the width of the plates 15 may be 7 mms. and spaced from the centre of the outermost rods 11 a distance of 1 mm. Two characteristic curves for a valve constructed in accordance with Figure 6 and with the dimensions given are shown in Figure 7. From the first curve 18 it will be observed that with a voltage of 80 volts applied to the screening electrode and with an anode voltage of 150 volts the anode current is reduced to zero at about 11 volts negative potential on the control electrode. The second curve 19 indicates the condition in which a voltage of 50 volts is applied to the screening electrode and a voltage of 150 volts is applied to the anode, in this case, the anode current is reduced to zero at a negative potential of 7 volts. The ratio of the voltages for cut off, i. e., 11:7, is substantially equal to the ratio of the screen voltages, namely 80:50. The valve has therefore practically no tail.

It is found that the electron stream leaving the cathode can be made to take the form, in the case where at least two rod-like elements are employed, as the control electrode, of thin sheets of electrons travelling at right angles to the plane of the control electrode, and thereby the screening electrode need not be close to the control electrode to ensure that the screen current is small. The effect can be obtained by suitably arranging the control electrode with respect to the cathode and by choosing appropriate operating potentials. The arrangement shown in Fig. 6 can produce the effect mentioned. The screening electrode may take the form of a slotted plate or cylinder or composed of rods, the electron stream passing through the slit or slots or the space or spaces between the rods. In this way the input capacity can be reduced.

The control electrode may consist of a rod or rods which are sufficiently thick to enable heat to be conducted along them readily. Emission from the control electrode and leakage can therefore be reduced by joining the rods of the control electrode to one or more radiating fins at their ends. Alternatively, in very large valves, the said rod or rods may consist of tubes, means being provided for passing cooling liquid therethrough, or may be terminated at one or both ends in metal blocks which are cooled by liquid. These features can be applied to any type of valve using rods as the control electrode.

Whilst, as stated above, the invention has primarily been developed with a view to providing a valve having very little "tail," nevertheless, the general construction of valve described in Figures 1 to 6 can be altered so as to provide valves with a predetermined degree of "tail" to function as variable-mu valves. Figures 8 to 12 show various forms of this aspect of the invention and in all of these figures the cathode is indicated by the reference numeral 10, the control electrode by the reference numeral 11 and a cylindrical anode, which is shown in longitudinal section, by the reference numeral 12. In these figures the control electrode need not be displaced from the cathode a distance at least equal to two-and-a-half times the cathode diameter, although if the control electrode is so disposed, some advantages accrue.

In Figure 8 the control electrode 11 is shown of a nonuniform cross section and is in the form of a cone. It will be appreciated that with this construction the control electrode will exercise different control over different portions of the electron stream which is the essential function of a variable-mu valve.

In Figure 9 the control electrode 11 is bent along its length, such an arrangement also affording a variable-mu characteristic, the amount of bending of the control electrode 11 determining the amount of "tail."

Figure 10 illustrates a further form in which the control electrode 11 is in the form of a rod of uniform cross-section and the cathode 10 is of non-uniform section, as shown.

In Figure 11 the control electrode 11 is again in the form of a rod and the cathode 10 is bent along its length, as shown. Where the cathode 10 is of the directly heated type suitable supports will be provided to maintain the cathode 10 in the form shown.

In the arrangement shown in Figure 12, the cathode 10 and the control electrode 11 are both in the form of linear elements but are angularly displaced with respect to one another or are not parallel. This construction also affords a variable-mu characteristic.

In the examples described in Figures 8 to 12 the cathodes shown in Figures 8, 9, 11 and 12 may be either of the directly or indirectly heated type, but the cathode shown in Figure 10 is preferably of the indirectly heated type since it would be difficult to manufacture a directly heated cathode of the form shown in Figure 10. The cathodes 10 and the control electrodes 11 are preferably of circular form in cross section, but of course other sections may, if desired, be employed. Although in each of the examples described in these figures a single rod is employed as the control electrode, more than one rod and more than one cathode may, if desired, be used. Additional electrodes may be associated with the valves, such as screening electrodes, in known manner.

I claim:

1. An electron discharge device comprising a rectilinear cathode of uniform cross-section throughout its length, an anode electrode having

a surface parallel to the surface of said cathode, and a rectilinear control rod of greater diameter than said cathode and with its longitudinal axis parallel to said anode surface and to the longitudinal axis of said cathode, said rod being the control electrode nearest said cathode and spaced from said cathode a distance at least two and one-half times the diameter of said cathode, said anode electrode being spaced from said cathode to make the electron accelerating field at said cathode substantially uniform about said cathode.

2. An electron discharge device as defined in claim 1 in which the cathode is a filament and the control electrode is a straight rod of a diameter several times that of the cathode.

3. An electron discharge device as defined in claim 1 in which the cathode is a straight filament and the control electrode is a straight rod having a diameter about ten times that of said cathode and spaced from said cathode a distance about five times the diameter of said cathode.

4. An electron discharge device including an anode, a unipotential control electrode comprising two spaced rectilinear parallel rods, a rectilinear filamentary cathode of smaller diameter than the minimum diameter of said rods and positioned between and in the plane of the longitudinal axes of said rods and spaced from each of said rods a distance several times the diameter of said cathode, and an accelerating electrode comprising a pair of rectilinear parallel rods interposed between said anode and said control electrode with each rod of said control electrode coplanar with the corresponding rod of said accelerating electrode in a plane transverse to the plane of said control electrode.

5. An electron discharge device including an anode, a control electrode comprising a plurality of spaced rectilinear parallel rods, a filamentary cathode comprising rectilinear portions in the plane of the longitudinal axes of said rods, each of said portions being of smaller diameter than the maximum diameter of said rods and positioned between a pair of said rods and spaced from each of said rods a distance several times the diameter of said cathode portion, and an accelerating electrode comprising a plurality of rectilinear parallel rods corresponding to the rods of said control electrode interposed between said anode and said control electrode with each rod of said control electrode parallel to and aligned with a corresponding rod of said accelerating electrode in a plane which includes said corresponding rods and intersects said anode.

6. An electron discharge device including an anode, a control electrode comprising two spaced rectilinear parallel rods, a rectilinear filamentary cathode positioned between and in the plane of the longitudinal axes of said rods and spaced from each of said rods a distance several times the diameter of said cathode, and an accelerating electrode between said anode and said control electrode and comprising two rectilinear rods parallel to said control rods each of said rods of said accelerating electrode being coplanar with a corresponding rod of said control electrode in a plane normal to the plane of said control rods, said anode being imperforate and further from said cathode than said accelerating electrode.

7. An electron discharge device as defined in claim 6 having a pair of sheet electrodes at opposite ends of said control electrode and extending normal to the plane of said control electrode and connected to said cathode.

8. An electron discharge device including an anode, a pair of rectilinear control rods parallel to the surface of said anode, a rectilinear cathode between and coplanar with said rods and spaced from each control rod at least two and one-half times the diameter of said filamentary cathode, said cathode having a diameter less than the maximum diameter of either control rod, and an accelerating electrode between said anode and said control rods comprising a pair of rectilinear rods parallel to said control rods, each of said accelerating electrode rods being coplanar with a corresponding control grid rod in a plane which intersects the surface of said anode.

9. An electron discharge device comprising a tubular anode having a pair of diametrically opposite anode support rods, a pair of sheet screening electrodes inside said anode and normal to the plane of said anode support rods, a control electrode between said screening electrodes and comprising a plurality of rectilinear parallel control rods, a cathode comprising a filament smaller than said control rods and having a plurality of rectilinear sections less in number by one than said control rods, each section being between and coplanar with a pair of said control rods and spaced from said rods at least two and one-half times the diameters of said section, and an accelerating electrode comprising rectilinear rods equal in number to said control electrode rods, each of said control electrode rods being parallel to and coplanar with a corresponding control rod in a plane normal to the plane of said control electrode.

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