April 21, 1936. J. H. O. HARRIES 2,038,360

ELECTRIC DISCHARGE TUBE

Filed June 20, 1933 2 Sheets-Sheet 1

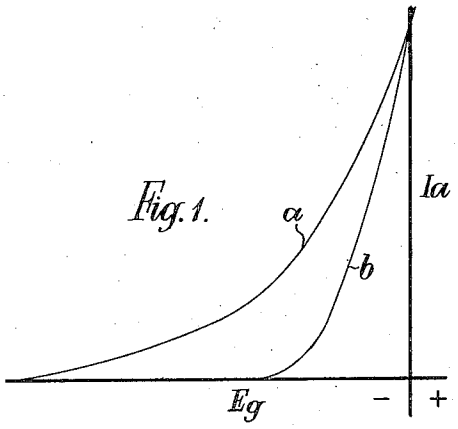


Fig. 1.

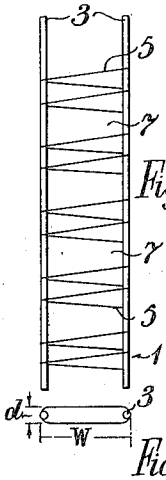


Fig. 2.

Fig. 2a.

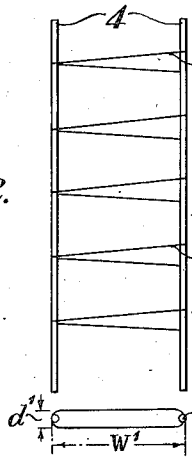


Fig. 3.

Fig. 3a.

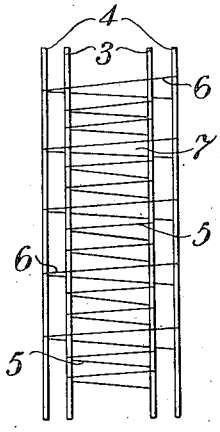


Fig. 4.

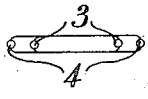


Fig. 4a.

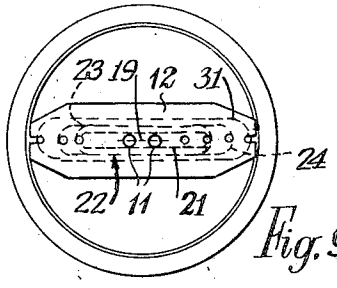


Fig. 9.

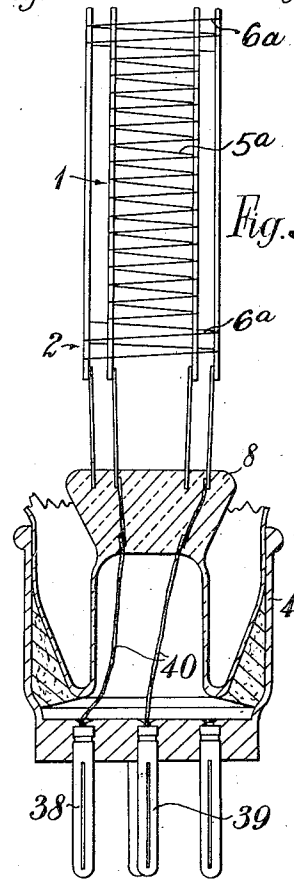


Fig. 5.

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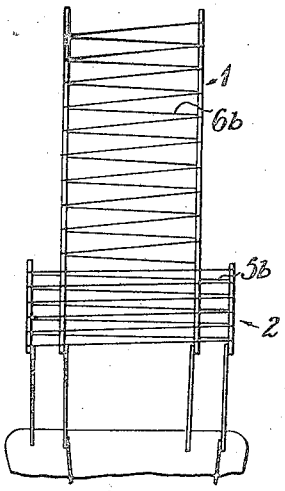


Fig. 6.

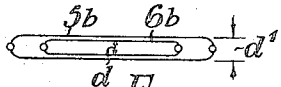


Fig. 7

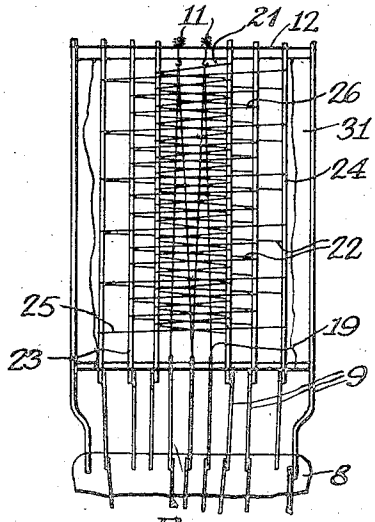


Fig. 8.

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UNITED STATES PATENT OFFICE

2,038,360

ELECTRIC DISCHARGE TUBE

John Henry Owen Harries, Frinton-on-Sea, England

Application June 20, 1933, Serial No. 676,639
In Great Britain June 27, 1932

8 Claims. (Cl. 250—27.5)

This invention relates to electric discharge devices and to the operation of the same. In particular, but not exclusively, the invention relates to thermionic valves, it being understood that the term "valves" however, has no necessary limitation to the shape of such devices.

It is desirable in thermionic valves and like devices to provide a method of controlling the degree to which the valve amplifies input voltages, and this control may be conveniently performed by altering the potential of an electrode or electrodes in the tube. In valves, for instance, curved characteristics may be obtained if the electrodes are asymmetrical or have different distances from each other over their area, or otherwise have different values of the electrostatic field between the electrodes at different parts of the area of the discharge. Such arrangements are sometimes found in valves due to accidental distortion of electrodes and produce a variable mutual conductance characteristic, but such a characteristic when obtained in this manner due to geometrical deformation of the electrodes is a permanent characteristic of the valve and cannot be controllably altered or eliminated.

This also applies in the case of inaccurately aligned electrodes and in the case of the deliberate malformation of the electrodes obtained, for instance, by uneven winding of the control grid.

The object of the present invention is to provide a definite or modified or improved method of controlling the degree to which a discharge tube, for instance, a thermionic valve, amplifies input voltages, especially by altering the potential of an electrode or electrodes in the tube, and further to control the degree to which the amplifying property of the valve is controllable, particularly from the aspect of providing a variable mu or volume control characteristic when desired, for instance, from the point of view of avoiding the necessity of manufacturing special valves having variable mu characteristics which would otherwise be necessary because of the unsuitability of variable mu valves for anode bend rectification, or for other purposes.

A further object of the invention is to produce an electric discharge tube having a control grid, and means to give a variable mu or a sharp cut off at will, and to do the latter without substantially reducing the maximum mutual conductance of the tube compared with a tube with which it is not possible to control the point of cut off.

According to the invention this result is produced by providing the tube with a cathode, a control grid and an anode and with at least one auxiliary electrode which is at a greater distance from the cathode than the control grid and which comprises a plurality of portions in substantially the same plane. The portions, however, should meet certain requirements in order to produce the desired result. At least one of said portions should have sufficient constituent parts (f. i. wires) without intervening constituent parts of other portions for the shielding effect or the electrostatic field over the area of the first mentioned portion to be substantially even whatever the potential of the other portion may be.

By means of a tube having these features the degree to which the amplifying property of the tube may be controlled can be adjusted by supplying different potentials to the individual portions of the composite auxiliary electrode.

The term "auxiliary electrode" refers to grid-like electrodes positioned in a valve or discharge tube in the path of the discharge after it has been controlled by the control grid, that is, in the space between the control grid and the anode. For example, the term "auxiliary electrode" may be taken to indicate the positively charged screen grid, or second grid in a screened grid valve. The expression may also refer to electrodes not consisting of a conventional wire mesh formation, for instance, to electrodes consisting of grids stamped out of metal or built up of segments or other constructions. A further definition is that a portion of an electrode which has an "even shielding effect or electrostatic field" in the present specification, is one the field of which is sufficiently separated from the field of the other portion or portions of the electrode, for the field density to be substantially unaffected by the potential of this other portion or portions.

Further, a divided electrode having a portion "the shielding effect or electrostatic field of which is substantially even over its area", is an electrode which is subdivided to a sufficiently small extent for the steepness and the cut-off of its characteristic (when the portions are connected to the same potential, curve *b*, Fig. 1) to be substantially the same as is found if the divided electrode is substituted in the discharge tube by a single electrode, with the same mesh, which is not subdivided.

In accordance with the present invention, it has been found that it is possible cheaply to manufacture auxiliary electrodes having a plurality of portions. This is not the case if (f. i.) the control grid of a tube be constructed to consist of a plurality of portions. Control grids, as a rule,

are very closely spaced and it is impracticable and expensive to construct divided control grids. Further a control grid is normally arranged at a very small distance from the cathode. A divided control grid is liable to produce noisy operation, due to very small relative movements of the various portions due to mechanical shocks. Further irregularities of the tube characteristic may be produced when the constituent portions of the control grid are not evenly spaced. Both of these troubles are produced by the small distance between the control grid and the cathode. When, however, an auxiliary electrode which is farther from the cathode than the control grid, is divided, these troubles do not occur.

Other objects, novel features and advantages of the invention will become apparent from the following specification and accompanying drawings, wherein:

Figure 1 is a graphical representation of characteristic curves given by one form of valve in accordance with the present invention.

Figure 2 is an elevation, and

Figure 2*a* is a plan of a portion of an auxiliary electrode, and

Figure 3 is an elevation, and

Figure 3*a* is a plan of another portion of a grid for association with the portions of the auxiliary electrode of Figures 2 and 2*a*.

Figure 4 is an elevation, and

Figure 4*a* is a plan of a complete electrode assembled from the portions illustrated in Figures 2 and 2*a*, 3 and 3*a*.

Figure 5 is an elevation of a modified arrangement of assembled portions of an auxiliary electrode.

Figure 6 is an elevation, and

Figure 7 is a plan of a modification of Figure 5.

Figure 8 is an elevation, and

Figure 9 is a plan of a complete electrode assembly in a valve.

In carrying the invention into effect in one form by way of example, the relationship between input or grid voltage plotted as abscissa E*g*, and output or anode current plotted as ordinates i_a, is shown in Figure 1, in which the curve *a*, as is the case in the well known variable mu valve has a gradually increasing curvature or mutual conductance as E*g* is reduced toward zero. This curve *a*, though suitable for controlling the mutual conductance and amplification of the valve by altering E*g*, is not suitable for many other purposes, e. g. some forms of push pull amplification. On the other hand the characteristic marked *b* has a very much more constant slope, or mutual conductance, and i_a becomes zero at a very much less negative value of E*g* than is the case with curve *a*. Curve *b* is suitable for all types of push pull amplification and power output working.

By means of the invention, either of the characteristics *a* or *b* may be made available at will in one valve. To obtain the characteristic curve *b* (Figure 1) in a valve, it is necessary that the electrostatic field of the electrodes in the valve be as even as possible over the area of the stream. Also, the source of any constituent of this field should be as far as possible in one plane, so that the field may be applied to the stream as closely as possible to the preceding electrode (e. g., the control grid) so that the characteristic, such as curve *b*, in Figure 1 will be as steep as possible. The electrostatic field will be even over the surface of an electrode, when its potential is even, if the screening effect of all portions of the electrode are the same. This screening effect is that usually referred to as the μ of the electrode, or of the portion thereof in question (see, for instance, Van der Bijl, "Thermionic Vacuum Tube" first edition, pages 227–234, and pages 380–382). The μ may be varied by altering the general configuration of the electrode, but, particularly in the case of the usual grid electrode, by varying the distances between the electrode and the succeeding electrode in the valve, or by varying the diameter of the mesh wires or apertures, or varying the number of wires or apertures per unit length.

The present invention therefore employs a grid or mesh auxiliary electrode consisting of portions which have substantially the same μ or screening effect, and which are substantially in the same plane. Such an electrode, when the portions are at the same potential, will cause the valve to give a satisfactorily steep characteristic between control grids E*g* and anode current i_a, as curve *b* in Figure 1. On arranging that the potentials of the various portions are different, then the electrostatic field over the area of the auxiliary electrode will be varied, and a variable mutual conductance, remote cut off, characteristic, such as that illustrated at *a* in Figure 1, will be produced.

The junction point of adjacent parts of the various portions of a grid auxiliary electrode in accordance with the present invention unavoidably introduces slight distortion of the electrostatic field. To bring this to its minimum it is desirable to reduce the number of such joints as much as possible. For this reason, therefore, in the present invention the number of joints or portions is cut down to the minimum by making at least one portion of the grid occupy as much as possible of the total area of the grid, and the electrostatic field of this portion is therefore substantially even over its area whatever the potential of the other portion or portions.

To obtain the desired similar configuration of the different parts of an auxiliary electrode which consists of a mesh, various means may be employed. These include constructing a single flat helical grid in two portions. The various portions of a mesh may be wound and supported on different supports, or may be wound on a single supporting member or members, portions being insulated therefrom by, for instance, a porcelain sleeve or insulating coating on the member.

In Figures 2 and 2*a* and 3 and 3*a* are illustrated two portions **1**, **2** of a suitable flat helical grid as mentioned above. The two portions are shown in side elevation and plan. That shown at **1** in Figures 2 and 2*a* has about the same "diameter" *d* as the corresponding "diameter" *d'* of the portion **2** shown in Figures 3 and 3*a*. The width W of the portion **2** shown in Figures 2 and 2*a* is however narrower than the corresponding width *w'* of the portion shown in Figures 3 and 3*a*. In each case the two inner supports **3** and **4** respectively are used in the two portions to support the mesh wires **5** and **6**. The wires **5** are spaced evenly, i. e. are of even pitch except for the gaps **7** which are twice the length of the pitch of the wires elsewhere. The wires **6** on the portion **2** are of uneven pitch and are spaced so as to correspond with the spaces **7** in the other portion **1**.

Figures 4 and 4*a* show the effect of slipping the portion **1** (Figure 2) inside the portion **2** (Figure 3) so that the wires **6** on portion **2** lie in the gaps **7** of portion **1**. The two portions, when

in electrical connection, act substantially as a single grid of even pitch. In practice d' may be slightly greater than d, thus assisting the assembly of the complete electrode, without appreciably affecting the result.

In Figure 5 another composite electrode with meshes 5*a*, 6*a* on the two portions 1, 2 is illustrated in side elevation. In this case however, the meshes 18 and 19 of the two portions 1 and 2 are not intermeshed in the same way as in Figures 2–5 but the mesh 6*a* is divided into two portions which are positioned one at each end of the mesh 5*a*. The two portions 1, 2 of the electrode are connected separately by wires 40 to separate pins 38, 39 of the conventional type in the base 41 of the valve.

The provision of separate contact pins 38 and 39 permits alteration of the connections to the portions 5*a* and 6*a* to give the curves *a* and *b* at will (Fig. 1). This arrangement permits connection or disconnection of the various portions of the electrode or alternating connection to points having different potential to the cathode of the valve or to a biasing battery.

When the portions 1, 2 of an auxiliary grid, Figure 4*a*, are connected together, the whole may be taken as acting as a normal auxiliary electrode and the mutual conductance of the tube may be comparatively constant (curve *b*, Figure 1). If, however, one of the portions (2 in Figure 3) is connected to another point having a different potential the auxiliary grid as a whole may be taken as acting as one having an uneven effective potential, and the curve *a* (Figure 1) will become effective. Thus, by switching the connection to the portions of an auxiliary electrode, the valve may be made to possess a variable mutual conductance characteristic or not as required.

The same general construction may be employed for various types of valve of the screen grid type, when for instance, the positive screen assembly may be arranged like the electrodes shown in Figures 2*a*, 3*a* and 4 and 4*a*.

In Figures 6 and 7 a somewhat similar arrangement to Figure 5 is shown with the exception that the part 2 of the composite electrode has a mesh 5*b* which is of slightly closer pitch than the mesh 6*b*, in order to produce an even intensity of electrostatic field over the area of the electrode when the two portions are in electrical connection, though the mesh 5*b* has been given a slightly greater "diameter" d' than diameter d of mesh 6*b*. This construction may be applied to the other composite auxiliary electrodes shown, that is, in general, the electrostatic field from electrodes is even over their area though the configuration of the different portions thereof is not the same, by adjusting the density of the field appropriately by adjusting the configuration of the electrode.

In carrying the invention into effect according to the modification shown in Figures 8 and 9, the method or arrangement is to divide the accelerating electrode or positively charged grid employed in a screen grid valve into two or more portions. An ordinary control grid may be employed and the usual electrostatic screen may be added to these electrodes in the normal manner. The method is capable of many variations to suit any desired type of valve. The above arrangements may be combined.

In Figures 8 and 9 is shown a sectional elevation and plan view of part of the electrode assembly in accordance with one form of this modification of method or arrangement. The glass seal 8 inside a glass bulb (not shown) supports the electrodes on wires 9. A filament 19 is supported from springs 11 fastened to a mica spacing plate 12 which also holds the various electrodes supporting wires in correct alinement. The control grid 21 is of the ordinary type having a single evenly spaced mesh. A screen electrode 22 is divided into two portions 24 and 23. These two portions have meshes 25 and 26 which are insulated from each other and intermeshed in a manner which may, for example, be similar to that illustrated in Figures 4 and 4*a*. An anode 31 surrounds the other electrodes. The screen 22 as a whole therefore has substantially an even or an uneven potential over its area according to whether the two portions 23, 24 respectively are at the same potential or not. When a variable mutual conductance characteristic is required the portions 23, 24 may be arranged to have different potentials. This may be performed by connecting them through resistances through which an external current is passed, or through which the discharge current passes which current has been picked up by the electrodes themselves from the discharge. The variable mutual conductance characteristic will be removed if the resistances are short circuited.

Figures 10 and 11 illustrate circuit arrangements of valves having electrodes in accordance with certain forms of the present invention, the valves being arranged to act as high frequency amplifiers. In these drawings a tuned input circuit L_1C_1 is arranged so that the potentials across it are amplified by a valve 25; a tuned output circuit L_2C_2 is connected in the anode circuit of the valve in the usual manner; the usual filament heating battery 26 and high tension battery 27 are provided. A grid-biasing battery 28 is connected across a potentiometer resistance 29. A condenser C_3 is arranged to by-pass high frequency currents from the potentiometer 29. The valve has a filament 30 and an anode 31.

General

The invention is not limited to the examples given above.

Details or particulars in the statements of the invention are to be taken as also being comprised in the description. In the cases where an uneven potential electrode or electrodes are employed, such electrode or electrodes may be composed of interwoven meshes, the different component meshes being arranged to be at different potentials. Such an electrode may then be given a substantially even potential as a whole when required, by connecting its component meshes so that they are all of the same potential.

The various component meshes or component parts of an electrode which are to be at different potentials may be connected to different tappings on a potential divider or other device.

The said potentiometer or resistance device may be included inside a discharge tube.

The variation in potential over the area of an uneven potential electrode may be suitably made to vary in relation to any given point over the area by suitably connecting the elements composing the electrode to tappings on the potential divider, or by other means.

To obtain the desired similar configuration of the different parts of an uneven potential electrode which consists of a mesh various means may be employed. One portion may be wound round two support wires spaced, say 1 cm. and

welded to the supports. The second portion of the grid may be wound round a former so proportional that the support wires are, say 1.2 cm. apart. The width of the cross section of each of the portions may be just sufficiently different for them to be slipped one inside the other and the support wires mounted in the usual glass pinch so that the two portions are one inside the other and so that the wires of each portion lie in the correct position in relation to each other and the grid as a whole has an evenly spaced mesh. The slight difference in the cross section of the two meshes may if desired be adjusted by bending in the wires of one mesh. Where for instance in an uneven potential electrode consisting of two meshes, one mesh may for mechanical reasons project a little in front of the other towards the cathode, this may result in the electrostatic field of the electrode as a whole being uneven, even when the potential of the two parts is the same; but, in accordance with the method above, the projecting parts of the mesh may be given a smaller spacing between the wires, this widening being sufficient to weaken the density of the field thereat and therefore produce substantially the same electrostatic force on the adjacent electrodes or parts in the tube as in other parts of the mesh.

The same arrangement may be applied to other electrode configurations.

The various electrode portions used in accordance with the invention may be connected to different pins in the usual interchangeable contact pin base of a valve. Then according to the connections of the corresponding sockets into which the valve base fits, so the valve will act as a variable mu tube or not.

In general apparatus for use according to the present invention may comprise a discharge tube such as a thermionic valve having electrodes therein which, when the said electrodes have a potential which is even over their area and over the area of the cross section of the stream, produce an even electrostatic field over the cross section of the stream, or discharge in the tube; an uneven electrostatic field over the cross section of the discharge being produced when required by varying the potential distribution over the area of an electrode or electrodes and to produce a variable mutual conductance property which is otherwise absent.

Though an uneven potential electrode is divided into various portions in certain embodiments of the invention, and these portions are peculiar in nature to the present invention, they may be conveniently employed for other purposes, e. g. for applying more than one controlling voltage to the valve at once, for instance, in the case of the divided control grid previously mentioned.

The various methods referred to herein may be used in combination as well as separately. A cumulative effect will then in general be produced.

The present invention is illustrated in conjunction with a filament type of cathode. The exact configuration and type of electrodes made in accordance with the invention may vary very much according to the shape of the cathode and other electrodes in the discharge tube, for instance the cross section of the meshes in Figure 4*a* may be round instead of oblong to fit a cathode of circular cross section. Also a cathode may be applied to electrodes not consisting of a conventional wire mesh formation for instance to electrodes consisting of grids stamped out of metal or built up of segments or other constructions.

Having now described my invention, what I claim as new and desire to secure by Letters Patent is:—

1. An electron discharge device having a cathode, a control electrode and an anode, and an auxiliary electrode interposed between said control electrode and anode and comprising electrically insulated sections constituting in effect a single electrode of uniform configuration.

2. An electron discharge device having a cathode, a control electrode and an anode, and an auxiliary electrode interposed between said control electrode and anode and comprising electrically insulated flattened tubular sections constituting in effect a single electrode of uniform configuration.

3. An electron discharge device having a cathode, a control electrode and an anode, and an auxiliary electrode interposed between said control electrode and anode and comprising electrically insulated flattened tubular mesh sections constituting in effect a single electrode of uniform configuration.

4. An electron discharge device having a cathode, a control electrode and an anode, and an auxiliary electrode interposed between said control electrode and anode and comprising electrically insulated grid sections of like pitch and having their corresponding straight reaches lying in the same plane, said sections constituting in effect a single electrode of uniform configuration.

5. An electron discharge device having a cathode, a control electrode and an anode, and an auxiliary electrode interposed between said control electrode and anode and comprising electrically insulated flattened helices constituting in effect a single electrode of uniform configuration.

6. An electron discharge device having a cathode, a control electrode and an anode, and an auxiliary electrode interposed between said control electrode and anode and comprising electrically insulated flattened helices of the same pitch and having their corresponding straight reaches lying in the same plane, said helices constituting in effect a single electrode of uniform configuration.

7. An electron discharge device having a cathode, a control electrode and an anode, and an auxiliary electrode interposed between said control electrode and anode and comprising electrically insulated sections, said sections being composed of flattened helices of the same pitch and having their corresponding straight reaches lying in the same plane, the helices of each section being spaced and the helices of one section being in register with the spaces of the other so as to constitute in effect a single electrode of uniform configuration.

8. An electron discharge device having a cathode, a control electrode and an anode, and an auxiliary electrode interposed between said control electrode and anode and comprising electrically insulated sections, one section being composed of a single flattened helix and the other section being composed of a pair of flattened helices mounted at the opposite ends of said single helix.

JOHN HENRY OWEN HARRIES.