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G. JOBST

2,072,637

ELECTRON DISCHARGE TUBE

Filed Oct. 26, 1933

Fig. 1

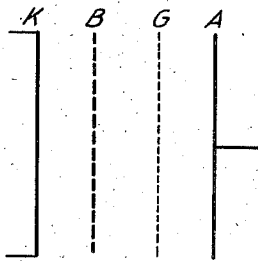


Fig. 2

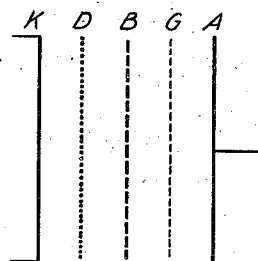


Fig. 3

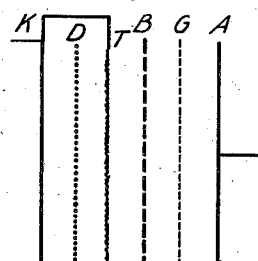


Fig. 4

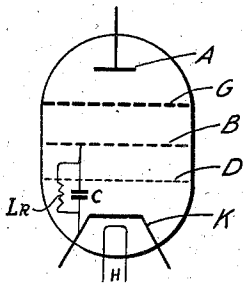


Fig. 6

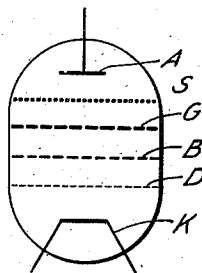


Fig. 8

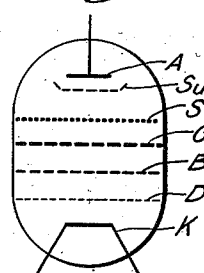


Fig. 5

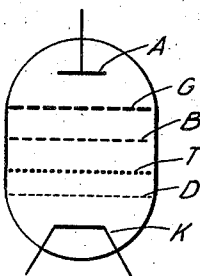


Fig. 7

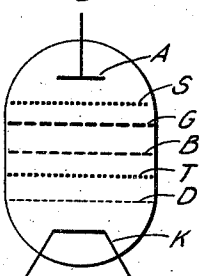


Fig. 9

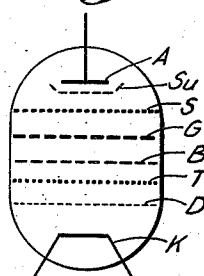


Fig. 10

- K - CATHODE
- A - ANODE
- G - CONTROL GRID
- B - ACCELERATION GRID
- D - CURRENT DENSITY CONTROL GRID
- S - SCREEN GRID
- T - SEPARATING GRID
- Su - SUPPRESSOR GRID

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ELECTRON DISCHARGE TUBE

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2 Claims. (Cl. 250—27.5)

The present invention has for its object an electron tube with more than two grids by which it is possible to separately control, as regards density and velocity, the electron current emitted by the incandescent cathode while the temperature of the cathode is maintained at constant value. By giving the electrodes suitable dimensions and by properly selecting the operating voltages a current distribution can be obtained by which externally of the cathode an equipotential surface is produced having zero potential. This surface can be considered as the locus of a virtual cathode which, relative to a control electrode, acts in the same manner as a real cathode. As a result of shifting the position of the virtual cathode into close proximity to the control electrode, the effectiveness of control or amplification of the tube can be considerably increased. In order to characterize by a brief term the electrode complex consisting of incandescent cathode and grids serving for the control of electron density and electron velocity the expression "control cathode" will hereinafter be used.

For a proper understanding of the present invention the functioning of a tube with control cathode is first described and is followed by a description of the constructive features of such tube. In an ordinary triode having a cathode capable of becoming saturated and having a positive (space charge) grid and an anode, the manner in which the potential varies between grid and anode is dependent on the current density in this region and on the voltages at the borders of this space, namely at grid and anode. At weak emission no appreciable space charge occurs and the potential variation is essentially determined by the electrode voltages and geometry only. With increasing electron emission the potential between grid and anode drops as we proceed from grid towards the anode, due to the presence of negative carriers of electricity in larger concentration and it may reach zero under certain conditions. This place of the minimum or zero potential can be considered as the location of a virtual cathode. It can be demonstrated that the position of the virtual cathode can be displaced by varying the current density and potential existing at the grid.

This condition can be utilized in order to increase the effectiveness of control of a tube. In the control, by means of a control grid of the current emanating from an incandescent cathode a decrease of the distance between cathode and grid presents an obvious means for improving the effectiveness. This means is limited in

practice by constructional considerations which do not exist in the case of a virtual cathode. That a virtual cathode acts with regard to a control electrode in a manner identical with that of a real cathode, is readily conceivable.

Briefly referring to the several figures of the drawing which are only illustrative of the present invention, Fig. 1 represents a space charge grid tube capable of forming a virtual cathode in the vicinity of the control grid; Fig. 2 illustrates an improved form of discharge tube capable of more efficient and more flexible control than that shown in Fig. 1; Fig. 3 is similar to Fig. 2 but with the addition of a separate grid interposed between the virtual cathode grids; and Figs. 4 to 9 inclusive, represent several other embodiments of the invention; Fig. 10 is the key to the elements of the several figures.

A tube suitable to form such virtual cathode as above mentioned therefore must at least have such elements as are schematically represented in Figure 1. Herein K is an incandescent cathode capable of saturation, G is the control grid, A designates the anode and B is a grid electrode maintained at positive potential and which may be termed the acceleration grid. A cathode with saturation capability is understood to represent such cathode whose emission depends upon the temperature only, but not upon the potentials of the nearby electrode. In suitably adapting the potential of B and the emission of K to each other (by means of temperature control) the formation of a virtual cathode can be produced in the direct proximity of G. Tubes of such construction are already known as space charge grid tubes. For various reasons however, they prove to be inadequate for accomplishing the present purpose. The control of the current density must be carried out by varying the cathode temperature and it is not possible to obtain entirely satisfactory control by such means. Since this possible control is not feasible in practice it would be necessary to limit favorable operation of the tube to very definite predetermined operating conditions, by means of a suitable position of the space charge grid between emitting body and control grid. It is questionable whether it would ever be possible to obtain the dimensioning necessary for an optimum control capacity with the required accuracy and uniformity. Furthermore there is the lack of any possibility of later influencing the course of the characteristic depending upon the condition of current density and electron velocity.

According to the invention such disadvantages can be overcome by placing between cathode K and accelerating grid B, as shown in Fig. 2, a further grid D serving for the current density control and having a positive potential which is lower than the potential of the accelerating grid B. The current density emerging through the grid D can be adjusted at will by suitably selecting the applied potential. It is thus possible to produce any desired combination of values of electron density and electron velocity. A direct action of the accelerating voltage on G upon the emission through the density grid can thereby always be compensated by a suitable small readjustment of the potential of the density grid D. However in order to obtain an entirely independent relation between the adjustment of the current density and velocity, the "through-grip"

20 $\left(\frac{1}{\mu}\right)$

of the accelerating grid to the cathode must be small. If this cannot be accomplished in the desired degree by appropriately establishing the width of the meshes of grid D, a screen grid T may serve in accordance with the invention for the electrical separation of the two electrodes D and B (Figure 3). To this "separating grid" the cathode potential, for instance, is applied. This connection can also be arranged within the tube.

In constructing the tube having a control cathode various structural measures are to be considered characteristic of this type of tube and forming a part of the present invention. In view of obtaining an optimum control capacity of such tube the local uniformity of emission by the cathode as well as the voltage distribution along the cathode is of importance. For this reason an equi-potential cathode, indirectly heated, will always be preferable, since in this case such virtual cathode is produced by which the required uniformity throughout the entire length of the electrode is insured. The equi-potential cathode is shown in Fig. 4 at K, and the heater at H, although it will be understood that the cathodes K in the remaining figures may be of similar construction. A further essential feature is to be seen in the symmetry of the arrangement, whereby the symmetric structure of concentric shape is to be preferred over the plane arrangement. Certain deviations may be admitted in this connection if a smooth course of the characteristic is desired for definite fields of application of the tube. In this case, as will be later elucidated, an eccentric disposition of the accelerating grid in respect to the control grid may even be conducive to stabilizing the control cathode. With regard to ensuring a homogeneous electron current and sharpness of the minimum potential zone necessary for obtaining the highest sensitivity of control, importance is also attached to the smoothness of the effective grid electrodes. A wide meshed control grid would for instance be entirely unsuited due to the non-uniformity of its effective potential surface.

Besides the control of the electron current in regard to density and velocity at the place of emission of the control cathode also the other electrode potentials present in the tube are obviously of influence upon the velocity of the electrons in the potential space between anode and cathode. This influence must be decreased as far as possible without however changing such voltages as are determined by the requirements for power or other desired results. For instance

the use of high anode voltages without a corresponding shielding or suitable shaping of the anode would involve high effective-potentials near the cathode in which case a very high current density would be required in order to accomplish the formation of a minimum potential surface in the manner above described. This is also the reason why it is not possible to attain such effects at voltages of practical importance by means of ordinary pentodes which as such have the required minimum number of three grids. Such pentodes (screen grid tubes with suppressor grid between screen grid and anode in order to avoid transition of secondary electrons from anode to screen grid) in which the screen grid would have to be regarded as an emitting surface of the electrons of a control cathode and wherein the suppressor grid would have to be regarded as control grid, (if the tube were intended to be operated in a manner different from the ordinary use, i. e., as a control cathode), are just so dimensioned that as few space charges as possible of primary electrons coming from the screen grid would accumulate about the suppressor grid, since this would involve an unfavorable distribution of screen grid and anode current. These tubes therefore have a "through grip"

30 $\left(\frac{1}{\mu}\right)$

of the suppressor grid of generally above 20%. At an anode potential of for instance 300 volts an effective potential of 60 volts would be produced at the screen grid.

Contrary thereto in a control cathode tube the "through grip" of the anode through the control grid to the control cathode is to be maintained so small that the effective potential at the accelerating grid will be supplemented by only a few volts produced by the anode potential which may be of the order of the range of control voltages. The control grid itself has thereby a negative bias against the electron emitting surface of the control cathode which is of a value somewhat larger than the velocity of the electrons when leaving the control cathode. In order to secure the above required reaction of the anode potential upon the emitting surface of the control cathode, the present invention prescribes that the "through grip" of the anode through the control grid must be less than 10%. Where a screen grid is placed between control grid and anode the above requirement holds true also for the "through grip" of the screen grid through the control grid.

The expression "through grip" as used herein may be defined thus: the through grip of a first electrode through a second one on a third electrode is a non-dimensional figure being always less than 1, and indicates the influence of the variation of the potential of the first electrode upon the effective potential of the third electrode, in comparison with the influence of an equally great variation of the potential of the second electrode.

The principle of the control cathode can be applied to the known types of tubes used for all purposes in that the simple incandescent cathode is replaced by the combination of electrodes defined as the control cathode. In this manner tubes having at least three grids are obtained, some embodiments of which are schematically represented in Figures 4-9 with designations for the electrodes explaining their use in the circuit.

A brief description of said figures follows: Figs. 4 and 5 are diagrammatic showings of tubes uti-

lizing the electrode systems of Figs. 2 and 3, respectively. In Fig. 5 the separating grid T may also be connected to the cathode as in Fig. 3, either inside or outside the glass envelope.

Fig. 6 shows a screen grid tube in which A represents the anode, S the screen grid, G the control grid, B the acceleration grid, D the current density grid, and K the cathode. The through grip of the screen grid S through the control grid G and upon the acceleration grid B should be less than 10%.

A further construction of this screen grid tube is shown in Figure 7 in which between the acceleration grid B and the grid D controlling the electron density, there is inserted a separation grid T. In Figure 8 A designates the anode, S_u is a suppressor grid for suppressing secondary emission, S is the screen grid, G designates the control grid, B is the acceleration grid, D represents the grid for the control of the electron density, and K is the cathode.

Fig. 9 shows the further development of this electrode system by inserting the separation grid T between the electrodes B and D. In both cases the through grip through the control grid G must be chosen less than 10%. In all cases it is essential that the through grip through the electrode respectively used as control grid and with regard to the nearest electrode at the cathode side of the said control electrode be less than 10% so as to obtain favorable working conditions.

It results from the above reasoning as regards the required condition for the "through grip" that the latter, through the electrode used respectively as control grid and in relation to the electrodes next to it on either side, must be smaller than 10% in order to attain favorable working conditions.

In order to destroy a space charge occurring within the control cathode and to obtain the effect at the accelerating grid with lower voltages it is furthermore suggested in accordance with the present invention to provide a gas filling in the tube having a pressure suitably within the limits of 10^{-2} and 10^{-4} mm. Hg. Care must be taken by proper shaping and in particular selecting of the distances between cathode, control grid and anode that an appreciable ionization tending to remove the space charge outside of the control cathode, does not occur.

There also exists the possibility to use a tube with a control cathode as a magnetron and to control the electron current by a magnetic field. The magnetic field lines extend parallel to the longitudinal axis of the electrode system i. e., parallel to the cathode. In this case it is of advantage to produce the electrodes of a non-ferrous-magnetic material or to at least subdivide the anode annularly by means of slots extending at right angle to the direction of the field.

The virtual cathode has been defined as an equipotential surface having zero potential which signifies, in other words, that at this place the electrons have the velocity equal to zero and that they can move in the direction towards the anode as well as in reverse direction to the emitting source. Thus the possibility exists that the electrons may perform pendulum movements

about the surface of minimum potential as known for instance from the electron oscillations according to Barkhausen-Kurz. In most cases such instabilities are however undesirable and can be eliminated in that the emitting surface of the control cathode, i. e., the accelerating grid is connected to the cathode across damping resistances such as condensers with losses so that the inner impedance of the control cathode is reduced to a value of for instance less than 10,000 ohms. In accordance with the invention such means for the suppression of oscillations are directly built into the tube and fixedly secured to the respective electrodes. By way of example this construction is shown in Fig. 4 where the condenser C is connected between the accelerating grid B and the cathode K, L_R representing the leak resistance or inherent losses of the condenser C. It is also possible to obtain in advance a small inner resistance of the control cathode path in making the "through grip" through the density grid correspondingly large such as above 10%.

The propagation of the pendulum movements of the electrons into the interior of the control cathode is also made impossible if the electrons in their return flow from the virtual cathode cannot reach the emitting source but arrive at the accelerating grid. In this case the accelerating grid must be provided with narrow meshes for instance by allowing this grid to have a "through-grip" of less than 5%.

Another means of preventing an oscillation excitation within the control cathode due to the pendulum movements of the electrons about the virtual cathode, consists of an unsymmetric tube structure for instance by placing the control grid in an unsymmetric position with respect to the accelerating grid. In this case the points of reversal for the electrons are in an unsymmetric position to the emitting source so that the pendulum movements occur at various places of the circumference at different frequency and phase thus making excitation of space charge oscillations within the cathode impossible. As previously pointed out, such unsymmetry in the electrode mounting is however only applicable when maximum steepness of the characteristic is not required.

What I claim is:

1. An electron discharge tube comprising an equipotential cathode, concentrically arranged control grid and anode electrodes surrounding the cathode, a pair of concentrically arranged electrodes interposed in the space between cathode and control grid adapted to be suitably energized by sources of constant positive potentials to control both the density and the velocity of the electrons emitted from the cathode and means within the tube connected between the cathode and the second of said pair of concentrically arranged electrodes from the cathode for preventing reversal in direction of electron flow.

2. An electron discharge tube according to claim 1, wherein the means for preventing reversal in direction of electron flow comprises a leaky condenser.

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