March 9, 1937. H. KNIEPKAMP 2,073,483

ELECTRON DISCHARGE DEVICE

Filed April 6, 1935

Fig. 1

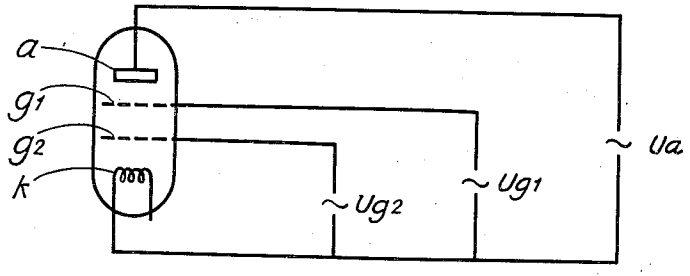


Fig. 2

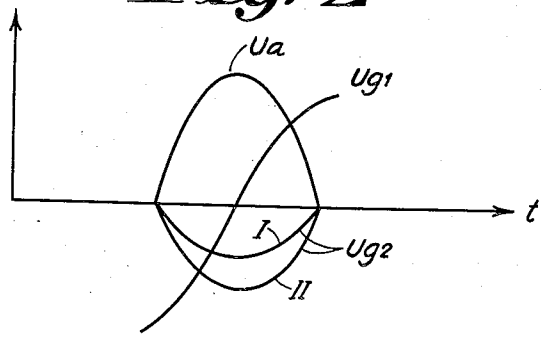
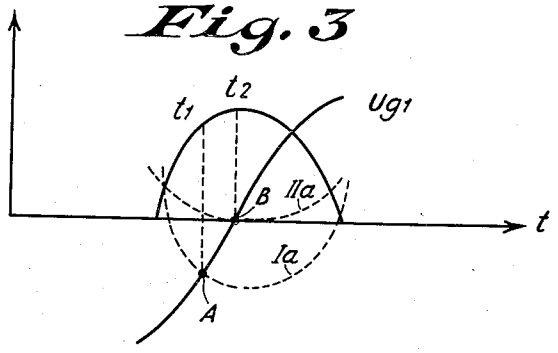


Fig. 3



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ELECTRON DISCHARGE DEVICE

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1 Claim. (Cl. 250—27.5)

My invention relates to electron discharge devices, and more particularly to grid actuated hot cathode vapor tubes or vapor convertors.

In thermionic electron discharge tubes the temperature of the cathode has little effect on the saturation current, although owing to the shortening of the active length of the cathode as a result of the cooling action at the ends, the slope of the current-voltage curve may be affected to a certain degree. However, the operating conditions of such a tube are substantially a function of the well-known space-charge law.

In the case of gas- or vapor-filled discharge tubes in which a control action is obtained by the selecting or fixing the point at which the ignition or gas discharge is initiated, which is termed the breakdown voltage, the temperature of the cathode has a very pronounced effect. In the non-conducting or static state, that is when no discharge current is flowing through the discharge tube, the control electrode or control electrodes are so adjusted that no electrons, or only a few electrons produced by the cathode will be able to reach the space between the anode and the control electrode. If this space does not contain any electrons, then, for given electrode dimensions and spacings, and at the existing gas pressure, no ignition or starting of the discharge will occur. The ignition or breakdown will be brought about only at the instant when the number of the electrons entering the space between the anode or plate and the control electrode has reached a certain magnitude. The entrance of these electrons and their number however, depends not only upon the resultant field of the anode and the control electrodes, but also upon the initial velocities of the electrons, and this factor is in turn a function of the temperature of the cathode. In contradistinction to high-vacuum tubes, initiation of ignition or discharge in the case of gas-filled tubes is dependent upon the saturation current of the cathode. This accounts for the marked dependence of the ignition characteristics of tubes of this kind on the temperature of the cathodes. Thus, all tubes of this kind are dependent to a large degree upon cathode filament or cathode heater voltage fluctuations of the supply-line. Inasmuch as the line voltage, especially where long-distance transmission networks are concerned, is, at times, temporarily subject to serious fluctuations amounting often to 10% and more, such voltage variations mean an aggravation of the difficulties of operating gas-filled tubes.

The same effect brought about by fluctuations in the heating potential is also caused by residual ions inasmuch as the presence of such residual ions will affect to varying degrees the electrons emitted by the cathode. The effect of the residual ions is particularly pronounced in connection with the use of hollow cathodes of the kind extensively and preferably employed in electron discharge tubes designed to handle heavy currents.

The influence of fluctuations of the supply-line potential and thus the variations of the cathode temperature is still more marked in the operation of tubes having two or more control or auxiliary electrodes.

The object of this invention is to provide a gaseous discharge tube having one or more control electrodes in which the voltage fluctuations of the supply-line and the resulting variations in the temperature of the cathode will not affect the operating characteristics of the tube.

This object is attained by providing control electrodes having predetermined dimensions and spacings so that the effective fields of the various electrodes on the cathode bear a predetermined relationship to each other.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claim, but the invention itself will best be understood by reference to the following description taken in connection with the accompanying drawing in which Figure 1 is a diagrammatic representation of a gaseous discharge tube embodying my invention and associated circuits, and Figures 2 and 3 are graphical representations of the operating current and voltage relationships of the tube and circuit shown in Figure 1.

Figure 1 shows the fundamental circuit diagram of a tube having a gas or vapor atmosphere and provided with two control grids. The tube contains a thermionic cathode k, an anode a and two control electrodes $g1$ and $g2$. Between cathode k and anode a is applied an alternating voltage u_a, between grid $g1$ and the cathode is applied an alternating voltage u_{g1} of constant amplitude and lagging in phase by an angle of 90 degrees and between the cathode k and the grid $g2$ is applied a variable alternating voltage u_{g2} presenting a phase displacement angle of 180 degrees with respect to voltage u_a.

In Figure 2 the voltage time relationships are graphically shown, the horizontal axis representing time and the vertical axis the voltage at any particular time. It will be observed that the voltage u_{g1} applied to grid $g1$ is 90 degrees out

of phase to the voltage applied to anode a whereas the voltage u_{g2} applied to grid $g2$ is 180 degrees out of phase with the anode voltage. The curve marked I represents one value of voltage applied to grid $g2$ whereas curve II represents another value of voltage applied to grid $g2$. The effect of the application of these two different voltages is graphically shown in Figure 3.

The horizontal and vertical axes in Figure 3 represent the time and voltage, and the curve marked Ia represents the critical grid voltage, that is the voltage at which the tube will break down if the voltage represented by curve I in Figure 2 is applied to grid $g2$, the voltage represented by u_{g1} in Figure 2 being applied to grid $g1$, and the voltage represented by u_a being applied to the anode. Similarly if the voltage represented by curve II in Figure 2 is applied to the grid $g2$ the critical grid voltages are as represented by the dotted line IIa, that is if any voltage is applied to the grid $g1$ corresponding to IIa the tube will break down and the discharge occur with voltages corresponding to u_a being applied to the anode. If voltage u_{g1} in Figure 3 applied to grid $g1$ has the value at some time $t1$ as represented by the intersection of the curve u_{g1} and curve Ia then the tube will break down at point A and a discharge occur at $t1$. Likewise, if the voltage IIa is applied to the grid $g2$ the discharge will occur at time $t2$ represented by the intersection of u_{g2} and dotted line IIa in Figure 3 at the point B. Thus, with the arrangement above described it is possible to change the time at which ignition or discharge will occur by varying the voltage u_{g2} which is applied to grid $g2$ and thus control the mean value of the alternating current at which break down will occur.

As has been pointed out above, ignition will occur whenever a sufficient number of electrons happen to get from the cathode into the space in front of the anode or plate. An adequate number of such electrons will not enter if the resultant field of anode a, grid $g1$ and grid $g2$ is such that electrons coming from the cathode are blocked. If the speed of the electrons emerging from the cathode were zero, then a potential of zero of the resultant field would suffice. However, inasmuch as the electrons have, as a matter of fact, a certain rate of velocity ranging between 1 and 2 volts, it will be seen that the resultant voltage of the combined or resultant field between the cathode and grids and anode likewise must amount to about −1 to −2V in order that a blocking action may be produced. The resultant field of anode a, grid $g1$ and grid $g2$ or the resultant voltage u_{st} in the light of the known laws of electrostatics is given by this relation:

$$u_{st}=u_{g2}-D_2u_{g1}-D_1D_2u_a$$

D_1 represents the voltage effect of the plate field across the grid $g1$, while D_2 represents voltage effect of the composite field of anode a and grid $g1$ through the grid $g2$. In the presence of a constant filament temperature the critical value of u_{st} is a constant, and at about 800 degrees C. cathode temperature it is about −2V. The harmful influence of voltage variations and of the ensuing temperature fluctuations of the cathode, according to the present invention, in the case of an electron discharge tube containing an anode, an electron source, at least two control elements as well as a gas or vapor atmosphere is diminished by having the anode field thru the grid $g1$ located closest to the anode (factor D_1) not more than one-tenth as effective as the field of anode a and grid $g1$ across the grid $g2$ closest to the cathode (factor D_2) in controlling the flow of electrons from the cathode to the plate. Expressed in another way the amplification factor of grid $g1$ with respect to the anode is only one-tenth as great as the amplification factor of grid $g2$ with respect to grid $g1$ and the anode. If the resultant voltage effect of the combined fields between the cathode and the other electrodes within the electron discharge device is represented by 100% then it has been found in practice that the grid $g2$ must be so designed and dimensioned that the resultant voltage effect of the composite field of anode a and grid $g1$ thru the grid $g2$ (factor D_2), should amount to 50% or over of the resultant voltage effect of the combined fields of all the electrodes while the voltage effect of the anode field thru the grid $g1$ (factor D_1) should vary between 1 and 3% of this resultant voltage.

This invention is directed not only to an electron discharge device with two control electrodes or grids but it will be found applicable in connection with tubes having a larger number of control electrodes.

While I have indicated the preferred embodiments 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 claim.

What I claim as new is:—

An electron discharge device having an envelope containing a gas or vapor atmosphere, a cathode, a first and second control grid, and an anode spaced from said cathode, said first control grid having an amplification factor with respect to said second control grid and anode which is ten times as great as the amplification factor of said second control grid with respect to said anode.

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