April 2, 1957 O. STERNBECK ET AL 2,787,729

MULTIPLE DISCHARGE TUBE WITH POSITIVE AUXILIARY ELECTRODES

Filed Sept. 22, 1954 3 Sheets-Sheet 1

Fig. 1

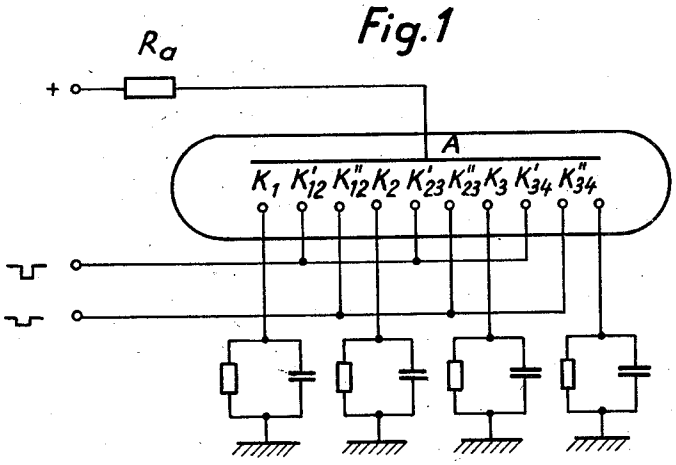


Fig. 2a

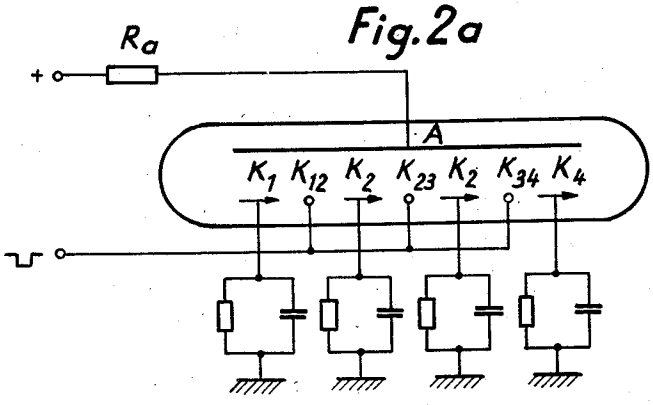
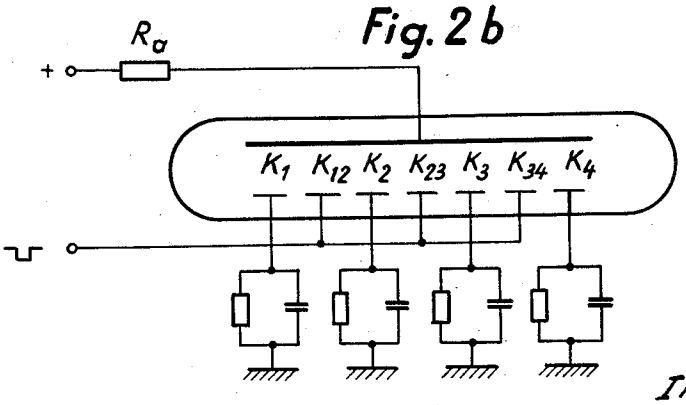


Fig. 2b



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Filed Sept. 22, 1954 3 Sheets-Sheet 2

Fig. 3

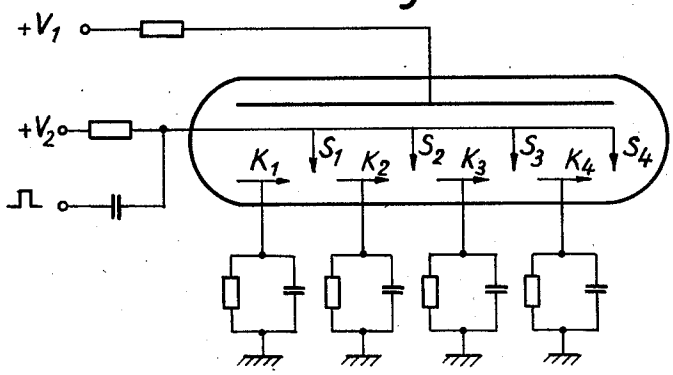


Fig. 4

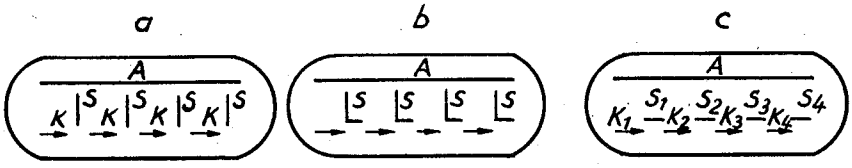


Fig. 5

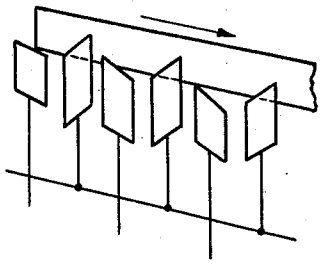
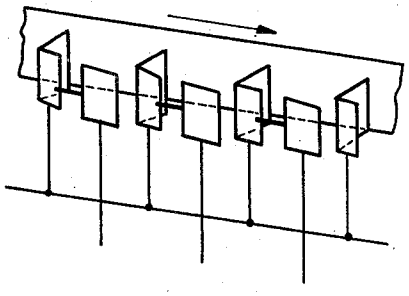


Fig. 6



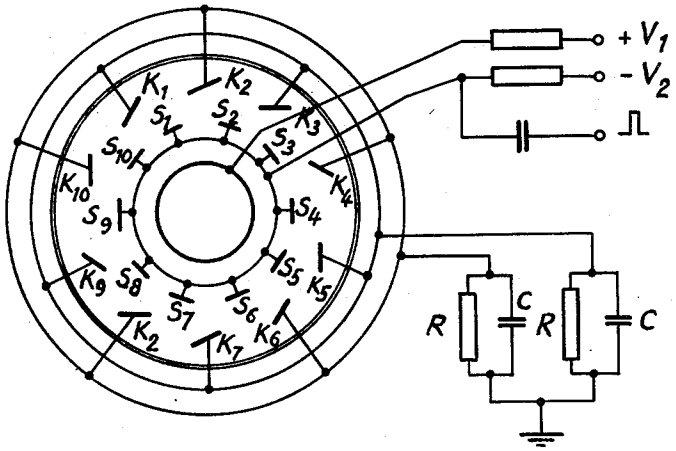
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April 2, 1957 O. STERNBECK ET AL 2,787,729

MULTIPLE DISCHARGE TUBE WITH POSITIVE AUXILIARY ELECTRODES

Filed Sept. 22, 1954 3 Sheets-Sheet 3

Fig.7



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MULTIPLE DISCHARGE TUBE WITH POSITIVE AUXILIARY ELECTRODES

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Application September 22, 1954, Serial No. 457,698

Claims priority, application Sweden October 26, 1953

12 Claims. (Cl. 315—84.6)

The present invention relates to glow discharge tubes with several discharge gaps and especially to tubes of the stepping kind, and its first object is an improvement of such tubes.

There are many different embodiments of such tubes, but the invention refers chiefly to the type consisting of a number of cathodes and of one anode common to these cathodes, a number of discharge gaps thus being obtained, which correspond to the number of cathodes comprised in the tube. In such tubes only one discharge gap is fired at a time, and when pulses are fed to the tube the discharge moves from one of the gaps to the other, in other words the tube steps along a row of discharge gaps. Discharge tubes of that kind are well suited for example for calculating and selecting connections. It is further known, for example by the Swedish patent (pat. appln. No. 6,200/53), to place auxiliary cathodes between the main cathodes to facilitate the stepping of the tube.

The present invention consists in the tube being provided with auxiliary electrodes of another type, which offers certain advantages compared with known types. The invention will be more closely described in the following with reference to the accompanying drawings and be compared with some earlier known constructions.

Fig. 1 shows a known type of multi-cathode tubes with double auxiliary cathodes for each step.

Fig. 2 shows multi-cathode tubes with directive cathodes, the main cathodes only having been shaped as directive cathodes in Fig. 2*a*, whereas in Fig. 2*b* the auxiliary cathodes also are of that type.

Fig. 3 shows the chief embodiment of a discharge tube according to the invention.

Fig. 4 shows three different types of auxiliary electrodes.

Figs. 5 and 6, respectively, are perspective views of some embodiments of electrode systems according to Figs. 4*a* and 4*b*, respectively.

Fig. 7, at last, discloses the principle of a stepping tube according to the invention with a number of auxiliary electrodes of the type shown in Fig. 4*c*.

The known kind if tubes shown in Fig. 1 comprises a main anode A, a number of main cathodes K_1, K_2, K_3 etc. and two auxiliary electrodes K_{12}', K_{12}'', K_{23}', K_{23}'' etc. in the spaces between the main cathodes. The shown connection with anode resistances and RC-circuits to the main cathodes is the most usual one, but the tube may also be connected in another manner. The connection according to Fig. 1 is however sufficient to illustrate the stepping principle. At rest one discharge gap is fired, for example the gap between the anode and the main cathode K_2. Owing to cathode resistance, K_2 has then a positive potential with respect to earth, and the anode has such a high potential, that the voltage between A and K_2 is equal to the sustaining voltage characteristic of the tube. The remaining voltage difference to the feed-voltage is absorbed by the anode resistance. The auxiliary electrodes are connected together into two groups and fed with a voltage somewhat higher than the main cathode voltage. At stepping a negative pulse is fed to each one of the groups of the auxiliary cathodes. These pulses are time-displaced in relation to each other in such a manner, that, of the auxiliary cathodes K_{12}'' and K_{23}' lying closest to K_2, it is the potential on K_{23}' which decreases first. Owing to the initial ionization from K_2 said auxiliary electrode is then fired simultaneously with the anode voltage decreasing. The discharge at K_2 is thereby extinguished and the de-ionization starts, whereas the cathode voltage is kept constant by the condenser in the cathode circuit. At the second pulse K_{23}'' is fired by the aid of the initial ionization from K_{23}'. K_{12}'' is not fired owing to the ionization from K_2 now being too small. At the end of the second pulse the next main cathode K_3 is fired and the stepping is completed.

The main cathodes in the above described device are not provided with so called directive effect and therefore double auxiliary cathodes are necessary to secure the stepping in a determined direction. A few examples with directive cathodes are shown in Fig. 2. The shown connection is not either in this case the only possible one, but it is sufficient to illustrate the stepping principle. The directive effect of the main cathodes shows itself in the following manner: if for example K_2 is fired, K_{23} will be fired at a negative pulse, in spite of K_{12} having the same potential. At the end of the pulse K_3 will then be fired because of K_2 still having a high potential. The extinction takes place in the same manner as in the device according to Fig. 1. With as well main cathodes as auxiliary cathodes provided with directive effect (Fig. 2*b*), the stepping is still further secured.

The directive effect can in principle be obtained in two different manners. On one hand the cathode can consist of two parts of different materials or be made unsymmetrical in some other manner, so that the glow discharge is concentrated towards one of the edges, i. e. the one lying closest to the following cathode, the ionization then being stronger in that direction, or else the two cathodes closest to the cathode active at that moment can be made differently sensitive to ionization from different directions. This can be achieved by the cathodes being located obliquely with respect to the anode, so that the distance to said anode is greater from one of the edges, than from the other one. Cathodes of the last mentioned type are described in the earlier referred to Swedish patent (pat. appln. No. 6,200/53).

The connection shown in Fig. 3 is the most usual one for a discharge tube of the present kind. According to the invention the tube is provided with a number of cathodes K_1, K_2, K_3 etc. connected to RC-circuits, and with one anode A_1 common to these cathodes and connected to a source of potential V_1 over an anode resistance. The tube is further provided with auxiliary electrodes S_1, S_2, S_3 etc. interconnected within the tube and connected to a source of potential V_2 over a resistance. Said auxiliary electrodes may also be applied positive stepping impulses.

Depending on which operating voltage said auxiliary electrodes are intended for, they may be considered in different manners. The voltage is either such that ignition takes place to the following cathode and the electrode is used as ignition electrode or auxiliary anode, as it is sometimes called, or else the voltage is such, that no ignition is obtained, the electrode only being a probe with control effect.

A device operated by auxiliary electrodes such as ignition electrodes or auxiliary anodes will now be described in connection with Fig. 3. At rest a discharge gap is fired, for example at K_2, and the auxiliary anodes S_1 and S_2 are applied a potential which is somewhat higher than the potential on K_2. In this case all the cathodes are provided with directive effect, which means that the ignition voltages of the two main discharge gaps lying near

to each other decrease with different values. The initial ionization of the auxiliary anodes S_1 and S_2 is also differently strong, and therefore a directive effect is also obtained in the auxiliary gaps formed by said auxliary anodes together with the respective cathode. When the positive pulse is applied to the tube, K_3 is fired with the help of S_2, the main anode voltage thereby decreasing and K_2 being extinguished. The time constants are chosen so that the de-ionization has time to be fulfilled before the voltage rises too much.

In tubes intended for the second operation method, the auxiliary electrodes or control electrodes, as they will be called in the following, are located between the discharge gaps and are normally applied a potential between that of the anode and that of the fired cathode, for example K_2, preferably relatively near the cathode potential. They are made so as partly to screen the discharge gaps from each other and only allow part of the ions and electrons migrating from the fired discharge gap to pass. How great this electron- and ion current will be, which reaches the adjacent discharge gaps K_1 and K_3, ionizing them, is depending on the potential of the control electrodes in such a manner, that a high control electrode current makes the ignition voltage of the adjacent gaps decrease more than does a low control electrode voltage. In this way a control of the stepping process is obtained with positive pulses with a small effect, since the current to the control electrodes is of the magnitude characteristic of a probe, and the pulse generator, which feeds the controlling pulse, may therefore have a relatively high internal impedance.

Fig. 4 shows three simple examples of possible embodiments of the control elements. In Fig. 4*a* they are perpendicular to the anode, in Fig. 4*b* they are angularly bent, and in Fig. 4*c* they are parallel with the anode. The distance between the cathodes and the properties of the gas in the tube determine the degree of screening, which is necessary.

Fig. 5 shows what the electrode system may look like with control electrodes of the type shown in Fig. 4*a*. In this special case the cathodes are of the above mentioned obliquely located kind, but other types are also suitable. The degree of screening of the control electrodes is varied by their width.

Fig. 6 is an example of an electrode system according to Fig. 4*b*. The cathodes are here of a known unsymmetrical type with one point directed towards the preceding discharge gap. A stronger control of the most important part of the plasma diffusion between the cathodes is obtained with the angularly bent control electrodes.

In Fig. 7 a decade discharge tube according to the invention is shown. Said tube comprises a cylindric anode, 10 cathodes and 10 interconnected auxiliary electrodes. The directive effect has been obtained by the cathodes being located obliquely with respect to the anode. The stepping direction is in this case clockwise and the cathodes have been arranged in a closed circle, which makes it possible for the tube to receive an unlimited number of pulses without any restoring mechanism having to be used. The tube is therefore well suited for decade counters. In the shown connection the cathodes are interconnected in two groups, each of which has an RC-circuit, components thus being avoided as well as inlets, if the interconnection is made within the tube. The disadvantage of this arrangement is that only an optical reading of the position of the discharge can indicate the digit in the decade. If an electrical indication is required as well the cathode must be connected to individual RC-circuits. If ten-transfer is to take place as well, one cathode must then be separate.

The device with positive auxiliary electrodes according to the invention entails considerable advantages compared with the use of auxiliary electrodes, said advantages being a greater stepping speed, a smaller pulse energy and a simplified interconnection of several decades. As regards the stepping speed in an auxiliary cathode tube it is chiefly limited by the time for two processes, on one hand the migrating of the ion-plasma from a glowing main gap connected to the auxiliary gap to the following main gap, and on the other hand the de-ionization of newly extinguished gaps, so that the preference is again given to a stepping forwards. The time for the ignition of the gaps plays a subordinate role. In a tube with positive auxiliary electrodes according to the invention the time for the migration of the plasma is considerably shortened since the main gaps are located so close to each other, that the ionization operates directly. The ignition with positive auxiliary electrodes takes place as quickly as in a usual glow discharge triode.

It is known that the stepping speed in a decade tube is highly dependent on the composition of the gas. Especially the de-ionizing properties of the gas have a great importance and a known way to reduce the de-ionization time and therewith increase the stepping speed of the tube is to add to the rare gas atmosphere a small quantity of impure gas, suitably hydrogen gas. Owing to the aforesaid advantages of the present type of tube compared with auxiliary cathode tubes, the stepping speed of the first mentioned type is however always higher.

When using auxiliary cathode tubes a great amplitude of the incoming negative pulse, a certain minimal pulse width and a low internal resistance are always required to enable the auxiliary cathode to absorb the whole current from the preceding main cathode or at least the main part of said current, at the same time as the discharge glow is given time to migrate over the whole surface of the auxiliary cathode. In a tube with positive auxiliary electrodes, on the other hand, the pulse amplitude needs only be so great, that the variations as regards the ignition voltage between different tubes and different gaps in the same tube are covered, and the pulse width may be as small as in a glow discharge triode. The necessary ignition current is never greater than in a triode and is especially small if the tube is operated without ignition taking place in the auxiliary gaps, according to what has been described in the preceding. By suitable choice of operating voltages and by the auxiliary electrodes being given a more or less great screening effect it is possible to operate the tube according to any of the two described methods or to a combination of both of them so that both control and ignition cooperate with the stepping mechanism. An increased pulse amplitude with ensuing current to the auxiliary anode, however, hastens the ionization and thereby increases the stepping speed.

It is a common feature of the auxiliary cathode tubes and of the tubes with positive auxiliary electrodes in the shown connections that the output signals from the cathodes are positive. This entails, that by means of an auxiliary anode tube a pulse from one of the cathodes can be shifted directly to a following tube, due to what the construction of a counter connection with several decades becomes very easy. By means of auxiliary cathode tubes, on the other hand, the pulse must first be given the opposite signs for example by means of an auxiliary tube.

The preceding description is only an example of applications of the invention. Many a modification is possible; thus, further electrodes may, for example for connection-technical or other reasons, be arranged for zero position and separate output of pulses for ten-transfer etc. Furthermore, the operation properties may possibly be improved by adding a screen electrode fed with constant potential. The principle of the invention is not affected thereby.

We claim:

1. A gas discharge device comprising several cathodes, a common anode forming a corresponding number of discharge gaps with the cathodes, several auxiliary electrodes, and a source of positive potential and a source of positive pulses connected in circuit with said auxiliary electrodes, said cathodes being preference type cathodes having dif-

ferent discharge efficiency on different parts, and each of said auxiliary electrodes being located substantially intermediate the discharge gap between each two adjacent cathodes to form in response to feeding with positive pulses, a discharge gap with the low discharge efficiency part of one of two adjacent cathodes and with the high discharge efficiency part of the other of said two adjacent cathodes.

2. Device according to claim 1, characterized by said cathodes and auxiliary electrodes being arranged in a closed ring concentric with the anode.

3. Device according to claim 1, characterized by one of the electrodes comprised in said device being arranged as a zero position electrode.

4. Device according to claim 1, characterized by one or more of the electrodes comprised in said device being arranged to give an electric indication of the position of the glow discharge.

5. Device according to claim 1, characterized by one of the electrodes comprised in said device being arranged as a screen electrode common to the whole device, said screen electrode not being intended for control.

6. Device according to claim 1, characterized by a mixture of a rare gas atmosphere and an impure gas comprised in said device.

7. A gas discharge device according to claim 1 in which each of said cathodes is connected to a ground circuit including a resistance means and a capacitance means connected in parallel.

8. A gas discharge device according to claim 1, wherein said auxiliary electrodes have surfaces extending substantially parallel to the discharge direction of the discharge gaps of the cathodes.

9. A gas discharge device according to claim 1, wherein said auxiliary electrodes each comprise a part having surfaces substantially parallel to the discharge direction of the discharge gaps of the cathodes and a part having surfaces substantially perpendicular to said discharge direction.

10. A gas discharge device according to claim 1, wherein said auxiliary electrodes have surfaces perpendicular of the discharge direction of the discharge gaps of the cathodes.

11. A gas discharge device according to claim 1, in which the cathodes and auxiliary electrodes are arranged in two closed circles concentric to the anode and opposite each other, said cathodes having surfaces disposed at a slant relative to the tangential direction of the respective closed circle of the cathodes, alternating cathodes being interconnected and included in a grounded circuit also including a resistance means and capacitance means connected in parallel.

12. A gas discharge device comprising several cathodes, a common anode forming a corresponding number of discharge gaps with the cathodes, and auxiliary electrodes each connectable to a source of positive potential and to a source of positive pulses, said cathodes being preference type cathodes, different parts of the surface of each cathode being able to discharge with a different intensity, and each of said auxiliary electrodes having a surface extending substantially parallel to the discharge direction of the respective discharge gap and being located intermediate of the discharge gaps of two adjacent cathodes so as to form in response to positive pulses, a discharge gap with the low discharge efficiency part of one of each two adjacent cathodes and with the high discharge efficiency part of the other of said two cathodes.

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