Jan. 4, 1938. L. L. VON KRAMOLIN 2,104,533

METHOD AND MEANS FOR CONTROLLING GAS-FILLED TUBES

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Fig. 1

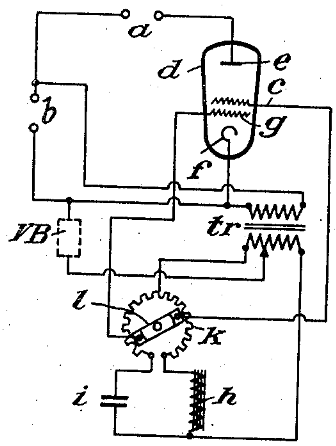
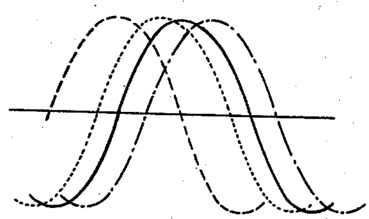


Fig. 2



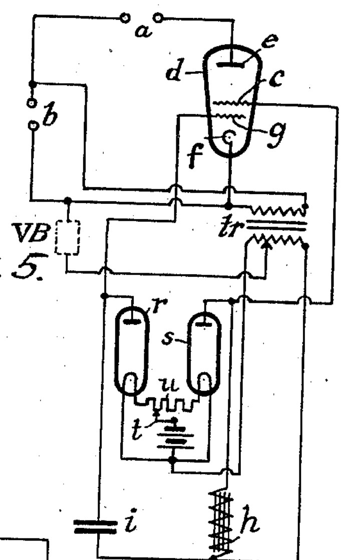


Fig. 5.

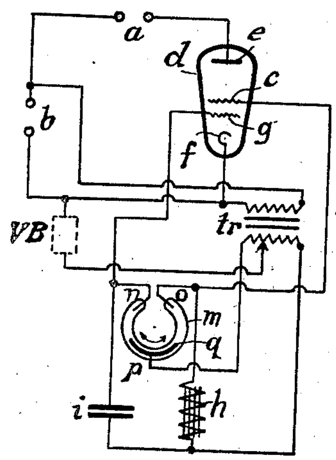


Fig. 4.

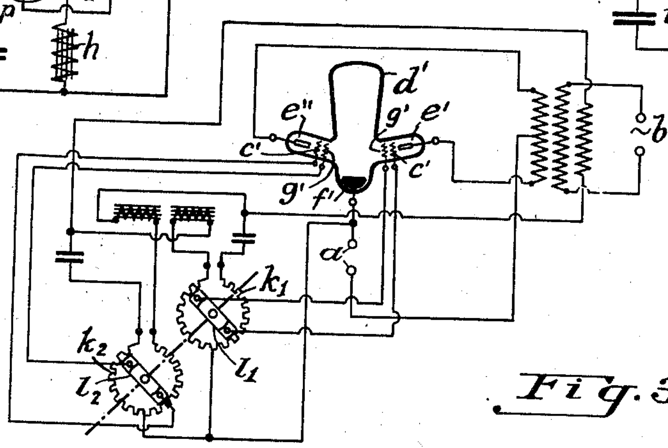


Fig. 3

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METHOD AND MEANS FOR CONTROLLING GAS-FILLED TUBES

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9 Claims. (Cl. 250—27)

This invention relates to a new method for controlling gas or vapour-discharge tubes by controlling auxiliary electrodes to effect a change in the energy supplied from a particular discharge device to a load. Furthermore, by my improved method all other problems may be solved the solution of which is otherwise possible by variable phase-shifting in connection with control electrodes for instance for purposes of frequency transformation or phase compensation and so on. In regulating arrangements employing phase-shifting arrangements of the type just mentioned, a phase-shifter or a similar body is used for shifting the phase of the potential effective at the control electrodes relatively to the potential of the main electrode for control purposes during the operation. But such a phase-shifter is an expensive part of the apparatus particularly in the case of relatively small apparatus.

This invention relates to a method and means for dispensing with a variable phase-shifter. As a substitute for such a phase-shifter, my invention in its simplest form provides an ordinary variable resistance which may be constructed like a potentiometer for radio purposes consisting essentially of a strip of insulating material bent to circular shape, on which is coiled a resistance wire engaged by two sliding contacts.

Reference is to be had to the accompanying drawing, in which Fig. 1 is a diagram illustrating one embodiment of my invention; Fig. 2 is a diagram showing the phase relation of certain voltage waves; Fig. 3 is a diagram representing another form of my invention; Fig. 4 shows a voltage-varying device; and Fig. 5 illustrates another device for regulating the control voltage or potential.

In Fig. 1 a simple embodiment of my invention is illustrated. *d* is a discharge device which contains an anode *e* and a cathode *f*, these two constituting a pair of main electrodes. The cathode is assumed as a hot electrode, but the heating circuit has been omitted for the sake of clearness. Of course, a mercury cathode may be used likewise, and the discharge device can be constructed in any well-known or approved manner. The discharge device can be filled with gases or vapours or mixtures of gases and vapours, for instance mercury vapour and rare gases. In this discharge device two control electrodes *g* and *c* are suitably placed between the main electrodes, that is to say, between the anode and the cathode. In the case of the example the two control electrodes may be put relatively near together. With the point *a* I connect any load or current-consuming device, with the point *b* an alternating current circuit. Parallel to the rectifier constituted by the discharge device *d*, a transformer *tr* is shunted producing the control potential. But it is also possible to dispense with such a transformer and to branch the control potential or voltage off the alternating supply directly. The secondary winding of the transformer is connected with two parallel circuits, one of these circuits being loaded inductively by a choke *h* and the other capacitively by a condenser *i*. Therefore in these two circuits or branches phase displacements appear with such an effect that the voltage wave in the one branch will run ahead of, and in the other branch lag behind, the voltage wave of the main electrode. In the branch containing the condenser *i*, as well as in the branch containing the choke *h*, there is included one half of the resistance *k* which is bent to annular or circular form. The middle point of the resistance is connected with the secondary of the control transformer *tr*. Besides, the control transformer *tr* is connected with the cathode *f* over a suitable tap which may be adjustable. In this connection a bias battery VB may be inserted which supplies a constant negative or positive direct potential to the grids *g* and *c*. But that is not necessary under all circumstances. By the described arrangement, I impress on the grids *g* and *c* control voltages having, relatively to the anode *e*, a phase displacement which is practically constant and which depends on the action of the condenser *i* and the choke *h*. Preferably the phase displacement between control voltages effected by the branch *i* and by the branch *h* should be about between 90 and 45 degrees, for instance about sixty degrees. The grids or control electrodes *c* and *g* are electrically connected with two contacts mounted at the ends of a lever or contact device *l* and arranged for sliding engagement with the resistance *k* as the said device turns about its central axis. By turning the contact device *l* the voltage on the one control electrode is increased while at the same time the voltage of the other electrode is decreased, and vice versa. By turning the contact device *l* the alternating voltage at each of the two control electrodes can be varied from the value 0 to a certain maximum value. If the contact device is in a position in which the grid *g* has a maximum voltage and the grid *c* a minimum voltage, substantially only the grid *g* will be effective with the peculiar phase position which is determined essentially by the condenser element i whereas the grid c will be out of function, and the current flowing through the discharge tube corresponds to a current such as would be supplied by a discharge tube a control electrode of which is controlled with the phase position determined by i. If the contact device l is turned through an angle of about 180 degrees, the discharge tube operates like a controlled gas-filled discharge tube which has only one grid controlled by a control voltage on the phase position of which is determined essentially by the choke element h. If the contact device l is in any intermediate position, the phase position determined by the two grids g and c will likewise have an intermediate value and it will be evident that in this manner a regulation can be achieved which enables me to generate at the grids a resultant control field which is changeable at will relatively to the main discharge as regards phase. In this case the changeable phase-displacement of the resulting field takes place in the tube itself. It is not necessary to use a phase shifter outside the tube. Therefore, a special phase shifter is not necessary for the tube as only voltages of a constant phase position are impressed upon the control grids and only the magnitude of control voltage is changed, but not its phase position. For changing the voltage value a simple resistance is sufficient. Therefore by a simple and cheap regulating resistance, for instance a potentiometer such as used for radio purposes, a regulation can be achieved which in its effect is similar to a regulation effected by a phase shifter with the difference that much simpler elements may be employed. As stated above, it is not absolutely necessary to use a transformer tr, as the control voltages can also be branched directly off the main conductor. This, however, would not create any appreciable complication because in most cases the controlled rectifiers have associated with them, transformers for generating the anode potential necessary for the particular purpose of each individual case. It is thus possible to wind the secondary of the transformer tr on the iron of the already existing transformer. The choke h or the condenser i may also be replaced by a pure ohmic resistance, since the purpose is simply to produce two parallel circuits having a suitable phase-displacement relatively to one another. The symmetry of the phase position of the two control electrodes g and c relatively to the phase of the main discharge, which symmetry is desirable for the carrying out of my improved method, can be achieved by suitable formation of the secondary winding of the transformer tr and placing such transformer at an appropriate point of the main transformer particularly if the main transformer is a polyphase transformer. In the latter case, by arranging the secondary winding of the transformer tr at certain points of the iron of the main transformer any desired phase position can be attained so that then even if an ohmic resistance is employed instead of i or h it is possible to insure that the phase of the voltage on the one control electrode will lag behind the phase of the main discharge by the same amount that the phase of the voltage on the other control electrode runs ahead of the phase of the main discharge. Besides, absolute symmetry is not necessary. As stated above, the control electrodes g and c should be put relatively near together, if the voltages on that part of k which is in the branch including the condenser i correspond approximately to the voltage of that part of k which is in the branch including the choke h. If there is a relatively large distance between the grids so that they differ in their control effect, i. e. the grids have different amplification factors, a compensation is necessary, and this is obtained by making the voltage which becomes effective at the respective control electrode, greater than the voltage at the other electrode, in proportion to the amplification factor of the respective control grid.

If desired, the grids g and c may be placed quite close together, that is, they may be arranged in the same plane, with the rods of the one grid between the rods of the other grid. It will be obvious that I may use as control electrodes, not only grids projecting into the discharge space but also metal parts fastened to the tube outside, for instance sleeves surrounding the tube in a well-known manner. Furthermore, an interior control grid can be combined with a control grid located outside the tube and so on. In the latter case, if uniform regulation is desired, it is preferable to choose the control voltages at the different grids as above described in such a manner that they will be proportional to their amplification factor. If, instead of h, an ohmic resistance is used, the whole regulating arrangement in its simplest form consists of one condenser i and of some ohmic resistances two of which are combined to form a regulating resistance similar to a potentiometer. The only change which this simplification requires as compared with the use of a special phase-shifter is the provision of a second grid; this, however, will not involve any appreciable increase in the cost of manufacture, in view of the highly developed skill now available in the making of glass apparatus. Even with large discharge devices constructed of metal the introduction of an additional electrode does not present any particular difficulty.

Fig. 2 shows the phase position of the main discharge (dotted) relatively to the dash and dash-dotted curves representing the voltages on the two control electrodes when the lever l is in a horizontal position, i. e. the voltages on g and c have the same value. These two voltages combined form, within the tube, a control field which has in this case the same phase position as the main discharge. When the voltage of the discharge shown in the curve formed of dashes is diminished and the voltage of the discharge indicated in dash-dotted lines is increased, an effective control field results which has about the form of the curve indicated by the solid line in Fig. 2, i. e. a field which is shifted toward the side of the dash-dotted curve.

Fig. 3 shows an arrangement with a two-way rectifier which will be readily understood from the above description. As a cathode, I have here chosen a mercury cathode f', but any other suitable type of cathode may be used, for instance active self-heating electrodes, etc. For each of the two anodes e', e^2 a control resistance k^1, k^2, respectively, is provided in this case and the tube control levers l^1 and l^2 are connected by a common shaft. This construction therefore has three main electrodes, which might be described as forming two pairs, the cathode f' being common to both pairs. Instead of two grids or control electrodes c', g', three grids or control electrodes can be used, thereby obtaining a still better regulation, since this will enable me to shift the phase of the resulting control field by 180 degrees in a perfectly uniform manner. For the majority of cases occurring in practice the methods illustrated by Figs. 1 and 2 are sufficient and a further improvement of the control can be achieved as indicated in Fig. 1 by adding a special bias battery VB or applying some other constant or variable direct voltage to the control grids g and c, in addition to the alternating voltages mentioned. In this manner effects can be achieved which are similar to the control with three control grids which are connected to three branches differing from each other in phase. These three phase-shifted branches can be obtained either by the provision of artificial phases, for instance resistances, condensers and self-inductances, or they can be branched off a main transformer directly if in this main transformer there is a rotating field, as is always the case with polyphase current. If such a polyphase transformer is employed, all phase-shifting arrangements may be dispensed with and the regulating arrangement is confined exclusively to the grids and the regulating resistances, for instance such as indicated at k, k^1, k^2 with their levers l, l^1, l^2 respectively.

This invention of course is not restricted to changing the voltage at the electrodes by resistances of the potentiometer type, but any other suitable means for changing the voltages at the electrodes will be within the scope of the invention. The salient feature of my invention lies in the fact that in a construction employing a plurality of control electrodes for each pair of main electrodes, the individual control electrodes are supplied with voltages having a substantially constant phase-displacement relatively to each other and that only the magnitude of the voltage applied to the individual control electrodes is changed for the purpose of regulation. These control electrodes can be arranged at any desired places of a discharge tube and the tube can be equipped with main and control electrodes of any suitable type. For instance all the main electrodes may, according to conditions, become either an anode or a cathode. The method of regulation described in this specification can be employed to cause the individual main electrodes to change from functioning as cathodes, to the anode function, or vice versa, according to the requirements of each particular case.

Fig. 4 shows an arrangement which may be substituted for the potentiometer resistances k, k^1, k^2 and their levers or voltage-dividers l, l^1, and l^2 respectively of Figs. 1 and 3 respectively, as a means for changing the voltage. m designates a discharge tube of any suitable insulating material bent to substantially circular shape. Two electrodes n and o are sealed in at the ends of this tube. Besides, the tube contains a filling of mercury q and a third lead-in wire or electrode p projecting into the filling. The space above the mercury can be filled either with any suitable gas or with a vapor, for instance mercury vapor. If currents differing in phase are supplied between the electrodes o—p on the one hand and the electrodes n—p on the other hand, and the tube m is turned either to the right or to the left as indicated by the double arrow, the gas or vapor pressure will decrease in the space containing the electrode n when such pressure increases in the space containing the electrode o, and vice versa. It is well-known that with a gas discharge between n—p or o—p the voltage at the gas discharge depends on the pressure; therefore by turning the tube in one direction or the other an increase of the voltage can be obtained in the right half of the tube, with a simultaneous decrease of the voltage in the left half, or vice versa. If with the two halves I connect the two control electrodes of a tube constructed according to Fig. 1, the voltages will be changed according to the filling of the tube and such an arrangement can be used for regulating the voltage in a main tube. The electrodes in the tube m may be active and the discharge in the tube may be either a glow discharge or an arc discharge as in both cases the operating voltage depends on the pressure. More particularly, an arc discharge affords the possibility of varying the voltage within wide limits depending upon the pressure, and an arrangement according to Fig. 4 has the further advantage that the voltage is independent in a high degree of the current flowing through the arrangement so that a constant control voltage will be available even with varying supply voltages.

A further arrangement for regulating the control voltage is illustrated in Fig. 5. There are two discharge devices r and s of the cathode tube type connected with the two supply busses to the control electrodes. By shifting a contact slide t along a resistance u either the tube r or the tube s can be heated more strongly, and if the control voltages are made so high that the tubes will operate at the saturation state, a constant voltage, depending only upon the regulation, can be obtained at the control electrodes even when the voltage of the supply current varies, provided the control currents transmitted through the discharge devices r and s are tapped on constant resistances. Instead of tubes with variable heating as illustrated in Fig. 5, I may also use grid-controlled vacuum tubes or other amplifier tubes, since any kind of voltage regulation may be employed. Sometimes, of course, it is unavoidable that the constructive means producing a voltage change at the electrodes will also cause changes of phase-displacements at the control electrodes. But such changes of the phase-displacements have no material influence on the regualtion.

I claim:

1. In apparatus for producing an electric discharge in an atmosphere of gas or vapor, a container for the gas or vapor, a set of main electrodes in said container and two control electrodes per anode of said set, means for supplying to said control electrodes alternating voltages of constant phase relatively to the anode voltages, and means for increasing the amplitude of the alternating voltage supplied to one of said control electrodes and for simultaneously decreasing the amplitude of the alternating voltage supplied to the other control electrode.

2. An apparatus according to claim 1, in which the two control electrodes are connected with two control circuits carrying alternating currents out of phase with each other, and in which a regulating device affecting both circuits is provided in such a manner that an increase of the control voltage in one of said circuits will be accompanied by a decrease of the voltage in the other circuit, and vice versa.

3. An apparatus according to claim 1, in which the two control electrodes are connected with two control circuits carrying alternating currents out of phase with each other, and in which a regulating device affecting both circuits is provided in such a manner that an increase of the control voltage in one of said circuits will be accompanied

by a decrease of the voltage in the other circuit, and vice versa, said regulating device comprising two confined gas bodies forming gaps, one of said bodies being adapted to be compressed when the other is permitted to expand, and vice versa, the connections for the control voltages being made at the ends of said gas bodies.

4. An apparatus according to claim 1, in which the two control electrodes are connected with two control circuits carrying alternating currents out of phase with each other, and in which a regulating device affecting both circuits is provided in such a manner that an increase of the control voltage in one of said circuits will be accompanied by a decrease of the voltage in the other circuit, and vice versa, said regulating device comprising a bent tube of insulating material containing two separate gas bodies and a body of mercury interposed between said bodies, the said tube being movable to increase or decrease the pressure to which said bodies are subjected, the connections for the control voltages being made at the ends of said gas bodies.

5. An apparatus according to claim 1, in which the control electrodes are connected with control circuits which also include discharge tubes, and in which means are provided for influencing said tubes to vary the amplitude of the said alternating voltage.

6. An apparatus according to claim 1, in which the control electrodes are connected with control circuits which also include discharge tubes, and in which means are provided for changing the emission of said discharge tubes and thereby varying the amplitude of the said alternating voltage.

7. The method of regulating the supply of current to electric discharge devices having a pair of main electrodes constituting anode and cathode, and two control electrodes for said pair of main electrodes, which consists in supplying to each of said control electrodes, alternating current voltages of constant phase relatively to the anode voltages, and increasing the amplitude of the alternating voltage supplied to one of the control electrodes while simultaneously decreasing the amplitude of the voltage supplied to the other control electrode.

8. In apparatus for producing an electric discharge in an atmosphere of gas or vapor, a container for the gas or vapor, a set of main electrodes in said container and a plurality of control electrodes per anode of said set, control circuits connected with said control electrodes and including means for supplying alternating voltages to said electrodes and also including discharge tubes, and means for influencing said tubes to vary the amplitude of such alternating voltages.

9. In apparatus for producing an electric discharge in an atmosphere of gas or vapor, a container for the gas or vapor, a set of main electrodes in said container and a plurality of control electrodes per anode of said set, control circuits connected with said control electrodes and including means for supplying alternating voltages to said electrodes and also including discharge tubes, and means for changing the emission of said discharge tubes and thereby varying the amplitude of such alternating voltages.

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