

Feb. 24, 1942.

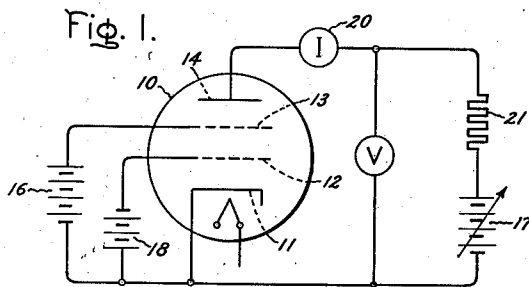
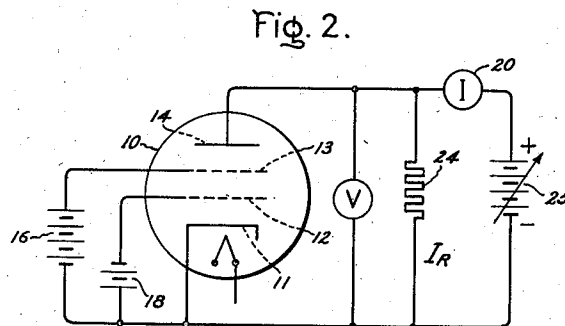
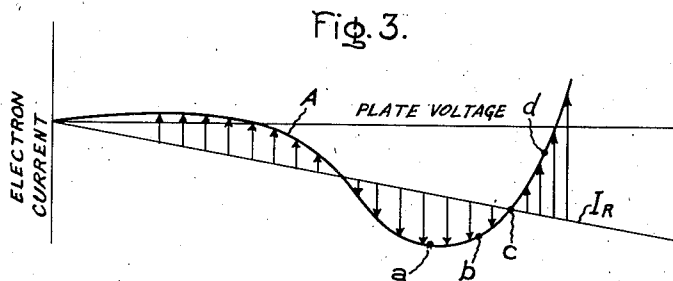
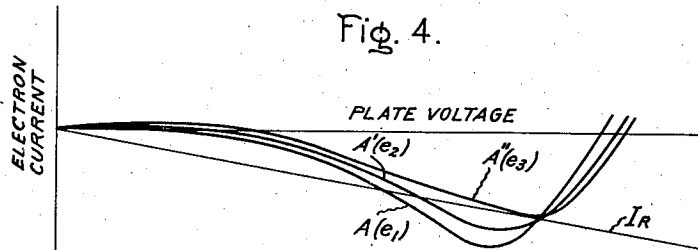
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2,274,369

ELECTRICAL CONTROL SYSTEM

Filed July 13, 1940

2 Sheets-Sheet 1



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Fig. 5.

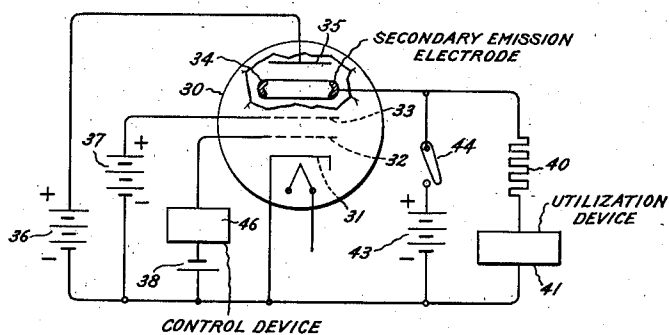


Fig. 6.

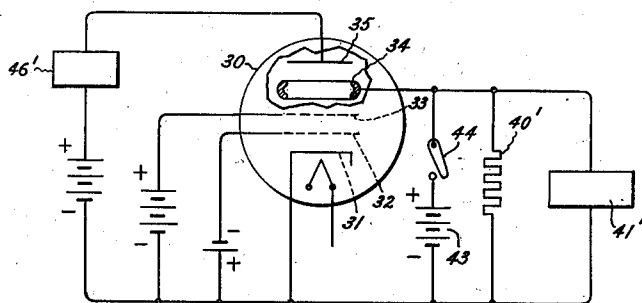
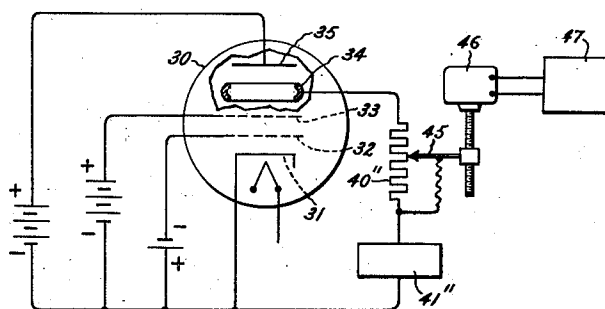


Fig. 7.



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UNITED STATES PATENT OFFICE

2,274,369

ELECTRICAL CONTROL SYSTEM

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4 Claims. (Cl. 250-27)

The present invention relates to an improved electrical control system.

According to the invention, use is made of a vacuum tube having a secondary emission electrode and a utilization device connected in circuit with the secondary emission electrode. There is also provided in the circuit with the secondary emission electrode a resistance of such value as to assure stable operation of the vacuum tube only over a fixed operating range. By varying the operating conditions of the tube to bring them outside the aforesaid fixed range it proves impossible to obtain abrupt deenergization of the utilization device, such deenergization being accomplished in an extremely short interval of time after the establishment of conditions which are favorable thereto.

I am aware that it has previously been proposed in Koller and Johnson Patent No. 2,168,165, granted August 1, 1939, to employ a secondary emission tube for the accomplishment of a control function. My invention differs from that described in the aforesaid patent, however, in the location of the utilization device with respect to the other elements of the control circuit and in that it offers the possibility of substantially constant current energization of the utilization device for all operating conditions other than that at which cut-off occurs. The advantages and explanation of this feature will be given more fully at a later point.

The features which I desire to protect herein are pointed out with particularity in the appended claims. The invention itself, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the drawings, in which Fig. 1 is a diagrammatic representation useful in explaining the invention; Fig. 2 is a modification of Fig. 1; Fig. 3 and 4 are graphical representations for explaining the operating characteristics of an arrangement such as that of Fig. 2; and Figs 5, 6, and 7 show diagrammatically various circuit arrangements which may be employed in the practical application of the invention.

Referring particularly to Fig. 1, there is shown a four-electrode vacuum tube 10, comprising a cathode 11, a control grid 12, a suppressor grid 13, and an anode 14. The electrodes 13 and 14 are respectively maintained at a positive potential with respect to the cathode 11 by means of batteries 16 and 17 while a negative bias (supplied by battery 18) is provided in connection with the grid 12.

By proper adjustment of the electrode potentials, a condition may be established in which the electrode 14 is caused to emit secondary electrons in response to the impingement thereon of primary electrons proceeding from the cathode

11. If the flow of secondary electrons from electrode 14 to the suppressor grid 13 exceeds the primary electron current to the electrode 14, a meter 20 placed in circuit with such electrode will indicate a movement of electrons from the battery 17 toward the electrode. As a result of this electron flow, a resistance 21 connected in series with the battery 17 will develop a voltage drop of such sign as to increase the potential level of the electrode 14. Consequently, the voltage of the battery 17 may be reduced to some extent without destroying the stability of operation of the system. Furthermore, if the value of resistance 21 be made large enough, the drop across it will become sufficiently great to permit stable operation of the system with the battery 17 entirely eliminated.

The significance of the foregoing may be explained in terms of the operating characteristics of the system by reference to the modified circuit arrangement of Fig. 2. In this case the electrodes 11, 12, and 13 and their energizing connections are in precisely the same relationship as in Fig. 1 so that the same identifying numerals are employed in the drawings. However, the supply circuit of the secondary emission electrode 14 is now shown as including a resistance 24 and a battery 25 connected in parallel.

The relationship between the total electron current flow to the electrode 14 and the potential applied to such electrode is indicated by the curve A of Fig. 3. In referring to this curve it will be understood that negative values of the curve indicate electron flow in a direction from the battery 25 to the electrode 14. The straight line I_R , on the other hand, represents the value of electron current which would be required to flow through the resistance 24 in order to maintain the potential of the electrode 14 at any particular value by virtue of such current flow. The current I which is supplied by the battery 25 consists of the difference between the curve A and the line I_R and is represented by the magnitude of the arrows which extend between the curve and the line in Fig. 3. The direction of the arrows indicates the relative direction of the current I .

If the current I is suddenly interrupted at any particular point of operation by opening the circuit of the battery 25, a readjustment of the system will necessarily take place.

Let it first be assumed that the operating condition at the instant of circuit interruption is as indicated by the point a on the curve A of Fig. 3. It will be understood that the anode voltage will be instantaneously maintained by the interelectrode capacity. Since this voltage demands a flow of current to the anode from the connected circuit which is in excess of that being supplied through the resistance 24 at the instant of circuit interruption, an increase in the current

through the resistance will occur. However, the resulting increase in voltage drop across the resistance will shift the operating point of the system progressively through the point *b* to the point *c*, at which point the current through the resistance becomes effectively equal to that required by the plate characteristic of the tube. Consequently, a condition of stable operation will be established at the point *c*.

A similar situation will develop if circuit interruption occurs at an operating point which is above the point *c*, say, at the point *d*. Under these circumstances, the current demanded by the plate characteristic of the tube at the point *d* is less than that required to flow through the resistance 24 in order to maintain stable operation. Consequently, the current will decrease until the stable operating point *c* has been reached.

It will be understood that the curve A of Fig. 3 pertains to a particular operating condition of the system including, for example, a particular potential relationship of the electrodes 12 and 13. If this relationship is varied by varying the potential of the grid 12, a new curve, or plate characteristic, will be realized. The importance of this consideration is illustrated in Fig. 4 in which the curves A' and A'' represent respectively the plate characteristics which are realized with grid voltages e_2 and e_3 which differ from the voltage e_1 employed in the determination of the plate characteristic which is represented by the curve A.

The curve e_3 obviously represents the most negative grid voltage for which a stable operating condition of the device can be realized. For more negative values of grid voltage the battery current will be positive (according to the convention adopted), for all values of plate voltage, so that the current flow through the resistance 24 would, upon the interruption of the battery circuit, fall to zero without passing through a point of stable operation. It is especially significant to note that the points of intersection of the curves A, A' and A'' with the line I_a are substantially coincident for the chosen value of R. This circumstance, which is readily obtainable with commercially available types of tubes, shows that with the circuit of the battery 25 open, the current flow through the resistance 24 for stable operation, would have a substantially constant value for all values of grid voltage between e_1 and e_3 . Consequently, the act of varying the grid voltage between e_1 and e_3 would not cause any corresponding variation of the current through the resistance until the critical value e_3 had been passed, at which point the current would fall abruptly to zero for the reasons already given.

The factor last referred to is important in that it offers the possibility of obtaining a form of relay action in which the current supply to the utilization device is maintained at constant value until a critical value of the control factor is attained, at which point the current level may fall abruptly to zero so as to produce nearly instantaneous deenergization of the device. This factor also has utility in timing circuits in which a current integrating arrangement is employed to measure time by measuring directly the integrated value of current flow. (If, as in the arrangement under consideration, the current is constant throughout the time of flow, it will be readily understood that its integrated value is directly proportional to its duration.)

A typical application of the invention is illustrated in Fig. 5, which is the conventional diagrammatic representation of the type of secondary emission tube described in U. S. Patent No. 2,159,774 granted May 23, 1939, in the name of C. F. Veenemans, E. H. Lopp, and Hajo Bruining. In this case, the tube, which is indicated as a whole by the number 30, comprises a cathode 31, a control grid 32, a screen grid 33, a secondary emission electrode which is shown as a ring-like member 34, and which is assumed to be shielded from direct exposure to the cathode, and an anode or electron-collecting electrode 35. The arrangement of the parts is such as to make use of the secondary emission properties of the electrode 34; that electrode being especially processed for the purpose by being exposed to the vapors resulting from flashing magnesium in an atmosphere of carbon dioxide.

In the use of the tube, the secondary emission current generated by the electrode 34 is collected by the anode 35, this anode being maintained at an appropriate potential level by means of a battery 36. Other batteries 37 and 38 of suitable polarity are provided in connection with the electrodes 32 and 33. In series with the electrode 34 there is provided a resistance 40 which is of such value (say, from 10,000 to 1,000,000 ohms or more, depending on the characteristics of the tube employed) as to maintain the system in stable operation over a considerable range of operating conditions, in accordance with the principles previously described. Also in circuit with the electrode 34 there is connected at 41 a primary load device for the system which is illustrated diagrammatically, but which may comprise the energizing coil of a relay or a component of a timing device or the like. (Obviously, in view of the unidirectional character of the current supply, the utilization device, whatever its nature, must be adapted to be energized by unidirectional current flow.) In order to render the system initially operative, a battery 43 is provided in parallel with the resistance 40 for applying a relatively high positive potential to the electrode 34. The circuit of this battery may be opened by a switch 44, as soon as sufficient secondary emission is developed to render the system stably operative.

Control effects may be obtained by the arrangement described through the use of any means which serves to bring the operating conditions of the system outside the range of stable operation. This may be done in one way by placing a source of control potential 46 in series with the control electrode 32 so as to vary its potential level in accordance with the variations of a control factor. If it is desired to use the system as a timing agency, the resistance 40 is preferably selected to be of such value with respect to the other constants of the system as to result in constant current flow through the resistance for all values of the control potential within the range of stable operation. Deenergization of the utilization device 41 occurs, of course, upon any departure of the control potential from the stable operating range.

An alternative mode of controlling the relay action of the system described above is illustrated in Fig. 6. In this figure the electrodes are identical with those of Fig. 5 and are, therefore, similarly numbered. However, the utilization device is connected in parallel with the resistance 40' rather than in series therewith as in Fig. 5. Moreover, the control element (num-

bered 46') is, in this case, placed in circuit with the collecting anode 35 so as to vary its potential. It will be understood that the effect of such variation is to change the operating characteristics of the system in such fashion as to modify the range within which stable operation will occur. That is to say, a value of grid voltage which represents a stable operating condition for a particular value of the collector potential may cease to represent stability for a different value of such potential. Consequently, abrupt cessation of current flow through the resistor 40' (and consequently through the utilization device 41') may be realized upon attainment of a critical value of the collector voltage.

A still further mode of control is illustrated in Fig. 7 in which the various parts previously described are again given similar numerals. Here the control function is accomplished by varying the effective value of the resistance 40''. This may be done, for example, by a variable contact 48, the position of which is controlled through a servo-motor 49 which is actuated by a control device 50. The act of varying the position of the contactor 48 is equivalent to varying the slope of the line I_R of Fig. 4. Since this obviously changes the range of stable operation of the system, it will be understood that a relatively slight variation of the resistance 40'' may be effective to produce abrupt transition of the utilization device 41'' from a condition of full energization to a condition of complete deenergization.

An important advantage of the control system described in the foregoing consists in its extreme rapidity of action. This factor is principally a function of the interelectrode capacity of the particular vacuum tube employed. Since this capacity may be made very small for practical tube constructions, extremely high operating speeds may be realized. Thus, in a particular case, deenergization of a device controlled by the system may be accomplished within less than one micro-second after the application of a favorable control potential.

While I have described particular embodiments of the invention in the foregoing, it will be understood that numerous modifications may be made by those skilled in the art and I therefore aim in the appended claims to cover all such equivalent variations as come within the true spirit and scope of the foregoing disclosure.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. In an electrical control system; a discharge tube having a cathode, an electrode emitting secondary electrons in response to the flow thereto of primary electrons from the cathode, and means for receiving the emitted secondary electrons; a resistance-containing circuit connected between the cathode and the secondary emission electrode for controlling their potential relationship in accordance with the net current flow to the latter electrode, the resistance of the circuit being such that a condition of stable operation exists only for a fixed range of operating conditions of the system; a primary load device responsive to unidirectional current flow included in the said circuit, and means for varying the operating conditions of the system in response to a control factor which tends to approach a value outside the said fixed range of stable operation, thereby to cause abrupt cessation of current flow through the said circuit and

load device upon attainment of the said value of the control factor.

2. In an electrical control system; a discharge tube having a cathode, an electrode emitting secondary electrons in response to the flow thereto of primary electrons from the cathode, an electrode for receiving the emitted secondary electrons, and a control electrode for varying the primary electron current from the cathode; a resistance-containing circuit connected between the cathode and the secondary emission electrode for controlling their potential relationship in accordance with the net current flow to the latter electrode, the resistance of the circuit being such that a condition of stable operation exists only for a fixed range of operating conditions of the tube; a primary load device responsive to unidirectional current flow included in the said circuit, and means for varying the potential of the said control electrode in response to a control factor which tends to approach a value outside the said fixed range of operating conditions, thereby to cause abrupt cessation of current flow through the said circuit and load device upon attainment of the said value of the control factor.

3. In an electrical control system; a discharge tube having a plurality of electrodes which form parts of the control system and which include a cathode, an electrode emitting secondary electrons in response to the flow thereto of primary electrons from the cathode, an electrode for receiving the emitted secondary electrons, and a control electrode; a resistance connected between the cathode and the secondary emission electrode for maintaining the latter electrode at a potential of effective secondary emission solely by virtue of the current flow through the resistance, said resistance being of such value that stable operation of the system occurs only for a fixed range of operating conditions of the system and being further of such value as to assure substantially constant current flow there-through within the said fixed operating range; a primary load device for the system connected in circuit with the said resistance so as to be directly responsive to variations in current flow through the resistance, and means for varying the potential of the said control electrode in response to a control factor which tends to approach a value outside the said fixed operating range, thereby to cause abrupt cessation of current flow through the resistance and utilization device upon the attainment of the said value of the control factor.

4. In an electrical control system, a discharge tube having a plurality of electrodes including a cathode, an electrode emitting secondary electrons in response to current flow thereto from the cathode, and an electrode for receiving the emitted secondary electrons; a resistance connected between the said cathode and secondary emission electrode for controlling their potential relationship solely in accordance with the current flow to the electrode through the resistance, a primary load device for the system also connected directly in circuit with the said secondary emission electrode so as to be energized only upon the occurrence of current flow to the electrode, and control means for varying the value of the said resistance from a point which permits stable operation of the system to a point which produces abrupt cessation of current flow to the secondary emission electrode.