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MARGINAL CONTROL OF GAS-FILLED TUBES

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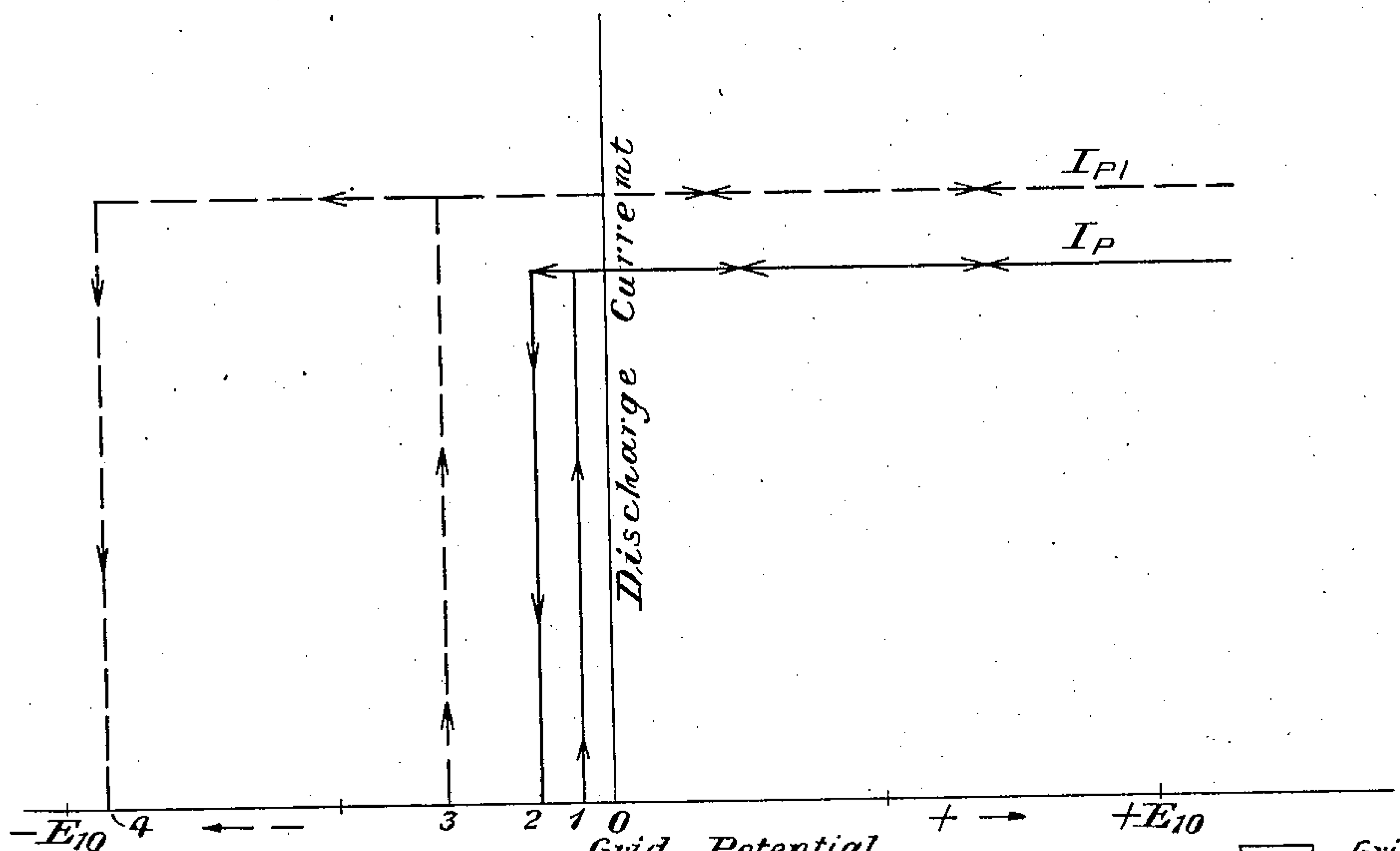

Fig. 1

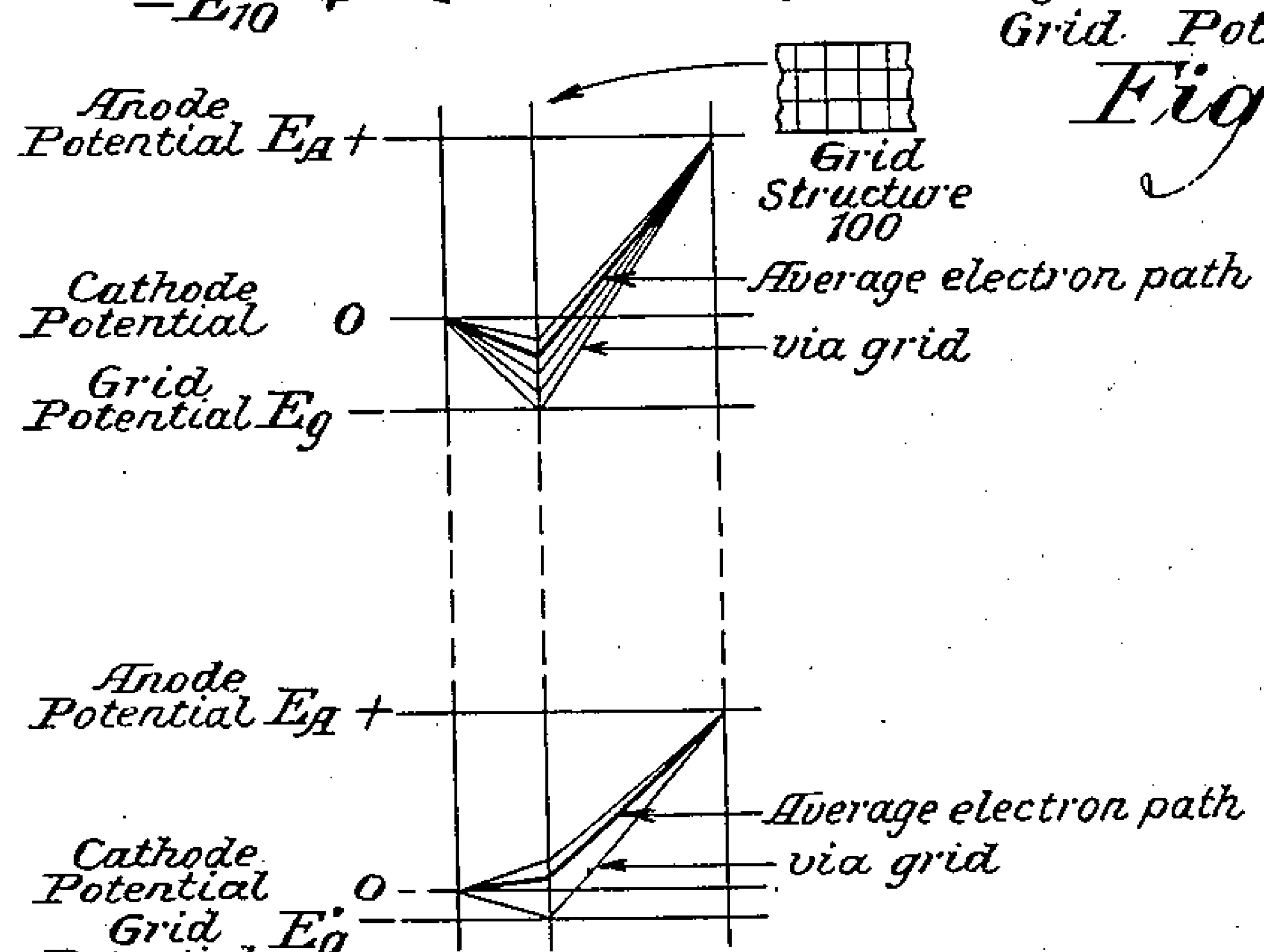

Fig. 2a

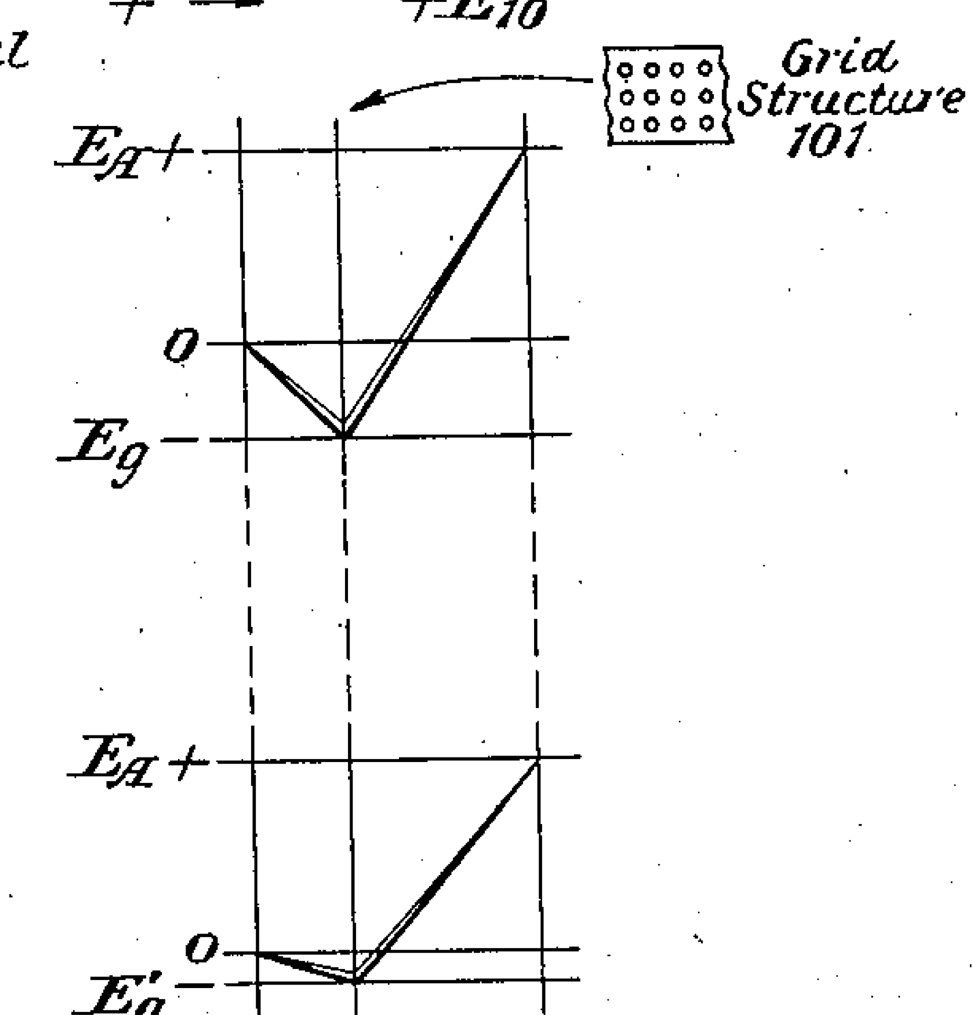

Fig. 2b

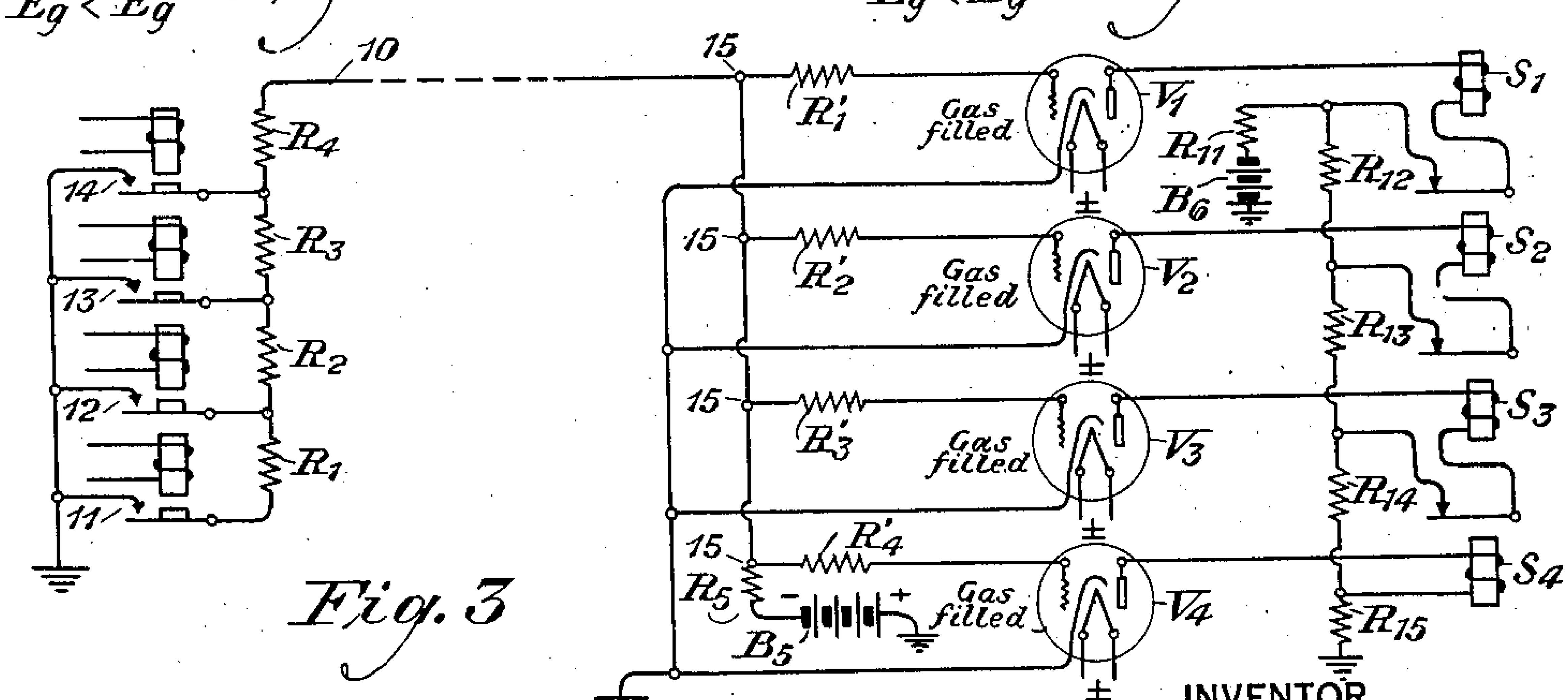

Fig. 3

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MARGINAL CONTROL OF GAS-FILLED TUBES

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1 Claim. (Cl. 177—353)

This invention relates to electrical circuits and more particularly to circuits employing gas filled tubes such, for example, as discharge tubes containing a gas such as argon, and also to arrangements whereby the structure and characteristics of such tubes may be utilized to obtain marginal control thereof.

In the past marginal operation has usually been obtained by means of electromagnetic relays. Such practice is limited by the performance limitations of the relays and to the variations encountered in other portions of the circuit. It has been necessary to separate the operate margins for the different steps rather widely and to design circuits for release values which bear fairly definite ratios to the operate values. Because of these limitations it has not in the past been customary to attempt marginal release features as well as marginal operate features. Even if this were done the ratio of operate to release current required by relays would limit such release values. The limitations of the relays, by commercial variations in other parts of the circuits and the tolerances required for maintenance were all such as to greatly restrict the number of independent margins which could be obtained. The objects of the invention and the methods of attaining them will appear more fully from the detailed description thereto hereinafter given.

It is one of the purposes of the invention to utilize the characteristics of gas filled tubes as determined by any or all of the various factors affecting the characteristics and to use the tubes and associated circuits for the control of margins, both for operation and for release and for combinations of operation and release. Such use may be made applicable to signaling or switching circuits or systems or to any uses where marginal control of circuits may be desired.

The invention may be more fully understood from the following description together with the accompanying drawing in the Figures 1, 2A, 2B and 3 of which the invention is illustrated. Figs. 1, 2A and 2B are graphical illustrations of certain principles of operation of the arrangements. Fig. 3 is a circuit diagram embodying one form of the invention.

Certain gas filled tubes have characteristics such as those shown in Fig. 1 in which I_p represents the discharge or anode current for one particular tube and for one set of conditions. For these conditions it is assumed that the cathode current and anode voltage are kept constant and that the grid potential is varied from a value represented by $-E_{10}$ to a value E_{10} and back to $-E_{10}$. At a point 1, which point is determined by the structure of the tube elements, by the gas in the tube, by the temperature of the cathode and by the value of potential impressed on the anode of the tube, ionization of the gas takes place and an arc is set up between the cathode and the anode. The magnitude of the arc or discharge current is represented by the line I_p and for all values of grid potential which are more positive than that at point 1 this value prevails. It also prevails upon lowering the grid potential to values negative to point 1 until a point 2 is reached at which positive ions are eliminated from the region between grid and cathode being all drawn to the grid. This reestablishes a region of negative potential gradient away from the cathode from which electrons can no longer escape. Ionization of the gas between cathode and anode ceases and the arc is extinguished. Thence until the value of grid potential $-E_{10}$ is reached or for any values between $-E_{10}$ and point 1 no current will flow between cathode and anode.

If now conditions are kept the same for the same tube, except that a different value of anode potential is employed the characteristic may be changed to that shown as I_{p1}. The same method of obtaining the characteristic is employed but in this case once the arc is established the grid potential may be restored almost to the value $-E_{10}$ before the discharge is stopped. By suitable selection of anode potentials any values of breakdown may be obtained between $-E_{10}$ and 0 or even for positive values of grid potential. Similarly the grid potential at which the arc is extinguished, which may be termed the quenching point, may also be controlled. An illustration of a gas-filled tube having characteristics such as those shown in Fig. 1 will be found in U. S. Patent No. 1,944,888, to H. H. Haglund, issued January 30, 1934.

The gas filled tube may be controlled in a marginal manner, as will be hereinafter pointed out, by varying other of their characteristics; for example, the gaseous content might be mercury vapor in which a discharge may be started at about 10 volts effective potential, while if the gaseous content were helium this would be increased to 20 volts. Thus by employing mercury and helium tubes in conjunction in a circuit marginal control could be effected, as a voltage which would sustain an arc in mercury vapor would be insufficient in helium. Another method of obtaining marginal control would be by varying the design of the tube elements; for example, the use of a grid having a fine mesh would result in a large control ratio, while a grid of coarse mesh would result in a low control ratio.

This latter effect may be illustrated by Figs. 2A and 2B which give an example of the effect of change in grid structure. In the upper portion of Fig. 2A is shown a set of curves illustrating the potential gradients which might exist from cathode to anode of a gas filled tube with a fairly open grid structure, such as the grid structure 100. The negative grid potential is shown as Eg. The lower of the light lines indicates the potential gradient via the grid structure itself. The other lines indicate the potential gradients, through the open sections of the grid. The heavy line indicates the average potential gradient. From the heavy and light lines, it will be seen that the potential gradient away from the cathode is negative and accordingly, the electrons cannot flow from the cathode to anode. Under such conditions the tube will not discharge. In the lower portion of Fig. 2A is shown a similar set of curves illustrating the potential gradients of the same tube with grid structure 100 under similar conditions except that the grid potential is changed to a value $E'g$. It will be noted that $E'g$ is algebraically greater than Eg. Under this changed condition of grid potential $E'g$, it will be seen that some of the potential gradient lines from cathode to anode will have a positive slope away from the cathode. Accordingly, electrons may flow from cathode to anode and a discharge will be started in the tube. In other words with a grid structure such as 100 it may be possible to cause the tube to discharge by changing the grid potential from a value Eg to $E'g$. In Fig. 2B are shown sets of curves illustrating the potential gradients between cathode and anode of a discharge tube having a solid grid structure perforated by very small holes, such as grid structure 101. In the upper portion of Fig. 2B the same cathode, anode, and grid potentials are used as in the case illustrated in the upper portion of Fig. 2A. In the lower portion of Fig. 2B the same cathode, anode and grid potentials are used as in the case illustrated in the lower portion of Fig. 2A. It will be seen that the average potential gradient away from the cathode as shown in the upper portion of Fig. 2B, with a grid potential of Eg will be negative. It will also be seen from the curves in the lower portion of Fig. 2B that, when the grid potential is changed to $E'g$, the potential gradient away from the cathode will also be negative. Accordingly, a change of grid potential from Eg to $E'g$ will not operate a tube with a grid structure such as 100. Thus it will be seen that by using tubes with different grid structures marginal control or operation thereof may be effected.

In Fig. 3 the gas filled tubes V_1, V_2, V_3 and V_4 are provided to give marginal steps for control of secondary circuit operations as represented by relays S_1, S_2, S_3 and S_4 respectively. In the arrangements of Fig. 3 the marginal control of the tubes is effected by providing the tubes with different fixed anode potentials and by applying different potentials to the grids thereof. Each of the relays S_1, S_2, S_3 and S_4, is connected from a source of anode potential B_6 to the anode of the tube corresponding to its marginal step. B_6 is shown as a common source of anode potential for all of the tubes and to give the desired difference in anode voltage a potentiometer device consisting of resistances R_{11}, R_{12}, R_{13}, R_{14} and R_{15} is used for the supply to the several tubes. Separate sources of different values of plate potential could be used if desired. With the arrangements shown it will be seen that the tube V_1 will have the highest anode potential. The anode potential for tube V_2 will be lower than that of V_1. The anode potentials of tubes V_3 and V_4 will in turn be lower than those of preceding tubes. The tubes all receive a negative grid potential from the common source B_5 of such a value as to keep them from discharging. Current limiting resistances R_1', R_2', R_3' and R_4' are provided in the individual grid circuits.

For convenience the tubes are of the so-called heater type with the cathode insulated from its heater supply. This is not necessary but is a convenience in separating working parts of the circuit from the source of cathode energy.

The control for the various marginal steps is obtained over conductor 10, which in practice may be a conductor between two offices or between two parts of an office interconnected by means of switches or otherwise. The control of the individual steps is lodged with relay or other switch contacts 11, 12, 13 and 14 which close a circuit from battery B_5, through resistance 5, conductor 10 and one or more of resistances R_1, R_2, R_3 and R_4.

In practice, if it is desired to operate marginal step S_1 but not the others, relay contact 11 is operated. This will connect ground through resistances R_1, R_2, R_3 and R_4, over conductor 10, and resistance R_5 to a battery B_5. This will reduce the negative potential provided for the grids of all the tubes by battery B_5 to such a value as to cause ionization in tube V_1 above. This is because tube V_1, as heretofore pointed out, has the highest anode potential of all the tubes. The anode potentials of the other tubes are sufficiently lower than that of V_1 so that the reduction of negative grid potential caused by operation of contact 11 will not be sufficient to cause ionization to take place therein at this time. Ionization of tube V_1 permits current to flow from battery B_6, through resistance R_{11}, winding of relay S_1, anode-cathode path of tube V_1, to ground. This will cause the relay S_1 to operate. It may control a work circuit not shown.

To operate relay S_2 the relay contact 12 will be closed. This will connect ground through resistances R_2, R_3 and R_4, over conductor 10, resistance R_5, to battery B_5. This will further reduce the negative potential applied from B_5 to the grids of the tubes to such a point that ionization will take place in tube V_2. As heretofore pointed out the anode potential of tube V_2 is less than that of V_1. Hence to cause ionization in V_2 the negative grid potential has to be reduced further than in the case of tube V_1. The ionization of tube V_2 will permit current to flow from battery B_6, through resistances R_{11} and R_{12}, winding of relay S_2, anode-cathode path of tube V_2, to ground. This will operate relay S_2, which may control a work circuit not shown. The operation of relay S_2 will open at its upper contact the plate circuit of tube V_1 and thus deenergize tube V_1.

In a similar manner the operation of switches 13 and 14 will further reduce the negative potential applied to the grids of the tubes and will cause the operation of tubes V_3 and V_4. It is pointed out that when S_3 operates it will open the plate circuit of tube V_2 and thus deenergize tube V_2. The deenergization of tube V_2 will cause the release of relay S_2. This will again close the plate circuit of tube V_1 and as the voltage on the grid of tube V_1 is below the value needed to break down this tube it will again be operated. In a similar manner the operation of S_4 will release S_3, and the release of S_3 will allow tube V_2 to again become energized.

It has been shown how the arrangements of Fig. 3 permit marginal or selective operation of the gas filled tubes V_1, V_2, V_3 and V_4. In a like manner it is possible to secure a marginal or selective release of these tubes. This may be accomplished in the following manner: As heretofore pointed out the release of switch 14 increases the amount of negative potential applied to the grids of the tubes V_1, V_2, V_3 and V_4. It has also been pointed out previously that tube V_4 has the lowest anode potential applied thereto and that progressively greater anode potentials are applied to tubes V_3, V_2 and V_1 respectively. Referring to Fig. 1, the characteristic designated I_p illustrates the variation in anode current when the grid potential is varied. The arc is started, as indicated by the vertical line rising from 1, and the quenching of the arc is shown by the vertical line from I_p to 2. It will be observed that the starting and quenching potentials are close together due to the low anode voltage. It will, therefore, be possible to so adjust resistances R_1, R_2, R_3, R_4 and R_5 that the release of switch 14 will make the grid of tube V_4 sufficiently negative to quench the arc therein. When this occurs relay S_4 will release completing the anode circuit of tube V_3, and since the quenching potential applied to the grid of tube V_4 is less negative than the potential at which the arc may be started in tube V_3, the arc will strike in tube V_3. Similarly, upon the opening of switch 13 it will be possible to cause tube V_3 to quench while tube V_2 has such potentials applied to grid and anode that an arc will strike. The same thing may be accomplished in the case of tube V_1 and switch 11, the requirement being that the quenching potential of each tube should be less negative than the starting potential of the preceding tube in the sequence. In other words, referring to Fig. 1, each curve I_p represents the operating characteristic of one tube, such as V_3. The curve I_{p1} must represent the characteristic of the adjacent tube V_2 and the characteristics of each of the pairs of tubes must be related in the manner shown in Fig. 1, so that the quenching potential of the one is less negative than the starting potential of the next. This condition can readily be secured by proper adjustments of anode and grid potentials and by proper choice of tube and resistances of the anode circuits. The anode and grid potentials are, of course, determined by the adjustment of resistances R_1 to R_5, inclusive, and R_{11} to R_{15}, inclusive. For the proper quenching operation of the tubes the values of the resistances of the windings of relays S_1, S_2, S_3 and S_4 should be properly chosen so that the total resistance of each individual anode circuit will be of the proper value. That the anode circuit resistance of each of the tubes is a factor entering into the proper quenching operation thereof will be seen from the following. When an arc exists in a tube of the type herein described the critical voltage at which the arc is quenched is determined by two factors: the applied anode potential, and the resistance between such source of anode potential and the anode terminal of the tube. This results from the fact that when the grid draws positive ions out of the discharge, a negative space charge is built up in the grid-to-cathode region of the tube. This reduces the anode current and results in a rise in potential at the anode. Should the anode voltage and anode resistance be of such value that this potential rise is sufficient to overcome the negative grid bias and restart the discharge, no quenching will occur. However, the anode voltage and anode resistance can in any case be so proportioned that the tube is substantially deionized by the action of the negatively charged grid and proper quenching action obtained.

While the invention has been disclosed as embodied in certain specific arrangements which are deemed desirable, it is understood that it is capable of embodiment in many and other widely varied forms without departing from the spirit of the invention as defined by the appended claim.

What is claimed is:

A selective signaling system comprising a set of gas filled discharge tubes, said tubes being of the type which have a critical negative grid potential at which breakdown occurs determined by the potential applied to the anode circuit and a different critical negative grid potential at which release occurs determined by the potential applied to the anode circuit together with the resistance of said anode circuit, means for adjusting the potentials applied to the electrodes of said tubes so that one of said tubes will have a fixed anode potential of a sufficiently lower value than that applied to the anode of the preceding tube in the set whereby said first mentioned tube will discharge and quench with lower values of negative potential applied to the grid thereof than will be needed to start a discharge in the preceding tube of the set, and means for selectively varying the negative potential applied to the grids of said tubes to cause their selective operation.

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