

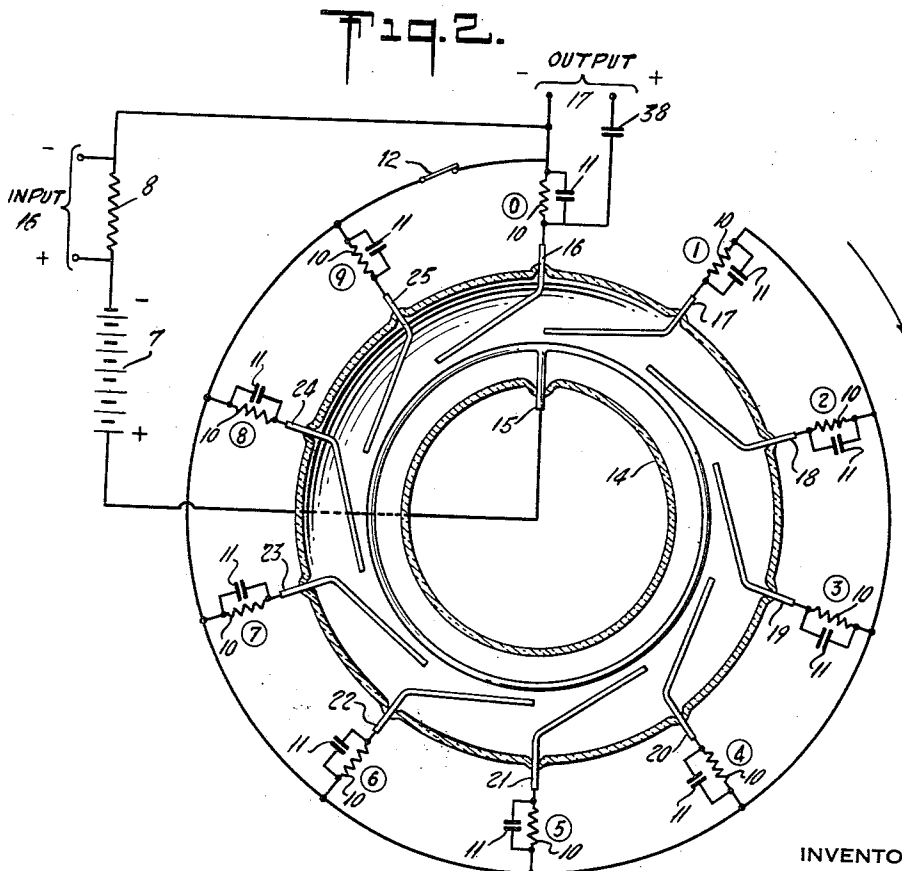
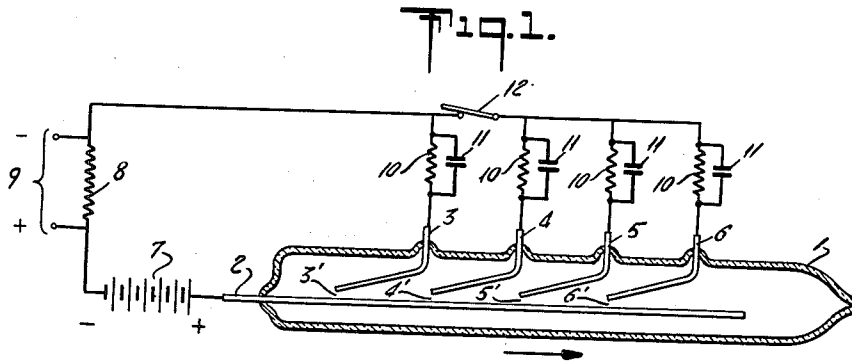
Aug. 24, 1954

N. B. WALES, JR
GASEOUS DISCHARGE REGISTER

2,687,496

Filed July 15, 1949

2 Sheets-Sheet 1



INVENTOR

Nathaniel B. Wales

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2 Sheets-Sheet 2

Fig. 3.

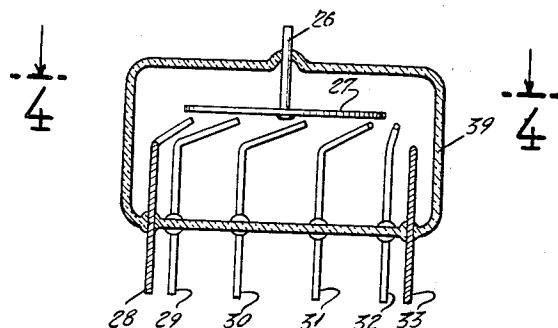
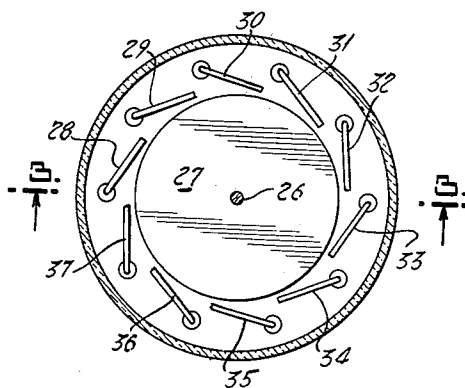


Fig. 4



INVENTOR.

Nathaniel B. Wales

UNITED STATES PATENT OFFICE

2,687,496

GASEOUS DISCHARGE REGISTER

Nathaniel B. Wales, Jr., Morristown, N. J., assignor to International Business Machines Corporation, New York, N. Y., a corporation of New York

Application July 15, 1949, Serial No. 104,980

13 Claims. (Cl. 315-167)

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This invention relates to a gaseous discharge tube which utilizes a novel method for positively displacing the position of the discharge so as to permit the controlled transfer of this discharge between a sequential plurality of cathodes.

In the art of digital calculating devices it has come to be recognized that any device having a plurality of states of stable equilibrium may be adapted to perform the operations of number storage, or of multiplex switching. In the class of such devices utilizing gaseous discharge the problem resolves to the provision of means for causing transfer of a discharge between these states of equilibrium. Further, it is desirable that such a device employ a minimum of auxiliary apparatus to enable this transfer. To this end it is also desirable that the electrical conditions at each state of equilibrium be similar, rather than progressively different, thereby obviating the need of any "resetting" device to make cyclic operation possible.

The subject invention achieves these objects by employing a common anode cooperating with a plurality of cathodes in such a way that input pulses to the system cause a positive transfer of the discharge from one cathode to the next in a direction determined by the geometry of these cathodes. The principle of this transfer means rests on the observed fact that when a gaseous discharge is made to be mutually exclusive between one of two electrodes and a third common electrode (such as by introducing a common series resistor to a common current supply) the discharge will transfer to the electrode having the higher potential relative to the common electrode providing only that adequate ions from some artificial source are present in the gas at the discharge gap between the common electrode and this higher potential electrode. My invention causes the cathode-anode potentials of the cathodes adjacent to the cathode enjoying the discharge to be higher than that of the discharge cathode simply by providing each cathode with a separate series resistor. Thus the current of discharge in passing through its private series resistor will drop the potential of this cathode relative to its neighboring cathodes. This condition is stable, however (for a suitable choice of series resistors) until some agency introduces an ion density into the gap of one of the other cathodes. The invention provides this ion density necessary for transfer by utilizing the phenomenon of cathode glow extension in conjunction with a geometry of cathode structure such as to place the breakdown point of any cathode ad-

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jacent to a position of one neighbor cathode which is more remote from its point of breakdown. In other words, the cathodes (preferably extended rod-like cathodes) each have a tip relatively close to the common anode and having the remainder of its surface progressively receding towards its "root" from the anode. Consequently, the breakdown of discharge will occur at the tip, being the shortest gap, and, for suitable pressures and currents, the cathode glow thus formed will progressively spread along the surface of the cathode away from the tip with increasing current. The potential required to sustain a glow discharge between the tip of the cathode and the anode being less than that for the region between the root and the anode so that a potential gradient exists along the length of the cathode due to its geometric arrangement. The common series limiting resistor ordinarily will limit this glow spread to a small region near the tip of this cathode. Further, each cathode tip is located so that its anode gap lies between the anode and the "root" of one of the adjacent cathodes.

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Consequently, if a positive current pulse is impressed on the discharge current (such as by applying a voltage pulse across the common limiting resistor), the cathode glow of the discharge will spread along the given cathode towards its "root" until it transports the cathode glow into intimate proximity with the breakdown gap of the adjacent cathode. This circumstance thus satisfies the before mentioned conditions for transfer, by setting up an ion density at the higher potential gap, and transfer of the discharge is effected in the direction determined by the one of the adjacent sequential cathodes whose tip underlies the root of the originally discharging cathode. In order to guarantee the reestablishment of a stable condition of discharge after transfer, each individual cathode resistor is provided with a parallel capacitance so that transient or oscillator behaviour will be inhibited. The input pulse length must therefore be chosen with respect to the time constants of these cathode RC products.

An object of this invention is to make possible an inexpensive and compact decade counter suitable for cascade operation without auxiliary equipment.

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Another object is to provide a novel gaseous discharge storage tube of the glow transfer type wherein the extension of the glow discharge on a first cathode causes an increased ionization of the breakdown gap associated with a second

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cathode to institute a transfer of the glow discharge to the second cathode thereby effecting the storage of an electrical manifestation.

A further object is to provide a novel gaseous discharge storage tube of the glow transfer type including only a single anode and a plurality of cathodes common thereto and equal in number to the storage capacity of the tube, said cathodes being arranged so that an increase of current through a cathode in circuit with a glow discharge causes transfer of the glow discharge to a preselected adjacent cathode to effect storage of a manifestation.

Other objects are implicit in the following specification and claims.

Referring to the drawings:

Fig. 1 is the schematic diagram of a simplified form of my invention to illustrate its operation;

Fig. 2 is the schematic diagram of a toroidal form of the invention adapted for decade cascade cyclic operation;

Fig. 3 is a section in elevation of the preferred form of tube incorporating my invention; and

Fig. 4 is a plan section of the invention shown in Fig. 3 with the top portion of the envelope cut away.

The glass envelope 1 in Fig. 1 contains a gas atmosphere under a reduced pressure suitable for the phenomenon of cathode glow. The gas may be neon, hydrogen or any suitable gas or mixture or gases which will not react appreciably with the materials of the elements or envelope. The common rod anode 2 extends the length of the cylindrical tube emerging through a seal for external connection to battery 7 and series limiting resistor 8.

The cathodes 3, 4, 5, and 6 enter the tube through radial tubulations as shown, thence undergoing a bend of some appreciable radius of curvature, and sloping downward toward the anode 1 to terminate at the anode-cathode gaps 3', 4', 5' and 6' respectively. The geometry of these electrodes is such that the breakdown gap 4' of cathode 4 lies underneath or near the bend or "root" of cathode 3, and similarly, gaps 5' and 6' lie under the roots of cathodes 4 and 5 respectively. That is, the breakdown gap of each cathode lies in the proximity of that portion of the adjacent cathode which will experience cathode glow last as the discharge current for this adjacent cathode is increased. Each of the cathodes 3, 4, 5 and 6 is provided with a separate resistor 10 and capacitor 11 in parallel. The ends of the resistor-capacity pairs remote from the cathodes are normally connected together and to the limiting resistor 8. Normally closed switch 12 is provided for initially setting up the discharge on cathode 3.

In operation, the device of Fig. 1 is caused to set up a discharge on cathode 3 by the opening of switch 12. By suitable choice of resistors 8 and 10 for the given battery voltage of 7 and the pressure and electrode spacing of the tube, this discharge may be limited to a cathode glow covering only the tip of cathode 3. Under these circumstances the discharge is stable and will continue so after the closing of switch 12 due to the fact that the voltage drop in resistor 8 caused by the discharge current reduces the potentials of the other cathodes below their normal breakdown potentials with respect to the common anode. If, however, a voltage pulse is impressed across terminals 9 with the indicated polarity, the current through the discharge will rise accompanied by a corresponding extension of the

boundary of the glow on cathode 3. As this glow sheath extends its boundary, it transports a region of ion density with it until the gap 4' experiences an attendant abundance of available ions. This condition effectively lowers the breakdown voltage of gap 4', and it consequently breaks down and captures the discharge. This capture is aided by the capacitors 11 associated with cathodes 4 and 3 since the former tends to continue the high potential of cathode 4 and the latter tends to continue the depressed potential of cathode 3. Thus the instantaneous current through series resistor 8 during the very brief time when both cathodes 3 and 4 are conducting is sufficient to depress the potential of cathode 3 to the extinguishing point while cathode 4 has still adequate potential, by virtue of its capacitance 11, to sustain the discharge. Consequently, the input pulse having by now subsided, the discharge remains stably on cathode 4 since the anode-cathode gap of cathode 3 near its root has a very high breakdown potential, and since the tip gap of cathode 5 is so remote from the short glow sheath of cathode 4 in its unimpulsed condition. Subsequent input pulses on terminals 9 will similarly transfer the discharge to cathodes 5 and 6 serially, thus performing a counting operation. Evidently, the input pulse length must be properly shaped as to amplitude and duration, since a single extended pulse would cause the discharge to move through all of the cathodes in sequence.

The toroidal tube of Fig. 2 operates in an identical manner to that of Fig. 1, and represents simply the extension of the linear tube into a cyclic form. Toroidal glass envelope 14 contains the common circular anode 15 and the ten plural cathodes 16 to 25 all suitably sealed therethrough, and positioned as shown. The functions of resistors 10, capacitors 11, battery 7, limiting resistor 8 and switch 12 are all identical to the corresponding functions of the identically numbered parts of Fig. 1.

In operation, opening and closing of switch 12 sets the tube to discharge on the index cathode 16. Subsequent pulses of the polarity shown, impressed on input terminals 16 causes the discharge to transfer to the successive clockwise cathode for each pulse, until, on the tenth pulse, the discharge returns to the index cathode 16. This return of the discharge current through the resistor 10 associated with cathode 16 causes a transient voltage pulse to pass through coupling condenser 38 and to appear across output terminals 17. This output pulse is suitable for impression on a second such decade counter as an input pulse for cascade operation.

The tube structure shown in Figs. 3 and 4 is more suitable for mass production and comprises a compact execution of the principles utilized in the tubes of Figs. 1 and 2. This tube has a cylindrical (glass) envelope 39 (filled with gas under suitable pressure) terminating in a multiple pin pressing through which pass the ten cathode pins 28 to 37 in the base, and terminating in a single lead 26 supporting disk anode 27 on the top. The ten parallel cathode pins 28 to 37 are preferably made of tungsten, and undergo a bend forming the "root" of each electrode, while having a tip terminating at the point of closest approach of each cathode to the common anode. Further, the tip of each cathode lies approximately in the shortest path connecting the root of the preceding cathode to the anode disk. This geometry

thus provides the conditions necessary to utilize breakdown gap of the next adjacent cathode.

The scope of this invention is intended to cover such variations of structure incorporating its principles as are obvious to those skilled in the art. Thus, for instance, the incoming leads to the cathodes may be brought by certain geometries directly to the point of initial anode breakdown, thence passing away to a "root" which could be the tip of the cathode wires.

What I claim is:

1. In a gaseous discharge storage device of the glow transfer type the combination comprising an anode and a plurality of extended similar cathodes each representing a preselected digital value and having a first point of closest approach to said anode and a second point more remote than said first point from said anode, said first points forming a plurality of substantially equal glow discharge gaps with said anode, said cathodes being so positioned that the first said point of a given cathode lies closer to the second said point of an adjacent cathode than to the first said point of said adjacent cathode, the first point of said given cathode being intermediate the second point of said adjacent cathode and the anode; voltage means connected between said anode and cathodes to sustain a glow discharge on one of said cathodes to the exclusion of others, said glow discharge being at the first point of closest approach of said cathode to said anode; current increasing means connected to said one of said cathodes for extending the area of glow discharge along that one of said cathodes to its said second point thereby placing said glow discharge between the first point of another adjacent cathode and said anode; and voltage maintaining means connected to said another adjacent cathode for transferring the discharge from said second point of said one cathode to the first point of said another adjacent cathode and establishing a stable glow discharge between the first point thereof and said anode.

2. The gaseous discharge device set forth in claim 1 including a resistor connected in series with each of said cathodes to limit the spread of the glow discharge along the respective cathode; said voltage maintaining means comprising a capacitor connected in parallel with each resistor to establish a stable glow discharge at said first point of each cathode when said glow discharge exists thereat.

3. In a gaseous discharge device the combination comprising an anode; a plurality of cathodes sequentially spaced to form a preselected discharge path, each said cathode having a point of preferential breakdown to said anode thereby forming a breakdown gap intermediate said anode and said cathode and a portion receding from said anode, said gap being located within the space intermediate said anode and the receding portion of a cathode adjacent thereto; circuit means for establishing a stable glow discharge between a preselected cathode and said anode; and means connected between said cathodes and anode to apply an electrical manifestation to said device for causing extension of the glow discharge along said preselected one cathode to lower the breakdown potential of said breakdown gap of a preselected adjacent cathode to transfer said glow discharge directly to said breakdown gap of said preselected adjacent cathode, resistive and capacitive means connected in parallel with each other and in series with said cathode to maintain

said glow discharge in stable equilibrium across said gap.

4. In a gaseous discharge storage tube of the glow transfer type; an anode; a plurality of cathodes arranged in a closed glow transfer path and equal in number to the number of stable conditions which the tube assumes in response to electrical manifestations, each of said cathodes being substantially equally spaced from said anode at a point of closest approach thereto to establish a gap of stable glow discharge therewith, each cathode receding from said anode to a point of remote approach to establish a gap of unstable glow discharge with said anode, each gap of unstable glow discharge being adjacent the gap of stable glow discharge formed by one adjacent cathode; an impedance in series with each cathode to provide a stable glow discharge across each gap of stable glow discharge when a discharge is thereacross; voltage means connected between a preselected one of said cathodes and said anode to establish a discharge across the gap of stable glow discharge associated with said preselected cathode; and electrical means connected between said anode and said cathodes for changing the voltage therebetween to increase the size of the glow at said gap of stable glow discharge associated with said preselected cathode to extend the glow discharge to the gap of unstable glow discharge associated therewith and thereby cause said glow discharge to transfer to the gap of stable glow discharge adjacent said unstable gap.

5. In a gaseous discharge storage tube of the sequential glow transfer type having a number of stable conditions equal to the number of cathodes; an anode arranged equidistant from each cathode to form a gap of stable glow discharge therewith; means mounting said cathodes so that a portion of each, remote to said gap of stable glow discharge, is aligned in a predetermined fashion with the portion of another cathode forming a gap of stable glow discharge thereby forming a gap of unstable glow discharge to enable a transfer of the glow discharge thereacross to said gap of stable glow discharge aligned therewith; pulse means connected to said cathodes to increase the size of the glow at a gap of stable glow discharge when a pulse is applied to the cathode associated therewith so that the glow discharge includes the gap of unstable glow discharge formed by the same cathode and thereby provide a glow discharge across the gap of stable glow discharge aligned with said gap of unstable glow discharge; and impedance means connected in series with each cathode to ensure a stable glow discharge across each said gap of stable glow discharge when a glow discharge is present thereacross to effect the storage of the electrical manifestations in said tube.

6. In a gaseous discharge device, the combination comprising an anode, and plurality of cathodes positioned in sequence along a closed path, each cathode having a first area of unstable glow and a second area of stable glow, said cathodes being positioned in such a way that the area of unstable glow for one such cathode is adjacent to the area of stable glow for one of its two adjacent cathodes.

7. In a gaseous discharge device for effecting storage of electrical manifestations wherein the transfer of a glow discharge from one stable position to another indicates the storage of one electrical manifestation, a single anode, and a plurality of cathodes positioned in sequence along a closed glow transfer path, each cathode being

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physically positioned relative to the anode to generate a gradient of electric field intensity along said path for each of said cathodes when a potential difference exists between that cathode and the anode.

8. In a gaseous discharge device for effecting storage of electrical manifestations wherein the transfer of a glow discharge from one stable position to another indicates the storage of one electrical manifestation, a disc-shaped anode, and a plurality of cathodes equidistant from said anode and positioned in sequence along a closed transfer path, each cathode being unequally spaced along its length from said anode to generate a gradient of electric field intensity along said path for each of said cathodes when a potential difference exists between that cathode and the anode.

9. In a gaseous discharge device, the combination comprising an anode, a plurality of cathodes equidistant from said anode and positioned in sequence along a closed path, and means including the unequal spacing of each cathode along its length relative to the anode to generate a gradient of electric field intensity along said path for each of said cathodes.

10. In a gaseous discharge storage device of the glow transfer type wherein the preselected transfer of a glow discharge from one area of stable glow discharge to another area of stable glow discharge, via a path of unstable glow discharge, represents the storage of a predetermined value; a plurality of cathodes equal in number to the storage capacity of the device; and an anode common to each of said cathodes, each cathode being formed from a single homogeneous material and positioned unequally along its length to said anode so that a preselected portion of each cathode constitutes a path of unstable glow discharge and a different portion of

each cathode constitutes an area of stable glow discharge.

11. In a gaseous discharge registering device, the combination comprising an anode, a plurality of cathodes positioned along a closed path, each cathode having a root area of unstable glow and a tip area of stable glow, the root area of any cathode being adjacent to the tip area of one of its two adjacent cathodes, and means to momentarily maintain a lower potential on a given cathode with respect to said anode than on its adjacent cathodes causing a glow discharge to transfer to one of said adjacent cathodes.

12. In a gaseous discharge device the combination comprising an anode, and a plurality of cathode surfaces each having a region of greater radius of curvature and a region of lesser radius of curvature, said cathode surfaces being positioned along a closed path in such a way that the region of lesser radius of curvature of any such surface is adjacent to the region of greater radius of curvature for one of its two adjacent cathode surfaces.

13. The device set forth in claim 12 wherein said cathodes are positioned so that said regions of lesser radius of curvature lie closer to said anode than said regions of greater radius of curvature.

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