

Filed April 2, 1965

3,329,863

2 Sheets-Sheet 1



INVENTOR.
W. H. WITMER
BY *M. T. Pfeffer*
ATTORNEY

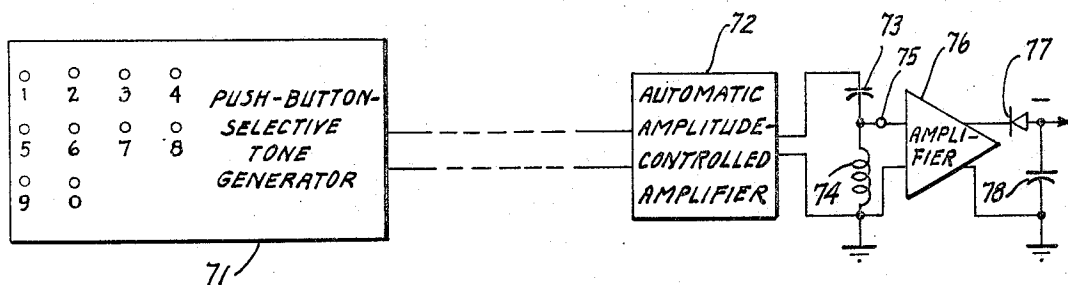
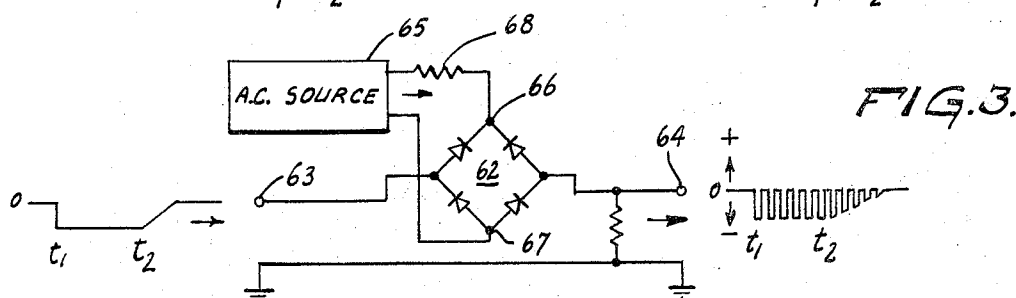
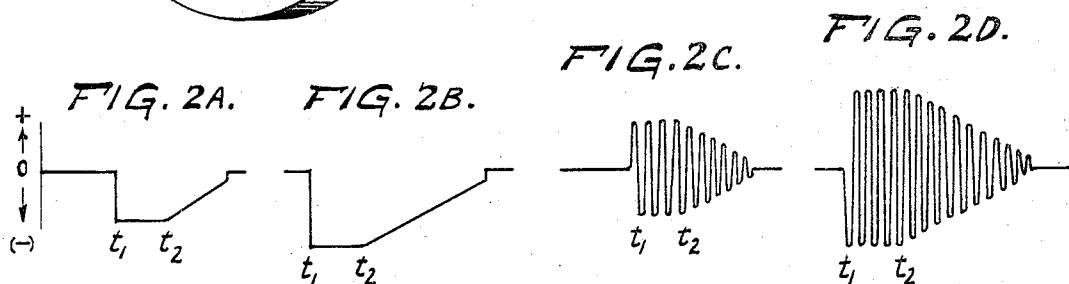
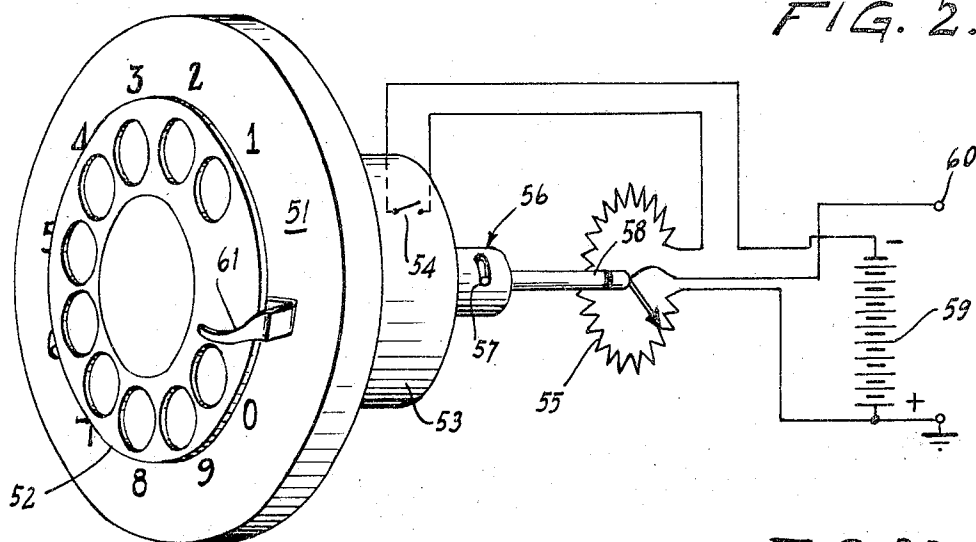
July 4, 1967

W. H. WITMER
MULTI-ELECTRODE STEPPING DEVICE REQUIRING
GRADUATED STEPPING POTENTIALS

3,329,863

Filed April 2, 1965

2 Sheets-Sheet 2



1

2

3,329,863

MULTI-ELECTRODE STEPPING DEVICE REQUIRING GRADUATED STEPPING POTENTIALS

Warner H. Witmer, Fullerton, Pa., assignor to Western Electric Company Incorporated, New York, N.Y., a corporation of New York

Filed Apr. 2, 1965, Ser. No. 445,011

10 Claims. (Cl. 315-84.6)

ABSTRACT OF THE DISCLOSURE

A multi-electrode selective-electric-path apparatus for causing current flow transfer steps in a predetermined progression in response to applied pulses, the number of steps being dependent on the pulse potential.

The present invention relates to multi-electrode gas discharge devices. More particularly, it relates to gas discharge devices of the stepping tube type, wherein a glow discharge is transferred from one electrode to the next electrode in response to an applied electrical signal.

One type of stepping tube of the prior art comprises a central round anode and a series of cathodes arranged in an annular pattern around the anode. These electrodes are positioned in an envelope containing a suitable gaseous medium at predetermined pressure for enabling a glow discharge to be established between the anode and a cathode. Alternate ones of the cathodes are stepping cathodes. They are interconnected and so arranged that by momentarily lowering the potential of the set of stepping cathodes relative to the intervening cathodes and then restoring their potential to a positive potential relative to the intervening cathodes, a glow discharge may be transferred in two steps from one of the intervening cathodes to a further one in the predetermined direction in which the glow discharge is to progress around the tube. Such a stepping tube is described in U.S. Patent No. 2,575,370, issued Nov. 20, 1951, to M. A. Townsend.

An object of the present invention is to provide electric apparatus having a multiplicity of paths for current flow, the apparatus being arranged to cause current flow in any of said paths to be superseded by current flow in a further one of said paths in a predetermined sense of progression in response to an applied transfer-inducing potential, the transfer-inducing potentials being graduated with respect to further paths in the progression.

Another object of the present invention is to provide a stepping tube arranged for selective response to a train of impulses according to the amplitude thereof.

A further object of the present invention is to provide apparatus selectively responsive to the amplitude of a series of pulses and capable of a variety of uses including indication and automatic control.

In accordance with the present invention, a stepping tube is arranged in such a way as to require progressively higher voltage pulses for accomplishing transfers of glow discharge farther along the series of cathode elements. Instead of continuing to respond to pulses in a given sequence with one pair of transfers for each pulse, the stepping tube of the present invention provides pairs of transfers in response to successive pulses only so long as the negative pulse amplitude is at least as great as the potential values required for further glow discharge transfer progression along the series of cathodes. Thereafter, further pulses of the same amplitude cannot bring about further transfers of the glow discharge. The stepping tube thus responds to the pulses by retaining its glow discharge at that output cathode corresponding to the magnitude of the pulses.

The invention will be understood more clearly and fully

from a detailed description with reference to the accompanying drawings, in which:

FIG. 1 is an illustrative embodiment of the invention with the glow discharge tube envelope shown in section;

FIG. 2 is a schematic diagram of an alternative embodiment of signalling apparatus for the glow discharge tube;

FIGS. 2A and 2B are potential graphs of the apparatus of FIG. 2;

FIGS. 2C and 2D are potential graphs of the apparatus of FIG. 2 with alternating voltage supply;

FIG. 3 is a schematic diagram of a pulse modulator suitable for use with the invention; and

FIG. 4 is a schematic diagram of a further alternative circuit usable with the stepping tube of the present invention.

Referring now to FIG. 1, the electric discharge device 30 comprises a vitreous enclosing vessel or envelope 31 having therein a central anode 23 and a series of cathodes positioned in a generally circular pattern around the anode. Within the envelope 31 is a gas suitable for use in glow discharge tubes, as for example, neon at a pressure of 50 millimeters of mercury.

A starting cathode 24 is spaced from anode 23 and arranged so that by application of a suitable potential, an initial glow discharge is established between these two electrodes. A capacitor 21 and a double-pole, double-throw switch 25 are provided along with a pair of voltage divider resistors for momentarily bringing cathode 24 to a high negative potential, to establish the glow discharge at said cathode. Cathode 20, spaced outward from cathode 24, is provided with tail part 32 extending radially inward to the vicinity of cathode 24. Proceeding clockwise around the circular array from cathode 20, cathodes 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 are output cathodes, and the intervening cathodes 11, 12, 13, 14, 15, 16, 17, 18 and 19, as well as cathode 20, are stepping cathodes. Each of the stepping cathodes is connected to a conductor 33. An output current load circuit is connected between each of the output cathodes and ground, one suitable form of load circuit, shown connected to output cathode 1, including a relay 38, zener diode 22, capacitor 28 and resistor 29, the latter elements providing a time constant longer than the interval between stepping pulses. Zener diode 22, which opposes conduction at low potentials, delays the flow of substantial current through relay 38 until the potential across the time constant circuit 28, 29 reaches a predetermined magnitude. Similar output circuits (not shown) are provided for output cathodes 2-10, inclusive. The diode 22, capacitor 28 and resistor 29 cooperate to provide sufficient time delay in the actuating current through the coil of relay 38 to allow for transfer of the glow discharge onward beyond its output cathode. Accordingly, relay 38 is actuated only if the glow discharge progresses up to its cathode and remains there. Elements 22, 28 and 29 may be eliminated by using a relay arranged for fractional-second time-delayed actuation.

A potential supply 34 comprising a transformer 40 and a conventional rectifier and filter and voltage regulator tubes 39 is arranged to apply a positive potential above ground, for example 300 volts, to a resistor 27 connected to the anode 23. The positive supply terminal also keeps capacitor 21 charged to a high potential with switch 25 in its normal position (as illustrated). When switch 25 is momentarily actuated to connect capacitor 21 between ground and the voltage divider connected to cathode 24, a glow discharge is established at the zero cathode, 24, and the stepping tube 30 is then ready to respond to suitable input signals.

The stepping cathode 20 is so arranged as to respond to a negative potential impulse by causing the glow dis-

3

charge to be transferred from the "zero cathode" 24 via tail part 32 to the large-area preferential glow discharge region of cathode 20, from which the glow discharge is further transferred to output cathode 1 at the end of the negative impulse. The stepping cathode 11 is so arranged that when a glow discharge prevails between the large-area preferential glow region of cathode 1 and the anode 23, transfer of the glow to the preferential discharge portion of cathode 11, and thence to output cathode 2, can be accomplished by the application of a negative potential impulse to transfer cathode 11.

An arrangement of cathodes for accomplishing such glow discharge transfer is described in detail in Townsend Patent No. 2,575,370. As said Townsend patent explains, by virtue of the cathode geometry and the circuit of the glow discharge device, the glow discharge is sustained between the preferential glow discharge area of one cathode and the anode until the next adjacent cathodes are made more negative than the one at which the glow discharge is occurring. While the glow discharge transfer to an adjacent cathode could occur in either direction, a lower order of magnitude of potential difference is sufficient to bring about transfer to that one of the two adjacent cathodes which has its tail portion extending to the region of the existing glow discharge. Thus, the cathode tail portions serve to "lead" the glow discharge from one cathode to the next, the glow discharge jumping to the tail portion of the next cathode ahead with a moderately greater negative potential and travelling at once along its tail to its large-area preferential glow discharge region, where it remains until the potential difference between that cathode and the next cathode in turn is such as to induce a further glow discharge transfer in the same direction, i.e., the clockwise direction in FIG. 1.

In accordance with an important feature of the present invention, the tail part 35 of stepping cathode 11 is positioned slightly less favorably with respect to the preferential glow region of output cathode 1 than is the tail part 32 of stepping cathode 20 with respect to the "zero cathode" 24. Similarly, the tail part 36 of stepping cathode 12 is disposed slightly less favorably with respect to the preferential glow discharge region of output cathode 2 than is the tail part 35 of stepping cathode 11 with respect to output cathode 1. In like manner, stepping cathodes 13, 14, 15, 16, 17, 18 and 19 have their tail parts progressively less favorably disposed, as for example, extending to progressively greater-spaced positions relative to the preferential glow regions of the respective output cathodes 3, 4, 5, 6, 7, 8 and 9. The purpose of this graduation of the spacing or other geometrical factor in the transfer attractiveness is to establish progressively higher requirements as to potential difference for accomplishing transfer of glow discharge at the successive steps around the ring. Thus, if it is only required to make stepping cathode 20 more negative than the zero cathode 24 by a three-volt potential difference, momentarily, in order to cause glow discharge transfer from cathode 24 to cathode 20, to be followed by transfer to output electrode 1, the spacing of the tail part 35 of stepping cathode 11 preferably is made slightly greater in order that a potential difference of approximately 6 volts will be required to cause transfer of the glow discharge from cathode 1 to cathode 11, followed by transfer from stepping cathode 11 to output cathode 2 at the cessation of the negative pulse on cathode 11. Similarly, a 9-volt pulse is sufficient to cause transfer via stepping cathode 12 to output cathode 3, a 12-volt pulse is sufficient to cause transfer from output cathode 3 via stepping cathode 13 to output cathode 4, and progressively higher-amplitude pulses are required to cause further steps around the ring.

By virtue of this arrangement, the electric discharge device 30 is made to function not primarily as a counting device but as a pulse amplitude sensing device. It is arranged so that it responds to a series of ten or more pulses of a given amplitude by causing the glow discharge to

4

step around to that output cathode immediately following the stepping cathode for which the pulse amplitude is just sufficient to cause glow discharge transfer from the preceding cathode. For example, taking the potential steps to be those which have been referred to in the foregoing illustration, after a glow discharge has been established between the "zero cathode" 24 and the anode 23, the application of a sequence of ten or more negative pulses of 10 volts amplitude to the conductor 33 which interconnects the stepping cathodes will cause rapid progression of the glow discharge via cathodes 20, 1, 11, 2 and 12 to output electrode 3, where it will remain despite the further 10-volt negative pulses applied to the stepping cathodes. This occurs because the 10-volt negative potential is insufficient to enable glow transfer to the slightly more widely spaced tail part 37 of stepping cathode 13 and thence to output cathode 4. By including in the circuit of each of the output cathodes a delayed-action relay like relay 38, so arranged as to be actuated only after current flow of a fraction of a second, such relays may be used to operate selective annunciator lights or complete selected telephone circuits, or for other uses.

One form of utilization circuit for the electron discharge device 30 is a push-button telephone circuit selector arrangement, as illustrated in FIG. 1. A relay 41 is arranged to be actuated through a switch 42 for supplying an alternating voltage to conductor 33 and the stepping cathodes. A push-button selector unit 43 is provided for limiting the negative half-cycles of the alternating voltage to a selected amplitude. The source of the alternating voltage supplied through relay 41 to the amplitude selecting system 43 may be either a 60-cycle sine wave source or an oscillator-amplifier circuit including oscillator 48 and amplifier 45. A selector switch 44 is arranged for selecting between the amplifier 45 and a coupling resistor 46 connected to a secondary winding terminal of the 60-cycle supply transformer 40.

With the switch 44 in the position shown, the amplifier 45 provides an alternating output voltage which substantially exceeds the highest potential available from the batteries in the amplitude selector system 43, the frequency preferably being several hundred cycles per second. When selector switch 44 is in the opposite position, it provides a similarly high amplitude supply at 60 cycles, via resistor 46.

After the switch 25 has been operated to apply high negative bias to cathode 24 and establish glow discharge between said cathode 24 and the anode 23, one of the selector buttons of unit 43 is depressed in order to determine the magnitude of the negative potential applied to the anode of diode 47. Switch 42 is then momentarily closed to actuate relay 41 and complete the circuit for the alternating voltage from resistor 46 or amplifier 45. The battery, push-button switches and diode 47 of amplitude selector 43 act as an amplitude limiter, limiting the amplitude of the negative pulses applied to conductor 33 and the stepping cathodes to the value represented by the desired push-button. It is the amplitude of the negative pulses applied to the stepping cathodes which determines how far the glow discharge will progress along the series of cathodes.

The condition with the desired push-button depressed and switch 42 closed is held for at least 10 cycles of the alternating voltage supplied to selector switch 44. In the event that the 60 cycle supply through resistor 46 is employed, the switch conditions are to be held for at least one-sixth second, so that at least 10 negative pulses will be applied in unison to the ten stepping cathodes. If amplifier 45 is used, supplied by a 200 cycle oscillator 48, for example (selector switch 44 being set as indicated in FIG. 1), then the conditions with the push-button depressed and switch 42 closed need only persist for at least 50 milliseconds.

Assuming that the push-button selected within limiter 43 provides 10 volts negative bias on diode 47, this diode

5

limits the potential supplied through relay 41 to 10 volts negative pulse amplitude, by virtue of the resistance 46 or the output resistance of the amplifier 45. The latter may be augmented by further series resistance in series with the armature of relay 41 if desired.

Assuming that the tail portions 32, 35, 36 and 37 are fixed for 3-volt, 6-volt, 9-volt, and 12-volt transfer potentials, respectively, the depression of the 10-volt selector button and the closing of switch 42 for a fraction of a second while the 10-volt selector button is depressed would result in stepping of the glow discharge around to output cathode 3, and the actuation of the output relay coupled thereto.

It will be readily apparent that for a multi-digit dial system, each output cathode of stepping tube 30 may have its relay connected to establish a circuit to a similar further stepping tube.

FIGS. 2 and 3 illustrate alternative means for signalling the stepping tube 30 with a series of stepping pulses of any of 10 predetermined amplitude values. FIG. 2 illustrates a telephone dial unit 51 comprising the usual manually operable dial 52 and the geared governor and switch mechanism 53 associated with telephone dial units. In accordance with ordinary practice, the dial unit includes switch means 54 arranged for circuit actuation only during the spring-driven, governor-controlled return of the dial 52 to its normal rest position. A potentiometer resistor 55 is coupled to the dial 52 through a lost-motion link comprising slotted bushing 56 and a radial pin 57 in potentiometer shaft 58, angularly movable in the slot of bushing 56. A battery 59 is connected across the terminals of potentiometer 55, so as to apply thereto a potential high enough to accomplish transfer of the glow discharge in the desired direction at any position in the stepping tube 30.

When the dial unit is at rest, switch 54 is open and no potential is applied to potentiometer 55. Accordingly, the output potential at the terminal 60 is zero. When the number "2" is being dialed, for example, the arm of potentiometer 55 is advanced to a 7-volt bias position. The release of the operator's finger from the "2" hole of the dial at the dial index stop 61 results in switch 54 closing and potentiometer 58 providing an output potential at terminal 60 as indicated at t_1 in FIG. 2A.

By virtue of the "lost motion" link between the slot in bushing 56 and the pin 57 in the potentiometer shaft 58, the arm of potentiometer 55 remains fixed in position (at the 7-volt position in the illustrative example) during approximately 30° of rotation of the dial 52, i.e., until time t_2 . Thereafter, the dial bushing 56 pushes the potentiometer arm back toward its rest position, at which it produces a negative output potential of approximately 1 volt negative, the switch 54 reopening as the dial 52 comes to rest. The decreasing output potential of potentiometer 55 after time t_2 is represented by the upwardly sloping portion of the graph in FIG. 2A. FIG. 2B illustrates the output voltage produced at terminal 60 as a function of time resulting from dialing the numeral "4." Again, the lost motion coupling 56, 57 between the dial 52 and potentiometer 55 provides an output voltage which remains constant from time t_1 to time t_2 , after which it decreases until the dial comes to rest and switch 54 reopens.

FIG. 3 illustrates one of many well-known circuits available for chopping an output voltage such as the output potential produced at terminal 60 in FIG. 2 into a series of pulses. A ring modulator 62 consisting of 4 diodes is connected between input terminal 63 and output terminal 64. An A.C. source 65 which may, for example, be a 200-cycle per second oscillator, is connected to the modulating terminals 66 and 67 of ring modulator 62 through a series resistor 68. When terminal 66 is positive relative to terminal 67, the four diodes in the ring modulator 62 are biased at high potential in the direction opposing their conduction of current. The ring modulator 62 at such time acts as an open switch between the input terminal 63 and the output terminal 64. On the opposite

6

half-cycle of the output of source 65, the modulator 62 acts as a closed switch, or conductive link, between input terminal 63 and output terminal 64. The waveforms shown at the left of input terminal 63 and the right of output terminal 64 illustrate the effect of the alternate closing and opening of switch 62 resulting from the alternating voltage applied thereto by the source 65. As will be readily appreciated, the amplitude of the negative pulses supplied at output terminal 64 is directly dependent upon the potential of the negative voltage supplied at input terminal 63, as for example, by the output terminal 60 of the dial-controlled potentiometer 55 of FIG. 2. With a switching oscillator frequency of 200 cycles per second and a dwell time (t_1 to t_2) of $\frac{1}{10}$ second, 20 negative pulses would occur in the time represented between t_1 and t_2 in FIG. 2A or FIG. 2B. These pulses at the output terminal 64 are suitable for application to conductor 33 (FIG. 1) which interconnects the stepping cathodes, the apparatus of FIGS. 2 and 3 thus replacing the amplifier 45, oscillator 48, resistor 46, switch 44, relay 41 and the selective amplitude limiter 43.

The apparatus of FIG. 3 may be obviated by supplying switch 54 and potentiometer 55 in FIG. 2 with an A.C. source instead of the battery 59. Using an A.C. source of a few hundred cycles, the output at terminal 60 will be as represented in FIGS. 2C and 2D for dialed numbers "2" and "4," respectively. With terminal 60 connected to conductor 33 of FIG. 1, the negative half-cycles of the alternating potential wave, at least ten of which occur at the maximum predetermined amplitude related to a dialed numeral, provide stepping of the glow discharge to the respective output cathode.

FIG. 4 illustrates yet a further signalling unit, wherein a push-button-selective tone generator 71 is arranged to produce any of ten desired output frequencies according to the depression of any of its ten control buttons. Generator 71 may comprise ten separate oscillators with inter-connected output circuits, each oscillator being provided with a push-button actuating switch. Alternatively, it may comprise an oscillator with push-button selected frequency control elements. Generator 71 supplies its output, directly or over a telephone line, to an amplitude-controlled amplifier 72. This amplifier may, if desired, comprise a multi-stage audio amplifier having an automatic volume control detector coupled to an intermediate amplifier stage, and arranged to provide variable negative bias to the control grids of variable- μ tubes used in audio amplifier stages both preceding and succeeding the AVC detector position. Alternatively, it may comprise an amplifier and fixed-biased versions of diode limiters similar to the variably biased limiter 43 of FIG. 1. Unit 72 supplies output voltage at whichever frequency is selected in tone generator 71, at a predetermined fixed amplitude. A filter comprising capacitor 73 and inductor 74 receives the output of amplifier 72 and provides at terminal 75 an alternating voltage which varies in amplitude directly with frequency.

The alternating voltage at terminal 75 may, if desired, be applied directly to the conductor 33 of FIG. 1 which interconnects the stepping electrodes, so that the stepping is carried out at the same frequency as is generated by tone generator 71 upon the depression of a selected push-button. Alternatively, the potential at terminal 75 may be amplified by amplifier 76, rectified and filtered by elements 77 and 78, and applied to a local switching or modulating circuit similar to that shown in FIG. 3, to produce the control voltage for the stepping action.

Referring once again to FIG. 1, the cathodes are susceptible of wide variation in their geometry. They may be of geometrical form corresponding to the cathodes illustrated in the aforementioned Townsend Patent 2,575,370, or may be arranged as discs with wire tails, of a type illustrated in U.S. Patent 2,780,747, issued Feb. 5, 1957, to T. M. Jackson. The speed of stepping action is dependent on the gas selected and the pressure thereof,

as taught in the Townsend patent. In providing for the graduation of the stepping potential requirements, the tails of the stepping cathodes not only may be adjusted to different lengths but may be varied in cross-section, or may be bent into different orientations, for example.

The graduated-potential stepping tube of the present invention is not limited to use for annunciation or selective circuit actuation. It is suitable for use in other apparatus, such as computing systems, wherein a variable or selectable voltage magnitude is significant.

Although specific embodiments of the invention have been shown and described, it will be understood that they are but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention.

What is claimed is:

1. A glow discharge device comprising:

an enclosure containing a low-pressure gaseous medium wherein a glow discharge is to be established; anode means in said enclosure; and

a series of cathodes juxtaposed to said anode means and each having a glow discharge preference portion and a non-preference portion,

successive cathodes in a desired direction of glow discharge progression along said series having their non-preference portions extending toward the glow discharge preference portions of the next preceding cathodes, alternate ones of said cathodes being stepping cathodes and the intervening ones being output cathodes, the first stepping cathode having its non-preference portion extending substantially to the glow discharge preference portion of the preceding cathode, and each further stepping cathode in said glow discharge progression direction having its non-preference portion less favorably arranged for inducing glow transfer from the glow discharge preference portion of the preceding cathode.

2. A glow discharge device as defined in claim 1, wherein said anode means comprises a disc and the cathodes in said series are disposed in an annular pattern adjacent the periphery of said disc, each cathode having a head and a tail, the head being the preference portion and the tail being the non-preference portion.

3. A glow discharge device as defined in claim 2, including a starting cathode positioned adjacent said disc anode means and the tail of the first stepping cathode, for establishing the starting point for each progression of the glow discharge around the annular pattern.

4. A glow discharge device comprising:

an enclosure containing a low-pressure gaseous medium wherein a glow discharge is to be established; anode means in said enclosure; and

a series of cathodes juxtaposed to said anode means and each having a glow discharge preference portion and a non-preference portion,

successive cathodes in a glow discharge progression direction along said series having their non-preference portions extending toward the glow discharge preference portions of the next preceding cathodes, alternate ones of said cathodes being stepping cathodes and the intervening ones being output cathodes, the first stepping cathode having its non-preference portion extending substantially to the glow discharge preference portion of the preceding cathode and each further stepping cathode in said glow discharge progression direction having its non-preference portion positioned relative to the glow discharge preference portion of the preceding cathode less favorably for glow discharge transfer than the preceding stepping cathode.

5. Glow discharge stepping apparatus comprising:

a glow discharge device including an enclosure containing a low-pressure gaseous medium wherein a glow discharge is to be established, anode means in said enclosure, and a series of cathodes juxtaposed to said anode means and each having a glow dis-

charge preference region and a tail portion, successive cathodes in a glow discharge progression direction along said series having their tail portions extending toward the glow discharge preference regions of the next preceding cathodes, alternate ones of said cathodes being stepping cathodes and the intervening ones being output cathodes, the first stepping cathode having its tail portion extending substantially to the glow discharge preference region of the preceding cathode and each further stepping cathode in said glow discharge progression direction having its tail portion arranged relative to the glow discharge preference region of the preceding cathode to be less conducive to glow discharge transfer than the preceding stepping cathode;

means for applying positive potential to said anode means relative to said cathodes; and

means for applying to said stepping cathodes a series of negative potential impulses relative to the output cathodes, each negative potential impulse providing a glow discharge transfer from a preceding cathode to a stepping cathode and thence to the following output cathode until an output cathode is reached from which further transfer is prevented by insufficiency of the negative potential of the further pulses.

6. Potential-responsive circuit selecting apparatus comprising:

a glow discharge device including an enclosure containing a low-pressure gaseous medium wherein a glow discharge is to be established, anode means in said enclosure, and a series of cathodes juxtaposed to said anode means and each having a glow discharge preference region and a tail portion, successive cathodes in a glow discharge progression direction along said series having their tail portions extending toward the glow discharge preference regions of the next preceding cathodes, alternate ones of said cathodes being stepping cathodes and the intervening ones being output cathodes, the first stepping cathode having its tail portion extending substantially to the glow discharge preference region of the preceding cathode and each further stepping cathode in said glow discharge progression direction having its tail portion arranged relative to the glow discharge preference region of the preceding cathode to be less conducive to glow discharge transfer than the preceding stepping cathode;

means for applying positive potential to said anode means relative to said cathodes to sustain a glow discharge between said anode means and a cathode;

means for supplying a series of negative potential pulses simultaneously to a plurality of said stepping cathodes relative to the other cathodes; and

means for fixing the negative pulse amplitude of the pulses applied to said stepping cathodes at a predetermined potential sufficient to cause glow discharge transfer to at least one of said stepping cathodes and thence to the next succeeding output cathode, but insufficient to produce glow discharge transfer beyond the output cathode at which the glow discharge is desired to be sustained.

7. Potential-responsive circuit selecting apparatus as defined in claim 6, further including electric-signal-responsive means connected to each of a plurality of said output cathodes, each said electric signal-responsive means being responsive to the electric part through a sustained glow discharge at its respective cathode in accordance with the negative pulse amplitude determined at the sending position.

8. Apparatus for selectively establishing any desired one of a plurality of circuit channels, comprising:

a glow discharge device including an enclosure containing a low-pressure gaseous medium wherein a glow discharge is to be established, anode means in

said enclosure, and a series of cathodes juxtaposed to said anode means and each having a glow discharge preference region and a tail portion, successive cathodes in a preferred direction of glow discharge progression along said series having their tail portions extending toward the glow discharge preference regions of the next preceding cathodes, alternate ones of said cathodes being stepping cathodes and the intervening ones being output cathodes, the first stepping cathode having its tail portion extending substantially to the glow discharge preference region of the preceding cathode and each further stepping cathode in said preferred direction having its tail portion arranged relative to the glow discharge preference region of the preceding cathode less favorably for glow discharge transfer than the preceding stepping cathode;

circuit-actuating relay means connected to each of said output cathodes for selectively activating the circuit associated with a given output cathode in response to a sustained glow discharge;

means for applying positive potential to said anode means relative to said cathodes for sustaining a glow discharge between said anode means and the cathode; and

means for applying simultaneously to said stepping cathodes a series of negative potential impulses relative to the output cathodes, the negative-potential amplitude of said impulses being fixed at a predetermined value sufficient to cause progression of the glow discharge along the series to a predetermined stepping cathode and the next succeeding output cathode but insufficient to cause glow discharge transfer from that output cathode to the next further stepping cathode, the circuit associated with the desired output cathode being thus activated.

9. Apparatus as defined in claim 8, wherein said means for applying a series of negative potential impulses to said stepping cathodes relative to the output cathodes comprises means for supplying at least as many negative impulses in each such series as the number of stepping cathodes in said glow discharge device.

10. Apparatus for selectively activating any desired one of several circuits, comprising:

an electric discharge device including an electron transfer medium, common electrode means for operation

with a potential of a first polarity, and a series of electrodes for operation with a potential of the opposite polarity, each of the electrodes of said series being juxtaposed to said common electrode means for electron transfer with said common electrode means through said medium;

means for substantially restricting said electron discharge device to electron transfer between said common electrode means and only one of the opposite-polarity electrodes in said series at a time;

means for extinguishing the electron transfer with one of said electrodes of said series and causing electron transfer to be established with a further one of said electrodes of said series in a predetermined direction of progression, said last-named means comprising means responsive to a change of electric potential between the active electrode of said series and electrodes of said series next adjacent thereto for unidirectional shift of the active electron transfer path to the one of said adjacent electrodes next ahead in said predetermined direction, means for establishing a higher minimum transfer potential for each succeeding shift of the active electron transfer path than the minimum transfer potential for each preceding shift in said predetermined direction, means for impressing a series of recurrent potential pulses of one potential on said electric potential change responsive means to cause the unidirectional shifting of the active electron transfer path along said series of electrodes until electron transfer is produced at an active electrode beyond which the minimum potential for a further shift exceeds said one potential, and means for selectively impressing on said electric potential change responsive means series of pulses of potential substantially different from said one potential to produce shifts along said series of electrodes extending to a different active electrode.

References Cited

UNITED STATES PATENTS

2,608,674	8/1952	Depp	-----	313—188 X
2,785,355	3/1957	Von Gugelberg	----	315—337 X

JAMES W. LAWRENCE, *Primary Examiner*.
ROBERT SEGAL, *Examiner*.