June 18, 1946. J. S. COMPTON ET AL 2,402,372

ELECTRONIC COUNTING DEVICE

Filed May 6, 1943

FIG. 1

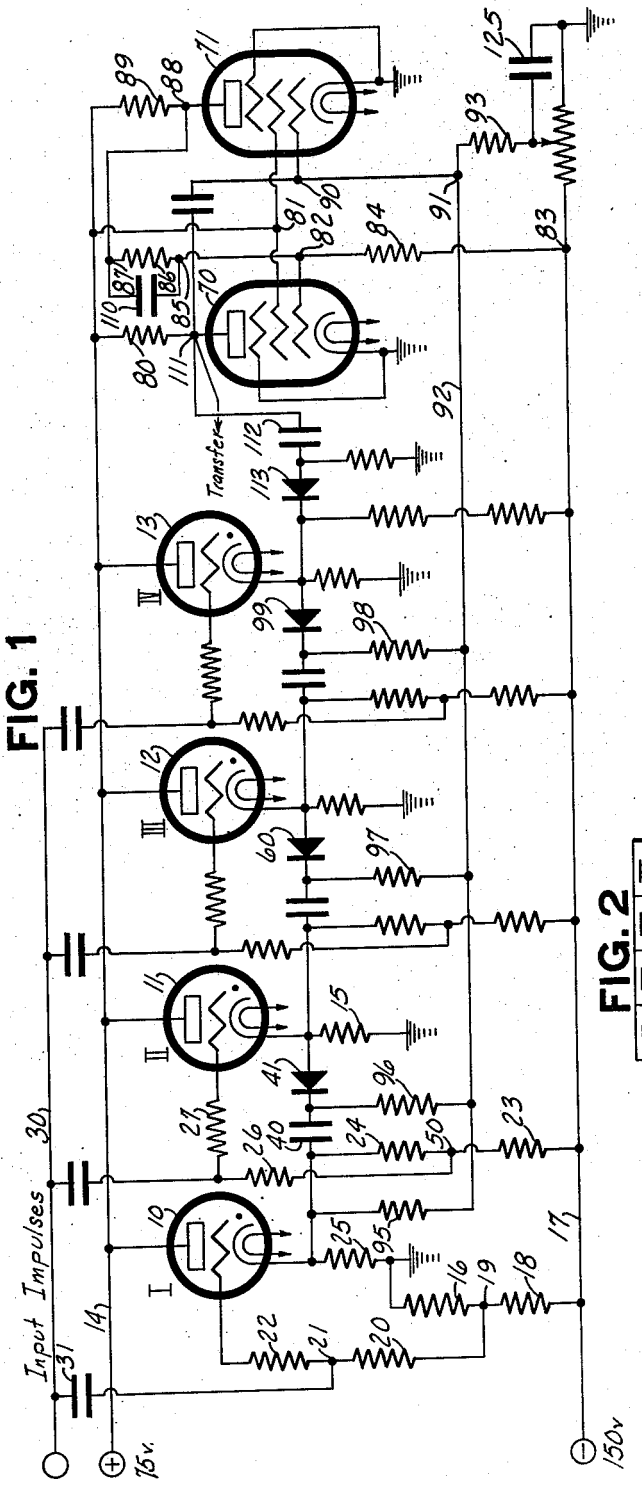

FIG. 2

	1	2	3	4	5	6	7	8	9	0
IV				X	X	X	X	X	X	
III			X				X	X	X	
II		X				X			X	X
I	X				X			X		X

Justin S. Compton and
Robert E. Mumma
Inventors

By Earl Bennett
Their Attorney

Patented June 18, 1946 2,402,372

UNITED STATES PATENT OFFICE

2,402,372

ELECTRONIC COUNTING DEVICE

Justin S. Compton, Lebanon, and Robert E. Mumma, Dayton, Ohio, assignors to The National Cash Register Company, Dayton, Ohio, a corporation of Maryland

Application May 6, 1943, Serial No. 485,850

15 Claims. (Cl. 315—323)

1

This invention relates to an electronic counting device wherein four counting tubes may be used to count up to ten.

The electron tubes are of the gaseous type and are connected in a circuit so that, upon receipt of electric impulses commonly impressed on the tubes, they will be actuated differentially serially and cyclically, so that the accumulated count is determined by the position of the tube or tubes that are in a conducting state. Upon the receipt of the tenth count, the tubes are automatically reset to a zero-representing state, wherein the tubes are non-conducting.

It is the principal object of the invention to provide a decimal electronic counting device based on a four-place combination code.

Another object of the invention is to provide means to differentially actuate a group of electron tubes by impulses which cause said tubes to be discharged in a diminishing cyclic operating pattern, step by step, wherein one or more tubes may be in a conducting condition at a given instant.

Another object of the invention is to provide novel unidirectional extinguishing means for operating a chain-connected group of electron tubes serially.

With these and incidental objects in view, the invention includes certain novel features of circuits and circuit elements, the essentials of which are hereinafter set forth in appended claims and a preferred form or embodiment of which is hereinafter described with reference to the drawing which accompanies and forms a part of this specification.

In the drawing:

Fig. 1 is a diagram of the circuit and elements of the counting device.

Fig. 2 is a representation of the four-place code used in representing the decimal system wherein the "X" represent conducting tubes.

General description

Four electron gas discharge tubes 10, 11, 12, and 13 (Fig. 1) of the triode type are supplied with anode potential of 75 volts, with reference to ground, through a conductor 14. (These gas tubes may be of the 2C4 type.) The cathode of each tube is grounded through a resistor like resistor 15 of 15,000 ohms.

The grid of tube 10 is normally supplied with a negative potential of 25 volts with respect to ground by being connected through resistor 16 of 25,000 ohms to ground and to a 150-volt negative supply conductor 17, through a 125,000-ohm

2

resistance 18. The point 19 is connected to the grid of said tube 10 through a resistor 20 of 500,000 ohms, point 21, and resistor 22 of 50,000 ohms.

The grids of tubes 11, 12, and 13 are given a normal negative bias of about 65 volts with respect to ground by being connected to conductor 17 through a resistor of 150,000 ohms, like resistor 23, and connected to ground through a 100,000-ohm resistor, like resistor 24, in series with the 15,000-ohm cathode resistor 25. Resistors like resistors 26 and 27 have the same value for all the tubes 10, 11, 12, and 13. The grid of each of the tubes 10, 11, 12, and 13 is connected to input impulse conductor 30 through an individual capacitor like capacitor 31 of 10 micro-microfarads to a point corresponding to point 21. Between the cathodes of tubes 10 and 11 is a capacitor 40 of approximately .005 microfarad in series with a rectifier oriented to pass positive impulses from the cathode of tube 11 to the cathode of tube 10. Similar chain connections are made between the cathodes of tubes 11 and 12, and between the cathodes of tubes 12 and 13, positive impulses produced anywhere on said chain passing toward the beginning of the chain as represented by the cathode of tube 10.

On application of a positive potential impulse of approximately 25 volts on conductor 30, assuming that no tube is conducting, the tube 11 will become conducting, as its grid is near enough the critical point to lose control on receipt of such impulse. Tubes of the type mentioned fire when the associated grid is at any potential more positive than about 12 volts negative with respect to the cathode potential. This is condition "1" shown in Fig. 2, wherein the I tube 10 is conducting, it being assumed that all of tubes 10, 11, 12, and 13 are non-conducting at the beginning of an operation. However, as tube 10 becomes conducting, its cathode rises in potential almost 60 volts, to within 15 volts of the anode potential, which changes the potential of the grid of tube 11, as the cathode of tube 10 is connected to grid biasing point 50, to about 25 volts negative with respect to the cathode of the II tube 11.

On the next positive impulse received on conductor 30, the II tube 11 will therefore become conducting, and a positive impulse caused by the rise in its cathode potential will be conveyed through rectifier 41 and capacitor 40 to the cathode of the I tube 10, causing it to overshoot the anode potential, thus extinguishing tube 10. This is condition "2" shown in Fig. 2, wherein only

the II tube 11 (Fig. 1) is left conducting. On receipt of the next impulse, tubes 10 and 12 will become conducting (as tube 10 is always ready to conduct on receipt of an impulse if not then conducting and the III tube 12 is primed to become conducting by reason of the II tube 11 having been conducting). As the III tube 12 becomes conducting, the impulse caused by the rise in potential of its cathode is conveyed through the rectifiers 60 and 41 to extinguish tubes 10 and 11. This is condition "3" shown in Fig. 2. On receipt of the fourth impulse, tubes 10 and 13 become conducting, and tubes 10 and 12 are extinguished as the positive rise in potential of the cathode of tube 13 is transmitted through rectifiers 99, 60, and 41 and their associated capacitors. On receipt of the fifth impulse, tube 10 becomes conducting and stays conducting, and tube 13 also stays conducting, as the positive extinguishing impulse originating at the cathode of tube 10 is ineffective, as it cannot go through the rectifiers toward the right (Fig. 1). All the conditions shown in Fig. 2 are gone through as the input impulses are received until at the end of ten impulses that portion of condition "0" (Fig. 2), wherein all the four tubes are conducting for the first time, is in effect. This first part of condition "0" is in effect for an instant only, as thereafter all the tubes are extinguished by the action of tubes 70 and 71 sending an extinguishing impulse through rectifier 113 and capacitor 112, as will next be described.

Vacuum type electron tubes 70 and 71 (which may be of the 6AG7 type) each have their cathodes grounded and have their anodes connected to the 75-volt positive supply conductor 14, each through a resistor like resistors 80 and 89 of 3,000 ohms each. Each vacuum tube has a screen grid connected to the 75-volt positive conductor 14 through point 81. Each vacuum tube has a suppressor grid connected to its cathode. Tubes 70 and 71 each have a control grid. The control grid of tube 70 is connected through point 82, resistor 84 of 150,000 ohms, and point 83 to the 150-volt negative supply conductor 17, and is connected through point 82, point 85, resistor 86 of 50,000 ohms, point 87, point 88, and resistor 89 of 3,000 ohms to the positive 75-volt supply conductor 14, which gives the said control grid of tube 70 a normal potential of about 20 volts positive with respect to the cathode, which causes said tube to be normally conducting.

The vacuum tube 71 is normally non-conducting, as its control grid is connected through point 90 and point 91 to conductor 92, which is connected through resistor 93 of 250,000 ohms to 25,000-ohm potentiometer 94, which grounds the negative 150-volt conductor 17. Conductor 92 is connected to the cathode of the I tube 10 through the 500,000-ohm resistor 95; is connected to the cathode of the II tube 11 through 500,000-ohm resistor 96 and rectifier 41; is connected to the cathode of III tube 12 through 500,000-ohm resistor 97 and rectifier 60; and is connected to the cathode of the IV tube 13 through 500,000-ohm resistor 98 and rectifier 99. Under these circumstances, when no tube of tubes 10, 11, 12, and 13 is conducting, the potentiometer is adjusted so that point 91 and the control grid of tube 71 are at 40 volts negative potential with respect to ground, and hence tube 71 is normally non-conducting. As one tube of the four 10, 11, 12, and 13 is conducting, point 91 becomes less negative to 30 volts negative with respect to ground; with two tubes, of tubes 10, 11, 12, and 13, conducting, point 91 will be 20 volts negative; with three tubes, of tubes 10, 11, 12, and 13, conducting, point 91 will be 10 volts negative; and with the four tubes 10, 11, 12, and 13 conducting (which is the 0 condition), point 91 will be at ground potential and tube 71 will commence to conduct. As soon as tube 71 commences to conduct, its anode drops in potential to about 15 volts positive due to the effect of resistor 89, which transmits a sharp negative impulse through points 88 and 87, through resistor 86 in parallel with capacitor 110, of .005 microfarad, and points 85 and 82 to the control grid of tube 70, stopping conduction therein, which causes a sharp positive potential impulse at point 111, which positive impulse is transmitted, through capacitor 112 of .005 microfarad and rectifier 113, to the cathodes of all the tubes 10, 11, 12, and 13, extinguishing them.

The internal capacity of the rectifiers 113, 99, 60, and 41 must be kept as small as necessary to convey the extinguishing impulses unidirectionally. If desired, diode vacuum electron tubes may be used as rectifiers, but low-capacity rectifiers of other types will do.

As soon as all the tubes are extinguished, which condition is shown on the bottom line of condition "0" (Fig. 2), tube 71 will again have a controlling bias on its control grid, stopping conduction therein. Tube 70 will therefore begin to conduct. The capacity connection of .005 microfarad of the control grid of tube 71 with the anode of tube 70 is provided to produce a rapid change in the mode of operation of tubes 70 and 71, which act as a modified trigger pair.

The circuit values have been given for illustration only, in connection with the characteristics of certain tubes mentioned, and they are not deemed to limit the principle of the invention.

It is to be observed, that in counting to ten, the tubes are operated serially in four cycles, each of which cycles has one less tube changing its operating condition. In the first cycle, tubes I, II, III, and IV are fired. In the second cycle, tubes I, II, and III are fired. In the third cycle, tubes I and II are fired. In the fourth cycle, tube I is fired alone.

The potential rise at point 111 as tube 70 ceases conducting may be used to cause a positive input impulse upon the input conductor to another higher denominational counting device, like the one shown in Fig. 1, to actuate it one step for each ten impulses introduced into the lower denomination. Thus a multiple denominational counting device is provided. The next higher denomination counting device need not necessarily be of the type herein described if it is responsive to such a denominational carry over electric impulse.

Capacitor 125 of 4 microfarads is introduced for filtering purposes.

It will be obvious to those skilled in the art that the extinguishing circuits including the rectifiers and capacitors may be used to connect the anodes together if the resistance in the anode-cathode supply circuits is placed in the anode branch and the rectifiers oriented to pass negative impulses toward the beginning of the counting chain.

The condition of conduction of the tubes may be sensed by the difference in cathode potential between the conducting and non-conducting states of a tube and the count translated into the decimal system by use of the chart of Fig. 2.

While the form of the invention herein shown and described is admirably adapted to fulfill the

objects primarily stated, it is to be understood that it is not intended to confine the invention to the one form or embodiment herein disclosed, for it is susceptible of embodiment in various forms all coming within the scope of the claims which follow.

What is claimed is:

1. In combination, a plurality of gaseous discharge electron tubes each having at least an anode, a cathode, and a control grid; means supplying anode-cathode potential to each tube sufficient to maintain conduction therein, said means including a resistance in each cathode supply; means for supplying normal potential to the grids more negative than the critical point of said tubes, the potential supplied to one of the grids being nearer the critical point than that of the other grids; means to impress positive electric impulses commonly on all of the grids sufficient to cause conduction in said one tube whose grid is nearest the critical point; means connecting the tubes in a chain cathode to grid, the first of the tubes in the chain being the one with its potential nearest the critical point, the cathode rise of a conducting tube causing the next tube in the chain to be responsive to the next received impulse by becoming conducting; and means connecting the cathodes of said tubes in a chain which includes a rectifier in series in said connection between each two adjacent tubes of the chain, said rectifiers being oriented to pass positive electric impulses toward the first tube of the chain whereby to extinguish any conducting tube between a tube commencing conduction and the first of the chain.

2. A plurality of gaseous discharge electron tubes; means supplying them with operating potential; means normally preventing conduction in any tube; means to impart electric impulses to the preventing means of all the tubes which impulses tend to render the preventing means ineffective to all the tubes and the first or any subsequent impulse of which means causes a first one of such tubes to conduct if not then conducting; chain connections between the tubes whereby the condition of conduction of a tube renders the next tube in the chain to such conducting tube conducting on receipt of the next impulse; and extinguishing connections between the tubes whereby the act of conduction commencing in any tube immediately thereafter renders all preceding tubes of the chain non-conducting whereby upon receipt of a number of impulses equal to

$$\frac{N(N+1)}{2}$$

where N equals the number of tubes, all of the tubes will be conducting.

3. A plurality of gaseous discharge electron tubes; means supplying them with operating potential; means normally preventing conduction in any tube; means to impart electric impulses to the preventing means of all the tubes which tend to render the preventing means ineffective to all the tubes and the first or any subsequent impulse of which causes a first one of such tubes to conduct if not then conducting; chain connections between the tubes whereby the condition of conduction of a tube renders the next tube in the chain to such conducting tube conducting on receipt of the next impulse; extinguishing connections between the tubes whereby the act of conduction commencing in any tube immediately thereafter renders all preceding tubes of the chain non-conducting whereby upon receipt of a number of impulses equal to

$$\frac{N(N+1)}{2}$$

where N equals the number of tubes, all of the tubes will be conducting; and means operative when all the tubes are conducting to cause all of them to become non-conducting.

4. A plurality of gaseous discharge electron tubes; means supplying them with operating potential; means normally preventing conduction in any tube; means to impart electric impulses to the preventing means of all the tubes which tends to render the preventing means ineffective to all the tubes and the first or any subsequent impulse of which causes a first one of such tubes to conduct; chain connections between the tubes whereby the condition of conduction of a tube renders the next tube in the chain to such conducting tube conducting on receipt of the next impulse; extinguishing connections between the tubes whereby the act of conduction commencing in any tube immediately thereafter renders all preceding tubes of the chain non-conducting whereby upon receipt of a number of impulses equal to

$$\frac{N(N+1)}{2}$$

where N equals the number of tubes, all of the tubes will be conducting; and an electron tube having an anode, a cathode, and a control grid arranged in the potential supply means so as to be conducting always except when all the chain connected tubes are conducting.

5. A plurality of gaseous discharge electron tubes; means supplying them with operating potential; means normally preventing conduction in any tube; means to impart electric impulses to the preventing means of all the tubes which tends to render the preventing means ineffective to all the tubes and the first or any subsequent impulse of which causes a first one of such tubes to conduct; chain connections between the tubes whereby the condition of conduction of a tube renders the next tube in the chain to such conducting tube conducting on receipt of the next impulse; extinguishing connections between the tubes whereby the act of conduction commencing in a tube immediately thereafter renders all preceding tubes of the chain non-conducting whereby upon receipt of a number of impulses equal to

$$\frac{N(N+1)}{2}$$

where N equals the number of tubes, all of the tubes will be conducting; a vacuum electron control tube having an anode, a cathode, and a control grid arranged in the potential supply means so as to be normally conducting except when all the chain connected tubes are conducting and having a resistance in its anode supply circuit; and means connecting the anode to the extinguishing connections so that the positive rise in potential of the anode as the control tube becomes non-conducting will cause all of the chain connected tubes to become non-conducting.

6. A plurality of gaseous discharge electron tubes; means supplying them with operating potential; means normally preventing conduction in any tube; means to impart electric impulses to the preventing means of all the tubes which

tends to render the preventing means ineffective to all but a first one of such tubes which is actually caused to conduct; chain connections between the tubes whereby the condition of conduction of a tube renders the next tube in the chain to such conducting tube conducting on receipt of the next impulse; extinguishing connections between the tubes whereby the act of conduction commencing in a tube immediately thereafter renders all preceding tubes of the chain non-conducting whereby upon receipt of a number of impulses equal to

$$\frac{N(N+1)}{2}$$

where N equals the number of tubes, all of the tubes will be conducting; a vacum electron control tube having an anode, a cathode, and a control grid arranged in a potential supply circuit so as to be normally conducting except when all the chain connected tubes are conducting and having a resistance in its anode supply circuit; and means connecting the anode to the extinguishing connections so that the positive rise in potential of the anode as the control tube becomes non-conducting will cause all of the chain connected tubes to become non-conducting, said control tube again becoming conducting as all the chain connected tubes become non-conducting.

7. A plurality of gaseous discharge triode electron tubes; electric supply means for said tubes sufficient to maintain conduction in any tube, the supply means for a tube including resistance; electric bias supply means for normally preventing a discharge in any of said tubes; electric impulse input means common to said tubes tending to render said tubes conducting but normally insufficient to do so to any but a first tube of the plurality; means interconnecting the tubes into an operative chain whereby the condition of conduction in a tube primes the next tube of the chain to become conducting on receipt of the next impulse despite the bias; and connections between the tubes operative by reason of said resistance for extinguishing a preceding tube in the chain but not a succeeding tube in the chain as any given tube becomes conducting, thus causing the tubes to become conducting cyclically and becoming conducting serially in a given cycle, each said cycle having one less tube in the serial operation until the last cycle, when all the tubes are left conducting.

8. A plurality of gaseous discharge triode electron tubes; electric supply means for said tubes sufficient to maintain conduction in any tube, the supply means for a tube including resistance; electric bias supply means for normally preventing a discharge in any of said tubes; electric impulse input means common to said tubes tending to render said tubes conducting but normally insufficient to do so to any but a first tube of the plurality; means interconnecting the tubes into an operative chain whereby the condition of conduction in a tube primes the next tube of the chain to become conducting on receipt of the next impulse despite the bias; connections between the tubes operative by reason of said resistance for extinguishing a preceding tube in the chain but not a succeeding tube in the chain as any given tube becomes conducting, thus causing the tubes to become conducting cyclically and becoming conducting serially in a given cycle, each said cycle having one less tube in the serial operation until the last cycle, when all the tubes are left conducting; and automatic means to extinguish all the tubes immediately they all become conducting.

9. In combination, four gaseous discharge electron tubes; circuits supplying operating energy to each tube; circuits for supplying conduction-controlling energy to each tube; connections forming the tubes into an operative chain, the condition of conduction in a tube causing the tube next in the chain to be primed for conduction; means connecting the tubes so that conduction commencing in one tube will stop conduction in any preceding tube of the chain; and input impulse circuits common to the tubes which, when impressed with an impulse, cause conduction in the first tube and any primed tube of the chain, whereby, if an operation is started with all the tubes non-conducting, then, on the receipt of ten input impulses, all the tubes are left in a conducting condition.

10. In combination, four gaseous discharge electron tubes; circuits for supplying operating energy to each tube; circuits for supplying conduction-controlling energy to each tube; connections forming the tubes into an operative chain, the condition of conduction in a tube causing the tube next in the chain to be primed for conduction; means connecting the tubes so that conduction commencing in one tube will stop conduction in any preceding tube of the chain, input impulse circuits common to the tubes which, when impressed with an impulse, cause conduction in the first tube and any primed tube of the chain, whereby, if an operation is started with all the tubes non-conducting, then, on the receipt of ten input impulses, all the tubes are left in a conducting condition; and automatic means to stop conduction in all the tubes when all the tubes are in a conducting condition.

11. In combination, four gaseous discharge electron tubes; circuits for supplying operating energy to each tube; circuits for supplying conduction-controlling energy to each tube; connections forming the tubes into an operative chain, the condition of conduction in a tube causing the tube next in the chain to be primed for conduction; means connecting the tubes so that conduction commencing in one tube will stop conduction in any preceding tube of the chain; input impulse circuits common to the tubes which, when impressed with an impulse, cause conduction in the first tube and any primed tube of the chain, whereby, if an operation is started with all of the tubes non-conducting, then, on the receipt of ten input impulses, all the tubes are left in a conducting condition; and electronic means to temporarily stop conduction in all the tubes between the receipt of the tenth and eleventh impulses.

12. In combination, two vacuum electron tubes arranged in a circuit wherein one is normally conducting and one is normally non-conducting; connections between the normally non-conducting tube and the conducting tube for reversing the state of conduction of the pair if the non-conducting tube is caused to conduct; a plurality of gaseous discharge electron tubes; and a resistance network interconnecting the plurality of gaseous discharge tubes, the normally non-conducting vacuum tube, and a source of potential so that when all the plurality of gaseous tubes, but not any less number, are conducting, the normally non-conducting tube is caused to conduct.

13. In combination, a plurality of gaseous discharge electron tubes; an adjustable resistance network connecting said tubes to a supply of elec-

tric energy so that conduction in said tubes changes the potential at a certain control point in said network according in degree to the number of tubes conducting; means when operative for extinguishing any conducting tubes; and means connecting the control point to the extinguishing means to cause the extinguishing means to operate when the control point reaches a certain potential.

14. In combination, a plurality of electron gas discharge tubes each having at least an anode, a cathode, and a control grid; means supplying anode potential to said tubes; means supplying cathode potential to said tubes including a resistance in series with each cathode, and said anode-cathode potential being sufficient to maintain conduction in said tubes; means to supply a normally controlling bias potential to each tube, that supplied to a first tube being less than the uniform controlling potential supplied to the remainder of the tubes; means to impress positive potential impulses on the grids of all the tubes so that the first tube will normally be caused to conduct and the remaining tubes will normally only tend to become conducting; connections between the cathode of one tube and the grid of another tube to form an operative chain, the act of conduction in a tube bringing the grid of the following tube to which its cathode is connected to a potential where said following tube will become conducting on receipt of the next impulse, said first tube being first in the chain; means coupling the cathodes of adjacent tubes in a chain, said couplings each having a rectifier and a capacitor in series with said rectifier oriented to pass a positive impulse only toward the beginning tube of the chain; a source of electric energy and a resistance network coupled in regular pattern to the cathodes of said tubes, said network having a control point therein whose potential

falls to a certain low potential as all the tubes become conducting; a vacuum tube arranged in a circuit so as to be normally conducting, said circuit including an anode resistor, said vacuum tube being coupled to said control point, which, when it is at said certain low potential, causes said vacuum tube to become non-conducting; and means including a capacitor and a rectifier in series coupling the anode of said vacuum tube and the cathode of the last tube of the chain whereby, when all the gaseous tubes are rendered conducting, the vacuum tube will be rendered non-conducting and cause all the gas tubes to be reset to a non-conducting condition, which in turn causes the vacuum tube to again become conducting.

15. In combination, a source of direct current; a plurality of electric discharge devices of the arc-like type connected in parallel circuits across said source; connections forming the devices into an operative chain, the condition of an arc in a device causing the device next in the chain to be primed for arcing; means connecting the devices so that arcing commencing in one device will stop arcing in any preceding device of the chain; and an input impulse circuit coupled commonly to the devices, which circuit, when impressed with an impulse, causes an arc in the first device of the chain and also causes an arc in any primed device of the chain, whereby, if an operation is started with all devices in a non-arcing condition, then, on the receipt of a number of impulses equal to

$$\frac{N(N+1)}{2}$$

where N equals the number of devices, all the devices will be in an arcing condition.

JUSTIN S. COMPTON.
ROBERT E. MUMMA.