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R. W. PEARSON ET AL

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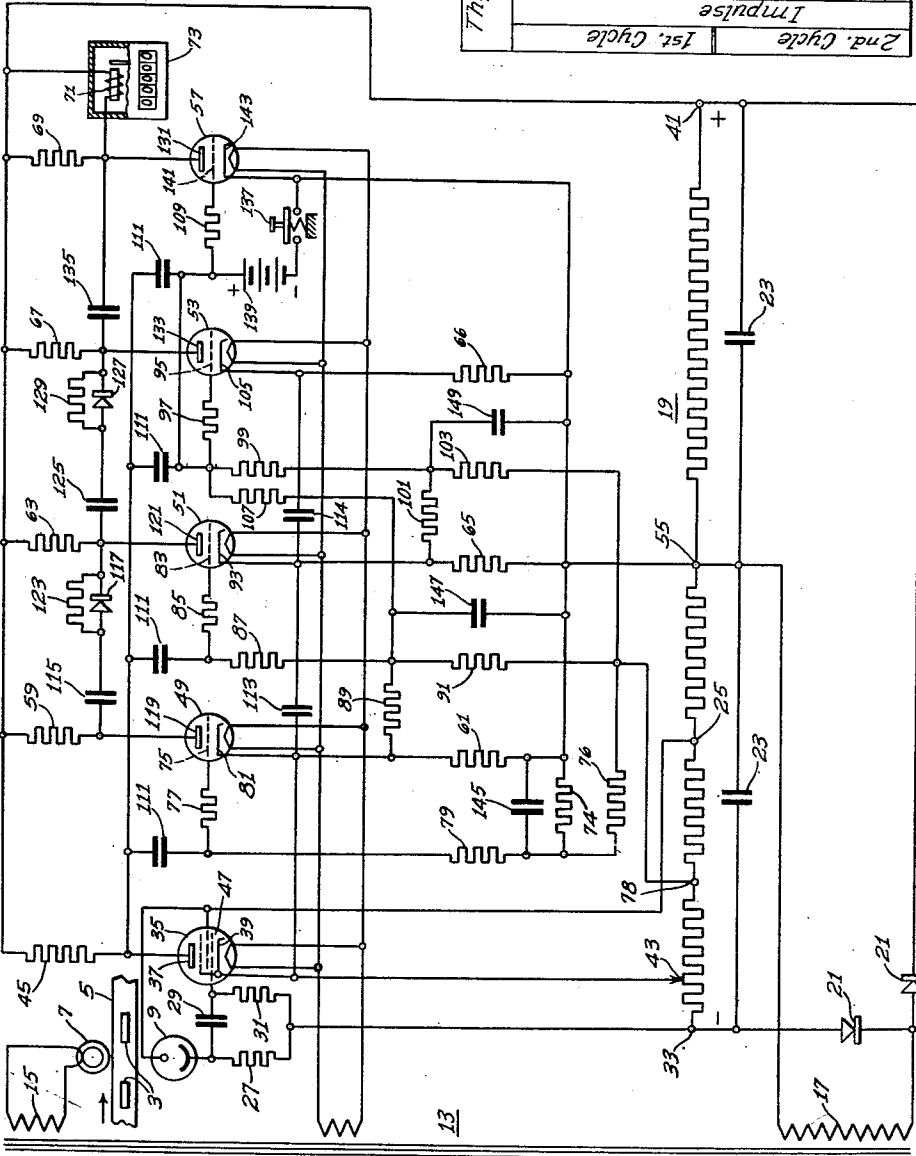
COUNTING SYSTEM

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Fig. 2.

Thyatron									
49	51	53	57						
1	X	O	X	X	X	O	X	O	X
2	X	O	X	X	X	O	X	O	X
3	X	O	X	X	X	O	X	O	X
4	X	O	X	X	X	O	X	O	X
5	X	O	X	X	X	O	X	O	X
6	X	O	X	X	X	O	X	O	X
7	X	O	X	X	X	O	X	O	X
8	X	O	X	X	X	O	X	O	X
1	X	O	X	X	X	O	X	O	X
2	X	O	X	X	X	O	X	O	X
3	X	O	X	X	X	O	X	O	X
4	X	O	X	X	X	O	X	O	X
5	X	O	X	X	X	O	X	O	X
6	X	O	X	X	X	O	X	O	X
7	X	O	X	X	X	O	X	O	X
8	X	O	X	X	X	O	X	O	X

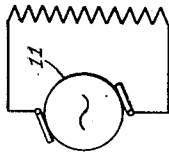
X - Conducting
O - Non-Conducting



WITNESSES:

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Fig. 1.



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COUNTING SYSTEM

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20 Claims. (Cl. 250—27)

This invention relates to a counting system and has particular relation to an electronic system for counting a plurality of moving articles.

In counting slowly moving articles, a system including an electromagnetically operated register energized once for each article under the control of a detecting mechanism, is often employed. However, when the articles are moved at high speeds past the detecting mechanism, the register cannot become deenergized between the detection of successive articles. To avoid faulty operation of the register and permit the articles to be moved at high speeds, an electronic counting system is interposed between the detecting mechanism and the register. The electronic system counts each article, but it operates the register only once for a predetermined number of articles. For example, the register may be operated once for each four articles, so that the speed of the moving articles may be four times that permissible when the register is operated once for each article.

An electronic counting system constructed in accordance with the teachings of the prior art employs a plurality of electric discharge devices of the arc-like type. The detecting mechanism is arranged to supply a potential impulse for each article to render the discharge devices conductive in succession. Each time an impulse is supplied, another discharge device is rendered conductive. When all of the discharge devices become conductive, the register is energized and the system is reset for another cycle of operation. It is then evident that the number of articles which may be counted in one cycle of operation is limited by the number of discharge devices in the system. From another viewpoint, the number of discharge devices provided must equal the number of articles to be counted in each cycle for any particular application.

It is to be noted that electronic counting systems of the type described operate satisfactorily in counting the number of articles passing a given point or other events which result in a supply of impulses from the detecting mechanism at such high speeds that several impulses must be included in each cycle of operation. The electronic counting system may also be employed to operate apparatus other than a register, such as apparatus for separating articles into groups for packaging purposes. In many possible applications of the electronic system, the advantage which may be obtained from high speed operation is offset to a large extent by the expense of providing a discharge device and its control

circuits for each article or event to be counted in a single cycle.

It is accordingly an object of our invention to provide an electronic counting system in which the number of events which can be counted thereby in one cycle of operation is considerably greater than the number of electric discharge devices employed in the system.

A more general object of our invention is to provide a new and improved electronic counting system.

Another object of our invention is to provide an electronic counting system in which at least several of the electric discharge devices are operated a plurality of times in each counting cycle.

An ancillary object of our invention is to provide a novel circuit for controlling a series of electric discharge valves.

More specifically, it is an object of our invention to provide apparatus for operating a work device upon a certain event occurring a predetermined number of times.

In accordance with our invention, a series of electric discharge devices of the arc-like type, preferably thyratrons, are connected in parallel circuits across a source of direct current. These devices may be designated as counting thyratrons. Control circuits for impressing a biasing potential on each counting thyatron to maintain it non-conductive are so arranged that the biasing potential on each thyatron after the first in the series is greater than the biasing potential on the preceding thyatron. A detecting mechanism is provided to impress a potential impulse in the control circuits of the counting thyratrons each time the event to be counted occurs. Each potential impulse supplied from the detecting mechanism is of such polarity as to oppose the biasing potentials of the counting thyratrons, but is of such magnitude as to overcome the biasing potential of the first thyatron only, to render it conductive. However, as each thyatron becomes conductive, the current flowing therethrough causes the biasing potential on each of the succeeding thyratrons to be reduced. The values of the biasing potentials are such that each thyatron is rendered conductive by the next impulse when all of the preceding thyratrons are simultaneously conductive. Each thyatron is also interconnected with the succeeding thyatron of the series by coupling means which is operable momentarily as a thyatron is rendered conductive to render all of the preceding thyratrons non-conductive.

However, the coupling permits each thyatron to remain conductive while all of the preceding thyratrons are again rendered conductive in the prescribed manner. Thus, after the first thyatron is conductive, the second thyatron becomes conductive and the first thyatron is extinguished. The first thyatron must be rendered conductive again before the third thyatron may become conductive. As the third thyatron becomes conductive, the first and second thyratrons are extinguished. It is obvious that three more impulses are required to render the first and second thyratrons simultaneously conductive, the third thyatron having remained conductive. This order of operation is continued until all of the counting thyratrons are simultaneously conductive.

A clearing device, which is also preferably a thyatron, is connected across the source of direct current in parallel with the counting thyratrons. The clearing thyatron is associated with the control circuits of the counting thyratrons in such a manner that it is rendered conductive by the next impulse when all of the counting thyratrons in the series are simultaneously conductive. The clearing thyatron is also coupled with the last thyatron in the series in such a manner that when the clearing thyatron is rendered conductive, all of the counting thyratrons in the series are rendered non-conductive. Another cycle of counting is then initiated by the next impulse. The clearing thyatron remains conductive until the last counting thyatron in the series is rendered conductive, at which time the coupling between the last thyatron and the clearing valve causes the latter to be rendered non-conductive. An electromagnetically operated register is arranged to be energized each time the clearing thyatron becomes conductive. Since the clearing thyatron becomes conductive only after all of the thyratrons in the series are simultaneously conductive, the register is energized once for each cycle of operation.

The novel features that we consider characteristic of our invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and its method of operation, together with additional objects and advantages thereof, will best be understood from the following description of a specific embodiment when read in connection with the accompanying drawing, in which:

Figure 1 is a diagrammatic view illustrating a specific embodiment of our invention; and

Fig. 2 is a table indicating the periods of conductivity of the various discharge devices.

As shown in Fig. 1, a plurality of articles 3 to be counted are carried on a conveyor belt 5 in the direction indicated by the arrow. A detecting mechanism, including a source of light 7 and a photo-sensitive cell 9, is located on opposite sides of the conveyor belt. Power is supplied to the system from a source of alternating current 11 through a transformer 13. One portion 15 of the secondary of transformer 13 is used to energize the light source 7. Another portion 17 of the secondary is used to establish a direct-current potential across a voltage divider 19 through rectifiers 21 and filter capacitors 23 connected in a manner familiar to those skilled in the art.

Light from the source 7 normally impinges upon the photo-sensitive cell 9, causing current to flow through a circuit extending from an intermediate point 25 on the voltage divider 19

through the cell 9 and a parallel circuit comprising a resistor 27 on one side and a capacitor 29 and resistor 31 on the other side to the negative terminal 33 of the divider. An amplifier 35, preferably a pentode tube, has its anode 37 and its cathode 39 connected between a positive terminal 41 and an intermediate terminal 43 of the divider through a resistor 45. The control circuit of the pentode 35 extends from its control electrode 47 through resistor 31 to the negative terminal 33 of the divider and from the intermediate terminal 43 to the cathode 39. While the photo-sensitive cell 9 remains conductive, the biasing potential on the control electrode 47 is such that the anode-cathode impedance of the pentode is low. However, when an article passes between the source of light 7 and the cell 9, the latter becomes non-conductive and capacitor 29 discharges through resistors 27 and 31. The current then flowing through resistor 31 develops a potential across the resistor 31 which causes the control electrode 47 of pentode 35 to become more negative with respect to its cathode 39. As a result, the anode-cathode impedance of the pentode 35 is greatly increased.

A series of electric discharge counting devices 49, 51 and 53, preferably thyratrons, are connected in parallel circuits between the positive terminal 41 and the intermediate terminal 55 of the divider 19. A clearing device 57, also a thyatron, is likewise connected between the positive terminal 41 and intermediate terminal 55 of the divider. When the first counting thyatron 49 is conductive, current flows from terminal 41 of the divider through a resistor 59, thyatron 49 and resistor 61 to terminal 55. When the second thyatron 51 is conductive, current flows from terminal 41 of the divider through resistor 63, thyatron 51 and resistor 65 to terminal 55. Current flowing from the divider through the third thyatron 53 passes through resistors 67 and 66, and current flowing from the divider through the clearing thyatron 57 passes through resistor 69 and the operating coil 71 of an electromagnetic register 73 in parallel therewith.

A pair of resistors 74 and 76 are connected in series with each other between the intermediate terminal 55 and a more negative terminal 78 of the divider 19. The control circuit of the first thyatron 49 may then be traced from grid 75 through grid resistor 77, a resistor 79, resistor 74 and resistor 61 to the cathode 39. The control circuit of the second thyatron 51 may be traced from its grid 83 through grid resistor 85, resistor 87 and through a parallel circuit comprising a resistor 89 and resistor 61 on one side and a resistor 91 and resistors 76 and 74 on the other side, and then through a resistor 65 to the cathode 39. The control circuit of the third thyatron 53 may be traced from its grid 95 through a grid resistor 97 and through parallel circuits and resistor 66 to the cathode 39. The first of the parallel circuits in the control circuit of the third thyatron extends through a resistor 99 and parallel paths through resistor 101 and resistor 65 on one side and resistor 103 and resistors 76 and 74 on the other side. The second parallel circuit extends through a resistor 107 and parallel paths comprising resistors 89 and 61 on one side and resistors 91, 76 and 74 on the other side. A careful consideration of the control circuits of the counting thyratrons reveals that the biasing potential impressed between the grid and cathode of the second thyatron 51 is greater than that between the grid

and cathode of the first thyatron 49. Likewise, the biasing potential between the grid and cathode of the third thyatron 53 is greater than the biasing potential of the second thyatron 51. The control circuit of the clearing thyatron 57 is the same as that of thyatron 53, with the exception that the grid resistor 97 of thyatron 53 is replaced by the grid resistor 109 of the clearing valve 57.

As previously pointed out, the impedance of the pentode 35 is greatly increased each time an article interrupts the light passing from source 7 to the photo-sensitive cell 9. The anode 37 of the pentode 35 is connected to the grids of counting thyratrons 49, 51 and 53 and clearing thyatron 57 through capacitors 111 and the corresponding grid resistors. The cathode 39 of the pentode 35 is connected to the cathode of counting thyatron 49 which in turn is connected to the cathode of thyatron 51 through capacitor 113, the cathode of thyatron 51 also being connected to the cathode of thyatron 53 through capacitor 114. The functions of capacitors 113 and 114 will be described hereinafter. Thus, the increase in the potential appearing across the pentode 35 which occurs as its impedance is increased, is impressed as an impulse between the grid and cathode of each of the counting thyratrons 49, 51 and 53 and the clearing thyatron 57. The potential impulse derived from the pentode 35 is of such polarity as to oppose the biasing potentials of the counting thyratrons and the clearing thyatron, but is of such magnitude as to overcome the biasing potential of the first thyatron 49 only. However, current flowing through the first thyatron 49 after it is rendered conductive by an impulse passes through resistor 61, which is in the control circuit of the second thyatron 51. A potential is then developed across the resistor 61 which reduces the biasing potential on the second thyatron 51 so that it is rendered conductive by the next impulse from the pentode 35. The potential developed across the resistor 65 when the second thyatron 51 is conductive, and the potential developed across resistor 61 while the first thyatron 49 is conductive, together, reduce the biasing potential of the third thyatron 53 so that it is rendered conductive by the next impulse when the first and second thyratrons are simultaneously conductive.

A capacitor 115 and an asymmetric conductor are connected in series between the anode 119 of the first thyatron 49 and the anode 121 of the second thyatron 51. The asymmetric conductor comprises a dry rectifier 117 connected to offer a low resistance to current flowing toward the anode 121 of the second thyatron 51, and a resistor 123 connected in parallel with the rectifier to offer a high resistance to current flowing toward the first thyatron 49. The resistor 123 may be eliminated if a rectifier having the correct back resistance is employed. While the first thyatron 49 is conductive, the capacitor 115 is charged with its negative plate connected to the anode 119 of the first thyatron by current flowing through resistors 63 and 123, the capacitor and the first thyatron. Upon the second thyatron 51 becoming conductive, the positive plate of capacitor 115 is connected through the low resistance of rectifier 117 and thyatron 51 and capacitor 113 to the cathode 81 of the first thyatron 49. As a result, the first thyatron 49 is rendered non-conductive. When the next impulse is received from the pentode 35, the first thyatron 49 is again rendered conductive. In the

meantime, capacitor 115 has been charged in the opposite direction. However, the second thyatron 51 is not rendered non-conductive when the first thyatron again becomes conductive, because the high resistance of resistor 123 prevents capacitor 115 from applying sufficient potential between the anode 121 and the cathode 81 of the second thyatron 51 to extinguish it.

A capacitor 125 and dry rectifier 127 with resistor 129 in parallel therewith, are connected between the anodes of the second and third thyratrons in the same manner in which capacitor 115, rectifier 117 and resistor 123 are connected between the anodes of the first and second thyratrons. It is then apparent that when the first and second thyratrons are simultaneously conductive, the charge on capacitor 115 approaches zero while capacitor 125 is charged with its negative plate connected to the anodes of the first and second thyratrons. Upon the third thyatron becoming conductive, the direction of low resistance of rectifiers 117 and 127 permit the potential of the capacitor 125 to be placed across the anode and cathode of both the first and second thyatron to render them non-conductive. The resistor 129 prevents the third thyatron from being rendered non-conductive while the first and second thyratrons are being rendered conductive again.

The clearing device 57 has its anode 131 coupled to the anode 133 of the third thyatron 53 by a capacitor 135. Capacitor 135 acts in a manner similar to capacitor 125 to extinguish the first, second and third thyratrons as the clearing device is rendered conductive. However, since a rectifier is not connected between the anodes of the third thyatron and the clearing thyatron, the latter is rendered non-conductive when the third thyatron again becomes conductive.

Capacitor 145 is a filter capacitor and the capacitors 111 serve to keep the biasing potentials of the various thyratrons separated and to transmit the potential impulses from the pentode 35 to the grid and cathode of each thyatron. The capacitor 113 connected between the cathode of thyratrons 49 and 51 permits a small portion of the current flowing through thyatron 49 to pass through the resistor 65 in the cathode circuit of the succeeding thyatron 51. This current develops a potential across the resistor 65 momentarily rendering the cathode 93 of the thyatron 51 more positive, thus preventing the thyatron 51 from being accidentally rendered conductive by the sudden surge of current flowing through the resistor 61 in its control circuit when thyatron 49 first becomes conductive. Capacitor 147 also acts to reduce the effect of the surge in current through thyatron 49 on the control circuit of thyatron 51. Capacitor 114 between thyratrons 51 and 53 and capacitor 149 operate in a similar manner. It is to be noted that the charges on capacitors 113 and 114 do not oppose the action of capacitors 115 and 125.

The operation of the system may be better understood by referring to the table of Fig. 2 in connection with Fig. 1. To prepare the system for operation push button switch 137 is momentarily closed to connect the potential source 139 between the grid 141 and cathode 143 of the clearing thyatron to render it conductive and the register is thereafter set to zero. As each article 3 interrupts the light from source 7 to the cell 9, the impedance of the pentode

35 is momentarily increased. The potential appearing across the pentode 35 is transmitted to the control circuits of its thyratrons so that a plurality of articles interrupting light from the source 7 causes a series of potential impulses to be transmitted to the control circuits. The first impulse renders the first thyatron 49 conductive. The second impulse renders the second thyatron 51 conductive, at which time the capacitor 115 causes the first thyatron 49 to become non-conductive. The third impulse again renders the first thyatron 49 conductive. Because of the resistor 123, and rectifier 117, the second thyatron 51 remains conductive. Thus, after the third impulse, the first and second thyratrons are simultaneously conductive, reducing the biasing potential on the third thyatron 53 so that the fourth impulse renders it conductive. When the third thyatron 53 first becomes conductive, capacitor 125 causes the first and second thyratrons to be extinguished and capacitor 135 extinguishes clearing thyatron 57. The fifth impulse renders the first thyatron 49 conductive again. The sixth impulse renders the second thyatron 51 conductive, and capacitor 115 at the same time extinguishes the first thyatron 49 which is then rendered conductive again by the seventh impulse. Thus at the end of seven impulses, all three counting thyratrons 49, 51 and 53 are simultaneously conductive. The eighth impulse causes the clearing thyatron 57 to become conductive, energizing the register 73. The instant the clearing thyatron 57 becomes conductive, the capacitor 135 extinguishes the first, second and third counting thyratrons, and another cycle of operation is initiated by the next impulse. The third thyatron again becomes conductive upon receipt of the fourth impulse of the second cycle, and capacitor 135 thereupon renders the clearing thyatron 57 non-conductive. The eighth impulse of the second cycle again renders the clearing thyatron conductive to again energize the register 73. Thus the register is reenergized once for every eight articles counted.

From the foregoing description, it is obvious that the number of thyratrons preceding the clearing valve may be varied, but the number is limited by the ability of the last coupling capacitor to extinguish all of the preceding thyratrons. It is also possible to eliminate the clearing valve 57 and install some other suitable clearing means, such as a series of relays, effective to disconnect the thyratrons from the source when all of the thyratrons are simultaneously conductive. If it is desired to count a large number of impulses in each cycle, several counting systems as described may be arranged in cascade with means responsive to the conductivity of the clearing thyatron of each system to supply impulses to the next system.

Since the counting thyratrons are rendered conductive singly, the total number of impulses required to cause all of the counting thyratrons to be conductive simultaneously, which shall be designated hereinafter as t , is equal to the sum of the number of times the various counting thyratrons are rendered conductive. Because of the extinguishing arrangement, each counting thyatron is rendered conductive twice for each time the succeeding thyatron becomes conductive with the exception of the last thyatron in the series which is rendered conductive only once before all of the counting thyratrons are con-

ductive simultaneously. The last thyatron then becomes conductive once, the next to the last thyatron is rendered conductive twice, and the second from the last thyatron is rendered conductive four times and so on for n number of thyratrons. Thus, the sequence of the number of times successive thyratrons become conductive forms a geometric progression in which the first term, a , equals 1 and the common ratio r equals 2. As is well known the sum of a geometric progression

$$t = \frac{a - ar^n}{1 - r}$$

Then

$$t = \frac{1 - 1 \times 2^n}{1 - 2} = 2^n - 1 = \text{total number of impulses}$$

to cause all of n number of counting thyratrons to be simultaneously conductive. Since the clearing thyatron is rendered conductive by the next impulse after all of the counting thyratrons are simultaneously conductive, the total number of impulses included in a complete counting cycle is equal to $2^n - 1 + 1$ or 2^n where n equals the number of counting thyratrons.

Although we have shown and described a specific embodiment of our invention, we are fully aware that many modifications thereof are possible. Our invention, therefore, is not to be restricted except insofar as is necessitated by the prior art and by the spirit of the appended claims.

We claim as our invention:

1. In combination, a source of direct current, a pair of electric discharge devices of the arc-like type connected in parallel circuits across said source, means for rendering said devices conductive singly, and coupling means interconnecting said devices so that the first of said devices is rendered non-conductive upon the second device being rendered conductive later than said first device and the second device remains conductive upon the first device becoming conductive later than said second device.

2. In combination, a source of direct current, a pair of electric discharge devices of the arc-like type, each of said devices having a plurality of principal electrodes connected in an individual circuit across said source, means for rendering said devices conductive singly, and coupling means interconnecting said devices so that the first of said devices is rendered non-conductive upon the second device being rendered conductive later than said first device and the second device remains conductive upon the first device becoming conductive later than said second device, said coupling means including a capacitor and an asymmetric conductor connected in series with each other between a principal electrode of one device and the corresponding electrode of the other device.

3. In combination, a source of direct current, a pair of electric discharge devices of the arc-like type connected in parallel circuits across said source, means for rendering said devices conductive singly, and coupling means interconnecting said devices comprising extinguishing means conditioned while either of said devices is alone conductive to render said conductive device non-conductive upon the other device being thereafter rendered conductive, and means in circuit with said extinguishing means for preventing it from rendering one of said devices non-conductive but permitting it to render the other device non-conductive.

4. In combination, a source of direct current, a pair of electric discharge devices of the arc-like type, each of said devices having a pair of principal electrodes connected in an individual circuit across said source, means for rendering said devices conductive singly, and coupling means interconnecting said devices so that the first of said devices is rendered non-conductive upon the second device being rendered conductive later than said first device and the second device remains conductive upon the first device becoming conductive later than said second device, said coupling means including a capacitor and a dry rectifier connected in series between a principal electrode of the first device and the corresponding electrode of the second device with the rectifier offering its highest resistance to current flowing toward the first device.

5. In combination, a source of direct current, a pair of electric discharge devices of the arc-like type, each of said devices having a pair of principal electrodes connected in an individual circuit across said source, means for rendering said devices conductive singly, and coupling means interconnecting said devices so that the first of said devices is rendered non-conductive upon the second device being rendered conductive later than said first device and the second device remains conductive upon the first device becoming conductive later than said second device, said coupling means including a capacitor and a dry rectifier connected in series between a principal electrode of the first device and the corresponding electrode of the second device with the rectifier offering its highest resistance to current flowing toward the first device and a resistor connected in parallel with said dry rectifier, said resistor having a resistance less than the highest resistance of said rectifier.

6. In combination, a source of direct current, a pair of electric discharge devices of the arc-like type connected in parallel circuits across said source, control means tending to maintain said devices non-conductive, said control means exerting a stronger influence on the second of said devices than on the first device, means for opposing said control means at intervals, said opposing means being sufficiently strong to overcome the influence of said control means on said first device only to render it conductive, means responsive to the conductivity of said first device for reducing the influence of said control means on said second device whereby it is thereafter rendered conductive by said opposing means, and coupling means interconnecting said devices and including extinguishing means conditioned while either of said devices is alone conductive to render said conductive device non-conductive upon the other device being thereafter rendered conductive whereby said first device is rendered non-conductive when said second device becomes conductive, said opposing means being effective to against render said first device conductive, and means for preventing said extinguishing means from rendering said second device non-conductive when said first device again becomes conductive.

7. In combination, a source of direct current, a pair of electric discharge devices of the arc-like type connected in parallel circuits across said source, control means tending to maintain said devices non-conductive, said control means exerting a stronger influence on the second of said devices than on the first device, means for opposing said control means at intervals, said opposing

means being sufficiently strong to overcome the influence of said control means on said first device only to render it conductive, means responsive to the conductivity of said first device for reducing the influence of said control means on said second device whereby it is thereafter rendered conductive by said opposing means, and coupling means interconnecting said devices so that said first device is rendered non-conductive upon the second device being rendered conductive, said opposing means being effective to again render said first device conductive, said coupling means permitting said second device to remain conductive upon said first device again becoming conductive.

8. In combination, a source of direct current, a pair of electric discharge devices of the arc-like type, each of said devices having a pair of principal electrodes connected in an individual circuit across said source, control means tending to maintain said devices non-conductive, said control means exerting a stronger influence on the second of said devices than on the first device, means for opposing said control means at intervals, said opposing means being sufficiently strong to overcome the influence of said control means on said first device only to render it conductive, means responsive to the conductivity of said first device for reducing the influence of said control means on said second device so that it is thereafter rendered conductive by said opposing means, and coupling means comprising a capacitor and an asymmetric conductor connected in series with each other between a principal electrode of the first and the corresponding electrode of the second device so that said first device is rendered non-conductive upon said second device becoming conductive, said opposing means being effective to again render said first device conductive, said coupling means permitting said second device to remain conductive upon said first device again becoming conductive.

9. In combination, a source of direct current, a pair of electric discharge devices of the arc-like type, each having a pair of principal electrodes connected in an individual circuit across said source and a control electrode, control means for impressing a biasing potential between the control electrode and one of the principal electrodes of each device to maintain it non-conductive, the biasing potential on the second of said devices being greater than on the first device, means for supplying a plurality of spaced potential impulses to oppose said biasing potentials, the magnitude of each of said impulses being sufficient to overcome the biasing potential on said first device only to render it conductive, means responsive to conductivity of said first device for reducing the biasing potential on said second device so that said second device is rendered conductive by the next impulse after said first device becomes conductive, and coupling means interconnecting said devices so that said first device is temporarily rendered non-conductive upon the second device being rendered conductive, said coupling means permitting said second device to remain conductive upon said first device again becoming conductive.

10. The combination comprising a source of direct current, a series of electric discharge devices of the arc-like type connected in parallel circuits across said source, control means tending to maintain said devices non-conductive, said control means exerting a stronger influence on each device after the first than on the device

preceding it, means for opposing said control means at spaced intervals of time, said opposing means being sufficient to overcome the influence of said control means on the first of said devices only to render it conductive, means responsive to the conductivity of each device for reducing the influence of said control means on each of the succeeding devices so that each device after the first device is rendered conductive by said opposing means only when all of the preceding devices are simultaneously conductive, and means operable momentarily as each device is rendered conductive to render all of the preceding devices temporarily non-conductive.

11. The combination comprising a source of direct current, a series of electric discharge devices of the arc-like type, each having a plurality of principal electrodes connected in an individual circuit across said source and a control electrode, control circuits for said devices including means for impressing a biasing potential between the control electrode and one of said principal electrodes of each device to maintain it non-conductive, the biasing potential on each device after the first in said series being greater than on the preceding device, means for impressing said potential impulses in said control circuits in opposition to said biasing potentials, said biasing potentials being of such magnitude that said impulses counteract the biasing potential on the first device only to render it conductive, means responsive to the conductivity of each device for reducing the biasing potential on each of the succeeding devices so that each device is rendered conductive by the next impulse when all of the preceding devices are simultaneously conductive, and means operable momentarily as each device is rendered conductive to render all of the preceding devices temporarily non-conductive.

12. The combination comprising a source of direct current, a series of electric discharge devices of the arc-like type, each having a pair of principal electrodes connected in an individual circuit across said source, control means tending to maintain said devices non-conductive, said control means exerting a stronger influence on each device after the first in said series than on the preceding device, means for opposing said control means at intervals, said opposing means being sufficient to overcome the influence of said control means on the first of said devices only to render it conductive, means responsive to the conductivity of each device for reducing the influence of said control means on each of the succeeding devices so that each device is rendered conductive by said opposing means only when all of the preceding devices are simultaneously conductive, and coupling means interconnecting said devices, said coupling means being effective momentarily as each device is rendered conductive to render all of the preceding devices temporarily non-conductive.

13. Apparatus according to claim 12 in which the coupling means comprises a capacitor and an asymmetric conductor connected in series between a principal electrode of each device and the corresponding electrode of the succeeding device of said series.

14. Apparatus according to claim 12 in which the coupling means comprises a capacitor and a dry rectifier connected in series between a principal electrode of each device and the corresponding electrode of the succeeding device of said series of devices said rectifier offering its

lowest resistance to current flowing toward the succeeding device.

15. Apparatus according to claim 12 in which the coupling means comprises a capacitor and a dry rectifier connected in series between a principal electrode of each device and the corresponding electrode of the succeeding device of said series of devices, said rectifier offering its lowest resistance to current flowing toward the succeeding device, and a resistor in parallel with said rectifier having a resistance no greater than the highest resistance of said rectifier.

16. For use in operating a work apparatus upon a certain event occurring a predetermined number of times, the combination comprising a source of direct current, a series of electric discharge devices of the arc-like type connected in parallel circuits across said source, control means tending to maintain said devices non-conductive, said control means exerting a stronger influence on each device after the first of said series than on the preceding device, means responsive to each occurrence of said event for opposing said control means, said opposing means being sufficient to overcome the influence of said control means on the first of said devices only to render it conductive, means responsive to the conductivity of each device for reducing the influence of said control means on each of the succeeding devices so that each device after the first is rendered conductive by said opposing means when all of the preceding devices are simultaneously conductive, means coupling said devices together and operable momentarily as each device is rendered conductive to render all of the preceding devices temporarily non-conductive, a clearing valve connected across said source in a circuit in parallel with said parallel circuits, said clearing valve being an electric discharge device of the arc-like type associated with said control means to be rendered conductive by said opposing means when all of said series of devices are simultaneously conductive, means for coupling said clearing valve to the last device of said series so that all of the devices in said series are rendered non-conductive upon said clearing valve becoming conductive and said clearing valve is rendered non-conductive upon said last device again becoming conductive, and means for effecting an operation of said work apparatus each time said clearing valve becomes conductive.

17. Apparatus according to claim 12 in which the coupling means comprises a capacitor and an asymmetric conductor connected in series between a principal electrode of each device and the corresponding electrode of the succeeding device of said series, and which includes an electric discharge clearing valve of the arc-like type having a pair of principal electrodes connected in an individual circuit across said source, said valve being associated with said control means to be rendered conductive by said opposing means when all of said series of devices are simultaneously conductive, a second capacitor connected between a principal electrode of said valve and the corresponding electrode of the last device of said series, said second capacitor being momentarily effective to render all of said series of devices non-conductive when said valve is rendered conductive and to effect extinguishment of said valve when said last device is again rendered conductive, a work apparatus, and means for operating said work apparatus in response to current flowing through said valve.

18. In apparatus for counting a plurality of electric potential impulses, a plurality of electric discharge devices responsive to each of said impulses, and interconnecting means between said discharge devices providing for the response of a different one or a different combination of any number of said discharge devices to a series of successive impulses.

19. In apparatus for counting a plurality of electric potential impulses, a plurality of electric discharge devices responsive to each of said impulses, interconnecting means between said discharge devices providing for the response of a different one or a different combination of any number n of said discharge devices to a series 15

of successive impulses equal in number to $2^n - 1$, and means responsive to another impulse after said series for resetting said devices for response to another series of impulses.

20. In apparatus for counting a plurality of electric potential impulses, a plurality of electric discharge devices responsive to each of said impulses, and interconnecting means between said discharge devices providing for the response of a different one or a different combination of any number n of said discharge devices to a series of successive impulses equal in number to $2^n - 1$.

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