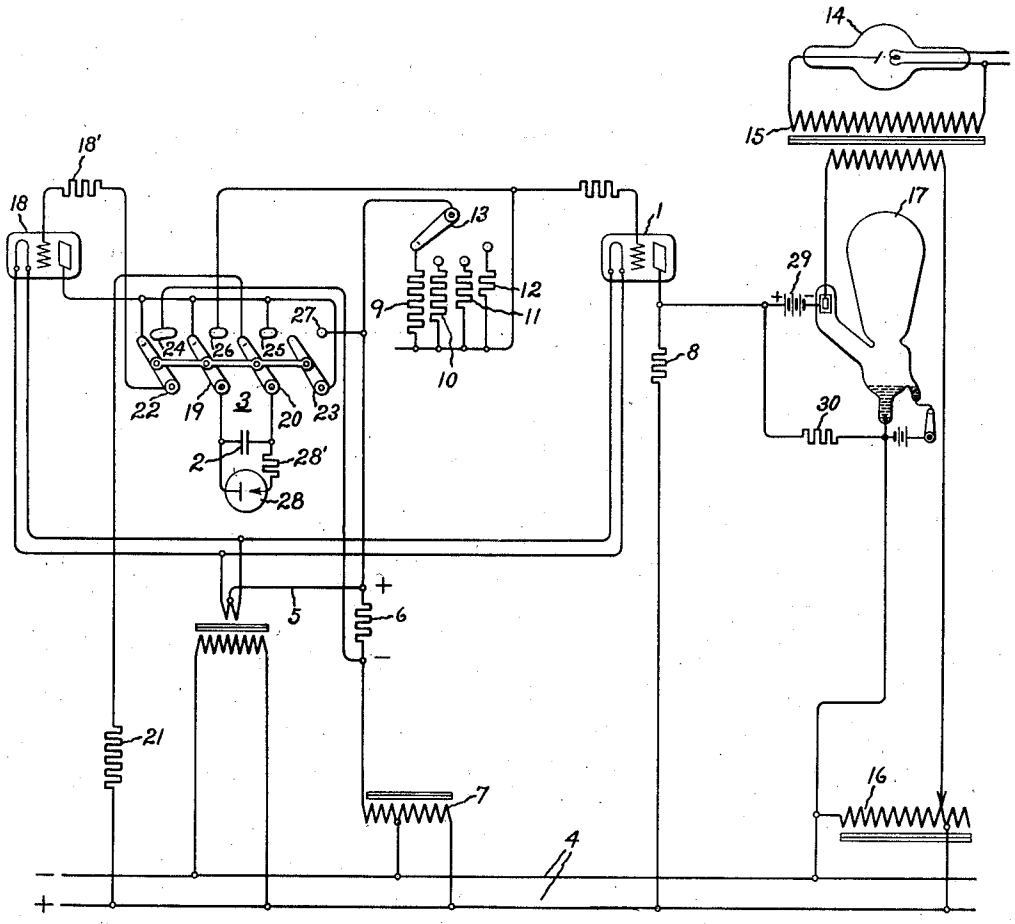
Aug. 18, 1931. W. K. KEARSLEY 1,819,999

TIME DELAY APPARATUS

Filed Oct. 28, 1930



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Patented Aug. 18, 1931 1,819,999

UNITED STATES PATENT OFFICE

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TIME DELAY APPARATUS

Application filed October 28, 1930. Serial No. 491,805.

My invention relates to time delay apparatus and more particularly to that class of time delay apparatus in which the rate of discharge of an energy storage device, such as a condenser connected between the control electrode and cathode of an electron discharge device is utilized to determine the time of operation of a control device connected in the anode circuit of the discharge device.

My invention has for one of its objects to provide time delay apparatus of the type indicated in which the time interval determined by the apparatus may be predetermined with greater accuracy than has heretofore been possible.

A further object of the invention is to provide a time delay apparatus of the type indicated which is particularly adapted for the accurate predetermination of time intervals of short duration.

In connection with equipment of the type indicated it is frequently desirable to employ discharge devices of the vapor electric type. These discharge devices have the characteristic that while the gas within the discharge device is ionized the electromotive force applied to the control electrode has no effect upon the anode current. Accordingly, the flow of anode current is independent of the grid electromotive force. However, if the anode current be interrupted, the subsequent ionization of the gas and the flow of anode current, may be prevented by the application of a suitable electromotive force to the control electrode of the discharge device.

If alternating electromotive force be applied between the anode and cathode of the vapor electric device it will be apparent that the anode current is interrupted during each alternate half cycle of the alternating current wave in which the anode is negative with respect to the cathode, and anode current flows during the opposite half cycle only if the potential of the control electrode is not such as to prevent ionization of the gas at the beginning of each of the half cycles when the anode is positive.

In accordance with my invention means are provided whereby a condenser, after being charged, is connected between the control electrode and cathode of the vapor electric device in such a way that a negative potential is applied to the control electrode having a value sufficient to prevent the initiation of anode current during a predetermined period dependent upon the rate of the discharge of the condenser. If it so happens, however, that the condenser is connected between the control electrode and cathode during a half cycle of the anode electromotive force in which the anode is positive, it will be apparent that it will have no control over the flow of anode current until after that current has been interrupted during the subsequent half cycle. At this instant, when the anode is positive, however, the impedance between the control electrode and cathode is relatively low due to ionization of the gas within the discharge device. Thus the charge on the condenser begins to leak off through the discharge device during this initial half cycle in which the condenser has no control over the anode current. The extent of this leakage is dependent upon the time during the half cycle when the connection of the condenser to the control electrode is made. Thus this discharge of the condenser prior to the control by the condenser over the anode current is likely to introduce error into the time interval to be predetermined by the condenser. When the equipment is used for purposes where the time interval predetermined by the device is small, as in determining the time of exposure of the films used in the making of X-ray photographs, these inaccuracies may be of serious consequence.

Thus a further object of my invention is to eliminate inaccuracies due to discharge of the condenser through the discharge device.

Still a further object of the invention is to provide an economical and satisfactory means whereby the above result may be accomplished.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation will

best be understood by reference to the following description taken in connection with the accompanying drawing in which the single figure represents an embodiment of my invention.

Referring to the drawing, I have shown therein an electron discharge device 1 between the control electrode, which may have the form of a grid, and cathode of which a condenser 2 may be connected by means of a multi-position switch 3 when in its right hand position. The anode of this discharge device is supplied with alternating electromotive force from a supply circuit 4 through a circuit extending from the cathode thereof through conductor 5, resistance 6, auto-transformer 7 and resistance 8 to the anode of the discharge device. Preferably this discharge device is one of the vapor electric type and is conductive upon each alternate half cycle of the alternating current wave. When the switch 3 is in its right hand position and the condenser 2 is connected between the grid and cathode of the discharge device, the initiation of anode current during each successive positive half cycle of the anode potential of the discharge device 1 is dependent upon the charge upon condenser 2. Thus for example, if condenser 2, prior to its connection to the grid of the discharge device 1, is charged with potential of such polarity that the grid of the discharge device is negative with respect to the cathode, the flow of anode current is prevented until such time as the condenser is discharged through such discharge paths as are available to it.

To control the rate of discharge of the condenser, resistances 9, 10, 11, 12, of different values, are arranged to be connected selectively in parallel with the condenser by means of a switch 13 when the switch 3 is in its right hand position.

Thus for example, if we assume that the condenser 2 is previously charged and the switch 3 is then thrown to its right hand position, the flow of anode current in the discharge device 1 is prevented for a time interval determined by the resistance 9, 10, 11, or 12, which is connected in parallel with the condenser. The device 1 thus constitutes in association with its condenser 2 and circuits a time delay relay which may be utilized for any desired purpose.

To illustrate one application of utility of my invention I have shown it as applied to the control of X-ray apparatus for the purpose, for example, of controlling the degree of exposure of the films employed. Thus in the upper right hand corner of the drawing I have illustrated an X-ray device 14 having an anode and cathode between which electromotive force is impressed by means of a transformer 15 the primary of which is energized from the supply circuit 4 through an auto-transformer 16 and an electron discharge device 17. The electron discharge device 17 preferably is one of high current carrying capacity and may, for example, comprise a vapor electric device having a cold cathode comprising a pool of mercury having any suitable means associated therewith for establishing a source of free electrons. This discharge device is provided with a grid which is connected to the cathode thereof through a circuit including a source of potential 29 and a resistance 30. The grid of device 17 is also connected to the anode of device 1 whereby the potential thereon is controlled by the potential of resistance 8, which is connected in the anode circuit of the discharge device 1. Thus for example when current flows in the anode circuit of discharge device 1 a strong negative potential is impressed upon the grid of the discharge device 17, in aiding relation with this source 29, thereby rendering this device non-conductive and deenergizing the X-ray apparatus 14. If we assume, however, that the condenser 2 is connected between the grid and cathode of the discharge device 1, and the anode current of discharge device 1 is interrupted thereby, the grid of the discharge device 17 will then be positive with respect to the cathod during the same half cycle of the alternating current wave in which the anode of device 17 is positive. The discharge device 17 is then conductive and the X-ray tube 14 is energized. Thus the X-ray tube is energized for a period determined by the rate of discharge of the condenser 2 since when condenser 2 becomes sufficiently discharged to again permit current to flow in the anode circuit of discharge device 1 the device 17 again becomes non-conductive.

To provide means for charging the condenser 2 an electron discharge device 18 is provided. This discharge device may be of any suitable construction but preferably is also of the vapor electric type. When the multi-position switch 3 is in its left hand position, this discharge device is connected in series with the condenser 2 through a circuit extending from the anode thereof through the movable switch member 19 of the switch 3, condenser 2, movable switch member 20, resistance 21, auto-transformer 7, resistance 6 and conductor 5 back to the cathode of the discharge device 18. The grid of the discharge device 18 is connected to the anode thereof through a resistance 18′ and the movable switch member 22. Thus the discharge device 18 operates as a two-element rectifier causing a unidirectional charge to be supplied to the condenser 2.

As previously pointed out, if the condenser 2 is now connected between the grid and cathode of the discharge device 1 by throwing the switch 3 to its right hand posi-

tion, and the switch members 19 and 23 engage their right hand stationary contacts during the half cycle in which the anode of the discharge device 1 is positive and the gas therein is ionized, it will have no effect upon the anode current of the discharge device 1 until the end of the succeeding half cycle. Further, as previously pointed out, unless means are provided to prevent it, the charge on condenser 2 will partially leak off through the low internal impedance of the discharge device during the initial half cycle.

To prevent this discharging of the condenser through the internal impedance of the discharge device 1 means are provided including an intermediate position of the switch 3 whereby the discharge device 18 is connected in series with the condenser 2 and the space between the grid and cathode of the discharge device 1, and whereby discharge device 18 is rendered of high impedance until the anode current in the discharge device 1 is interrupted. In this way the discharge path between the grid and cathode of discharge device 1 during the positive half cycle in which the condenser is connected to the grid thereof is interrupted.

To this end resistance 6 is included in the anode circuit of the discharge device 1. The terminal of this resistance which is at negative po ential when current flows in the discharge device 1 is connected to the grid of device 18 through the stationary contact 24 on the switch 3 and the movable switch member 22 when the switch 3 has been partially operated toward its right hand position. The terminal of resistance 6 which is at positive potential when current flows in the anode of discharge device 1 it is connected to the cathode of discharge device 18 through conductor 5. Thus when the switch member 22 is in engagement with contact 24 the potential of resistance 6 is applied directly between the cathode and grid of discharge device 18 in such a direction as to render this device of high impedance.

The cathodes of discharge devices 1 and 18 are of course directly connected together and the anode of discharge device 18 is connected to the grid of discharge device 1 in series with condenser 2 through movable switch members 19 and 20 which engage respectively right hand stationary contacts 26 and 25. The stationary contacts 24, 25, and 26 are slightly elongated so that their cooperating movable switch members engage these contacts slightly prior to engagement of the switch member 23 with the contact 27, the contact 24 being slightly longer than the contacts 25 and 26.

Thus as the switch 3 is thrown in the right and switch members 19 and 20 leave their left hand contacts, the charging circuit for condenser 2 is broken. When switch member 22 engages its right hand contact 24 the negative potential of resistance 6 is impressed between the grid and cathode of discharge device 18 thereby rendering this device non-conducting. Switch members 19 and 20 next engage their respective contacts 26 and 25 thereby connecting the discharge device 18 in series with condenser 2 and the space between the grid and cathode of discharge device 1. At this instant if current is flowing in the anode circuit of discharge device 1, the discharge of the condenser through the grid and cathode of discharge device 1 and through the resistance 9, 10, 11, 12, is prevented by the high impedance of discharge device 18. When the switch 18 finally reaches its right hand position and switch member 23 engages its contact 27 the discharge device 18 is short circuited through a circuit extending from the anode thereof, through switch member 23, contact 27, and conductor 5 to the cathode of the discharge device 18. At the same time one of resistances 9, 10, 11, 12, dependent on the position of switch 13, is connected in parallel with condenser 2 through the switch member 23 thereby finally establishing a discharge path across the condenser 2 by means of which the time interval to be predetermined may be fixed. Thus if the switch 13 is in its left hand position a longer time will be required for discharge of the condenser 2 than is required were it in one of its other positions in which a resistance of lower value is connected in parallel with the condenser.

Very satisfactory operation of the device would be had were the switch 3 left in the above described intermediate position throughout the entire period to be predetermined, i. e. were switch member 23 omitted. Under this method of operation after the first interruption of anode current in device 1 the grid of device 18 is no longer negative with respect to the cathode, and discharge of condenser 2 then takes place through device 18, and the resistance 9, 10, 11, or 12 which is connected in circuit. The grid of device 1 is held negative for the predetermined interval by the potential on the resistance 9, 10, 11, or 12 as the case may be. It is desirable, however, to provide the switch member 23 and its cooperating contact connected as shown thereby to short circuit device 18 and to connect the discharge resistance 9, 10, 11, 12 directly in parallel with the condenser. Under either method of operation it will be seen that the discharge of the condenser through resistance 9, 10, 11, 12 and through device 1 is prevented until the anode current in device 1 is interrupted, ordinarily a time interval greater than a half cycle is required for the switch 3 to pass through the intermediate position in which members 19 and 20 engage contacts 26 and 25 and prior to engagement of member 23 with contact 27. This switch may be operated manually but

preferably is operated electromagnetically through means not shown.

To further insure accuracy in the interval determined by the equipment, a two-element electron discharge device 28 is connected in parallel with the condenser 2 through a resistance 28′. This discharge device is preferably one of well known construction, and has cold electrodes arranged in an atmosphere of attenuated gas such as neon, helium, or argon. As shown, electromotive force is applied thereto through resistance 21. This device thus serves to maintain the voltage on condenser 2 at a constant value independently of variations of the voltage of the supply circuit 4. That is, the device 28 has the characteristic that after it breaks down the voltage between its electrodes is maintained constant independently of the current flowing between its electrodes. The resistance 28′ is included in circuit between condenser 2 and discharge device 28 to prevent surges of current through the discharge device immediately upon break down thereof.

While I have shown a particular embodiment of my invention it will of course be understood that I do not wish to be limited thereto since many modifications may be made both in the circuit arrangement and in the instrumentalities employed, and I contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In a timing device, a vapor electric device having an anode, a cathode and a control electrode, a source of alternating electromotive force connected between said anode and cathode whereby current flows in said anode during alternate half cycles, means for preventing the starting of current to said anode during a predetermined period, said means comprising an energy storage device, and means whereby said energy storage device is charged and connected between said grid and cathode, whereby when current to said anode is interrupted said storage device prevents the subsequent starting thereof during successive alternate half cycles over a period determined by the rate of discharge of said condenser, and means for preventing discharge of said storage device through said vapor electric device prior to interruption of current to said anode.

2. In a timing device, a vapor electric device having an anode, a cathode, and a control electrode, a source of alternating electromotive force connected between said anode and cathode, an energy storage device, a source of charging potential therefor, means for connecting said energy storage device to said source of charging potential and then disconnecting it therefrom and for connecting it between the control electrode and cathode of said vapor electric device whereby it controls the initiation of current in said vapor electric device, and means for preventing discharge of said energy storage device through said vapor electric device during the half cycle in which it is connected thereto if the anode during said half cycle is positive.

3. The combination, in a timing device, of an electron discharge device having an anode, a cathode and a grid, a source of alternating electromotive force connected between the anode and cathode, a condenser, a second electron discharge device, means for connecting said condenser between said grid and cathode through said second electron discharge device, and automatic means for rendering said second electron discharge device of high impedance until the anode current in said first discharge device is interrupter.

4. The combination, in a timing device, of an electron discharge device having an anode, a cathode and a grid, a source of alternating electromotive force connected between the anode and cathode, a condenser, means for charging said condenser, a resistance connected between the grid and cathode of said discharge device, a second electron discharge device, means for connecting said condenser between said grid and cathode through said second electron discharge device, and means responsive to the anode current in said first device for controlling the impedance of said second device thereby to prevent discharge of said condenser until the anode current in said first device is interrupted and thereafter to permit said condenser to discharge through said resistance.

5. In a timing device, a vapor electric device, having an anode, a cathode and a control electrode, a source of alternating electromotive force connected between the anode and cathode, a condenser, means for charging said condenser, means for connecting said condenser when charged between said cathode and control electrode whereby the starting of current between said anode and cathode is prevented for a period determined by the rate of discharge of said condenser, and means controlled by current to the anode of said vapor electric device for preventing discharge of said condenser through said vapor electric device prior to interruption of current to said anode, a discharge path for said condenser, and means operable responsively to the anode current in said vapor electric device whereby said means is operated after a predetermined interval subsequent to interruption of said anode current determined by the rate of discharge of said condenser through said discharge path.

6. In combination, an electron discharge device having an anode, a cathode, and a control electrode, an electron discharge rectifier,

means for supplying alternating electromotive force to the anode of said electron discharge device and to said rectifier, a condenser, switching means for connecting said condenser alternatively to said rectifier and between the control electrode and cathode of said electron discharge device whereby said condenser is alternatively charged by said rectifier and utilized to control said electron discharge device, and means including said rectifier for preventing discharge of said condenser through the control electrode and cathode of said electron discharge device during the half cycle of the alternating electromotive force applied to the anode thereof in which said condenser becomes connected to said control electrode and cathode.

7. In combination, a pair of electron discharge devices, each of said devices having an anode, a cathode and a grid, means for supplying alternating electromotive force between the anode and cathode of each of said devices, a condenser, switching means for alternatively connecting said condenser in circuit with the anode of one of said discharge devices and between the grid and cathode of the other of said discharge devices in series with the anode and cathode of said first discharge device, means responsive to current to the anode of said other discharge device for impressing a negative charge on the grid of said first discharge device thereby to prevent discharge of said condenser through said other discharge device prior to interruption of current to the anode thereof, a discharge path for said condenser connected between the grid and cathode of said other discharge device, and means responsive to current to the anode of said other discharge device, whereby said means is operable at a predetermined time subsequent to interruption of said current determined by the rate of discharge of said condenser through said discharge path.

8. In combination, an electron discharge device having an anode, a cathode, and a grid, an electron discharge rectifier, means for supplying alternating electromotive force to said rectifier and between the anode and cathode of said discharge device, a condenser, connections including a switch having opposite positions and an intermediate position whereby when said switch is in one of said opposite positions said condenser is connected to said rectifier, when said switch is in said intermediate position said condenser is connected in series with said rectifier and the grid and cathode of said discharge device, and when said switch is in the other of said opposite positions said condenser is connected directly between the grid and cathode of said electron discharge device, and means responsive to anode current in said discharge device to render said rectifier of high impedance when said switch is in said intermediate position, thereby to prevent discharge of said condenser prior to interruption of said anode current.

In witness whereof I have hereunto set my hand this 27th day of October, 1930.

WILLIAM K. KEARSLEY.