

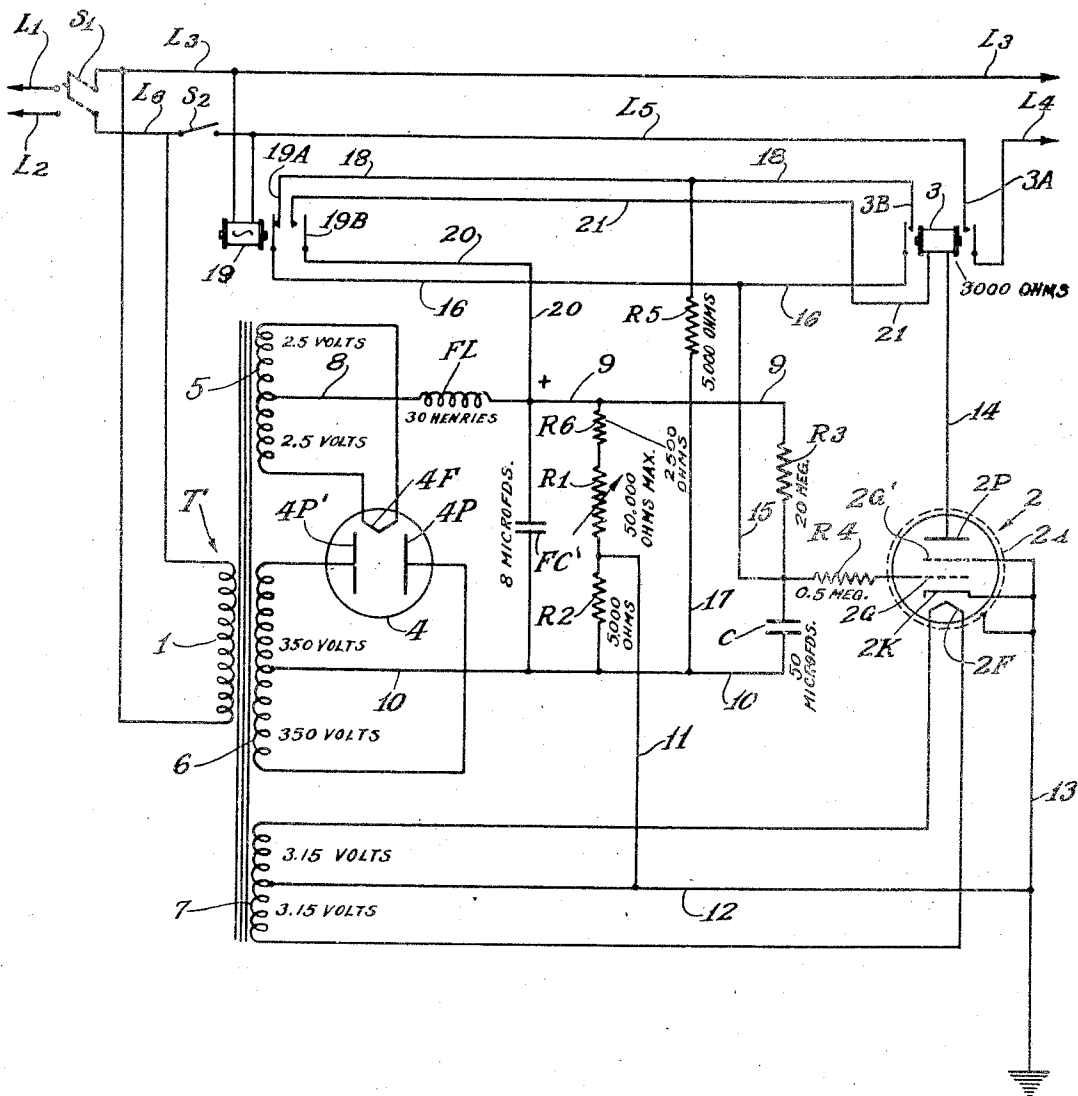
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ELECTRONICALLY CONTROLLED TIME DELAY SYSTEM

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ELECTRONICALLY CONTROLLED TIME
DELAY SYSTEM

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This invention relates to control devices and particularly to electrically operated safety controls operable to afford a time delay of selected duration which may be interposed, for example, when other apparatus is to be set in operation, to thereby insure proper conditioning of such apparatus for operation.

There are numerous instances where it has been found desirable or necessary to afford a comparatively long interval between the time when machinery or other equipment is conditioned for operation and the time when it is rendered fully operative. An example of such an instance is in connection with commercial heating systems including baking or drying chambers. In such systems it is customary, after starting up the system but before setting the burners or other heating units in operation, to interpose a time interval on the order of, say, several minutes to a half hour, or longer, for the purpose of enabling the ventilating equipment included in the apparatus such as circulating fans and the like, to clear the combustion chambers and allied parts of the system of any combustible gases or vapors that might be present therein. Thereafter the heating units may be rendered operative, which is to say, the burners may be ignited, without the danger of explosions or like hazards occurring.

Heretofore it has been proposed to afford time delays of the magnitude indicated above by mechanical or electromechanical means, such as synchronous electric clockwork mechanism, of rather intricate construction and having a large number of moving parts. It has been found, however, that such mechanical devices require frequent servicing, and moreover, where they are used in conjunction with electrical control apparatus of a character entailing only non-moving parts and electrical connections therefor, the service costs are relatively large due to the practical necessity of separately servicing the two types of control equipment. A further disadvantage of mechanical timers is that they are somewhat inflexible in their construction, as compared with electrical circuit elements and wiring which can be assembled in crowded quarters of almost any shape, a marked advantage where economy of space is essential. Also, many manufacturers of control apparatus prefer to have as much similarity of construction as possible in all portions of the apparatus and thereby decrease the need for different types of servicing and thus since modern control equipment is for the most part electrically operated it is desirable

to have timing equipment that is to be used with such control equipment also operated electrically.

Prior types of electrical timing devices that have been free of moving parts have only been useful to afford comparatively short delay intervals, that is, time delays of two minutes or less. Such devices have not heretofore been capable of affording longer time delays with sufficient reliability and accuracy, and hence, despite the above set forth and other advantages, they have not been employed, for example, in safety control apparatus designed for use in commercial heating systems, where much longer time delays are required, as has been explained hereinabove.

The charging or discharging time of an electrical condenser may advantageously be employed to afford a time delay and this may be done without the use of moving parts, and it is an object of our invention to do so in a novel manner.

It is well known that when a condenser is being charged or discharged, there is initially almost a straight-line variation of voltage with respect to time, but when the charge on the condenser commences to approach a steady-state value after expiration of a relatively long time interval, the variation in voltage with respect to time tapers off to smaller and smaller increments, and the time required to attain a given voltage level becomes quite uncertain. For this reason, it is necessary, in a condenser-controlled timing device, to insure that the voltage variation during the selected delay interval remains within the substantially linear range of the charging or discharging characteristic (variation of voltage with respect to time) of the condenser. In devices of this type the varying voltage of the condenser is usually employed to vary the potential of the control grid of an electron tube, and when this potential reaches a predetermined level, the tube passes plate current to thereby operate a means, such as a relay, in the plate circuit of the tube. The time required for the condenser voltage to reach this critical level is the measure of the amount of delay afforded.

In all such prior devices the arrangement of the circuit elements has been such that the charging or discharging characteristic of the condenser has provided a range of varying grid voltage values lying entirely to one side of the cathode potential of the tube. Hence, because it was undesirable to work along the end of the characteristic, the critical grid voltage of the tube had to be adjusted to a value relatively far removed from the zero or cathode level. We have found that under these circumstances, the per-

formance of the timing device is quite unsatisfactory where time delays of several minutes to a half hour or longer are required. Among other things, the timing is seriously affected by fluctuations in the value of the supply voltage when the critical or firing voltage of the tube is not at or near zero as compared with the initial grid voltage applied thereto at the initiation of the timing operation. For instance, a drop of a few volts in the line voltage has been observed to affect the accuracy of such prior devices by five or six minutes over a period of about a quarter of an hour, and in a commercial burner installation this could easily prove disadvantageous or even dangerous.

A further disadvantage, particularly in the case of those devices which rely upon the discharging time of a condenser, is that leakage and other common defects in the condenser produce a very unsatisfactory condition by unduly increasing the rate of discharge of the condenser and thereby shortening the delay period. This, of course, could easily lead to a dangerous condition in a burner installation, for example, by shortening the time of the scavenging period and prematurely initiating operation of the burners when there may still be combustible gases present in the system which have not yet been cleared out by the ventilating equipment.

In view of the foregoing, we rely upon the charging time of a condenser rather than upon its discharging time, whereby the device remains in its normal inoperative condition if the condenser has excess leakage. To insure accuracy of timing substantially independently of the fluctuations in line voltage which would ordinarily be encountered in practice, we have so arranged the circuit that the critical or firing voltage of the tube is at or near zero in comparison with the voltage initially applied on the control grid; and the charging characteristic of the condenser is such that it tends to sweep through a range of values which includes this critical voltage at a substantially linear portion thereof, thus eliminating to a great extent the uncertainty in timing during relatively long intervals, which formerly discouraged the use of electrical timers for this purpose.

Another disadvantage which has existed in prior electrical timing devices employing condensers is that no provision has been made to automatically return the condenser to its normal condition upon failure of the supply voltage or upon completion of the timing operation. Failure to normalize the condenser in either of these events results in the condenser being left in a partially charged or discharged condition, and when the apparatus is subsequently recycled, the condenser does not commence to vary its voltage from the proper starting point and hence the timing is adversely affected with the detrimental effects indicated hereinabove.

Thus, a primary object of the present invention is to afford an accurate and reliable time delay of relatively long duration by the use of novel apparatus of simple and economical construction and without the use of moving parts.

Another object is to afford a high degree of flexibility in the arrangement of the component parts of the timing means and to enable the duration of the time delay afforded by such means to be selected within wide limits.

Further objects are to utilize the charging time of a condenser to control the extent of time delay afforded; to vary the charging time of such

condenser by varying the amount of resistance in circuit therewith; to render an electron tube means responsive to the voltage across the condenser for operating the apparatus to be controlled thereby when a critical voltage has been attained; to so embody the condenser and electron tube means in a circuit including the aforesaid resistance that the undesirable effects of such imperfections as may exist in the condenser are minimized in so far as the electron tube means is concerned so that the accuracy of timing is not adversely affected by such imperfections; and to so arrange the foregoing elements that they may be expeditiously incorporated in a control apparatus comprising another or other electron tube circuit or circuits.

A still further object is to maintain the condenser of a timing means in a normal or discharged condition whenever it is not being utilized to effect a time delay; or in the event of an interruption of the supply voltage during the delay period, to normalize or discharge said condenser, to thereby suspend the operation of the timing circuit and restore same to normal condition.

Still another object is to enable the timing device to function satisfactorily for effecting selected time delays of several minutes to a half hour, or longer, without being unduly sensitive to fluctuations in line voltage.

Other and further objects of the present invention will be apparent from the following description and claims and are illustrated in the accompanying drawing, which, by way of illustration, shows a preferred embodiment and the principle thereof and what we now consider to be the best mode in which we have contemplated applying that principle. Other improvements of the invention embodying the same or equivalent principle may be used and structural changes may be made as desired by those skilled in the art without departing from the present invention and the purview of the appended claims.

A selected embodiment of our invention is diagrammatically illustrated in the accompanying drawing.

In the operation of the timing device shown in the drawing the switch S1 is first closed to connect the supply line wires L1 and L2 to the wires L3 and L6, respectively, and thereby condition the device for operation. However, a time delay period is not initiated until closure of the switch S2, which connects the wire L6 with the wire L5 and also causes the control condenser C to commence building up a charge thereon. The amount of time which elapses from the instant this charge build-up of the condenser C is initiated until the charge potential reaches a predetermined critical value is determined by the setting of a variable resistor R1. The voltage across the condenser C influences the value of the potential at the control grid 2G of a grid-controlled gaseous discharge tube 2, which is preferably of the type known as a gas tetrode. When the grid potential reaches the value of the firing voltage of the tube 2, this tube is ignited and passes current through its anode circuit. A relay 3 is included in the anode circuit of the tube 2 and is operable, when the tube 2 has been ignited, to close its normally open contact 3A and thereby connect the wire L5 with the wire L4, so that the wire L4 will be connected, through the wire L6, closed switch S2, wire L6, and closed switch S1, to the line wire L2. Thus, the result of the foregoing operations is that the wires L3 and L4 will have been connected to the line wires

L1 and L2, respectively, a selected period of time after the switch S2 has been closed, and the wires L3 and L4 are thereby potentialized for enabling the operation of other apparatus controlled by the timing device, which other apparatus might be, for example, the flame detecting safety control unit of an industrial burner system.

Preferably the apparatus is designed to operate on alternating current and therefore a transformer T and a full-wave rectifier tube 4 have been provided, as well as a filter inductance FL and a filter condenser FC. The primary winding 1 of the transformer T is connected across the wires L3 and L6. The secondary windings 5, 6 and 7 are all provided with center taps. The secondary 5 supplies the voltage for the filament 4F of the rectifier tube 4, and a conductor 8 leads from the center tap of the winding 5 to one terminal of the filter inductance FL, the other terminal of this inductance being connected to a conductor 9. The opposite ends of the secondary 6 are respectively connected to the anodes 4P and 4P' of the tube 4, while a conductor 10 is connected to the center tap of the winding 6. The filter condenser FC is connected between the conductors 9 and 10 and cooperates with the series inductance FL to smooth out the pulsating potential furnished by the rectifier tube 4. Thus the conductors 9 and 10 afford a substantially direct-current potential for the remainder of the apparatus to the right of the condenser FC, as viewed in the drawing, the conductor 9 being positive with respect to the conductor 10.

A fixed resistor R6, connected at one end to conductor 9, is in series with the variable resistor R1, which in turn is in series with a fixed resistor R2 connected to conductor 10, so that the combined series resistance of the resistors R6, R1 and R2 is in parallel with the filter condenser FC. A conductor 11 is connected to the resistors R1 and R2 at the junction thereof and to a conductor 12, which latter conductor is connected to the center tap of the secondary winding 7 and also to a conductor 13 which is connected to the cathode 2K of the tube 2. Secondary 7 supplies the voltage for the filament 2F of the tube 2.

The tube 2 includes a shield grid 2G' connected to the cathode 2K, and preferably a metal shield 2S is provided around the tube 2. The shield 2S, cathode 2K and shield grid 2G' are preferably all connected to ground through the conductor 13. The anode 2P of the tube 2 is connected by a conductor 14 to one terminal of the winding of the relay 3. The other terminal of said winding is connected by a conductor 21 to one terminal of a normally open contact 19B of a relay 19, described more fully hereinafter; and a conductor 20, tapped onto the conductor 9, is connected to the other terminal of the contact 19B.

A resistor R3 and the control condenser C are connected in series with each other and are also respectively connected to the conductors 9 and 10 in such a manner that the combined series impedance thus afforded is in parallel with the resistance comprising the resistors R6, R1 and R2 in series. The control grid 2G of the tube 2 is connected through a resistor R4 to the resistor R3 and the condenser C at the junction thereof.

Because of the connections which have thus been provided, the potential of the control grid 2G with respect to the cathode 2K is determined by the voltage drop across the condenser C minus the drop in voltage through the resistor R2, inasmuch as the positive end of resistor R2 is connected to the cathode 2K through the conductors 11, 12

and 13, while the positive terminal of the condenser C is connected to grid 2G through the resistor R4, the opposite or negative terminals of the resistor R2 and condenser C being connected together by the conductor 10.

One terminal of the condenser C is joined by a conductor 15 to another conductor 16 which is connected to a terminal of the normally open contact 3B of the relay 3. The other terminal of the condenser C is connected through the conductor 10 to a conductor 17 and thence through a resistor R5 to a conductor 18 that leads to the other terminal of the contact 3B. Hence when the relay 3 is energized, in a manner to be described hereinafter, the resistor R5 is shunted across the condenser C. This enables the condenser C to discharge without sparking when the relay 3 is energized. The resistance of R5 is negligible in comparison with the resistance of R3 so that condenser C is, in effect, short-circuited by the resistor R5 when the latter is shunted across it.

The conductors 18 and 16 are also connected to the terminals of the normally closed contact 19A of a relay 19, the winding of which relay is connected across the line wires L3 and L5. If switch S2 is open, the wire L5 is not potentialized and therefore the relay 19 is deenergized, thereby connecting the conductor 16 to the conductor 18 through its contact 19A and maintaining the resistor R5 shunted across the condenser C. This prevents the presence of stray charges on the condenser C when the apparatus is not in operation. When the switches S1 and S2 are closed to initiate operation of the apparatus, the relay 19 is energized and opens its contact 19A and thereafter the condenser C will not be shunted by the resistor R5 unless and until the relay 3 becomes energized to close its contact 3B, provided the line voltage does not fall and thereby deenergize relay 19, which would result in the closure of contact 19A of this relay and the re-establishment of the shunt R5 across the terminals of the condenser C.

Before describing the operation of the timing device shown in the drawing, it will be assumed that such device has been completely shut down, which is to say, that both the switches S1 and S2 are open. In this event, the first step preliminary to initiating operation of the device is to close the switch S1. This connects the wires L3 and L6 to the line wires L1 and L2, respectively, and thus potentializes the primary 1 of the transformer T. The secondaries 5 and 7 of transformer T thereupon supply current to the filaments 4F and 2F of the rectifier tube 4 and control tube 2, respectively. Secondary 6 applies alternating potential to the anodes 4P and 4P' of the rectifier tube 4, and this tube thereupon furnishes a pulsating full-wave voltage to and filter inductance FL and filter condenser FC. These elements function to smooth out the pulsating voltage and to apply a direct-current voltage on the conductors 9 and 10, the conductor 9 being positive with respect to the conductor 10.

Switch S2 is now closed to initiate operation of the timing device, and the delay period commences to run as of this time. Closure of switch S2 connects wire L5 to wire L6, so that line voltage is now established across the wires L3 and L5. Relay 19 is thus energized to open its contact 19A and close its contact 19B. Closure of contact 19B tentatively establishes the anode circuit of the control tube 2 by connecting conductors 20 and 21 together, so that there is a

path from conductor 9 through conductor 20, relay contact 19B, conductor 21, winding of relay 3, and conductor 14 to the anode 2P of tube 2. However, for reasons which will be apparent from the following description, current does not immediately flow in this anode circuit, but only at the termination of the time delay interval; hence relay 3 remains deenergized for the duration of the delay period.

Opening of relay contact 19A breaks the connection between conductors 16 and 18, inasmuch as contact 3B of relay 3 is open at the time operation of the timing device is initiated; therefore the resistor R5 is disconnected from the condenser C, it being recalled that resistor R5 is connected in parallel with the condenser C only so long as either of the relay contacts 19A or 3B is closed. When the shunt resistor R5 has thus been disconnected from the condenser C, the control grid 2G of the tube 2 is initially at a substantial negative potential with respect to the anode 2P because of the existence of a voltage drop in the resistor R3 and because there is no appreciable charge potential, as yet, on the condenser C, inasmuch as the equivalent impedance or counter-voltage of a previously discharged condenser that is being newly charged is initially zero. Likewise, there is an initial negative potential on the grid 2G with respect to cathode 2K, the magnitude of which is to a large extent determined by the voltage across the resistor R2, it being recalled that such grid potential is dependent upon the voltage across the condenser C which is initially zero, minus the voltage drop through the resistor R2. As has been mentioned hereinabove the tube 2 is a gaseous discharge tube and is controlled primarily by the grid 2G; therefore, there will be no discharge whatsoever between the cathode 2K and the anode 2P unless and until the potential of the grid 2G with respect to the cathode 2K becomes more positive, or less negative, as the case may be, than a predetermined value, namely, the firing voltage of the tube.

Thus, at the initiation of operation of the timing device the control grid 2G of the tube 2 is at a negative potential with respect to the cathode 2K and also with respect to the anode 2P, and the initial negative potential of the grid 2G with respect to cathode 2K created by the voltage drop in resistor R2 is ordinarily sufficient to block the flow of current through the tube 2. The magnitude of the voltage drop through the resistor R2 is initially dependent upon the setting of the variable resistor R1. If the resistor R1 has been adjusted to a relatively low value, there is a relatively large voltage drop in the resistor R2 and the initial negative potential of the control grid 2G is comparatively great; whereas if the resistance R1 is at a high value, the drop in the resistor R2 is small and the initial negative potential of grid 2G is correspondingly small. As will appear subsequently, the initial magnitude of this grid potential determines the amount of time delay afforded.

Thus far it has been assumed that the counter-voltage of the condenser C is relatively small, which is the condition that prevails initially upon removal of the shunt resistor R5 from around the condenser C when the switch S2 has been closed. However, the voltage across the condenser C commences to build up rapidly thereafter, this being due to the increasing counter-voltage offered by the condenser C to the flow of current therethrough. The condenser voltage tends to

increase toward the upper limiting value of the difference in potential between the supply conductors 9 and 10, and in the course of so doing, it rises to a level comparable with the value of the voltage drop through the resistor R2, so that the difference in potential between the control grid 2G and the cathode 2K of tube 2 gradually decreases. The magnitude of the potential on grid 2G, with respect to cathode 2K, thus tends to change gradually from a large negative value (voltage drop through R2) to a large positive value (voltage drop through R6 and R1). However, when this grid potential is decreased in value from its negative limit to a certain point, which in the illustrated embodiment is at or near zero voltage, where it can no longer prevent discharge from taking place between the cathode 2K and the anode 2P, the tube 2 commences to pass current, so that in addition to the current flow from conductor 9 through the resistors R6 and R1 to the resistor R2 and thence to conductor 10, there is another path of current flow from the conductor 9 through conductor 20, now closed relay contact 19B, conductor 21, winding of relay 3, anode 2P, cathode 2K, conductors 13, 12 and 11, and resistor R2 to conductor 10, and this added current flow through the resistor R2 tends to cause the negative potential on the grid 2G, which up to this time had been decreasing, to tend to increase negatively. However, because of the characteristics of the tube 2, any changes in the potential of the grid 2G, once discharge has been initiated, will have no appreciable effect on tube 2, so that the discharge continues until interrupted upon removal of the supply voltage, which ordinarily occurs upon the opening of either or both of the switches S1 and S2 for recycling or shutting down the control apparatus.

Thus, once the discharge has been initiated through the tube 2, it continues and the relay 3 therefore energizes and remains energized to maintain its contact 3A closed. The line wires L1 and L2 will have therefore been connected to the line wires L3 and L4, respectively, by the time such discharge is established in the tube 2, the connection from L2 to L4 being effected through wire L6, closed switch S2, conductor L5, and the now closed relay contact 3A, and it being recalled that wire L3 was connected to line wire L1 when switch S1 was closed. Contact 3B of relay 3 closes and connects the resistor R5 across the terminals of the condenser C, and the charge which previously accumulated on the condenser C rapidly leaks off through resistor R5.

In the foregoing description of operation it has been assumed that the timing device was originally in a shut-down condition, that is, with both switches S1 and S2 open, in which event the switch S1 was closed as a preliminary operation, and switch S2 was then closed to start the delay period running. However, the usual operation is that of recycling the apparatus. For example, assuming that an abnormal condition arises elsewhere in the system which requires that a new starting cycle be initiated, such as flame failure at one or more burners in a multiple fuel burner system having a common safety control means governed by the timing device in the drawing, the switch S2 is first opened to thereby deenergize relay 19. Opening of relay contact 19B upon deenergization of relay 19 opens the anode circuit of the tube 2, extinguishing the discharge therein and deenergizing relay 3. Opening of contact 3A of relay 3 removes potential from the line wire L4. Opening of contact 3B of this relay tends to re-

move the shunt resistor R5 from the condenser C; however, closure of contact 19A of relay 19 maintains resistor R5 connected across the condenser C. Switch S1 is not opened in this recycling operation. To recycle the apparatus, switch S2 is again closed to energize relay 19 and initiate a new time delay operation as described hereinabove. Subsequent operations take place as explained hereinabove. Subsequent operations the energization of the relay 3, with the effect aforesaid.

The time interval which elapses from the instant the switch S2 is closed to the instant when the relay 3 becomes energized is mainly dependent upon two factors, namely, the initial voltage drop through the resistor R2, and the rapidity with which the condenser C commences to build up its full charge potential after the shunt R5 has been removed therefrom. The rapidity of charging of the condenser C, in turn, is determined largely by the values of the resistance R3 and the capacity of the condenser C, although it is to some extent influenced by the values of the resistors R6, R1 and R2, and other impedances in the timing delay circuit. The values of resistance and capacity of the resistor R3 and condenser C, respectively, as well as the values of other circuit impedances are so selected as to accommodate the maximum amount of time delay that may be required in practice. For example, where the maximum delay is of relatively short duration, say, up to about five minutes, the capacitance of condenser C can be made lower in relation to the resistance of the resistor R3 than would be the case if the contemplated time delays required were on the order of, say, ten to twenty minutes.

Assuming that the values of R3 and C have been selected to provide the desired initial rate of build-up of the voltage across the condenser C, for accommodating a given range of delay intervals, the next consideration is the selection of a particular amount of time delay within the available range, and this is accomplished by adjusting the resistor R1. For example, if a relatively long delay interval is to be selected, the resistance of R1 is made comparatively low to provide a high voltage drop through the fixed resistor R2 connected in series therewith. Under these circumstances, the voltage that is built up across the condenser C upon closure of the switch S2 and removal of the shunt R5 will not approach the value of the voltage drop in the resistor R2 until a relatively long time interval has elapsed. Therefore, the potential on the cathode 2K of the tube 2, which cathode, as has been explained, is connected to the upper or positive end of the fixed resistor R2, as viewed in the drawing, remains appreciably more positive than the potential on the control grid 2G of said tube for a relatively long period, inasmuch as the potential of grid 2G is dependent upon the voltage drop existing across the condenser C; or in other words, a sufficient negative potential is present on the grid 2G to prevent discharge between cathode and anode of the tube 2 so long as the voltage drop across the condenser C remains substantially below the level of the voltage drop in the resistor R2.

Discharge in the tube 2 is not initiated until these voltages approach equality, it being assumed, for the reasons given hereinafter, that the firing voltage is at or near zero; but when such discharge occurs, upon equalization of the voltage drops across the resistor R2 and con-

denser C, and the anode 2P of the tube 2 passes current to cathode 2K, the winding of relay 3, in series with the anode 2P, is thereby energized to cause relay 3 to close its contacts 3A and 3B. Closure of contact 3A connects the wires L4 and L5, so that line wire L2 communicates with the wire L4 through wires L6 and L5. Closure of contact 3B connects the resistor R5 in shunt with the condenser C, for discharging the latter. This disrupts the relation which existed between the potentials on grid 2G and cathode 2K at the initiation of the discharge in tube 2. However, as has been explained previously, once the tube 2 has been set in operation, it continues to function independently of any subsequent changes in bias of the grid 2G, and hence relay 3 in the anode circuit of the tube 2 remains energized, so long as switch S2 remains closed to maintain contact 19B of relay 19 closed, and provided the rectifier tube 4 continues to potentialize the conductors 9 and 10, which is to say, so long as switch S1 is closed to supply power to the transformer T, and also provided the supply voltage does not fail.

If a relatively short time delay is required, the resistor R1 is adjusted to a high value to thereby decrease the voltage drop in the resistor R2. This has the effect of decreasing the difference in potential initially existing between the upper or positive terminals of the resistor R2 and the condenser C, as viewed in the drawing, so that the potential of the control grid 2G is less negative with respect to the cathode 2K, on starting, than was the case in the preceding example of operation. Hence, the condenser C does not have to build its voltage up to such a high value as formerly in order to equalize the potentials on the cathode and control grid of the tube 2, and thus a shorter time delay is afforded between the initiation of operation of the device and the instant when the tube 2 commences to discharge.

As has been stated hereinabove, the shield grid 2G' of the tube 2 is preferably connected directly to the cathode 2K of this tube. Under these conditions the firing voltage of the tube 2, is very close to zero, in comparison with the high negative potential originally impressed on the control grid 2G at the initiation of the timing period. It has been found that under these conditions the length of the timing period is substantially independent of fluctuations in line voltage, provided such fluctuations do not develop into sudden and prolonged changes. To render the circuit more highly accurate under the latter circumstances, it will be desirable to bring the firing voltage of the tube 2 exactly to zero, and this can be conveniently done by affording an adjustable bias on the shield grid 2G', such bias having a range of adjustment, say, from zero to three volts. By proper selection of the shield grid bias the firing voltage can be brought to zero, and this renders the firing time substantially independent of the magnitude of the current flowing through the resistors R6, R1 and R2 at the critical instant when the potential on the control grid 2G is approaching the firing voltage. Hence, the device will not be unduly affected by sudden variations in the supply voltage occurring at this critical time in the delay period. However, under ordinary circumstances, the fluctuations in voltage are not severe enough to necessitate adjusting the firing voltage of the tube 2 exactly to zero, and therefore the preferred arrangement shown in the drawing is highly satisfactory.

It is believed to be apparent from the foregoing description that we have provided a time delay device in which only simple and economical parts need be used and wherein a high degree of selectivity of time delay intervals on the order of, say, a minute to a half hour, or longer, is available by merely adjusting the resistor R1. Preferably, in a commercial installation, the adjusting means is kept locked to prevent manipulation thereof by any persons other than those having authority to determine the amount of time delay to be afforded. Moreover, there is no excessive heating of the elements of the device, so that they may be compactly assembled. Another advantage is that the construction is distinctly electrical in nature, rather than mechanical or electro-mechanical, does not employ moving parts, and is peculiarly adapted to be assembled and serviced as part of other control apparatus of a similar character.

Another feature is that the tube 2 is rendered operative in dependence upon the charging time of the condenser C, rather than the discharge time of the condenser; hence, if the condenser has excessive leakage and cannot build up a proper charge, the negative potential of the grid 2G of tube 2 remains at a value where it is able to block current flow through the tube 2 and thereby prevent the relay 3 from energizing to initiate operation of the apparatus controlled thereby. In electrical timing devices which are controlled by the discharge of a condenser, excess leakage is not only fatal to the accuracy of timing, but may prematurely initiate operation of the apparatus controlled thereby.

It is to be noted that the adjustment of the timing device to afford a selected delay interval is effected solely by manipulation of the variable resistor R1 and that it is not necessary to alter the capacity of the condenser C for such purpose, or to add or remove condenser units in case a plurality of condensers is utilized. The capacity of condenser C is preferably made sufficiently high so that the contemplated range of potentials to which the condenser must be charged to equalize the voltage drops that may be initially set up in the resistor R2 by adjustment of resistor R1, will lie well within the substantially straight-line portions of the charging characteristic (or, variation of potential with respect to time) of the condenser C. This minimizes the harmful effect of such deviations in the charging characteristic of the condenser as may be encountered in practice, for manifestly if the voltage drops that may be initially set up in the resistor R2 are, in all instances, well below the level at which the characteristic of the condenser C becomes appreciably asymptotic with respect to its steady-state value, a slight deviation in the characteristic of the condenser produces only a correspondingly slight change in the amount of time delay afforded from zero potential to the level at which the charge potential equalizes the voltage drop in resistor R2 to ignite or fire the tube 2.

Provision has been made for insuring that the condenser C is always in a completely discharged condition before the apparatus is recycled. Thus, when the tube 2 has been ignited, relay 3 closes its contact 3B and places the shunt resistor R5 across the condenser C for discharging the same without sparking.

When the apparatus is in its normal inoperative condition, relay 19 is deenergized and by means of its closed contact 19A maintains the

shunt resistor R5 across the condenser C. If the power supply should fail while the apparatus is being recycled and before the tube 2 has fired, the relay 19 deenergizes and closes its contact 19A to thereby discharge the condenser C through the resistor R5 in preparation for a subsequent recycling operation.

A fluctuation in supply voltage occurring while the condenser C is charging does not adversely affect the accuracy of the device, but merely produces a deviation in the charging characteristic, the effect of which, as has been noted hereinabove, is minimized by the peculiar circuit arrangement in so far as tube 2 is concerned.

Thus while we have illustrated and described a selected embodiment of our invention it is to be understood that it is capable of variation and modification and we therefore do not wish to be limited to the precise details set forth but desire to avail ourselves of such changes and alternations as fall within the purview of the following claims.

I claim:

1. In a timing control device for selectively determining the amount of time delay afforded subsequent to the initiation of operation thereof and prior to the operation of other apparatus to be controlled thereby, the combination, with a direct-current voltage supply means, of a resistance having at least a portion thereof variable, an impedance including a condenser, direct-current supply conductors connecting said resistance and said impedance in parallel to said direct-current voltage supply means, a gaseous discharge tube including a cathode, a control grid and an anode, means connecting said cathode to a point in said resistance the potential of which is intermediate the potentials of said supply conductors and the magnitude of which potential is determined by the setting of said variable portion of said resistance, other means connecting said control grid to a point in said impedance the potential of which is of a magnitude that varies in accordance with the state of charge of said condenser, whereby the potential of said control grid with respect to said cathode at any instant is dependent upon the difference between the value of the voltage drop through said condenser at that instant and the value of the voltage drop through a certain portion of said resistance, shunt means normally connected in parallel with said condenser, a starting relay operable to disconnect said shunt means from said condenser to thereby render said direct-voltage supply means effective to initiate charging and consequent voltage build-up of said condenser and thus initiate operation of the timing control device and operating in the event of failure of said voltage supply means to re-connect said shunt means to said condenser, means connecting said anode in a circuit to said voltage source and including an operating relay which is rendered operative to control said other apparatus when the voltage drop through said condenser is of a value sufficient to bring the potential on said control grid with respect to said cathode to a predetermined firing voltage for igniting said tube, the time interval elapsing between such initiation of operation of the timing control device and the instant when the voltage drop through said condenser has reached said sufficient value being determined by the setting of said variable portion of said resistance, and means under control of said operating relay for re-connecting said shunt means to said condenser when said oper-

ating relay has been operated, said starting relay and said operating relay thereby functioning to shunt said condenser for discharging the same at all times except while the time delay operation is being duly performed by the timing device.

2. In an electrically operated time delay device, a source of direct-current voltage including two supply conductors across which a predetermined direct-current voltage is maintained, a resistance connected between said supply conductors, an impedance comprising a condenser and another resistance connected in series with each other, said impedance being connected to said supply conductors in parallel with the first-named resistance, a grid-controlled gaseous discharge tube including a control grid, a cathode and an anode, means connecting said anode in a circuit to the positive side of said voltage source and including operating means which is rendered effective when said tube is ignited to initiate operation of other apparatus governed by the timing device, means connecting said cathode to a point in the first-named resistance the potential of which is intermediate the potentials of said supply conductors, means connecting said control grid to said condenser at the junction thereof with said other resistance, whereby the potential of said control grid with respect to said cathode is determined by the voltage drop through said condenser less the voltage drop through a portion of the first-named resistance, and means for rendering said direct-current voltage source effective to initiate charging of said condenser to thereby cause said condenser to build up a voltage varying from substantially zero to approximately the difference in potential between said supply conductors, said tube being so constituted and arranged that under normal anode voltage it has a firing grid voltage of substantially zero with respect to said cathode so that said tube is ignited to thereby establish current flow in its anode circuit for operating said operating means when the voltage of said condenser becomes substantially equal to the voltage drop through said portion of the first-named resistance.

3. In an apparatus as set forth in claim 2, means responding to a failure of said voltage source to discharge said condenser.

4. In an apparatus as set forth in claim 2;

means controlled by said operating means for discharging said condenser when said tube is ignited.

5. In a circuit of the character described, the combination of a condenser adapted to be energized from a voltage supply line, means including a device responsive to a predetermined difference in potential across said condenser for energizing a control circuit, means under the control of said energizing means for automatically discharging said condenser, and means responsive to a failure in the voltage supply line for automatically rendering said condenser discharging means effective to discharge said condenser.

6. In a circuit of the character described, the combination of a condenser adapted to be energized from a voltage supply line, means including a device responsive to a predetermined difference in potential across said condenser for energizing a control circuit, means under the control of said energizing means for automatically discharging said condenser, and means including a relay responsive to a failure in the voltage supply line for automatically rendering said condenser discharging means effective to discharge said condenser.

7. In a circuit of the character described, the combination of a condenser adapted to be energized from a voltage supply line, means including a device responsive to a predetermined difference in potential across said condenser for energizing a control circuit, a resistance under the control of said energizing means for automatically discharging said condenser, and means responsive to a failure in the voltage supply line for automatically rendering said resistance effective to discharge said condenser.

8. In a circuit of the character described, the combination of a condenser adapted to be energized from a voltage supply line, means including a device responsive to a predetermined difference in potential across said condenser for energizing a control circuit, a resistance under the control of said energizing means for automatically discharging said condenser, and means including a relay responsive to a failure in the voltage supply line for automatically rendering said resistance effective to discharge said condenser.

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