The present invention relates to improvements in electronic timing apparatus for effecting a time delay in the actuation of a relay element by means of the controlled dissipation of electric energy stored for that purpose.

It is the main object of the invention to provide a device for the above purpose which is organized especially with a view to simplicity of construction, exactness, reliability of and constant readiness for operation, and adaptability to varied industrial and scientific purposes.

In one aspect, the invention has the object of providing a circuit which is continuously ready for initiating a timed control function by a single operation, as closing a switch or varying an electric constant therein. In another aspect, the invention has the object of providing a circuit which permits, if desired, continuous indication of readiness for operation as for example inexactness for an emergency function, and also, if desired, indication of its timing function properly. In still another aspect the invention has the object of controlling the operation of external circuits or other apparatus for predetermined effectiveness during single or repeated periods of time whose duration may also be controlled as function of a determining value.

Still further objects are to provide a time delay relay circuit adapted for visual indication of readiness for operation as well as operation of the relay; to provide a new and improved time delay relay employing a light sensitive device for controlling the period of the time delay effect in the energization and deenergization of an external circuit or other apparatus; to provide a time delay relay circuit which can be in the simplest possible manner modified for various ways of operation as for example for simple time delay operation, or time delay operation with controlled instantaneous cycle interruption, or continuous cycle operation through a certain period of time.

One of the features of the arrangement according to the invention which makes the above advantages possible, is the introduction of an element in its circuit which supplies, so long as the circuit is conditioned to be ready for operation, a potential which is, or can be rendered, more positive than the simultaneously prevailing potential of a control element; for example, the positive potential of a point connected to one terminal of the supply source may be permanently applied to one plate of an energy storing condenser whose other plate is connected to the control grid of an electron tube connected to the source and which condenser can discharge in controlled manner. The condenser can be normally kept charged by the grid current through the conducting tube, but if the potential of the above point is changed as for example by connecting it with an element carrying a lower potential, as the other source terminal which supplies the cathode of the tube, or by modifying an existing connection thereof with such an element, the control grid will be rendered more negative than the cathode due to the condenser charge algebraically added to the newly introduced potential. In this manner it is possible to interrupt or modify the conductivity of the tube, dependent upon the discharge of the condenser or other energy storing means, for example through an impedance which may be permanently set to a predetermined energy dissipating value or which may itself be a function of a controlling value.

Among other advantages, the above feature offers that of continuous readiness for immediate response to a single circuit modification as closing of a switch, of adaptability to various ways of operation and for correlation with further similar circuits with a minimum of interrelating elements, and of the possibility of variably conditioning the tube conductivity as controlled by the grid.

These and other objects, aspects and features of the invention will be apparent from the following description of several embodiments thereof by way of illustrating its genus and referring to a drawing in which:

Figs. 1 is a diagram of a circuit according to the invention;

Figs. 2 to 4 are similar diagrams of several modifications of the invention according to Fig. 1; and

Fig. 5 is a further modification employing two electron tubes.

In Fig. 1, two terminals A and B of an alternating or direct current source supply a conventional electron discharge tube T with anode a, control electrode g and cathode k, the latter being for example heated in conventional manner by means of heater element h.

Connected to grid g is a condenser C which is in parallel with dissipating impedance D; condenser C and impedance D are dimensioned to provide for discharge of the condenser through the impedance to a predetermined potential during a given time; for example if d and c stand for impedance and capacitance respectively, of elements D and C, and a dissipation time of the approximate magnitude of 1 minute is desired,
a product of about 10 would be chosen. Across the supply terminals A, B, there are connected a resistance consisting for example of a constant range selecting portion R1 and a variable portion therefor in series thereon, a circuit making and breaking arrangement consisting for example of normally open switch S1 and normally closed switch S2. At point X, the energy storing and dissipating system C, D is connected to resistance R2, for example by means of a movable tap.

The cathode is connected to one source terminal, for example B, and the anode to the other terminal, for example A. Devices responsive to conductivity changes of tube T may be connected in the cathode-anode circuit; for example a solenoid 1 actuating armatures 2 and 3, may be inserted between anode a and terminal A, a sustaining condenser 5 being connected across magnet 1. Armature 2 may normally, that is when solenoid 1 is energized, connect conductor 10 of a controlled circuit O with contact 11, and when 1 is deenergized with contact 12 of that circuit. Armature 3 forms with contact 13 a normally open holding circuit bridging switch S1.

The operation of the circuit illustrated in Fig. 1, is as follows:

Assuming for purposes of illustration that the circuit is supplied with alternating current and that switch S1 is open whereas switch S2 is closed, if terminal A is at a given instant positive, tube T will pass current sufficient to effect energization of solenoid 1 causing its armatures 2 and 3 to retain closed external contact 11 and to retain open external circuit contact 12 and holding circuit contact 13. This results from the circumstance that, with switch S1 open, only the very low grid current is flowing in impedances R1 and R2, hence tap X will be at substantially the same voltage as terminal A and condenser 10 will be charged, due to the grid current, to approximately the maximum peak voltage between terminals A and B. Under these conditions the potential of point Y between the grid and the energy storing-dissipating device is relatively negative with respect to the potential at tap X, to an amount substantially equal to that peak voltage. The energy corresponding to this potential difference between tap X and connection Y normally tends to discharge through dissipating impedance D, but since, in an arrangement of this type, the time constant of the discharge is very high as compared with the alternating current frequency of the potential difference between points X and Y, very little discharge takes place during one alternating current cycle, so that the charge on C can be considered to be substantially constant.

On the reversal of polarity when terminal A is negative, the tube will not pass current but, due to the effect of sustaining condenser 5, solenoid 1 will remain energized and the positions of the armatures 2 and 3 unchanged during this half cycle.

If now switch S1 is closed (switch S2 being still closed), then the potential at point X changes relative to its original potential and approaches the potential at terminal B. Accordingly, due to the voltage across condenser C, the potential at connection Y is changed a corresponding amount, and grid g now becomes negative relative to cathode k; the change made in the potential of grid g with respect to cathode k corresponds and is equal to the change made in the potential of tap X relative to the potential 55 of terminal B. By properly selecting the electric constants of the circuit in accordance with standard practice, the bias of grid g can be caused to drop below the blocking potential of the tube and hence to interfere with the current flow through the tube during each half cycle when terminal A is positive and terminal B is negative. Consequently solenoid 1 is deenergized, wheupon armature 2 opens the controlled circuit contact 11 and closes contact 12, and armature 3 closes the holding circuit at 13.

As mentioned above, the holding circuit with switch 3, 13 is connected in parallel with switch S1 of the relay circuit; hence, if starting switch S1 (which may be a push button switch) is momentarily closed causing grid g to interrupt current flow through the tube T and to deenergize solenoid 1, the armature 3 will lock the holding circuit into the relay circuit, so that the initial operating potentials of the latter are maintained even though the starting button S1 is immediately released. It will now be understood that the deenergization of solenoid 1 will continue for an appreciable length of time dependent upon the duration of interruption of the current flow through tube T which, in turn, is dependent upon the relation of condenser C and impedance D controlling the discharge of the former. This discharge will continue until the grid potential becomes higher than the blocking value, wheupon the tube again becomes conducting, armatures 2 and 3 are attracted, the holding circuit opened and the external circuit restored from 12 to 11.

In order to reenergize solenoid 1 at any moment during the time delay measured by the rate of discharge of capacitor C, the normally closed stop switch S2 may be used. Opening of this switch immediately destroys the grid bias, the tube becomes conducting, and solenoid I reenergized. Push buttons S1 and S2 may be located at, or operated by remote control from starting and stopping stations at different points.

If it is desired to prevent premature interruption of a timing interval, switch S2 can be shunted by means of a jumper. Still another mode of operation can be provided by opening the energizing circuit, for example at 20, and permanently short circuiting switch S2. The remaining switch SI will then operate as a sustaining switch; closing of switch S1 starts a timing cycle which will be completed if the switch is kept closed during its entire duration. The timing cycle will be interrupted and magnet 1 reenergized as soon as switch S1 is released.

The rate at which the grid potential rises relatively to the cathode potential is governed by the dissipating impedance D and the capacity of condenser C and the time delay can be adjusted by changing resistance D, as indicated at 21 of Fig. 1; in many instances it is however preferable to regulate the timing period by varying the relation of the potential between cathode and grid on the one hand and the potential between points X and Y due to the charge on condenser C on the other hand, by adjusting the position of tap 11 relatively to impedance R2. As mentioned above, larger step by step changes can be made by means of exchanging impedance R1.

For practical purposes of the invention it is a quite important feature that the point chosen for operation is continuously indicated by the glow of tube T if a tube suitable for that purpose is used, or by an indicator (as 36 or 37 of Fig. 2, see Fig. 2).
low); the timing period will be accordingly indicated by the non-conductivity of the tube.

Any means for lowering the potential of point X with respect to the cathode will be satisfactory for the operation of the circuit, but it should be noted that for proper functioning, tap X must previously have been at a higher potential than the cathode. It is feasible to charge condenser C previously, in some manner, with voltage in the proper direction, as, for example, to drive it positive with respect to the voltage source. This is for example indicated in Fig. 1 where a battery 22 may be introduced and R4 disassociated from the supply source by opening connector 23.

A circuit of this type may be used for control by the auxiliary voltage source. For example, the voltages of dry cells may be tested in this manner, the time delay period being proportionate to these voltages. It will be understood that, although the operation of the circuit according to the invention has been described for an alternating current supply, it will work in the same manner if connected to a direct current supply.

As mentioned above, the time delay period can be varied by varying impedance D. This effect may be utilized for controlling the time delay by means of a rheostat. For example, as shown in Fig. 2, resistor D may be replaced by a variable impedance element or elements, for example, light-sensitive cells as phototubes 30, 31. With tap X at a fixed point on resistor 22 the time of deenergization of solenoid I is thus made a function of the quantity or intensity of light falling on the light-sensitive circuit element. If several phototubes are placed in series, as indicated in Fig. 2, the time delay interval will depend on the least quantity or intensity of light on any of the phototubes, that is to say, the time delay will be governed by the darkest cell. By means of a change over switch 35, or by permanently reconnecting the tubes, the latter can be arranged in parallel; the time delay will then depend upon the average quantity or intensity of light on all the cells. It will be understood that any suitable electronic device can be used as a variable dissipating impedance controlling the time delay period.

Instead of employing the circuit according to the foregoing and closing or opening a controlled circuit, it can be used for selectively delayed initiation of differentiated controlled effects; an arrangement of this type is also shown in Fig. 2. In this figure, R is a resistance with a number, for example two, switches S3 and S4 for shunting portions of the resistance. R has a value, and tap X is so arranged that, with switches S3 and S4 open, the grid current will charge condenser C as above described, whereas closing of switch S3 or S4 will bring the potential at X more or less below the value at which current flow through tube T is blocked and magnet 1A deenergized. The time delay periods following the closing of one of the switches will differ accordingly.

Instead of selecting the electrical constants involved in such a manner that lowering of the potential at X (for example by closing switch S3 or S4) will cause the tube to become substantially non-conductive, they can be so selected that, upon closing switch S3 or S4, the respective potentials at X will be above the blocking potential, but reduce the conductivity of the tube to correspondingly low degrees. In this instance the varying conductivity of the tube may be utilized for effecting varying functional stages of a controlled device; for example a gaseous discharge lamp 36 may be operated with light intensities varying to a predetermined degree through periods selectively predetermined by means of switches 31 and 32. Similarly, a voltage responsive device, indicated at 37, can be used as controlling relay element. As mentioned above, the delay periods can be further controlled through the dissipating impedance, for example the above discussed photosensitive elements 31 and 32. Switches S3 and S4 can be operated in any one of the ways above described with reference to switches S1, S2 and S0 of Fig. 1.

Instead of using a switch or a stepped ohmic resistance for lowering the potential at X for initiating a time delay period, a continuously variable impedance, for example the inductance coil L1 of Fig. 3 can be employed. Such a coil may be in parallel with a resistance 41 and have an iron core 42, for example movable by means of a feeder 43 running on a controlling pattern 44, for example the end of a strip of magnetic material. The potential at X is set to be, under normal conditions, not more positive than the cathode potential. Upon movement of the core 42, the impedance of L1 changes, the potential at X increases accordingly, and draw a current which again applies a proportionate charge to condenser C. Upon return of the core to original position, the timing begins and the period during which the tube is non-conductive will be proportionate to the maximum travel of core 42 which may be proportional to either the minimum or the maximum dimension of the article to be supervised. The duration of the time delay period, proportionate to the measured extreme value, can be measured by suitable means as for example a counter 45 started and stopped upon deenergization and reenergization respectively of magnet 1B.

It is further understood that the various above-mentioned impedance elements may predominantly represent ohmic resistances, capacitances or reactances, as the particular purpose may require. The use of a reactance for varying the potential at X has already been explained; Fig. 4 shows as a further example in this regard an alternative connection of the dissipating impedance D in which it will be understood that any energy consuming element effective to increase the grid potential during the time delay period by diminishing the potential difference between points X and Y will serve the purpose.

Fig. 4 shows further a modification of the circuit according to Fig. 1 which permits continuous operation for initiating series of periodical impulses. In Fig. 4, C and D are the energy storing and dissipating elements, respectively, connected to supply source A, B, tube T and conductivity responsive element 1B as described with reference to Fig. 1.

A switch S5 is connected between one source terminal and point X and this switch is bridged by a holding circuit with normally open contacts 3D, 13D in a manner similar to the arrangement of switch S1 and contacts 3, 13 of Fig. 1. The contact 12D of the controlled circuit is in this instance connected to the source terminal B, and contact 11D to the other source terminal over a switch 56 and a ring at S10 of 55, 57, 58 and 59, 60 and 61, 62 to close switch S5 upon energization. Care is taken by conventional means that, upon ener-
4. Gization of magnet 1b, contact 1bb will not close before holding contact 3b opens, and that, upon deenergization of 1b, contact 1bb will not open before contact 3b closes.

Assuming that switches S6 and S8 are open, then if 1b will be conductive, magnet 1b energized, contacts 2b and 12b are open and contact 11b closed, and L2 will carry current. If now switch S8 is closed, magnet 51 will close switch S8, the grid potential will be lowered below the blocking value, 1b will be deenergized, the holding circuit established, the circuit of magnet 51 interrupted at 11b, and the contacts of external circuit closed at 12b. Condenser C now discharges through D4 and the tube will resume conductivity after a time interval determined by the values of C, R and D and the settings of X and Y. 1b is again energized, the holding circuit opened and 51 energized to start another cycle; this will continue until switch S6 is opened.

More elaborate timing functions can be performed by combining, according to another aspect of my invention, several timing circuits; an example of such arrangements will now be described with reference to Fig. 5.

In Fig. 5, A and B are the supply terminals, I and II are two time delay units connected thereunto, and O is an external controlled circuit. Each unit has a tube (T1, T2), an impedance (R3, R4) in series with a timer switch (63, 64), an energy storing and dissipating element (SD1, SD2), and a magnet (61, 62). Elements SD1 and SD2 are connected at points X1 and X2 respectively to impedances R3 and R4 and at the points Y1 and Y2 to the grids of tubes T1, T2 respectively. Magnet 61 closes switch 64 if energized and magnet 62 similarly keeps switch 63 closed so long as it is energized. Magnet 1c of the control circuit is in series with switch 63 and will close contact 14 if switch 63 is closed, but change over to 12 if 63 is open.

Assuming for example that switch 64 of unit II is closed, during a period when the potential at T2 is below its blocking value but gradually increases due to energy dissipation at SD2, tube T2 will become non-conducting and switch 63 open. Hence, tube T1 of unit I will be conducting and keep switch 64 closed, as assumed. As soon as the potential at T2 rises above the blocking value, tube T2 becomes conducting, switch 63 closes, connecting the exterior circuit to 14 and starting a time delay interval during which tube T1 is non-conducting and causes opening of switch 64. Energy is now stored at SD2 until the potential at Y1 rises above the blocking potential, switch 64 closes and starts another energy dissipating and time delay interval at unit II during which switch 63 is open and contact 12 closed. In other words, the following sequence of operations will prevail. Contact 11 stays closed during an interval controlled by unit I; if 11 opens and 12 closes; 12 stays closed during an interval controlled by unit II; 12 opens and 11 closes; 11 stays closed, etc. It will be evident that the above time intervals can be independently controlled by suitably setting units I and II for respective timing periods, or varying them according to an independent function for example in the manner explained with reference to Figs. 2 and 3.

The operation of a circuit according to Fig. 5 can be illustrated by closing switch S6 in the circuit of one of the timer switches.

It should be understood that the present disclosure is for the purpose of illustration only and that this invention includes all modifications and equivalents which fall within the scope of the appended claims.

Claim:

1. A time delay device comprising a source of electric potential, an electron discharge device having cathode, anode and control grid, substantially permanently supplying power from said cathode and said anode to said source, means responsive to the conductivity of said discharge device, substantially permanently effective means for supplying a potential which can be rendered more positive than the simultaneously prevailing potential of said cathode and raising the energy of said storing means to said grid for lowering its potential relatively to said cathode and raising it again as the energy is dissipated at a predetermined rate, said conductivity being controlled through said application of said energy to said grid and the nature of said dissipating rate.

2. A time delay device comprising a source of electric potential, an electron discharge device having cathode, anode and control grid, substantially permanently supplying connections from said cathode and said anode to said source, means responsive to the conductivity of said discharge device, substantially permanently effective means for supplying a potential which is more positive than the simultaneously prevailing potential of said cathode, means adapted for storing electric energy substantially permanently connected between said grid and said potential supply means, and means for applying the energy of said storing means to said grid for lowering its potential relatively to said cathode and raising it again as the energy is dissipated at said predetermined rate, said conductivity being controlled through said application of said energy to said grid and the nature of said dissipating rate.

3. A time delay device comprising a source of electric potential, an electron discharge device having cathode, anode and control grid, substantially permanently supplying connections from said cathode and said anode to said source, means responsive to the conductivity of said discharge device, substantially permanently effective means for deriving from said source a potential which can be rendered more positive than the simultaneously prevailing potential of said cathode, means adapted for storing electric energy substantially permanently connected between said grid and said potential deriving means, means for dissipating said energy at a predetermined rate connected to said storing means, and means for applying the energy of said storing means to said grid for lowering to a predetermined degree its potential relatively to said cathode and raising it again as the energy is dissipated at said predetermined rate, said conductivity being controlled through said application of said energy to said grid and the nature of said dissipating rate.

4. A time delay device comprising a source of electric potential, an electron discharge device having cathode, anode and control grid, supply connections from said cathode and said anode to respective terminals of said source, means responsive to the conductivity of said discharge device in one of said connections, an impedance con-
ected to said anode terminal, means adapted for storing electric energy and for dissipating it at a predetermined rate connected between said impedance and said grid, and circuit making and breaking switch means connected in parallel to said cathode supply connection, at a point between said impedance and said storing means on the one side and said cathode terminal on the other side, said conductivity being controlled through the energy stored when said switch means is open, and applied to said grid upon closing of said switch means.

5. A time delay device comprising a source of electric potential, an electron discharge device having cathode, anode and control grid, substantially continuously effective supply connections from said cathode and said anode to respective terminals of said source, relay actuating means responsive to the conductivity of said discharge device in one of said connections, an impedance and a switch connected in series between said anode terminal and said cathode terminal, in parallel to said supply connections, a condenser connected between a point of said impedance and said grid, and a control impedance connected across said condenser, said conductivity being controlled by the potential supplied to said condenser through the grid current when said switch is open, applied by the condenser to the grid upon closing said switch, and diminishing by its discharge through said control resistance.

6. A time delay device comprising a source of electric potential, an electron discharge device having cathode, anode and control grid, supply connections from said cathode and said anode to respective terminals of said source, means responsive to the conductivity of said discharge device in one of said connections, an impedance connected to said anode terminal, means adapted for storing electric energy and for dissipating it at a predetermined rate connected between said impedance and said grid, and a step by step adjustable impedance means connected in parallel to said cathode supply connection, at a point between said impedance and said storing means on the one side and said cathode terminal on the other side, said conductivity being varied through the stored energy applied to said grid at a bias level determined by the impedance means.

7. A time delay device comprising a source of electric potential, an electron discharge device having cathode, anode and control grid, supply connections from said cathode and said anode to respective terminals of said source, means responsive to the conductivity of said discharge device in one of said connections, an impedance connected to said anode terminal, means adapted for storing electric energy and for dissipating it at a predetermined rate connected between said impedance and said grid, continuously adjustable impedance means connected, in parallel to said cathode supply connection, at a point between said impedance and said storing means on the one side and said cathode terminal on the other side, and means for adjusting said impedance in conformity with a controlling value, said conductivity being varied through the stored energy applied to said grid at a bias level determined by said impedance means.

8. A time delay device comprising a source of electric potential; two electron discharge tubes each having cathode, anode and control grid, supply connections from said cathodes and said anodes to respective terminals of said source, current responsive actuating means in one of the connections of each tube, circuit making and breaking means controlled by said actuating means to be in circuit-closing position during conductivity of the tube of the respective actuating means, means for supplying a potential which can be rendered more positive than the simultaneously prevailing potential of the respective cathode, and means adapted for storing electric energy and for dissipating it at a predetermined rate permanently connected between the grids and the potential supply means of the respective tubes; said circuit making and breaking means of each respective tube being connected between the cathode supply terminal and said potential supply means of the other tube; and impulse transmitting means controlled by one of said actuating means.

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