

Feb. 11, 1947.

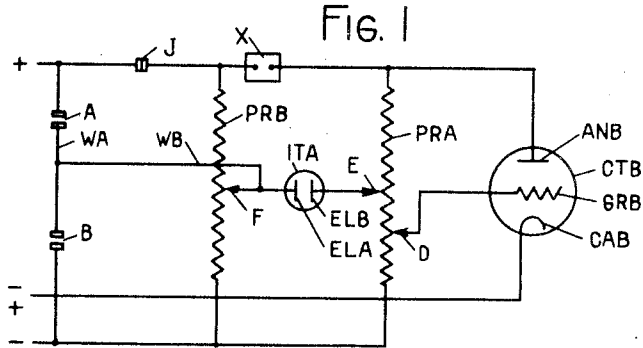
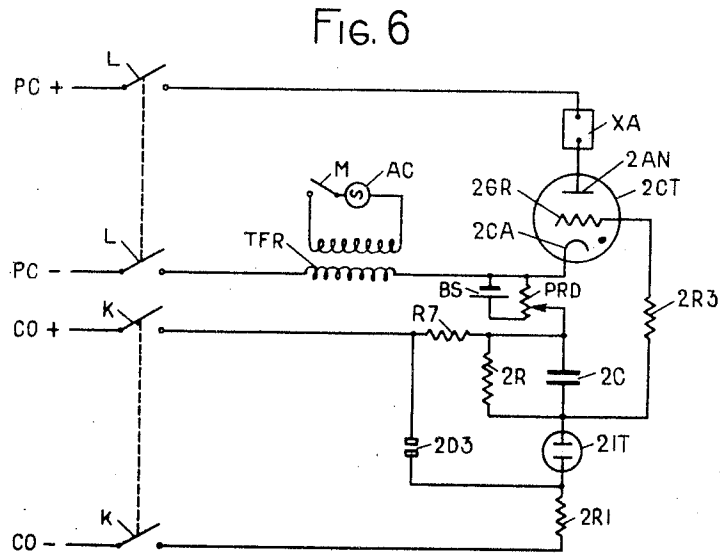
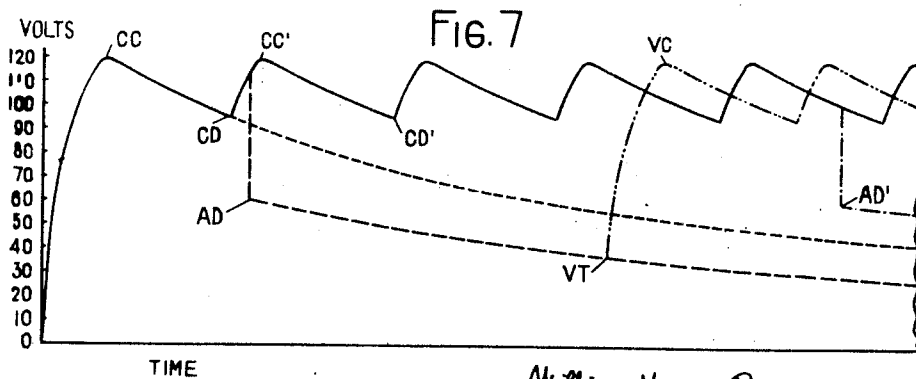
W. H. BRUNS

2,415,457

ELECTRICAL CONTROL CIRCUIT

Filed June 24, 1944

2 Sheets-Sheet 1



William Henry Bruns INVENTOR

BY *Matthew B. Bradley* ATTORNEY

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ELECTRICAL CONTROL CIRCUIT

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2 Sheets-Sheet 2

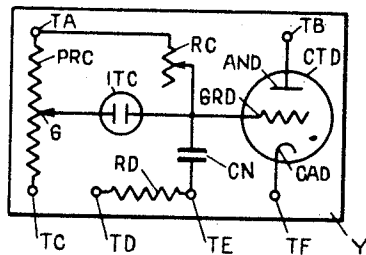


FIG. 2

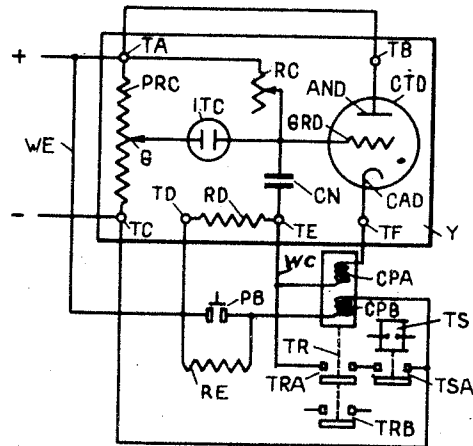


Fig. 3

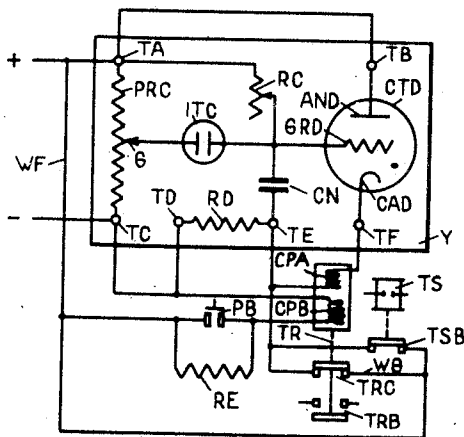


Fig. 4

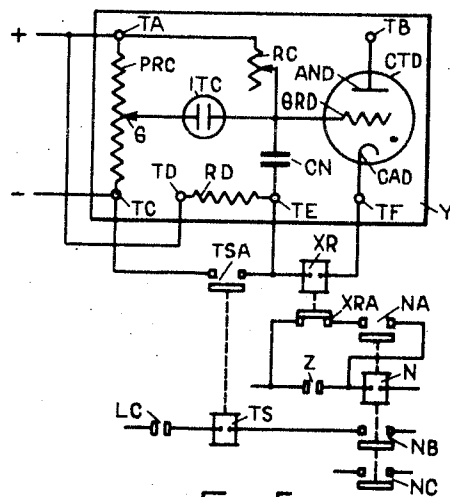


FIG. 5

William Henry Brune INVENTOR

BY Walter R. Bradley ATTORNEY

UNITED STATES PATENT OFFICE

2,415,457

ELECTRICAL CONTROL CIRCUITS

William Henry Bruns, Lincolndale, N. Y., assignor to Otis Elevator Company, New York, N. Y., a corporation of New Jersey

Application June 24, 1944, Serial No. 541,971

19 Claims. (Cl. 320—1)

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The invention relates to electrical circuits in which high impedances are involved.

Electronic tubes are often arranged in electrical circuits in which high impedances, in the order of megohms, are connected to an electrode of the tube. While electronic tubes of only two electrodes may be employed in such circuits, it is more usual to employ tubes of more than two electrodes, one of which is a control electrode, usually in the form of a grid, to which the high impedance is connected. Such high impedance network may be associated with a low impedance network for purposes of control. However, there may be current flow between the high impedance network and the low impedance network as for example due to the open circuit impedance of a connecting circuit or of the low impedance network which would affect the high impedance network in such way as to have undesirable effects upon intended operations. For example, where the charge on a condenser is being utilized in a high impedance network for controlling the grid-cathode potential of a controlled electronic tube, the impedance under open circuit conditions of a circuit leading to the condenser may have a considerable effect on the condenser charge and thus may adversely affect the grid control of the tube.

The object of the invention is to prevent the flow between a high impedance network and a low impedance network of unwanted current which would adversely affect the desired functioning of the high impedance network.

The invention involves isolating a high impedance network from an associated low impedance network so as to prevent the flow of leakage or stray currents which would interfere with the desired operation. More specifically, an isolating electronic tube having an extremely high and uniform resistance when extinguished and which passes current freely when conducting is connected at such point between the high impedance network and the low impedance network that it prevents any unwanted effect upon the control of a controlled electronic tube.

The invention is applicable to alternating current circuits, to direct current circuits, or to a combination thereof. For the most part however, the invention will be considered in connection with direct current circuits. Also, while the invention is of general application and will be so described, it will also be described as applied to control circuits in which condensers are utilized in timing the change of potential difference applied to an electronic tube. There are various

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arrangements of timing circuits in which condensers may be thus utilized. In some arrangements, the timing is obtained by controlling the rate of charging of a condenser by the value of resistance in the charging circuit, in others by controlling the rate of discharge of a condenser by the value of resistance in the discharge circuit. In many instances in which these arrangements are utilized to control the potential difference applied to an electronic tube, as for example to control the potential difference between the control electrode (hereinafter referred to for convenience as a grid) and cathode of the tube, these resistances are of high ohmic value, usually in the order of megohms. Where such high resistances have connections to control circuits, leakage resistance in these control circuits as for example the resistance across open switch contacts, may affect the operation. In applying the invention to such circuits, the isolating electronic tube may be provided in the condenser charging circuit or the condenser discharge circuit, depending upon the arrangement of the various circuits and the manner in which the condenser is being utilized.

In the embodiments shown, the isolating electronic tube is illustrated as a two electrode gas filled tube. It is preferred, especially where the controlling circuits to which the high impedances are connected run to some remote point, to arrange this tube and the high impedance circuits as a unit, suitably enclosed to protect against moisture and dirt and to shield it against stray electrostatic and electromagnetic effects. In timing circuits, the isolating tube may be arranged along with the condenser, the condenser timing resistance and controlled tube as a unit, with the unit arranged for connection to other circuits. In certain circuit arrangements, this unit may embody other elements, such as auxiliary resistances.

Circuit arrangements are shown in which the charging of a condenser is utilized in timing the change of potential difference between a pair of electrodes of a controlled electronic tube. In the embodiments of these arrangements which are illustrated, the isolating tube is connected in the discharge circuit for the condenser. In this position the isolating tube acts in lieu of switch contacts to control the condenser discharge circuit and insures an extremely high and uniform resistance in this circuit under open circuit conditions. A direct current voltage source is utilized in association with the isolating tube and condenser to cause sufficient voltage to be applied

to this tube to effect the discharge of the condenser to a low value. This source is illustrated as in the form of a resistance connected across the charging source and adapted for connection of an adjustable portion thereof in the discharge circuit. Such resistance arrangement will hereinafter be termed a potentiometer resistance. Also, resistance is provided which is of such value and is connected in the circuits in such a way as to prevent any appreciable effect on the condenser charging due to any leakage under open circuit conditions across contacts controlling the condenser charging circuit. With such arrangement, a uniform timing operation for control of the grid potential of the controlled tube is assured.

A circuit arrangement is also shown in which the discharging of a condenser is utilized in timing the change of potential difference across the grid-cathode of the controlled tube. In the embodiment of this arrangement which is illustrated, the isolating tube is located in the charging circuit for the condenser. It is also in an auxiliary discharge circuit provided to cause discharge of the condenser to a uniform voltage value for the start of the timing operation, this value being determined by the voltage at which the isolating tube becomes non-conducting. In this position, the isolating tube when it is extinguished provides a gap of extremely high and uniform resistance in the condenser charging circuit and auxiliary discharge circuit. A resistance is connected in the charging circuit for the condenser at such point as to prevent a short circuit on the line when the auxiliary discharge circuit is closed. This resistance is of such value as not to delay appreciably or prevent the desired charging of the condenser due to leakage resistance of the auxiliary discharge circuit when this circuit is open.

Modes of carrying out the invention and various features and advantages thereof will be gained from the above statements and from the following description and appended claims.

In the drawings:

Figure 1 is a schematic wiring diagram of circuits illustrating generally an application of the invention;

Figure 2 is a diagrammatic illustration of a unit for controlling the change of grid potential of an electronic tube by the charging of a condenser;

Figure 3 is a diagrammatic illustration of the unit of Figure 2 connected to other circuits in which the engagement of switch contacts starts the charging of the condenser;

Figure 4 is a diagrammatic illustration of the unit of Figure 2 connected to other circuits in which the separation of switch contacts starts the charging of the condenser;

Figure 5 is a diagrammatic illustration of the unit of Figure 2 in which the condenser energy is utilized to act through an electronic tube to cause momentary functioning of a translating device;

Figure 6 is a schematic wiring diagram of circuits in which the change of grid potential of an electronic tube is controlled by the discharge of a condenser; and

Figure 7 is a set of curves illustrating the actions which take place in the circuits of Figure 5.

Referring to Figure 1, the arrangement there illustrated is for the purpose of setting forth the invention as applied to circuits in general. It will be understood that there are many different

circuit arrangements to which the invention is applicable and that the manner in which the invention is applied depends upon the particular circuit arrangement. Thus, the circuits of Figure 1 do not serve as a basis for explaining all possible applications of the invention but do admit of an explanation of the principles involved. The circuits shown are for controlling grid potential with respect to cathode of a controlled electronic tube, designated CTB. This tube is illustrated as a three electrode tube and may be either gas filled or high vacuum type. The anode of this tube is designated ANB and the grid is designated GRB. The cathode of the tube is designated CAB and may be of the type indirectly heated by a filament (not shown), the directly heated type or cold cathode type, depending upon the particular circuit requirements. While the controlled tube may be supplied with and/or controlled by alternating current or direct current, direct current supply will be assumed. Three supply lines are illustrated to enable a negative potential on the grid with respect to the cathode to be obtained when desired. Accordingly, these supply lines are designated, +, $\mp$ and - , $\mp$ line being negative with respect to line + and positive with respect to line -. A potentiometer resistance PRA is connected across lines + and - the grid GRB is connected to an adjustable point on this resistance as indicated by arrow D. The plate circuit of the controlled tube extends from line +, through switch contacts J, a translating device X, plate ANB, cathode CAB to line $\mp$. Switch contacts A and B are connected in series by wire WA across lines + and -, and a point between these contacts on wire WA is connected to an adjustable point indicated by arrow E on potentiometer resistance PRA.

While the potentiometer resistance PRA may in certain applications be of relatively low ohmic value, in other applications it would be of high ohmic value in the order of megohms. In such event an isolating tube ITA is provided in the connection between wire WA and arrow E. The isolating tube ITA, the controlled tube CTB and resistance PRA are positioned in close proximity and preferably arranged as a unit which may be enclosed to protect against moisture and dust and to shield against extraneous electrostatic and electromagnetic effects. The isolating tube is preferably a simple gas filled two electrode tube with its electrodes designated EIA and ELB. However, it may be of the type having one element a cathode and the other an anode, or may be of a greater number of electrodes in which event a high vacuum tube may be employed in certain applications as by controlling the flow of current therethrough by controlling the grid voltage or by placing a bias on the grid to give the tube cut-off characteristics. Also where tubes of more than two elements are employed, only two of the elements may be utilized as for example the grid and cathode. Therefore, it is to be understood that in a general sense a two electrode tube as referred to herein is meant a tube of two or more electrodes, but two of which are utilized in the isolating circuit. A second potentiometer resistance PRB is provided for fixing the potential on the low impedance side of the isolating tube when contacts A and B are open. The isolating tube and the wire WB are connected to a point on this resistance by arrow F adjustable so that when contacts A and B are open substantially no potential difference exists on the two sides of the isolating tube due to the

potential drops across corresponding portions of potentiometer resistances PRA and PRB. Resistance PRB is of relatively low ohmic value so as not to be appreciably affected by any parallel leakage resistance across contacts A and B. With such arrangement, the isolating tube isolates the high impedance network to the right of this tube from the low impedance network to the left of the tube.

In operation, assume that controlled tube CTB is a hot cathode gas filled tube and that the arrow D is adjusted to such point on resistance PRA as to provide a bias on grid GRB with respect to cathode CAB to prevent the firing of the control tube. To fire the tube, contacts A are closed to short circuit the portion of resistance PRB between line + and arrow F. Thus a by-pass circuit is established through contacts A and isolating tube ITA for the portion of resistance PRA between line + and arrow E and the isolating tube becomes conducting. Arrow E is positioned so that this raises the potential of the grid with respect to cathode of the controlled tube to a point sufficient to fire the tube. The voltage drop between arrow E and line — being the voltage drop across lines + and — less the voltage drop across isolating tube ITA, arrow E is positioned so that the potential drop between arrow E and line — is such that, for the position of arrow D, the grid potential with respect to cathode is raised to the desired value.

It is believed that it will be understood from the above description that the controlled tube may be fired in other ways. For example, in case of the hot cathode tube the arrows could be positioned so that the separation of contacts B would raise the grid potential with respect to cathode to a point sufficient to fire the controlled tube. Also, the grid potential with respect to cathode of a cold cathode tube may be similarly controlled by proper positioning of the arrows. Contacts J are included for breaking the plate circuit of the controlled tube, which puts out the tube. A high vacuum controlled tube may be controlled in similar ways to vary the current flow in the plate circuit.

If isolating tube ITA and potential fixing resistance PRB were not provided, in case the controlled tube is a gas tube or a high vacuum tube with cut-off characteristics and is rendered conductive by the closing of contacts A, leakage resistance between line + and wire WB when contacts A are separated might be sufficiently low relatively to the resistance of potentiometer resistance PRA between line + and arrow E to cause unwanted conduction of the controlled tube. Similarly, if the conduction is controlled by the separation of contacts B, leakage resistance between wire WB and line — might be sufficiently low to prevent the controlled tube becoming conductive. Similarly, in case the controlled tube is a high vacuum tube of other characteristics, such leakages might prevent the desired control of the current flow through the controlled tube. However, with the isolating tube and resistance PRB provided, such leakage resistances can not cause the isolating tube to become conductive so that they have no effect upon the control of the controlled tube.

Reference may now be had to Figures 2, 3, 4 and 5 which show circuit arrangements embodying the invention in which the functioning of a gas filled controlled tube CTD is timed by timing the charging of a condenser CN. The condenser is connected in series with timing re-

sistance RC to delay the building up of the condenser charge. The grid-cathode circuit of the controlled tube is connected across the condenser so that the building up of the grid potential with respect to cathode to break down value is delayed by the delay in building up the charge on the condenser. Since the potential drop across the grid-cathode is being controlled, resistance RC is of high ohmic value, in the order of megohms. The grid of the controlled tube is designated GRD, the anode AND and the cathode CAD. An isolating tube ITC is provided in the condenser discharge circuit. A potentiometer resistance PRC is provided in conjunction with the isolating tube for controlling the discharging of the condenser. The isolating tube is connected between the point of connection of grid GRD, condenser CN and timing resistance RC and adjustable point G on the potentiometer resistance. Also a protective resistance RD is provided, this resistance being of relatively low ohmic value. These elements are arranged as a unit and enclosed as indicated by Y to seal against moisture and dirt and to shield against extraneous electrostatic and electromagnetic effects. The unit disconnected from external circuits is diagrammatically shown in Figure 2.

The unit is arranged for use with external control circuits in which either making or breaking contacts are available for the control operation. To facilitate connection of the unit in either control arrangement, terminals TA, TB, TC, TD, TE and TF are provided. Terminals TA and TC are for connection to a source of direct current, terminal TA being connected to the positive supply line and terminal TC to the negative supply line in the circuit arrangements illustrated. Potentiometer resistance PRC is connected across terminals TA and TC. As the potentiometer resistance is used to provide a voltage to maintain conduction in the isolating tube during discharge of the condenser, other sources of direct current may be employed such as a battery connected between the isolating tube and either supply line. Timing resistance RC is connected between terminal TA and the side of the condenser connected to the grid of the controlled tube. The other side of the condenser is connected to terminal TE along with one end of resistance RD. The other end of resistance RD is connected to terminal TD. The anode of the controlled tube is connected to terminal TB and the cathode to terminal TF. The circuits are shown without provision for a bias of the grid with respect to the cathode. It is to be understood, however, that a bias may be provided when desirable for certain types of tubes. In the case of a thyratron for example, a negative bias may be provided off potentiometer resistance PRC.

The unit is adaptable to various timing arrangements, the circuit connections depending upon the requirements of the particular application. It may be utilized, for example, in timing arrangements in which the timing operation, once started, is continued to completion, or in which the timing operation may be interrupted before completion. For such timing arrangements it is preferred to position arrow G so that the potential difference between line + and the arrow is not less than the extinction voltage of the isolating tube, and to employ an isolating tube of such characteristics relative to the line voltage that during the charging of the condenser, it is not caused to break down by the net voltage that exists in any closed circuit across

the tube. This will be discussed in detail later. The circuits of Figures 3, 4 and 5 all admit of interruption of the timing interval.

In Figures 3 and 4 the unit is shown connected to external circuits in which the current in the plate circuit of the controlled tube is utilized to cause the functioning of an electroresponsive device. The timing operation is started by a time initiating switch TS. In the circuits of Figure 3, contacts of this switch are engaged to start the timing operation, these contacts being designated TSA. In the circuits of Figure 4, contacts of the switch are separated to start the timing operation, these contacts being designated TSB. In each case, this operation is effected by the energization of the coil of switch TS in the arrangements of circuits illustrated, but it could not be effected by the deenergization of this coil. The electroresponsive device in the plate circuit of the controlled tube is illustrated as the coil of a time relay designated TR, the circuits being such as to cause the desired operation of this relay upon the expiration of a certain time interval after the operation of switch TS. However, other electroresponsive devices may be controlled by the controlled tube. In the particular arrangement shown the time relay has two coil portions in the form of two separate coils, one designated CPB for operating the relay and the other designated CPA for neutralizing the operating coil to drop out the relay. The plate circuit is through neutralizing coil portion CPA, this coil portion being located on the cathode side in the circuit in the interests of standardization and to limit the amount of current flow in the grid-cathode circuit as the tube breaks down. A push button PB is illustrated for completing the circuit for operating coil portion CPB to cause the time relay to operate. Upon operation, the time relay engages contacts TRB in a work circuit. It also engages contacts TRA in Figure 3, or separates contacts TRC in Figure 4, preparatory to the initiation of the timing operation. A circuit through resistance RE maintains relay TR operated after the push button is released.

The circuit arrangements of Figures 3 and 4 might be utilized, for example, in collective control push button elevator systems in which one or more motor generator sets are shut down upon the expiration of a predetermined time interval after the last call has been answered. Such a system is usually arranged so that, if another call is registered before the time interval expires, the timing operation is interrupted and the mechanism restored to initial condition for the start of a subsequent time interval. In applying the timing circuits to a system of this character, the registration of a call, represented by depressing of push button PB, would cause operation of relay TR and switch TS would be arranged to be deenergized so long as any call is registered and to be energized upon the last call being answered.

In operation of the arrangement of Figure 3, upon the pressing of push button PB the circuit is completed for the operating coil portion CPB of time relay TR. This relay operates to engage contacts TRA and TRB. The engagement of contacts TRA prepares the time initiating circuit. When the time arrives to start the timing operation, the time initiating switch TS operates to engage contacts TSA which completes the charging circuit for the condenser. This circuit is from line +, through timing resistance RC, condenser CN, and by wire WC through contacts

TRA and TSA to line -. At the same time protective resistance RD is connected by contacts TRA and TSA across the supply lines. The condenser starts to charge at a rate determined by the capacity of the condenser and the value of resistance RC. Upon the charge on the condenser building up to a point to raise the potential of grid GRD with respect to cathode CAD to a certain value, the controlled tube breaks down. The voltage applied across the anode-cathode of the tube is sufficient for the discharge to transfer to the anode, completing a circuit for the neutralizing coil portion CPA of time relay TR and thus causing this relay to drop out. This circuit is from line + through the anode-cathode of controlled tube CTD, coil portion CPA, and contacts TRA and TSA to line -. Upon the relay dropping out, it separates contacts TRA to break the charging circuit for the condenser. The separation of these contacts also renders the isolating tube subject to the combined voltage existing across the condenser and between line + and arrow G. This voltage breaks down the isolating tube, completing the discharge circuit for the condenser. This circuit is from the point of connection of the condenser to the grid GRD through isolating tube ITC, the portion of potentiometer resistance PRC between arrow G and line +, wire WE and resistance RD to the other side of the condenser. Should switch TS be deenergized before the time interval expires, as for example in response to the registration of a call in an elevator system such as above discussed, contacts TSA separate to break the charging circuit and the isolating tube breaks down to establish the discharge circuit, provided the voltage across the condenser plus the potential drop between line + and arrow G is equal to or above the tube's break down voltage. Once the isolating tube breaks down, current flow therethrough continues until the net applied voltage falls to the value of the extinction voltage of the tube, whereupon the tube goes out. Any charge on the condenser which is not discharged by way of the circuit through the isolating tube is dissipated in a discharge circuit through charging resistance RC, wire WE and protective resistance RD.

In the circuits of Figure 4, contacts TRC and TSB in parallel short-circuit the condenser charging circuit when either of these contacts are engaged. In operation, relay TR is operated in response to pressing of push button PB as before. This relay becomes self-holding through resistance RE and separates contacts TRC in preparation for the timing operation. Upon operation of switch TS, contacts TSB separate to break the by-pass around the charging circuit for the condenser, starting the timing operation. The charging circuit is from line + through resistance RC, condenser CN, and resistance RD, to line -. Upon the expiration of the time interval, the controlled tube breaks down causing the dropping out of relay TR as before. This relay reengages contacts TRC which reestablishes the by-pass for the condenser charging circuit which is part of the discharge circuit for the condenser. This discharge circuit is through isolating tube ITC and the portion of potentiometer resistance PRC between arrow G and line + as before, wire WF, wire WG and contacts TRC, back to the other side of the condenser. Owing to the fact that the voltage now applied to the isolating tube is sufficient to break down this tube, the condenser is discharged. Should

switch TS be deenergized before expiration of the timing interval, its contacts TSB engage to reestablish the by-pass circuit. Any charge on the condenser which is not discharged through the isolating tube is dissipated in a discharge circuit through resistance RC, wire WF, wire WG and contacts TRC.

In Figure 5 the unit is shown connected to external circuits in which the current in the grid-cathode circuit of the controlled tube is utilized to cause the functioning of an electroresponsive device, illustrated as the coil of a relay XR. This coil is connected in the grid-cathode circuit of the tube on the cathode side across condenser CN. The timing operation is started by switch TS. Switch TS, upon operation, engages contacts TSA completing the charging circuit for the condenser and connects resistance RD across the supply lines. Upon the potential on the grid reaching a certain value, the controlled tube breaks down completing the circuit for the coil of relay XR. Inasmuch as the energy of the condenser is utilized to break down the tube, this current flow is of short duration so that the operation of relay XR is momentary.

This circuit arrangement may be utilized for various applications. It is particularly suitable for interrupting holding circuits inasmuch as the opening of such circuit need be only long enough to enable the held switch to drop out. Such an application has been illustrated and as an application of this character is especially suitable for shutting down a motor generator set of an elevator installation such as previously described, the circuits are arranged for such operation. The held switch is designated N. The circuit for its coil is completed by contacts Z. Upon operation switch N engages contacts NA, NB and NC. Contacts NA complete a self-holding circuit through contacts XRA to maintain switch N operated after contacts Z separate. Contacts NB prepare the circuit for the coil of switch TS. Contacts NC are in a control circuit for the motor generator set. Upon the last call of the elevator system being answered, contacts LC engage to complete the circuit for the coil of switch TS. Switch TS upon operation engages contacts TSA, completing the condenser charging circuit and thus starting the timing operation. Upon the voltage of the condenser reaching a certain value, the controlled tube breaks down and the charge on the condenser causes sufficient energization of the coil of relay XR to cause the separation of contacts XRA to break the holding circuit for the coil of switch N. Switch N drops out, separating contacts NA, NB and NC. The separation of contacts NC causes the shut down of the motor generator set. The separation of contacts NB breaks the circuit for the coil of switch TS. Switch TS drops out separating contacts TSA to break the charging circuit for the condenser. This renders the isolating tube ITC subject to the combined voltage of the condenser and the portion of potentiometer resistance PRC between arrow G and line +, causing the discharge of the condenser to take place as previously described. Should a call be registered before the time interval expires, contacts LC separate causing the dropping out of switch TS. The separation of contacts TSA enables the discharge of the condenser to be effected, isolating tube ITC breaking down provided sufficient voltage has been built up on the condenser.

While the circuits in Figure 5 are shown in connection with contacts of switch TS which make

to initiate the timing operation, it will be apparent from previous description that contacts of switch TS which break could be utilized to initiate the timing operation as for example by connecting these contacts across the condenser and timing resistance with terminal TD connected to the negative line instead of the positive line. Also, while a three-element controlled tube has been illustrated, a tube having only two elements may be utilized instead.

In order that the above described operations may be more clearly understood, assume that the voltage of the supply lines is 120 volts and that a cold cathode controlled tube is utilized which breaks down upon the grid becoming 85 volts positive with respect to the cathode, with a grid-cathode potential drop of 60 volts after the tube has been fired. Assume also that a tube of such characteristics is also utilized as an isolating tube with the grid and cathode serving as the electrodes. This would be of advantage in a timing unit from the standpoint of replacements. Thus the isolating tube would have a break down voltage of 85 volts and an extinction voltage of 60 volts. A smaller difference between break down and extinction voltages may be had if desired, as by employing a tube having a probe. In a control arrangement in which the timing operation is always carried to completion, arrow G would be positioned so that the potential drop between line + and the arrow is 60 volts to insure the full discharge of the condenser through the isolating tube. However, if such adjustment were provided for elevator control circuits such as above discussed and if a call is registered during the charging of the condenser before the condenser voltage reaches 15 volts, whatever voltage the condenser has built up to would be left on the condenser for dissipation in resistance RC as this voltage added to the 70 volts provided by the potentiometer would be insufficient to break down the isolating tube. It would be preferred therefore to position arrow G to provide a voltage drop between line + and arrow G of 72.5 volts. As will be explained below, this would insure that no greater condenser charge than that due to a potential drop of 12.5 volts + or - would be present to be dissipated in the circuit through resistance RC, which can be more quickly effected.

With arrow G positioned to provide a voltage drop of 72.5 volts between line + and the arrow, only 47.5 volts are applied to the terminals of the isolating tube upon completion of the charging circuit, assuming the initial charge on the condenser is zero. As the condenser charge builds up, the voltage across the isolating tube decreases and becomes zero as the condenser charge reaches 47.5 volts, and then builds up to 37.5 volts in the opposite direction as the condenser charge reaches 85 volts to effect the break down of the controlled tube. Thus at no time during the charging operation is there sufficient voltage applied to the isolating tube to cause this tube to break down so that the rate of condenser charge is determined by resistance RC. Upon the breaking of the charging circuit for the condenser, the voltage applied to the isolating tube is the 72.5 volts potential drop between line + and arrow G, plus the voltage across the condenser. If the condenser voltage is such that the total voltage applied to the isolating tube is 85 volts or above, the isolating tube breaks down to effect the discharge of the condenser which takes place very quickly as resistance RD is of low ohmic value. The isolating tube remains conductive until the

voltage applied thereto decreases to extinction value, namely 60 volts, resulting in the application of 12.5 volts negative to the condenser to build up a negative charge thereon. If the condenser voltage is below 12.5 volts + so that the total voltage applied to the isolating tube is less than 85 volts, the tube does not break down. Thus there can be only a small charge not greater than 12.5 volts to be dissipated by the discharge circuit through resistance RC.

The isolating tube eliminates any adverse operation which might be had due to leakage resistance across contacts in the discharge circuit. Assume for example that, instead of utilizing the isolating tube and potentiometer resistance, the discharge circuit around the condenser is completed by switch contacts. Leakage resistance across these contacts is in the order of megohms, as is timing resistance RC, and might be of such value that the voltage applied to the condenser due to the potentiometer effect of the leakage resistance and the timing resistance would be insufficient to bring the grid up to break down potential. However, with the isolating tube and potentiometer resistance provided, inasmuch as the internal resistance of the isolating tube is very high as compared with that of timing resistance RC and as this tube is protected against leakage, the possibility of any appreciable effect on the charging of the condenser due to the isolating tube circuit is eliminated. In addition, the isolating tube serves as a switch to complete the condenser discharge circuit and also in conjunction with the potentiometer resistance assures the full discharge of the condenser or that it will have a minimum negligible charge for dissipation through resistance RC preparatory to the next timing operation, depending upon circuit requirements. While leakage resistance may exist across contacts of time initiating switch TS such leakage resistance can have very little effect upon the charge on the condenser as protective resistance RD is of low ohmic value so that, owing to the potentiometer effect, the voltage applied to the condenser is negligible. While one end of resistance RD is shown connected to terminal TD to enable connections to be made to effect the start of the timing operation either by the opening or the closing of a control circuit, this terminal may be omitted and the connection of such end of resistance RD made permanent within the unit as by connecting it to either terminal TA or terminal TC.

Reference may now be had to Figure 6 which shows a circuit arrangement embodying the invention in which the firing of a gas filled controlled tube 2CT is timed by timing the discharging of a condenser 2C. The arrangement shown is based on the multiple timing circuits applied to an elevator control system in the copending application of Gavin Watson, William Henry Bruns and Harold Edward Galanty, filed June 24, 1944, Serial No. 541,970. The circuits of Figure 6, however, are considerably simplified and involve only one timing circuit. The anode of the controlled tube is designated 2AN, the grid is designated 2GR and the cathode is designated 2CA. The circuits are particularly adapted for the utilization of a hot cathode controlled tube which is prevented from firing by a negative grid voltage provided by the charge on condenser 2C. However, other tubes may be employed, as for example a cold cathode tube in which a source of direct current of sufficient voltage to fire the tube could be connected in the grid circuit to

oppose the condenser bias. A source of positive biasing voltage BS is illustrated in the grid-cathode circuit on the cathode side. In case of hot cathode tubes, this biasing source may be utilized to cause firing of the tube at a higher value of negative condenser voltage, and in conjunction with a potentiometer resistance PRD to regulate the time interval. It will be assumed for purposes of further description that the controlled tube is an indirectly heated hot cathode tube.

Two sources of direct current supply are illustrated to enable the condenser to be charged to provide a negative grid voltage and to provide for the connection of the biasing source BS on the cathode side of the grid-cathode circuit. The supply lines for these sources are designated PC+ and PC- for the plate circuit and CO+ and CO- for the condenser charging circuit. The condenser 2C is connected across its supply lines through isolating tube 2IT and resistances 2R1 and R1, this being the condenser charging circuit. Timing resistance 2R is connected across the condenser to delay the condenser discharge. The grid of the controlled tube is connected to the negative side of the condenser, thereby connecting the grid-cathode circuit across the condenser and a portion of potentiometer resistance PRD so that the decrease of negative potential of the grid with respect to cathode to a point to fire the tube is delayed by the delay in the discharge of the condenser. A resistance 2R3 is provided in the grid circuit, the purpose of which will be explained later. Since grid voltage is being controlled, condenser discharge resistance 2R is of high ohmic value, in the order of megohms. An auxiliary discharge circuit is provided for the condenser. This circuit is from the positive side of the condenser through current limiting resistance R1 for the isolating tube, contacts 2D3, isolating tube 2IT, to the negative side of the condenser. The plate circuit for the controlled tube extends from line PC+ through translating device XA which may be the coil of a switch, anode 2AN, cathode 2CA, the secondary of the transformer TFR, to line PC-. Alternating current voltage is superimposed by transformer TFR on the direct current voltage applied to the plate circuit of the controlled tube. Alternating current is supplied to the transformer by a source of alternating current designated AC. This source is connected to the transformer as by a knife switch designated M. The value of this superimposed voltage with respect to the direct current plate voltage is such as to cause the resultant voltage applied to the tube to be negative for a fraction of a cycle, enabling the grid to retain control to shut off the tube. The connection of the direct current supply lines to the condenser charging circuit is illustrated as controlled by a knife switch designated K. Similarly, the connection of the direct current supply lines to the plate circuit is illustrated as controlled by a knife switch designated L. Switch L is closed a certain time, depending upon the characteristics of the controlled tube, after the closing of switch K. This is to enable the cathode to become heated and to permit the condenser to become charged to place sufficient negative potential on the grid with respect to cathode to prevent the firing of the controlled tube when switch L is closed. The controlled tube, condenser, isolating tube and resistances may be arranged as a unit and this unit sealed against moisture and dirt and shielded against extraneous

electrostatic and electromagnetic effects. Other elements may be included in this unit for convenience, as for example transformer TFR.

When utilized in an elevator control system such as set forth in the aforementioned co-pending application of Watson, Bruns and Galanty, contacts 2D3 are contacts of a floor relay and in the specific arrangement illustrated are contacts of a floor relay responsive to a down hall button for a floor above the first floor. The call registered by this floor relay is picked up by a down travelling car or may be responded to by an up travelling car provided it is the highest call to which the car is subject. The purpose of the timing circuits as embodied in such system is to enable a down call to be made effective for stopping an up travelling car, if the call has remained unanswered for more than a certain length of time, even though a call exists for a floor above. It is desirable to interrupt the timing operation for any down call picked up in regular operation before the time interval expires and condition the circuit for a subsequent operation. The particular timing circuit illustrated admits of interrupting the timing interval and, while particularly adapted for such operation, it may also be utilized for applications where the timing operation once initiated is carried to completion.

In operation, to condition the circuits for timing, switch M is closed to apply alternating current voltage to the primary of transformer TFR. Also switch K is closed to complete the charging circuit for the condenser. The value of the applied voltage is sufficient to cause the break down of isolating tube 2IT to effect the charging of the condenser. As the condenser charge builds up, the potential drop across isolating tube 2IT decreases until extinction value is reached whereupon the tube goes out. The condenser then starts to discharge by way of discharge resistance 2R until, due to the lowering of the condenser charge, the voltage applied to the isolating tube rises to a point sufficient to break this tube down. This recharges the condenser to a value to cause the isolating tube to extinguish. This cycle of operation is continuously repeated. The charging of the condenser places a negative potential on the grid with respect to cathode of the controlled tube sufficient to prevent the firing of this tube upon the closure of switch L. The closure of switch L places the circuits in condition for the timing operation.

Upon the closure of contacts 2D3, the auxiliary discharge circuit for the condenser is completed and resistance 2R1 is connected across the line. The potential drop across the condenser is sufficient to cause the isolating tube to break down for current flow in a direction opposite to that for charging the condenser and, owing to the fact that resistance R1 is of low ohmic value, the condenser discharges immediately to the value of the extinction voltage of the isolating tube. As this point is reached, the isolating tube goes out and the condenser now discharges into discharge resistance 2R. Owing to the high ohmic value of resistance 2R, this discharge takes place slowly, the rate depending upon the value of resistance 2R.

If contacts 2D3 remain engaged, upon the expiration of a certain time interval the negative potential on grid 2GR with respect to cathode 2CA decreases to a point to permit the controlled tube to fire. This results in current flow through electroresponsive device XA. Upon the subse-

quent separation of contacts 2D3, the condenser is recharged and, upon the potential of the grid with respect to cathode becoming negative a certain amount, the controlled tube is shut off by the action of the superimposed alternating current voltage. The condenser becomes fully charged after contacts 2D3 separate and the discharge recharge cycle is repeated as before awaiting the subsequent engagement of contacts 2D3. Should contacts 2D3 separate before the expiration of the time interval and thus before the controlled tube has fired, the condenser is fully recharged and the discharge recharge cycle is repeated as before.

In order that the above described operations may be more clearly understood, assume that the direct current voltage of lines PC+ and PC- is 110 volts, that the peak value of the superimposed transformer secondary alternating current voltage is 141 volts, and that an indirectly heated hot cathode tube having characteristics suitable for these voltages and a critical grid voltage of approximately -2 volts is utilized. Assume further that the potential across lines CO+ and CO- is 180 volts, that a 4 microfarad condenser with a 20 megohm discharge resistance is utilized, and that the isolating tube has a break down voltage of 85 volts and extinction voltage of 60 volts. Resistances 2R1, R1 and 2R3 are of relatively low ohmic value, being about 100,000 ohms, 1,000 ohms and 50,000 ohms respectively. By utilizing a positive grid biasing voltage of 28 volts, the controlled tube may be caused to fire when the condenser has discharged to 30 volts.

To further facilitate understanding of the operation, curves illustrating the potential drop across the condenser under different conditions of operation are illustrated in Figure 7. Other than to conform to the voltage values above assumed, these curves are not to scale. The potential drop across the condenser is plotted against time. Upon the closure of switch K to charge the condenser initially, the full 180 volts potential drop of lines CO+ and CO- is across resistances R1, 2R1 and the isolating tube. This causes the tube to break down to charge the condenser. The condenser charges relatively rapidly owing to the low resistance of the charging circuit. Upon the condenser voltage drop reaching 120 volts, the voltage drop across the isolating tube falls to 60 volts and this tube goes out. This initial charging curve of the condenser is represented by the full line between O and the point CC. As soon as the tube goes out the condenser starts to discharge through resistance 2R. Due to the high value of this resistance, this discharge takes place relatively slowly. If this discharge were uninterrupted it would follow the full line from point CC to point CD and then the dotted line. Only a portion of this discharge curve is shown and it is understood that it would continue on as a logarithmic curve. However, upon the voltage across the condenser falling to 95 volts, the point CD, the voltage across the isolating tube reaches 85 volts, causing the tube to break down again. As a result, the condenser immediately recharges from the point CD to the point CC' whereupon the isolating tube goes out and the condenser discharges again from point CC' to point CD'. These operations are continuously repeated as indicated by the full line curve.

Assume now that contacts 2D3 are closed. This may occur at any time during any one of

the condenser discharge, recharge cycles. Assume first that contacts 2D3 are closed during the condenser recharge period represented by the line extending from point CD to point CC'. The action under such assumption is indicated in dash lines. The isolating tube is conductive during this recharge portion of the cycle so that upon the engagement of contacts 2D3 to apply the condenser voltage to the isolating tube, the direction of current flow in the tube is reversed to discharge the condenser. Owing to the fact that resistance R7 is of low ohmic value, the potential drop across the condenser drops instantly to the extinction voltage value of the tube, namely, 60 volts, represented by the point AD. The condenser then discharges slowly into discharge resistance 2R. The operation had upon the closure of contacts 2D3 during the discharge portion of the cycle is represented in dot dash lines. The isolating tube is not conductive during the discharge portion of the cycle so that upon the application of the condenser voltage to the tube it breaks down to discharge the condenser to the point AD', whereupon the isolating tube goes out. From this point on the condenser discharges slowly into its discharge resistance as before. Should contacts 2D3 separate during the discharging of the condenser, the condenser is recharged as represented by the curve extending from the point VT to the point VC and the discharge recharge cycles are resumed. This is indicated in dash double dot lines.

It is to be noted that, regardless of when the contacts 2D3 close, the condenser voltage falls immediately to the extinction voltage value of the isolating tube, namely, 60 volts, thereby providing a uniform starting point for the timing operation. Upon the condenser voltage decreasing to 30 volts negative, the grid potential with respect to cathode, is reduced to 2 volts negative which fires the controlled tube. Owing to alternating current voltage being superimposed on direct current voltage for application to the plate circuit of the controlled tube and to the values of these voltages, the tube goes out and refires each alternating current cycle and is conductive for the major portion of each cycle. This operation is repeated so long as contacts 2D3 remain closed. Upon the separation of contacts 2D3, the charging circuit for the condenser is reestablished. When the controlled tube fires the grid potential becomes positive with respect to the cathode and the negative charge on the condenser is reduced. The values of resistances 2R3 and 2R1 are such as to enable the condenser to be recharged upon the establishment of the charging circuit with the result that the tube is shut off when the grid voltage becomes 2 volts negative. The condenser is recharged to 120 volts and resumes its discharge recharge cycles in accordance with the charging curve of Figure 7.

Thus it is seen that the isolating tube, being in a wire common to a charging and auxiliary discharge circuit, isolates the grid side of the condenser from the operating circuits. Also, in conjunction with resistance 2R1 it enables the timing operation to be controlled by the auxiliary discharge circuit by means of which during any discharge recharge cycle, such operation may be stopped by the closing of contacts 2D3 to by-pass the condenser and isolating tube. This isolating tube serves as a switch when this by-pass is completed to interrupt the auxiliary discharge circuit at a fixed voltage, thereby starting the actual

timing operation at a fixed voltage to insure uniform timing operations. It also serves as a switch to interrupt the charging operations during the discharge recharge cycles. Any leakage resistance across contacts 2D3 or from these contacts to line CO— is of no appreciable effect because of resistance 2R1 which is of relatively low ohmic value. Inasmuch as the internal resistance of the isolating tube is high and as it is protected against leakage, the possibility of any appreciable effect on the timing operation when the tube is out is eliminated.

While various circuit arrangements have been described in which an isolating tube is so positioned in circuits in which high impedance is connected to the control electrode of an electronic tube to isolate this electrode from the open circuit impedance of control circuits, it is to be understood that the invention is applicable to various other circuit arrangements. Also, while the isolating tube in conjunction with other apparatus enables certain control functions to be obtained, the relationship of this tube to such apparatus and the particular apparatus employed and arrangement thereof may be varied, depending upon the requirements of the particular application. While, the invention has been described in connection with gas filled controlled and isolating tubes, which are the preferred arrangements, high vacuum tubes may be employed, as for example a triode with cut-off characteristics as an isolating tube and a triode which provides in the range of operating current of the electroresponsive device a large change in plate current for a small change in grid voltage as a controlled tube. Therefore, as many changes could be made in the above constructions and circuit relationships and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. In combination, a condenser, a source of direct current for charging said condenser, a resistance of high ohmic value connected to said condenser to control the rate at which the charge on the condenser changes, an electronic tube having a plurality of electrodes, one of which is connected to the point of connection of said condenser and said resistance, a translating device controlled by said tube, a control circuit for said tube, and a second electronic tube having at least two electrodes, one of which is connected to said point of connection of said condenser and said resistance and the other to said control circuit.

2. In combination, a condenser, a source of direct current for charging said condenser, a resistance of high ohmic value connected to said condenser to control the rate at which the charge on the condenser changes, an electronic tube having a plurality of electrodes, one of which is connected to a point of common connection with said resistance and said condenser, a translating device controlled by said tube, and a second electronic tube connected between said point and said source adapted upon the application of voltage of a certain value thereto to permit the free flow of current therethrough but having a high impedance when the voltage applied thereto is below a certain value.

3. In combination, a condenser, a source of direct current for charging said condenser, a low

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impedance control circuit for said condenser connected to said source, a high resistance connected in series with said condenser to said source for controlling the rate of charging of said condenser, an electronic tube having an anode, a cathode and a control electrode, said control electrode being connected to the junction of said resistance and said condenser, a translating device in the anode-cathode circuit of said tube, and a second electronic tube connecting said junction and said control circuit, said second tube having two electrodes and having such characteristics as to permit the free flow of current therethrough upon the application of voltage of a certain value thereto but having a high impedance when the voltage applied thereto is below a certain value.

4. In combination, a condenser, a source of direct current for charging said condenser, a resistance of high ohmic value connected in series with said condenser to said source for controlling the rate of charging of said condenser, an electronic tube having an anode, a cathode and a control electrode, said control electrode being connected to the junction of said condenser and resistance, a translating device connected in the anode-cathode circuit of said tube, a second electronic tube having two electrodes, one of which is connected to said junction, and a low impedance circuit extending from the other electrode of said second electronic tube back to the other side of said condenser to provide a discharge circuit for said condenser through said second electronic tube.

5. In combination, a condenser, a source of direct current for charging said condenser, an electronic tube having two electrodes, a discharge circuit for said condenser extending through said electrodes, and means providing a direct current voltage of a certain value connected in series with said electrodes in said discharge circuit so that its voltage acts cumulatively with the condenser discharge voltage.

6. In combination, a condenser, a source of direct current for charging said condenser, an electronic tube, a potentiometer resistance connected across said source, and a discharge circuit for said condenser extending through said tube and a portion of said potentiometer resistance to provide a direct current voltage in series with said condenser voltage.

7. In combination, a condenser, a source of direct current for charging said condenser, a resistance of high ohmic value connected in series with said condenser to said source for controlling the rate of charging of said condenser, an electronic tube having a control electrode connected to the point of common connection of said condenser and said resistance, a second electronic tube, a discharge circuit for said condenser extending through said second electronic tube, and means providing a voltage at least equal to the extinction voltage of said second electronic tube connected in series with said second electronic tube in said discharge circuit so that its voltage acts cumulatively with the condenser voltage.

8. In combination, a condenser, a source of direct current for charging said condenser, a resistance of high ohmic value connected in series with said condenser for controlling the rate of charging of said condenser, a switch adapted upon operation to one position to effect the charging of said condenser from said source, a gas filled electronic tube having an anode, a cathode and a control electrode, said control electrode being connected to the junction of said condenser

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and said resistance, a translating device in the anode-cathode circuit of said tube, a two electrode gas filled electronic tube connected to said junction, and a discharge circuit for said condenser extending from said junction through said two electrode electronic tube and including means which provides a voltage adapted upon operation of said switch to the other position to combine with said condenser voltage to cause breakdown of said two electrode tube to complete said discharge circuit and to maintain said two electrode tube conductive until such combined voltage decreases to the extinction voltage of said two electrode tube.

9. In combination, a condenser, a source of direct current for charging said condenser, a high resistance connected in series with said condenser for controlling the rate of charging of said condenser, a two position switch adapted upon operation to one position to effect the charging of said condenser from said source, a gas filled electronic tube having an anode, a cathode and a control electrode, said electrode being connected to the junction of said condenser and said resistance, an electroresponsive device in the anode-cathode circuit of said tube, a potentiometer resistance connected across said source, a two electrode gas filled electronic tube connected between said junction and a point on said potentiometer resistance, and a discharge circuit for said condenser extending from said junction through said two electrode electronic tube and the portion of said potentiometer resistance between said point and one side of said source, said point being such as to provide a voltage between it and said one side of said source adapted upon operation of said switch to the other position to combine with said condenser voltage to cause, if such combined voltage is at or above breakdown voltage of said two electrode tube, said two electrode tube to conduct and remain conducting until such combined voltage decreases to the extinction voltage of the two electrode tube, said tubes, condenser and resistances being enclosed as a unit to seal them against moisture and dirt and to shield them against extraneous electrostatic and electromagnetic effects.

10. In combination; a source of direct current; an electroresponsive device; a potentiometer resistance; a condenser; a charging resistance for said condenser connected between one side of said condenser and one end of said potentiometer resistance; an electronic tube having an anode, a cathode and a control electrode, said control electrode being connected to the junction of said condenser and charging resistance and said cathode being connected to the other side of said condenser; an electronic tube having two electrodes connected between said junction and a point on said potentiometer resistance; a third resistance having one end connected to said other side of said condenser; a control switch operable to start the charging of said condenser; and circuits connecting said potentiometer resistance across said source with said one end thereof connected to the positive side of said source, connecting said electroresponsive device between said other side of said condenser and said cathode, connecting the other side of said third resistance to one side of said source, and connecting the other side of said source to said other side of said condenser through said control switch, at least said tubes, condenser and charging resistance being an enclosed unit.

11. In combination in an enclosed unit hav-

ing a plurality of terminals for making external connections thereto; a potentiometer resistance connected between a first and second of said terminals; a condenser having one side connected to a third of said terminals; a charging resistance for said condenser connected between the other side of said condenser and said first terminal; an electronic tube having an anode, a cathode and a control electrode, said control electrode being connected to the junction of said condenser and charging resistance and said cathode being connected to a fourth terminal; an electronic tube having two electrodes connected between said junction and a point on said potentiometer resistance; and a third resistance having one end connected to said third terminal.

12. In combination in an enclosed unit for operation from a source of direct current for effecting the timed control of an electroresponsive device under the control of a control circuit; a potentiometer resistance adapted for connection to said source; a condenser; a charging resistance for said condenser connected between one side of said condenser and the end of said potentiometer resistance adapted for connection to the positive side of said source; an electronic tube having a cathode adapted for connection through said electroresponsive device to the negative side of said source, an anode, and a control electrode connected to the junction of said condenser and charging resistance; an electronic tube having two electrodes connected between said junction and a point on said potentiometer resistance; and a third resistance having one end connected to said other side of said condenser and its other end adapted for connection to either end of said potentiometer resistance, said other side of said condenser and the end of said potentiometer resistance opposite to that to which said third resistance is connected being adapted to receive the connections of said control circuit.

13. In combination, a condenser, a source of direct current for charging said condenser, a discharge resistance for said condenser of high ohmic value connected in parallel with said condenser, an isolating gas filled electronic tube, a protective resistance, a charging circuit for said condenser extending from the negative side of said source in series through said protective resistance, isolating tube and parallel connected condenser and discharge resistance to the positive side of said source, a controlled electronic tube having a control electrode connected to the junction of said isolating tube and condenser, a normally open switch, and an auxiliary discharge circuit for said condenser through said isolating tube and said switch by-passing said discharge resistance, the voltage of said source being of such value relative to the break down and extinction voltage values of said isolating tube as to cause repeated charge discharge cycles of the condenser when said switch is open and to cause the condenser voltage to be high enough when said switch is closed to break down said isolating tube to cause discharge of said condenser by way of said auxiliary discharge circuit until the condenser voltage falls to the value of the extinction voltage of said isolating tube.

14. In combination, a condenser, a source of direct current for charging said condenser, a discharge resistance for said condenser of high ohmic value connected in parallel with said condenser, an isolating electronic tube, a protective resistance, a charging circuit for said condenser extending from the negative side of said source in

series through said protective resistance, isolating tube and parallel connected condenser and discharge resistance to the positive side of said source, a normally open switch, an auxiliary discharge circuit for said condenser through said isolating tube and said switch by-passing said discharge resistance, a controlled electronic tube having an anode, a cathode and a control electrode, said control electrode being connected to the junction of said isolating tube and condenser, and a translating device in the anode-cathode circuit of said controlled tube.

15. In combination, a condenser, a discharge resistance for said condenser of high ohmic value, a source of direct current for charging said condenser, one side of each of said condenser and discharge resistance being connected to the positive side of said source, an electronic tube having an anode, a cathode and a control electrode, said control electrode being connected to the junction of the other side of said condenser with the other side of said discharge resistance, a translating device in the anode-cathode circuit of said tube, an isolating electronic tube having two electrodes, one of which is connected to said junction, a protective resistance connected between the other electrode of said isolating tube and the negative side of said source, and a normally open switch connected between the junction of said protective resistance and isolating tube and the positive side of said source, said isolating tube acting upon the application thereto of voltage above a certain value to permit the free flow of current therethrough to enable the charging of said condenser to be effected and to permit discharge of said condenser through said switch when said switch is closed but having a high impedance when the voltage applied thereto is below a certain value to prevent charging of said condenser or discharge thereof through said switch to enable the discharge of said condenser to be effected through said discharge resistance.

16. In combination, a condenser, a discharge resistance for said condenser of high ohmic value, a source of direct current for charging said condenser, one side of each of said condenser and resistance being connected to the positive side of said source, an electronic tube having an anode, a cathode and a control electrode, said control electrode being connected to the junction of the other side of said condenser with the other side of said resistance, a translating device in the anode-cathode circuit of said tube, and an isolating electronic tube connected between said junction and the negative side of said source adapted upon the application of voltage above a certain value thereto to permit the free flow of current therethrough to charge said condenser but having a high impedance when the voltage applied thereto is below a certain value to enable the discharge of said condenser to be effected.

17. In combination, a condenser, a source of direct current for charging said condenser, a discharge resistance for said condenser of high ohmic value connected in parallel with said condenser, an isolating gas filled electronic tube, a protective resistance, a charging circuit for said condenser extending from the negative side of said source in series through said protective resistance, isolating tube and parallel connected condenser and discharge resistance to the positive side of said source, a second gas filled electronic tube having an anode, a cathode and a control electrode, said control electrode being connected to the junction of said isolating tube and con-

denser, an electroresponsive device in the anode-cathode circuit of said second tube, a normally open switch, and an auxiliary discharge circuit for said condenser through said isolating tube and said switch by-passing said discharge resistance, the voltage of said source being of such value relative to the break down and extinction voltage values of said isolating tube as to cause when said switch is open repeated cycles of charging of said condenser until the voltage across said isolating tube falls to extinction value and then discharging of said condenser into said discharge resistance until the voltage across said isolating tube rises to break down value and to cause the condenser voltage when said switch is closed to exceed the break down voltage value of said isolating tube to cause discharge of said condenser by way of said auxiliary discharge circuit until the condenser voltage falls to the extinction voltage value of said isolating tube and to thereafter cause discharge of said condenser into its discharge resistance from a uniform voltage value.

18. In combination, a condenser, a source of direct current for charging said condenser, a discharge resistance for said condenser of high ohmic value, a gas filled electronic tube, a protective resistance, a charging circuit connecting said condenser to said source through said protective resistance and tube, a normally open switch, and an auxiliary discharge circuit for said condenser through said tube completed by the closing of said switch to effect discharge of said condenser to the extinction voltage value of said tube to thereby provide a uniform voltage on said condenser when said tube is extinguished for discharge into said discharge resistance.

19. In combination, a condenser, a source of direct current for charging said condenser, a dis-

charge resistance for said condenser of high ohmic value connected in parallel with said condenser, an isolating gas filled electronic tube, a protective resistance, a charging circuit for said condenser extending from the negative side of said source in series through said protective resistance, isolating tube and condenser to the positive side of said source, a second gas filled electronic tube having its grid-cathode circuit connected across said condenser and parallel discharge resistance, a normally open switch, and an auxiliary discharge circuit for said condenser through said isolating tube and said switch by-passing said discharge resistance adapted when said switch is closed to effect discharge of said condenser until the condenser voltage falls to the extinction voltage value of said isolating tube to thereby provide a uniform voltage on said condenser for discharge thereof into its discharge resistance.

WILLIAM HENRY BRUNS.

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