Aug. 4, 1936. H. H. GEFFCKEN ET AL 2,049,647

GAS DISCHARGE RELAY

Filed Oct. 15, 1932

Fig. 1

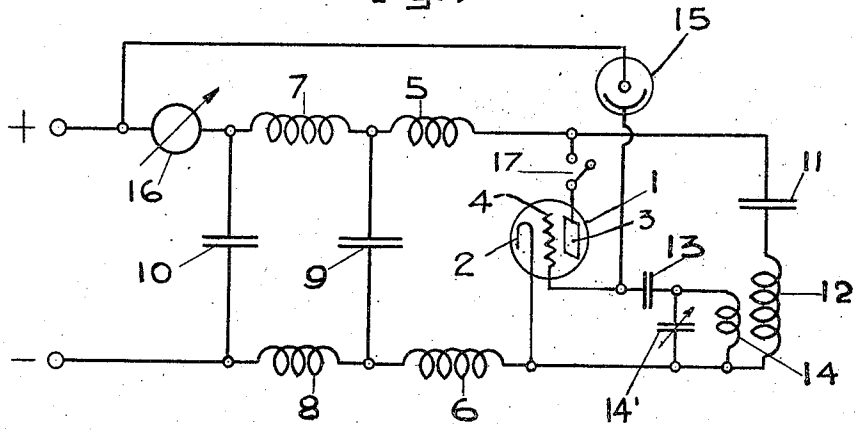


Fig. 2

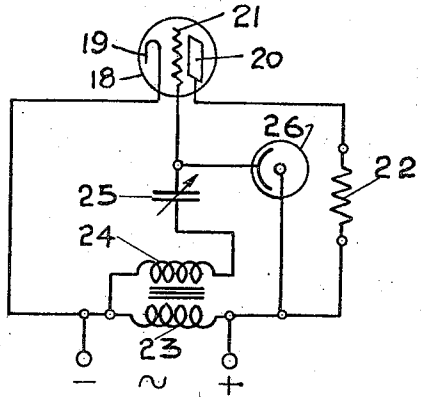


Fig. 4

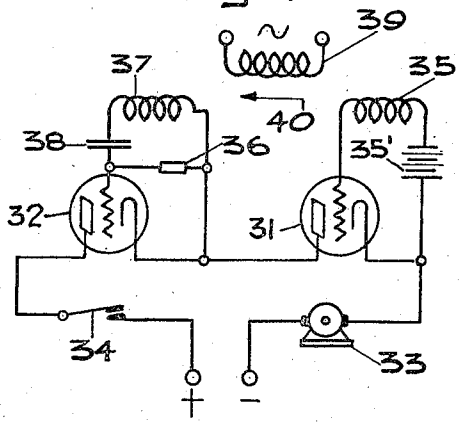
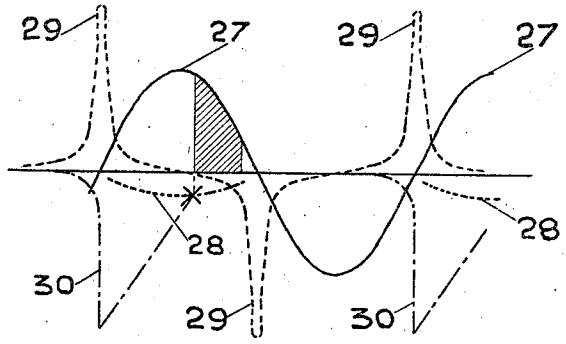


Fig. 3



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GAS DISCHARGE RELAY

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8 Claims. (Cl. 250—41.5)

Our invention relates to gaseous discharge devices and more particularly to gaseous discharge relays.

Gaseous discharge relays known in the art generally consist of a sealed vessel filled with a suitable rarefied gaseous atmosphere, such as of mercury, helium, neon or a mixture thereof, a pair of main electrodes included in the vessel, and an auxiliary or control electrode also called an ignition electrode, for controlling the discharge.

Heretofore discharge or glow relays of this nature have been provided with an electron emitting cathode, preferably an incandescent cathode, for increasing the intensity of the discharge current and decreasing the operating potential and the losses incurred in the tube. These tubes known as grid glow tubes, are used extensively for power controlling and relay purposes in both the signalling and power fields.

The essential differences of gaseous discharge relays of the above described type as compared with the usual electronic discharge tubes operating with a high vacuum as used extensively in the radio and allied arts, reside in the control or ignition electrode. In the case of vacuum tubes, the control electrode is effective during the entire duration of the discharge; in the case of gaseous discharge relays, the control electrode controls the starting of the discharge only without exerting any further influence upon the discharge, once it has been started. During the discharge interval, the control or ignition electrode assumes an average free potential determined by the discharge current.

In order to provide a continuous and quantitative control of a gaseous discharge relay in accordance with input potential variations applied to the control or ignition electrode similar to the operation of electron tubes, it is necessary to interrupt the anode or output circuit of the discharge device immediately after each ignition of the discharge. According to a well known method, in order to effect such continuous control, the discharge relay device is operated by an alternating current potential or by an interrupted direct current potential. In this manner, short extinguishing periods occur between the individual discharge periods. During these extinguishing periods, the discharge gap of the device carries no current and must regain its initial condition relative to the free potential or a negative biasing potential of the control electrode, which condition is characterized by a substantially complete freedom from ionization of the discharge space.

One object of our invention is to provide means including novel circuit connections for effecting a quantitative control of the discharge current of a gas discharge relay device in accordance with a varying input potential impressed upon the control electrode.

Another object of our invention consists in the provision of a gaseous discharge relay with means including novel circuit connections whereby periodic discharge periods are obtained of substantially equal duration and a frequency dependent on the value of the varying input control potential.

Another object of our invention is to provide a novel circuit for gaseous discharge relay for accurately timing the starting of the discharge in accordance with a varying input control potential.

Still a further object of our invention is to provide a circuit for operating a gaseous discharge relay for securing a continuous and gradual control of the discharge output current in accordance with input signalling variations independent of the use of either an alternating or direct current operating voltage.

Another object of our invention is to provide a novel control circuit for gaseous discharge relays adapted for frequency reduction.

Further objects and novel aspects of the invention will appear from the following detailed description wherein we have set forth several preferred embodiments of our invention. We wish it to be understood, however, that the description in connection with the drawing should be regarded as illustrative only of the broader and underlying principles of the invention which, as will become obvious, is subject to many variations and modifications coming within the broadest scope and spirit of the invention, as expressed in the appended claims.

Figure 1 illustrates a novel circuit arrangement in accordance with the invention for affording a quantitative control of the output current of a gaseous discharge relay utilizing an oscillatory circuit to react on the discharge device for producing a discharge timing potential on the control electrode.

Figure 2 illustrates another embodiment of the invention utilizing a highly saturated iron core transformer for securing properly timed control potential.

Figure 3 illustrates a number of illustrative curves explanatory of the operation of the circuit according to Figure 2.

Figure 4, by way of example, illustrates one

practical application of the novel control arrangement according to the invention applied to the automatic operation of a railroad cross-bar.

Similar reference numbers denote similar parts throughout the different views of the drawing.

The invention, as mentioned, relates to a novel method of operating gaseous discharge relays, preferably of the incandescent cathode type. Principally the invention contemplates the provision of means for applying a negative charge to the grid of a gas discharge device prior to the starting of the discharge and means for consecutively allowing said charge to leak off during a time period varying in accordance with a variable input condition until reaching a value sufficient to effect the starting or restarting of the discharge through the tube. For instance, in an arrangement in which the discharge is effected periodically, such as by the use of an alternating current anode potential, a positive charge may be applied to a condenser connected to the grid through immediately prior to the positive or operating cycles of the anode voltage, which charge is then allowed to leak off through a variable input impedance, such as a photoelectric cell, variable resistance or the like, whereby varying discharge periods are secured, resulting in current impulses of varying duration through the output circuit of the tube. In this manner the average current flow through the output circuit may be quantitively and continuously controlled in accordance with the variation of an input condition, such as the illumination of a photoelectric device or the like. This method affords a greatly simplified circuit and besides, involves a number of unexpected novel effects adapted to increase to a large extent the practical uses of such discharge devices.

Referring now more particularly to Figure 1 of the drawing, we have shown at 1, a gas discharge device comprised of an incandescent cathode 2, anode 3, and a control electrode 4 surrounding the cathode. The discharge device 1 is supplied with operating energy from a direct current potential source, indicated by the plus and minus signs in the drawing, through a filter comprised of series chokes 5, 6, 7, 8, and parallel condensers 9 and 10. Furthermore, a series oscillatory circuit comprised of a condenser 11 and inductance coil 12 is connected in parallel to the discharge device 1, as shown. The ignition electrode or grid 4 is coupled through a condenser 13 and coupling coil 14 with the circuit 11—12 and is furthermore connected to the positive pole of the potential source through a photoelectric cell or any other control device, such as high ohmic resistance, etc. An instrument 16 or other translating device is provided for measuring the direct current flowing through the system. The filter 5—10 may be omitted and a counting device substituted for the instrument 16. The heating circuit of the incandescent cathode 2 has not been shown for the sake of simplicity as being unnecessary for the proper understanding of the operation of the invention; it is necessary that the heating circuit is always closed some time before the closing of the switch 17 which serves for putting the system into operation.

The operation of the system as shown by Figure 1 is as follows: When the switch 17 is closed, the tube 1 is ignited and a discharge started. Condenser 11 which has previously been charged to the full operating potential is then discharged through the tube in the form of an oscillatory discharge. Considering the negative or electron current flow of this discharge, it is seen that the electrons accumulated on the lower plate of condenser 11, due to the negative charge thereon, will flow through the coil 12 and the tube 1 to the upper or positive plate, thus establishing a discharge current. Due to the electro-magnetic inertia of the self-inductance coil 12, more discharge current will flow through the circuit than would be necessary to just neutralize the positive and negative condenser charges, as is well understood in accordance with the theory of electric circuits, resulting in a temporary reversal of the polarity of the charges on the condenser; that is, the upper plate will temporarily become negative and the lower plate positive due to the further action of the choke coils 5, 6, 7, 8 of the filter circuit which prevent the oscillatory discharge current from entering the remaining circuit portions of the system. By the temporary reversal of the condenser potential, the plate 3 of the device 1 will become negative for a short period relative to its cathode 2, thus stopping or extinguishing the discharge through the tube and restoring the original condition, whereupon the same phenomena will take place in periodic succession, as is well understood.

During the oscillatory discharge, a potential impulse has been applied to the grid circuit through the condenser 13 and by means of the induction coil 14 in coupling relationship with the coil 12. By proper arrangement of the polarity of coil 14, the right hand plate of the condenser 13 is made positive, resulting in a corresponding negative potential being established on the left hand plate connected to the grid 4. The necessary electrons for the negative potential are attracted from the emission current through the tube supplied by the cathode 4.

In order to secure proper phase adjustment, a condenser 14' is arranged in parallel with the inductance coil 14. During the above operation, as pointed out, electrons are trapped on the plate of the condenser 13 connected to the control electrode 4. These electrons are attracted by the control electrode from the discharge emission of the cathode 2, but will, however, flow back to the ignition electrode as soon as the induced voltage impulse produced in the induction coil 14 begins to assume a negative value. These electrons thus produce a negative charge on the control electrode 4, increasing thereby the discharge potential of the tube 1 to such an extent that the starting of a new discharge is, at this instant, made impossible. Only after the charge has leaked off again through the photoelectric cell 15, the operation as described will repeat itself.

The principle of trapping and discharging electrons by means of a grid condenser and grid leak resistance as used according to the invention resembles the well known operation of vacuum tubes for detecting modulating signal energy also known as audion detector effect. While in the latter the charges are continuously applied to the grid and carried away by the leak resistance, in the case of the invention periodic impulse charges are applied at definite time interyals for determining the re-starting time of the gas discharge during periodic operating cycles in accordance with the novel purpose and function of the system according to the invention. In this manner, periodic discharge currents will flow through the discharge tube 1 having a frequency, dependent on and substantially proportional to the illumination of the

photoelectric cell 15. Since during each discharge the same amount of electricity passes the discharge tube, the reading of the instrument 16 will be also proportional to the degree of illumination of the photoelectric cell 15.

In place of the series oscillatory circuit shown for producing a timing potential in connection with the electron trapping condenser 13, it is obvious that any other self-interrupting arrangement may be substituted. It is only necessary, in accordance with the spirit of the invention, that during the interrupting periods of the discharge, a negative potential impulse is applied to the ignition electrode 4. For this purpose, as is obvious, both oscillatory circuits or contact devices could be provided.

Referring now to Figure 2, we have shown another embodiment of our invention in which an alternating operating current is used for operating the discharge device. The discharge tube 18 has an incandescent cathode 19 which, in the same manner as in the case of Figure 1, is preferably of the indirect heater type, an anode 20 and an ignition or control electrode 21. A load impedance 22 is included in the main circuit as shown. A small transformer 24 supplied from an alternating current source indicated at 23 and having a highly saturated iron core, has one of its secondary terminals connected to the ignition electrode 21 through the condenser 25, the other terminal being connected to the cathode 19. The ignition electrode 21 is furthermore connected with the anode through the photoelectric cell 26 to provide a leaking path in a manner similar as described by Figure 1.

The operation of this circuit will be explained more clearly in connection with the explanatory diagram shown in Figure 3. In this latter, the full curve 27 represents the operating supply voltage; curve 28 illustrates the critical or breakdown potential of the electrode 21, being different for each operating potential as is well known; curve 29 represents the voltage supplied by the secondary of the transformer 24; and curve 30 represents the potential of the control electrode 21. A discharge will be produced through the tube during the period, as indicated by the cross-hatched area in the diagram.

The transformer 24 is designed in such a manner that its core becomes fully saturated with very low instantaneous values of the alternating supply current such as at about 8 to 10 volts in case of a 110 volt supply source. In this manner, steep voltage peaks are produced in the secondary and applied to the condenser 25.

At the beginning of each alternation during which the incandescent cathode 19 is negative, a positive potential impulse is applied to the lower plate of the condenser 25 provided the polarity or winding sense of the secondary 24 is properly chosen. Due to this positive potential, a corresponding negative potential is induced on the upper plate of condenser 25 whereby the required negative electrons are absorbed by the control electrode 21 from the discharge current of the tube and accumulated on the condenser 25 in a manner similar as described in connection with Figure 1. With decreasing transformer voltage or cessation of the impulse voltage as shown at 29 in Figure 3, the electrons on the upper plate of condenser 25 will return to the ignition electrode, thus producing a high negative charge thereon, such as shown by the curve 30 in Figure 3. This charge will then leak off through the photoelectric cell 26. The discharge branch of the potential curve 30 approaching the abscissa axis, will be more or less steep, dependent on the intensity of the current or impedance of the photoelectric cell 26. As will be understood the discharge will be started at the point of intersection of the critical potential curve 28 and the falling branch of the curve 30 representing the charging and discharging potential.

In this manner, as is seen, the starting of the discharge during the periodically recurring positive or operating cycles of the tube after the grid has re-gained its control may be accurately timed in accordance with variations of a physical characteristic to be controlled, such as varying illumination of an input photoelectric cell as shown resulting in a corresponding variation of the integrated or average current flow through the tube as described.

One advantage, among others, of a system and method for controlling gaseous discharge tubes according to the invention over the aforementioned phase control method known in the art is due to the fact that the operation is substantially independent of slight variations of the capacity of the grid condenser caused by atmospheric or other influences, induced charges, etc., as compared to the phase control system where slight capacity variations will cause subtantial interference with the proper operation, as is obvious.

A further advantage of the invention resides in the fact that it is possible, by means of an arrangement just described, to extend the control over a greater number of alternations of the supply voltage. For this purpose it is only necessary to design the circuit in such a manner that prior to the setting in of the discharge, a very steep positive half wave is applied to the transformer 25, as illustrated in Figure 3, in such a manner to prevent a re-starting of the discharge during several alternations of the alternating supply current until the negative charge on the control electrode 21 has decreased to a proper value by leaking off through the photoelectric cell or other input impedance, and the grid regains its control on the discharge.

As the rate of the decrease of the grid potential after the impression of the negative charge impulse is dependent not only upon the intensity of the photoelectric current or the impedance of the cell 26 but also upon the size of the capacity of the condenser to be discharged, an adaptation and adjustment of the sensitivity in accordance with the prevailing conditions may also be secured by adjusting the value of the capacity of the condenser 25. For this purpose condenser 25, in Figure 2, has been shown to be variable.

The applicability of the invention, as is obvious, is not limited to the control of gaseous discharge relays by photoelectric cells only, as shown in the embodiments of the drawing. The photoelectric cell shown in the figures may be substituted by any other discharge device, such as an electronic tube, an ionization chamber, and the like, or by any input impedance, such as a high ohmic resistance. Thus, the system as described in Figures 1 and 2 may be used for theatre lighting or motor control, etc. by substituting a finely controllable resistance for the photoelectric cell 15 whereby large output current in the translating device 16 (Figure 1) or 22 (Figure 2) may be gradually and continuously controlled.

By substituting using a resistance of suit-

able ohmic range in such a manner that the discharge time through the grid leak or photoelectric cell as represented by the slanting portion of the curve 30 according to Figure 3 is extended to cover more than one cycle of the operating current the number of operating or discharge periods is reduced as compared to the frequency of the operating current. In this case the device may serve as a frequency reducing system for producing a lower frequency from currents of higher frequency.

In order to still further illustrate the numerous applications of the invention, we have shown a special embodiment of a practical control system which will be described in connection with Figure 4 of the drawing, referring to the automatic operation of a control mechanism through a relay, servo-motor, etc., by a vehicle or object moving in a predetermined direction.

This may be achieved by means of a circuit arrangement as illustrated schematically in the drawing. We have shown two gaseous discharge tubes 31 and 32 respectively, connected in series and supplied from a direct current potential operating source indicated by the plus and minus signs. The circuit furthermore includes an electric motor 33 serving to directly operate a control mechanism and a switch 34. The control electrode of the discharge tube 31 is negatively biased by means of a battery or other potential source 35' in such a manner that the ignition potential of this tube is higher than the operating potential. An induction coil 35 is included in the grid circuit of the tube. The control electrode of the discharge tube 32 is connected with the cathode through a high ohmic resistance 36 in such a manner that the ignition potential of this tube is very low under normal conditions. An inductance coil 37, in series with the condenser 38, is furthermore connected between the control electrode and the cathode of the tube 32, in accordance with the invention, serving for imparting a control potential to the control electrode.

The coils 35 and 37 are arranged at a certain distance from each other. A coil 39 is furthermore arranged on the vehicle or moving object, and a current of medium or high frequency constantly passed through this coil. Thus, if the coil 39 passes the stationary coils 35 and 37 in the direction of the arrow 40, it will induce at first a potential difference on the grid of the tube 31 in opposite direction to the biasing battery voltage 35, whereby the discharge is started. This will at once cause in turn a discharge of the second tube 32, thus setting in operation the servo-motor 33 operating the desired control mechanism. As soon as the latter arrives in its final position, it will open contacts 34, thus stopping movement of the motor 33.

If, on the other hand, the coil 39 passes the stationary coils 35 and 37 in a direction opposite to the arrow 40, at first a positive potential will be produced upon the control electrode of the tube 32 through the coil 37 and condenser 38, resulting in an attraction of electrons from the discharge emission, and a consequent increase of the ignition potential of this tube beyond the operating voltage. If, then in the manner above described, tube 31 is opened for a short period, a breakdown is thus prevented. The negative charge of the control electrode of tube 32 will then gradually leak off through the resistance 35, thus returning the system to its initial operating state after the lapse of several seconds. This system may serve for counting, traffic control or similar purposes, as is understood, where a record or operation of a control mechanism, such as for example the lowering of road barriers at a railroad crossing is desired for vehicles or other objects moving in a predetermined direction.

From the above it is seen that our invention in its broadest aspects contemplates novel means and a method for operating gas discharge tubes comprising an electron emitting cathode, anode and a control electrode. According to the underlying principle operation of the invention as seen from the above, a periodic ignition and extinction of the discharge through the tube is effected with the provision of means, such as a combination of condenser and leak resistance, for storing a negative impulse charge on the control electrode during the extinction periods and for consecutively allowing said charge to leak off through a variable impedance in accordance with the variation of an input or controlling condition in such a manner as to secure corresponding variations of the average output current flowing through the tube by timing the starting of the discharge during the ignition periods.

We claim:

1. An electrical system comprising a gaseous discharge tube having a sealed envelope filled with a gaseous atmosphere; a pair of main electrodes therein, one of said electrodes being an electron emitting electrode; a third electrode for controlling the discharge current; an output circuit including a source of direct current operating potential for said main electrodes; a controlling circuit connected between said control electrode and said electron emitting electrode including a series condenser having one plate connected to said control electrode; an oscillatory circuit connected between said main electrodes and coupled with said control circuit; and an impedance varying in accordance with a controlling magnitude connected to said control electrode and the positive terminal of said direct current source to serve as a leak resistance.

2. In an electrical system as described in claim 1, in which said oscillatory circuit consists of a series arrangement of a condenser and an inductance coil; a further inductance coil in said control circuit coupled therewith; and means for regulating the phase of the induced current in said control circuit comprising a variable condenser connected in parallel across said further inductance.

3. An electrical system, comprising a gaseous discharge tube having a cathode, anode and a grid electrode; a condenser having one plate connected to said control electrode; a source of alternating current connected between said cathode and anode for periodically starting and stopping an ionic discharge through said tube; means for applying a peaked potential impulse to the other plate of said condenser in a period of substantially lesser duration than the discharge periods of said tube and in substantially the same phase relation as the corresponding potential applied to said anode for storing a corresponding negative discharge preventing potential on said first mentioned condenser plate; and a leak resistance connected to said grid adapted to vary in accordance with a controlling magnitude for timing the starting instants of the discharge.

4. In a system as described in claim 3, in which said leak resistance is comprised of a photoelectric device, and a translating device inserted in the anode output circuit of said discharge relay.

5. In combination, a discharge device comprising an envelope; an inert gas atmosphere therein, a cathode, an anode and a grid therein; an alternating anode potential source connected between said anode and cathode for periodically starting and stopping an ionic discharge through said tube for producing alternate operating and non-operating cycles of said tube; further means for applying peaked negative potential impulses to said control element of substantially lesser duration than and prior to the beginning of the conducting cycles; means for storing the peak negative potential at said grid and means for gradually removing said stored potential at variable rates in accordance with variations of a physical controlling magnitude for timing the starting of the discharge at variable instants during the conducting cycles, and a translating device connected in the anode circuit of said tube.

6. The method of gradually varying the output current of a vapor discharge device in accordance with variations of a controlling magnitude which consists in periodically alternately starting and stopping an ionic discharge through said device at a definite frequency to produce periodic conducting and non-conducting periods; and controlling the average discharge current by correspondingly periodically variably delaying the starting of the discharge by subjecting it to a short discharge preventing peaked potential impulse of substantially lesser duration than and prior to the conducting periods; storing said discharge preventing potential; and gradually removing said stored potential during variable time periods in accordance with variations of a controlling magnitude.

7. The method of gradually varying the output current of a vapor discharge device having a cathode, an anode and a control element in accordance with variations of a controlling magnitude consisting in periodically producing alternate conducting and non-conducting periods and varying the average discharge current flow by electrostatically delaying the starting of the discharge during the conducting periods for variable time intervals by applying peaked discharge preventing potential impulse to said control element of substantially lesser duration than and prior to the conducting periods, storing said discharge preventing potential; and consecutively gradually removing the stored impulse charges at variable rates in accordance with variations of a physical controlling magnitude.

8. In combination, an electric discharge tube filled with a rarefied gaseous atmosphere; a cathode and anode and a control element therein; an alternating current source connected to said cathode and anode for periodically starting and stopping an ionic discharge through said tube; a condenser having one electrode connected to said control element; a highly saturable iron core transformer connected between the other electrode of said condenser and said cathode for applying a peaked positive potential impulse to said condenser prior to the discharge periods of said tube and storing said potential at said grid; and a leak impedance varying in accordance with a physical controlling magnitude connected to said control element.

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