

Jan. 4, 1938.

R. K. HONAMAN ET AL

2,104,128

GAS DISCHARGE TUBE DELAY CIRCUIT

Filed Dec. 27, 1935

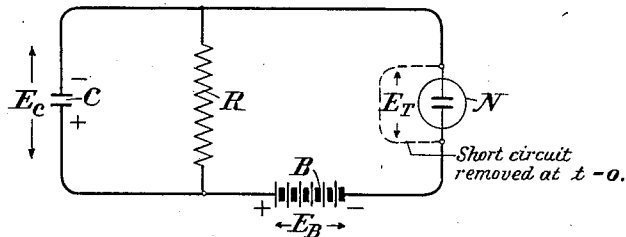


Fig. 1

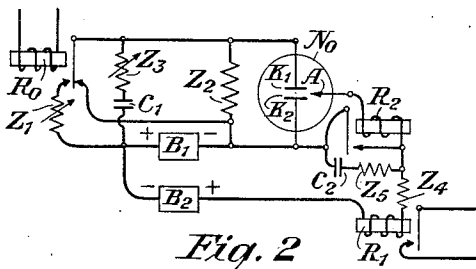


Fig. 2

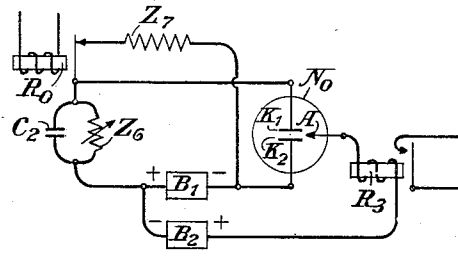


Fig. 3

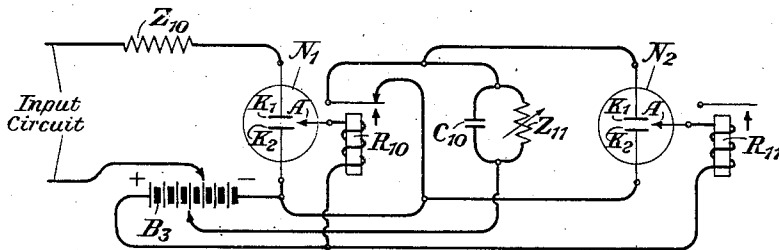


Fig. 4

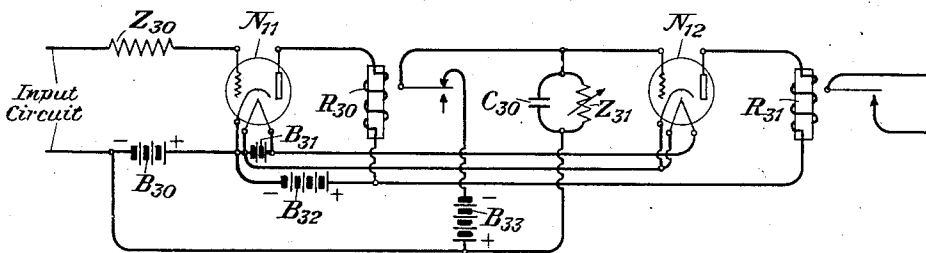


Fig. 5

INVENTORS
R. K. Honaman and
BY L. K. Swart
ATTORNEY

UNITED STATES PATENT OFFICE

2,104,128

GAS DISCHARGE TUBE DELAY CIRCUIT

Richard Karl Honaman, Bloomfield, and Leland Kasson Swart, Mountain Lakes, N. J., assignors to American Telephone and Telegraph Company, a corporation of New York

Application December 27, 1935, Serial No. 56,395

9 Claims. (Cl. 250—27)

This invention relates to gas discharge tubes and to circuits therefor. This invention also relates to delay circuits and to delay circuits employing gas discharge tubes.

5 In making measurements of induced voltages it becomes desirable to segregate surges of, for example, the 60 cycle type from short-lived transients due to lightning, static, etc., which may be imposed upon conductors and tend to interfere with the accuracy of the measurements. These extraneous voltages, if of the character of lightning discharges, may be of such a wide range of amplitude and frequency as to render filtering difficult if not impossible. In general, such extraneous voltages last but a very brief period of time and their effect may be eliminated by having the measuring apparatus respond only if the applied voltage has persisted for a longer period.

One of the objects of this invention is to provide arrangements for obtaining predetermined and controllable time delays. The various methods and circuits for accomplishing this objective may employ gas discharge tubes, condensers, resistors and sources of potential of such magnitudes and so arranged as to introduce a delay of any desired interval.

One of the features of this invention is based upon the fact that the delay interval may be determined from the time required for a charged condenser to discharge through a resistor.

Another of the features of this invention is that the delay may be determined from the time required for a condenser in conjunction with a resistor to become charged to a predetermined voltage.

Other and further objects and features of this invention will be better understood from the detailed description hereinafter following, when read in connection with the accompanying drawing in which Figure 1 illustrates a circuit showing merely some of the principles of the invention. Fig. 2 shows the invention applied to the circuit of a three-element cold cathode gas discharge tube, Fig. 3 is a modification of the arrangement shown in Fig. 2, Fig. 4 illustrates the delay circuit coupled to two three-element cold cathode gas discharge tubes, and Fig. 5 shows the invention applied to circuits of hot cathode gas discharge tubes.

Referring to Fig. 1 of the drawing, there is shown one method for producing delay. A condenser C is connected in parallel with a resistor R and the parallel combination is connected to a battery B or other source of voltage as well as

to a gas-discharge tube N. Assume that the gas-discharge tube N is entirely shunted by a conductor, as shown in dotted lines. Then, in this assumed circuit, the condenser C will be charged to the voltage of the battery B.

If, now, the shunt around the tube N is opened or removed, the two electrodes of the tube N will be connected in series with the battery B and the resistor R-condenser C combination. The voltage across the tube will be zero at that instant for the reason that the battery electromotive force and the counter-electromotive force across the condenser C will equal and balance each other. The condenser C will begin to discharge through the shunt resistor R. The potential at the terminals of the condenser will decrease exponentially at a rate determined by the constants of the condenser and resistor. At the same time, the potential across the terminals of the tube—which is the difference between the battery potential and the condenser potential—will commence to rise logarithmically. When this voltage reaches the breakdown voltage of the tube N, the gas within the tube will become ionized. Accordingly, a relay or other device (not shown in this figure) may then be operated in a manner which will be apparent from the description of other circuits hereinafter following.

The elements just described form a circuit which operates according to some of the fundamental principles of this invention. It will be apparent that a number of sequential operations are required to produce delay, some of which are the shunting of a gas discharge tube, removing this shunt around the tube, changing the state of charge of a condenser, discharging the tube, etc. The delay is not alone dependent upon this step-by-step operation but also upon the very constants of the elements that cooperate to produce delay of any desired magnitude.

If E_B is the voltage of battery B, C the capacity of condenser C in farads, R the ohmic resistance of resistor R, E_C the voltage across condenser C, E_T the voltage across the terminals of tube N, the time t may be considered to be zero and to start running upon the removal of the shunt circuit around the tube. The condenser C begins to discharge through the resistor R, starting with an initial voltage E_B . Then,

$$E_C = E_B e^{-\frac{t}{RC}} \quad (1)$$

The voltage across the tube is

$$E_T = E_B - E_C = E_B \left(1 - e^{-\frac{t}{RC}} \right) \quad (2)$$

Thus the voltage across the tube rises from zero at a rate given by (2). From (2) we get

$$e^{-\frac{t}{RC}} = \frac{E_B - E_T}{E_B} \quad (3)$$

and

$$-\frac{t}{RC} \log_{10} e = \log_{10} \frac{(E_B - E_T)}{E_B} \quad (4)$$

The expression (4) determines the relationship between E_T and the time t required to reach the voltage E_T . Thus

$$t = \frac{RC}{0.43} \log_{10} \frac{E_B}{(E_B - E_T)} \quad (5)$$

If E_T is made equal to the breakdown voltage of the tube N , then the Equation (5) will determine the time t required to ionize the gas within the tube after the short-circuit around the tube is removed.

Thus, if tube N has a breakdown voltage of 70 volts, for example, and the battery B is one of 135 volts, then

$$t = \frac{RC}{0.43} \log_{10} \frac{135 - 70}{135}$$

or

$$t = \frac{0.317}{0.43} RC = 0.74 RC$$

It will be clear, therefore, that the delay may be increased by increasing the capacity of the condenser C or by increasing the ohmic resistance of resistor R or by decreasing the voltage of battery B . These factors may be set at definite values and a circuit based thereon will produce delay with considerable accuracy.

In Fig. 2, the relay R_0 is in a signal or other circuit which applies current to the relay winding to initiate operation of the system and delayed operation of relay R_1 . The armature of this relay R_0 is connected to the cathode K_1 of a three-element gas discharge tube N_0 known as a cold cathode tube, the other cathode K_2 of which is connected to the make-contact of relay R_0 through a circuit which includes the battery or voltage generator B_1 and the variable resistor Z_1 . The resistor Z_2 is bridged across the cathodes K_1 and K_2 of the tube N_0 . The battery B_1 is connected to the condenser C_1 and the variable resistor Z_3 and supplies current for maintaining the condenser C_1 in a continuously charged condition. This battery is of a voltage which exceeds that required to ionize the gas between cathodes K_1 and K_2 of the tube N_0 . When the relay R_0 is unoperated, a circuit will be established which will completely shunt not alone the resistor Z_2 but also the cathodes K_1 and K_2 of the tube N_0 .

The anode A of tube N_0 is connected in a circuit which includes the winding of relay R_2 , resistor Z_4 , the winding of relay R_1 , battery or voltage generator B_2 , battery or voltage generator B_1 and the cathode K_2 of tube N_0 . It will be apparent also that the sources B_1 and B_2 may be but a single source of voltage, that is, a single battery and that it may be tapped so as to give the effect of the two separate sources shown. The electrodes A and K_2 of tube N_0 form a gap which is initially under the control of the gap between the cathodes K_1 and K_2 of the tube. The relay R_2 is a vibrating relay, vibrating continuously while the gas within tube N_0 is ionized in re-

sponse to the application of sufficient voltage between the cathodes K_1 and K_2 and while in vibration, this relay maintains the relay R_1 continuously operated as described, for example, in connection with Fig. 7 of Patent No. 1,977,256, issued October 16, 1934. The armature and contact of the vibrating relay R_2 are shunted by series elements of resistance Z_5 and capacitance C_2 , the armature and contact of the relay R_2 being connected across the circuit of the electrodes A and K_2 through the winding of this relay.

Before relay R_0 operates, the source B_1 supplies charging current to the condenser C , over the circuit which includes the back contact and armature of relay R_0 and the variable resistor Z_3 . This current charges the condenser C_1 at a rate depending upon the magnitude to which the resistor Z_3 has been previously adjusted. The potential of the source B_1 exceeds that required to ionize the gas between the electrodes K_1 and K_2 of the tube N_0 but by virtue of the short-circuit around these electrodes formed by the armature and back contact of relay R_0 , ionization between these electrodes of the tube is prevented. Under normal conditions, the battery B_1 will charge the condenser C_1 to a voltage approximately equal to the voltage of this battery and after the condenser C_1 becomes fully charged practically no current will traverse resistor Z_3 .

After the relay R_0 operates in response to the flow of sufficient current through its winding, the resistor Z_1 becomes connected to the circuit and provides a discharge path for the condenser C_1 , this discharge path including both resistors Z_1 and Z_3 and the armature and make-contact of the relay R_0 . The discharge current depends upon the combined resistance of resistors Z_1 and Z_3 . The operation of the relay R_0 at the same time removes the shunt circuit around both resistor Z_2 and the cathodes K_1 and K_2 of the tube N_0 . Some time after the operation of relay R_0 , the condenser C_1 will become discharged to a voltage which, when combined with that of the battery B_1 , will equal the voltage required to ionize the gas between the cathodes K_1 and K_2 of the tube N_0 . Assuming the battery B_1 to be of 90 volts and the ionization potential between cathodes K_1 and K_2 to be 70 volts, the ionization potential will be reached when the condenser has been discharged to a voltage of approximately 20 volts. When this lower potential across the condenser C_1 is reached, the impedance between the cathodes K_1 and K_2 will be reduced to a negligible value and allowing current to pass between electrodes A and K_2 of the tube. The batteries B_1 and B_2 will then drive current through the circuit which includes the winding of relay R_1 , the resistor Z_4 , the winding of relay R_2 , and between electrodes A to K_1 of the tube N_0 . The relay R_1 will operate and remain operated as long as the voltage between the cathodes K_1 and K_2 exceeds the value required for ionization. Upon the operation of the relay R_2 , however, the armature and contact of this relay will shunt the circuit containing the electrodes A and K_2 of the tube and the winding of relay R_2 . This will promptly deionize the gas between these electrodes and current will cease through the winding of relay R_2 , allowing the latter relay to release. "B" battery voltage will thus again be applied between electrodes A and K_2 . As long as the gas between electrodes K_1 — K_2 continues to be ionized, relay R_2 will again be operated, again shunting the circuit between the

electrodes A and K₂, etc. Thus, the relay R₂ will vibrate its armature continuously as long as the gap K₁—K₂ remains ionized. The relay R₁ will be continuously operated during that entire interval, but upon the quenching of the gap K₁—K₂, both relays R₁ and R₂ will be released.

In the circuit of Fig. 2, the biasing potential of the source B₁ is not variable and it becomes effective for the purpose of ionizing the gas within the tube N₀ only after the condenser C₁ has become discharged to a sufficiently low value. No relay winding or other inductive element is included in the circuit of the cathodes K₁ and K₂.

So, it will be seen that the operation of the relay R₀ removes the shunt around the circuit of the electrodes K₁ and K₂ a predetermined period of time after the operation of the relay R₀ and effects the operation of the work circuit of relays R₁ and R₂. If, perchance, the operation of the relay R₀ is interrupted before the condenser C₁ has discharged to the required low value, the gap K₁ and K₂ will not become ionized and the work circuit will then not be operated. Hence, if the relay R₀ is operated merely by virtue of some transient effect such as a lightning surge, it will be impossible to bring about the operation of the work circuit of the arrangement in response to that surge. But, where the relay R₀ remains operated longer than the time required to sufficiently discharge condenser C₁, the work circuit will be operated for a period of time which will closely match the period in which the relay R₀ remains operated, less the time for discharging the condenser.

In Fig. 3, the cathodes K₁ and K₂ of the tube N₀ are connected to the biasing source of potential B₁ through a parallel circuit comprising condenser C₂ and resistor Z₆. The relay R₀ is normally unoperated and its armature and back contact bridges the resistor Z₇ across the gap K₁—K₂. The resistor Z₇ is one of low magnitude while the resistor Z₆ is one of large magnitude.

The condenser C₂ becomes charged by the battery B₁ through the circuit of resistor Z₇ and the armature and back contact of the relay R₀. The voltage across the condenser will approximate that of the battery B₁ and therefore there will be no effective potential across the resistor Z₇ or across the gap K₁—K₂. After the relay R₀ operates, however, the shunt resistor Z₇ will be effectively removed from the circuit and the condenser C₂ will discharge through the resistor Z₆. At a predetermined interval after this discharge has started—an interval determined by the capacity of the condenser C₂, the magnitude of the resistor Z₆ and the time required to discharge the condenser to a potential of predetermined low order—the difference between the potentials of the battery B₁ and that across the condenser C₂ will equal the ionization voltage of the gap K₁—K₂ of the tube. Ionization will then occur and the batteries B₁ and B₂ will then send current through the circuit of the winding of the relay R₃, and electrodes A and K₂ of the tube N₀, and the relay R₃ will operate and remain operated as long as the relay R₀ has operated. No deionization circuit has been shown for the anode or work circuit of the tube but any deionization circuit may be used in this arrangement. If, however, the relay R₀ operates for an interval which is less than that required to sufficiently discharge the condenser C₂, the gas within the tube N₀ will not become ionized and the work circuit of relay R₃ will not be operated.

Fig. 4 shows a delay circuit of a somewhat dif-

ferent type. Here the cathodes K₁ and K₂ of the tube N₁ are connected to the input circuit through a current-limiting resistor Z₁₀ and a portion of the battery B₃ employed for biasing purposes. The anode A of the tube is connected to the cathode K₂ through a circuit which includes the winding of relay R₁₀ and the battery B₃. The armature and back contact of the relay R₁₀ furnishes a circuit for completely shunting the gap formed by the cathodes K₁ and K₂ of the tube N₂. The anode A of the tube N₂ is connected to the cathode K₂ through the winding of the relay R₁₁ and the battery B₃. The condenser C₁₀ is normally charged to the voltage determined by the lower tap and the right-hand terminal of the battery B₃, the charging circuit including the armature and back contact of the relay R₁₀, and this condenser is shunted by a resistor Z₁₁ which is of large (and variable) magnitude.

After a sufficiently high potential has been applied to the input circuit of the arrangement shown in Fig. 4, the gas between the gaps K₁ and K₂ of the tube N₁ will become ionized as will the gap between the anode A and cathode K₂ of tube N₁ and the relay R₁₀ will operate, the current for the relay operation being supplied by the battery B₃. As the armature of the relay R₁₀ leaves its back contact, the shunt around the gap K₁—K₂ of the tube N₂ will be removed. The condenser C₁₀ will at the same time begin to discharge through the resistor Z₁₁. As the voltage across the condenser C₁₀ becomes reduced to a value such that the difference between that voltage and the voltage between the lower tap and right-hand terminal of the battery B₃ approximates the voltage required to ionize the gas of the gap K₁—K₂ of the tube N₂, the gas within the latter tube will become ionized and current will then flow through the winding of relay R₁₁ and through electrodes A and K₂ of tube N₂, the current for the latter operation being also supplied by the battery B₃. The delay in the operation of relay R₁₁ is determined by a number of factors, some of which are the capacity of the condenser C₁₀, the magnitude of the resistor Z₁₁ and the voltages to which the condenser C₁₀ is normally charged and must be thereafter discharged to ionize the gas within the tube N₂. Of course, if the input circuit of the system is supplied with a transient voltage or surge of extremely minute duration, the surge may be of too short duration to allow the condenser C₁₀ to become sufficiently discharged and, of course, the relay R₁₁ will therefore remain unoperated. No deionization circuit has been shown for either of the tubes of this arrangement but such deionization circuits as are well known in the art may be employed for this purpose.

Fig. 5 shows a delay circuit as part of an arrangement including hot-cathode tubes N₁₁ and N₁₂. One side of the input circuit is connected to the grid of the tube N₁₁ through the current-limiting resistor Z₃₀ and the other side of the input circuit is connected to the cathode of the tube N₁₁ through the battery B₃₀. The battery B₃₁ supplies current to the heaters of both tubes N₁₁ and N₁₂. The anode of the tube N₁₁ is connected to the cathode by a series path which includes the winding of the relay R₃₀ and the battery B₃₂. The armature and back contact of the relay R₃₀ are in a circuit which connects the battery B₃₃ to the condenser C₃₀ and this circuit maintains the condenser C₃₀ normally charged. The condenser C₃₀ is shunted by a resistor Z₃₁ and it is also connected between the grid and

cathode of the tube N_{12} by means of the battery B_{30} . The anode of the tube N_{12} is connected to the cathode of this tube by a path which includes the winding of the relay R_{31} and the battery B_{32} .

- 5 Ionization of the gas within the tube N_{12} can only occur after the condenser C_{30} has become discharged to a sufficiently low value and, of course, the relay R_{31} cannot operate until this has happened. But, after the gas within the tube 10 N_{11} has become ionized in response to application of sufficiently high voltage to the input circuit, the relay R_{30} will operate and as the armature of the latter relay leaves its back contact, the condenser C_{30} will be disconnected from its charging 15 circuit. Discharging at a rate determined by the magnitude of the resistor Z_{31} , the condenser C_{30} will ultimately reach a voltage which will be so far below the voltage of battery B_{30} that ionization may then take place in the grid circuit of the tube N_{12} . When this occurs, the relay R_{31} will 20 operate and remain operated as long as sufficient voltage continues to be applied to the input circuit of the arrangement.

In this arrangement of Fig. 5, deionization circuits for tubes N_{11} and N_{12} are not shown but any well known deionization circuits may be associated therewith. Any one of the various deionizing circuits of Patent No. 1,977,256, dated October 16, 1934 may be employed for this purpose.

- 30 While this invention has been shown and described in certain particular arrangements merely for the purpose of illustration, it will be understood that the general principles of this invention may be applied to other and widely varied 35 organizations without departing from the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. The combination of a three-electrode gas 40 discharge tube, a condenser, a source of potential connected in series with the condenser and two of the electrodes of the tube, the potential of said source being greater than that required to ionize the gas between said two electrodes, a work circuit 45 connected between the third electrode and one of the other electrodes, and means for varying the state of charge of the condenser to operate the work circuit.
2. The combination of a condenser, a gas 50 discharge tube having first and second gaps, a source of potential the magnitude of which exceeds the ionization voltage of the first gap, means for connecting said source to the condenser for charging the condenser to the voltage of the source, said 55 source and said charged condenser being connected in opposition and to the first gap of the tube, means for slowly discharging the condenser for thereafter ionizing the gas within the first gap, and a load circuit connected with the second gap and operated in response to the ionization of 60 the gas within the first gap.
3. A delay circuit comprising a normally deionized gas discharge tube, a condenser, a source

of voltage connected in series with said condenser and with the electrodes of said tube, a circuit of negligible resistance in shunt with the electrodes of said tube, a resistor in shunt with said condenser, and means for ionizing the gas within the 5 tube, said means including means for opening the circuit of negligible resistance in shunt with the tube.

4. The combination of a gas discharge tube, a capacitive element, charging means connected in 10 series with said capacitive element and with the electrodes of said tube, means for preventing ionization of the gas within the tube, means for uncoupling the ionization preventing means from the tube, and means for discharging the capaci- 15 tive element.

5. The combination of a condenser, a source of potential, a gas discharge tube connected in series with said condenser and said source, and means for charging the condenser to a prede- 20 termined voltage, said predetermined voltage at charge and that of said source being together equal to the ionization voltage of the tube.

6. The combination of a source of potential, a condenser charged to the potential of said source, 25 a gas discharge tube having an ionization potential below said potential, said tube being connected to said source and said condenser so that their potentials mutually oppose each other, and means for reducing the potential across the con- 30 denser to a point such that the difference between the potential across the condenser and that of the source equals the ionization potential of the tube.

7. The method of delaying the operation of a 35 circuit dependent upon the ionization of the gas within a gas discharge tube which consists in producing a fixed and substantially invariable voltage, charging a condenser to a counter-voltage approaching said fixed voltage, slowly discharg- 40 ing the condenser, and ionizing the gas within the tube when the voltage across the condenser is reduced below said fixed voltage by a predetermined amount.

8. The method of producing delay with a gas 45 tube which consists in shunting the tube out of circuit, charging a condenser to a voltage exceeding the ionization voltage of the tube, removing the shunt around the tube, and discharging the condenser in series with a source of voltage to a 50 voltage together approximating the ionization voltage of the tube.

9. The method of operating a gas discharge tube which consists in charging a condenser to a voltage exceeding the tube breakdown voltage, 55 opposing the voltage of the condenser by an equal voltage, discharging the condenser to a progressively lower voltage and operating the tube when the voltage of discharge differs from the opposing voltage by an amount corresponding to the tube's 60 breakdown voltage.

RICHARD KARL HONAMAN.
LELAND KASSON SWART.