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CONTROLLING OPERATING TIME OF ARC
DISCHARGE DEVICESHarold F. Wilder, Chatham, N. J., assignor to The
Western Union Telegraph Company, New York,
N. Y., a corporation of New York

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3 Claims. (Cl. 250—27)

This invention pertains to the automatic control of the operating period or duration of time that energy is supplied to an electric circuit across an arc discharge path of a gaseous conduction device capable of a sustained discharge after being initiated by a starting electrode.

The object of my invention is to provide a circuit arrangement embodying two or more thermionic arc discharge tubes, one of which may serve as an automatic regulator or time-limit device for the other tube or tubes. The duration of operation of the energy supplying tube being determined by the electrical constants of the grid circuit of the time-limiting tube and which may be varied so that the cycle of operation that may take place is from .01 of a second to several minutes.

In the following detailed description I shall refer to the accompanying drawing in which,—
Figure 1 is a schematic diagram of a circuit having two thermionic arc discharge tubes arranged to function in accordance with my invention, one of the tubes supplying energy to an appropriate device or load and the associated tube definitely controlling the duration of time that this energy is supplied, by automatically limiting the functioning of the first tube at an instant determined by the electrical constants of the secondary tube grid circuit; and Figure 2 is a graphical representation of the several current and voltage transients during the initiation and at the conclusion of these functions.

Referring to Figure 1, the gaseous arc discharge tubes T_1 , T_2 are of the well-known type in which the grid completely surrounds the cathode and merely functions to initiate a discharge between the plate and cathode, with no further control. The discharge is instantaneous upon the application of the critical voltage to the grid and the current rises abruptly to full value, which features are especially applicable to my purpose.

Both tubes are supplied from a D. C. source indicated as 120 volts, the regulator of timing control tube T_1 being connected through a resistance R_2 and the energy supplying tube T_2 through the load. The grid bias is impressed by the potential drop across the resistor R_1 in the common return from the cathodes. The filaments are thus at a positive potential with respect to the grid element. It will be shown that a timing action may be obtained with an increase of the IR drop across the common cathode lead resistance R_1 , caused by the difference in magnitude of the respective anode currents. It is evi-

dent that this resistance R_1 cannot be replaced by an equivalent battery.

The time-limit or control tube T_1 arcs continually except during the period tube T_2 is operating. The manner in which one tube may be caused to extinguish the other when capacitively coupled by a condenser C is described in U. S. Patent No. 1,855,380 granted to A. W. Breyfogel. My present invention provides a method of varying the cycle of operation with precision within wide limits determined by the electrical constants of the circuit.

The arc is struck in the energy-supply tube T_2 by raising the effective grid bias, that is, the actual potential difference between the grid element and the cathode, to nearly zero volts. At this level the few electrons attracted to the anode acquire such velocity that an arc discharge quickly occurs. Current thus flows through the load circuit, attaining full value at once while the grid loses all practical control of the current density.

Such a positive increase in the grid potential may be effected in a number of ways. I have illustrated the impulse as induced in the secondary coil of a transformer TR, but other devices will readily occur to engineers, for instance: the rise in E. M. F. acting in the grid resistance directly coupled to a light sensitive device; or the increase in the D. C. output level of a beat frequency oscillator, which in turn is a function of the moisture content, or the thickness of a stationary or moving web of material; or again the tube may be "triggered" by direct connection to a telegraph signal amplifier.

Let it be assumed that the load is to be supplied with 9 units of current at a potential of 90 volts for a period of say, $\frac{1}{2}$ second, and at the conclusion of this interval the current is to be made zero in preparation for an additional pulse. The maximum load current depends mainly on the rating of the particular tube used.

As noted above, the tube T_1 arcs continually except when the tube T_2 is operating. Accordingly prior to the reception of a starting impulse from the input circuit, the conditions are as follows: The arc in tube T_1 is maintained by the current $(3)I_{p1}$, which passes through resistance R_2 with a developed IR drop of 95 volts. The current passing through the arc at this particular vapor pressure and current density produces a voltage drop of 20 volts and in passing through the common resistor R_1 to negative battery, produces a drop of 5 volts. This IR drop in resistor R_1 provides the grid bias voltage E_{g2} for tube T_2 ,

although actually the cathodes of both tubes are made positive with respect to the grid elements. The stopping condenser C is charged to a potential of 95 volts, produced by the IR drop in resistance R₂, the upper plate of the condenser being negatively charged. At this time the tube T₂ is inactive and hence no current flows through the load. The anode or plate potential of the tube T₂ is 120 volts while the potential difference between the cathode and anode is 115 volts due to the bias E.M.F. of 5 volts. These numerical values of voltages will, of course, change somewhat with other circuit conditions but are sufficiently close to those usually encountered.

The resistance R_T and the condenser C_T associated with the grid of tube T₁, constitute the "timing" element of this circuit and upon the time constant R_TC_T depends the duration of time that tube T₁ will remain inoperative or arcless when once extinguished.

Under the static conditions assumed, the condenser C_T is charged positively to a voltage determined by several variable quantities, but for practical consideration may be assumed to be 7 volts. Of the 7 volts, five volts are supplied by the drop E_g across the common resistor R₁ by the passage of the current (3)I_{p1}. The remaining two volts is produced in the tube and is due to the electrical position of the grid in the arc of the tube.

It will be appreciated by those familiar with the attempts to determine the potential gradient in an arc discharge by means of an exploring element such as a grid, that the indicated voltage is a function of the physical size of the grid, its position in the arc mechanically with respect to the other electrodes, the arc density, and the vapor pressure, in that the size of the arc column is varied in diameter and the ionization potential is influenced. In this circuit the resistance R_T although of the order of several megohms enters the result.

Description of the transients attending the starting of tube T₂

At the desired instant an impulse received by the input transformer TR induces a small oscillatory pulse in the secondary coil shown in heavy lines in the diagram of Figure 2 and which is indicated by the arrow. This raises the voltage E_{g2} (to be differentiated from E_g) to nearly zero volts, thereby developing an arc in the tube T₂ in approximately 10 micro-seconds. The current across the load rises abruptly to (9)I_{p2}, causing a drop of 90 volts across the load, approximately 15 volts in the tube and 15 volts across the common resistor R₁. As the anodes of the tubes are connected through the condenser C, the instantaneous drop at the anode of the tube T₂ causes the voltage at the anode of tube T₁ to instantaneously drop to approximately 80 volts negative with respect to its cathode, thereby extinguishing the arc of tube T₁. During the short period that the condenser C is being charged at the reversed polarity, the ions in tube T₁ are enabled to recombine (de-ionization). As indicated in the diagram, the current (3)I_{p1} through the tube T₁ was not only brought to zero but actually reversed in direction for an instant, due to the scavenging effect in the inter-electrode space of tube T₁ by the negative potential on condenser C. The current in the tube T₂ not only reached its full value (9)I_{p2}, but, as indicated, increased slightly above this due to the charging current which passed through resist-

ance R₂ to the condenser C, as indicated in the diagram by the cross-hatched portion. This initial heavy current momentarily decreased the potential E_{p2} of 30 volts at the anode as indicated in the diagram by the heavy cross-hatching. Of the 30 volts at the anode, 15 volts constitute the drop across the arc of the tube and 15 volts constitute the drop across the common resistor R₁. Also due to the somewhat greater current during the charging time, the potential E_{g2} at the grid was increased slightly in a negative direction as indicated by the cross-hatching.

Action of the timing circuit

The cessation of the arc in tube T₁ prevents the 7 volt charge on condenser C_T from escaping through the arc and as the anode potential E_{p1} quickly reaches 120 volts, condenser C_T now charges more positively through the resistance R_T. The expression for the voltage rise on the condenser C_T is:

$$V_{C_T} = E_{p1} \left(1 - e^{-\frac{t}{R_T C_T}} \right) - 7e^{-\frac{t}{R_T C_T}}$$

E_{p1} = 120v
E_g = 7v

The value of the electro-static charge on condenser C_T will ultimately approach and oppose the new biasing potential level of 15 volts E_g across the resistor R₁.

Stopping tube T₂

At the instant the potential E_{g1} at the grid of tube T₁, increasing progressively along the line AB or A'B', is sufficient to oppose the biasing voltage E_g, an arc is formed in the tube T₁. The condenser C was charged to a potential of 90 volts by the IR drop across the load and hence the starting of the tube T₁ causes a drop at the anode of tube T₂ to minus 70 volts, that is, 90 volts minus the drop across the arc in tube T₁. The current (9)I_{p2} instantly drops to zero with a slight reversal which is somewhat greater than that previously in the tube T₁ as a greater number of ions exist between the electrodes. The current and voltage relations which existed before the starting of tube T₂ now return to their previous normal values.

While it was previously known, as in said prior patent, that two thermionic arc discharge tubes may be arranged in a circuit so as to be mutually extinguishing, the time-limit of any discharge was dependent on externally timed pulses or other external means. My invention disclosed herein provides means for making the timing action automatic by introducing a time constant in the grid circuit of one tube which may be varied to suit different conditions. This automatic action is a function of the increase in voltage drop over a common resistance caused by a difference in anode currents and the rise in anode potential of the time-limit tube when extinguished. I have illustrated one arrangement of circuits which may be employed in carrying out my invention but it will be evident to engineers that various modifications can be made within the scope of the invention.

I claim:—

1. An electrical system, comprising a pair of electrostatically controlled arc discharge tubes connected in parallel, a translating device in series with the load tube and a resistance element in series with the other tube, the latter

tube constituting a time-limit device for the load tube, means including circuit arrangements whereby the starting of either tube by the application of a critical voltage to its grid element
5 causes the extinction of the discharge in the other tube, and impedance means connected to the grid of the time-limit tube, said impedance means having a time-constant which is proportioned to cause the last mentioned tube to operate at the expiration of the predetermined
10 period of inaction.

2. In an electrical system for supplying energy to a load or translating device, a source of electrical energy, a pair of gaseous conduction devices having starting elements and capable of
15 sustained discharge independent of the starting element after being started, and connected respectively in series with the load and in shunt thereto, circuit arrangements whereby the starting of either device causes the extinction of the
20 arc in the other device, a starting circuit connecting the grid of said shunt tube to its anode through a resistance and to the common return from the cathodes of both tubes through a condenser, the time-constant of said interconnected
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resistance and condenser determining the interval between the extinction and the automatic restarting of the arc in said tube.

3. In an electrical system for supplying energy to a load or translating device, a source of electrical energy, a pair of electrostatically controlled
5 arc discharge tubes having starting elements or grids and capable of sustained discharge after being started, and connected respectively in series with the load and in shunt thereto through a
10 resistance, circuit arrangements whereby the starting of either tube causes the extinction of the arc of the other tube, the grid input of said shunt tube being connected respectively to its anode through a resistance and to the common return
15 of both tubes through a capacity, and a resistance in said common return, the normal grid voltage of the shunt tube being sufficient to start a discharge therethrough, and the time constant of the circuit including said grid resistance and
20 capacity being proportioned to cause a predetermined interval between the extinction and restarting of the arc in said shunt tube.

HAROLD F. WILDER. 25