

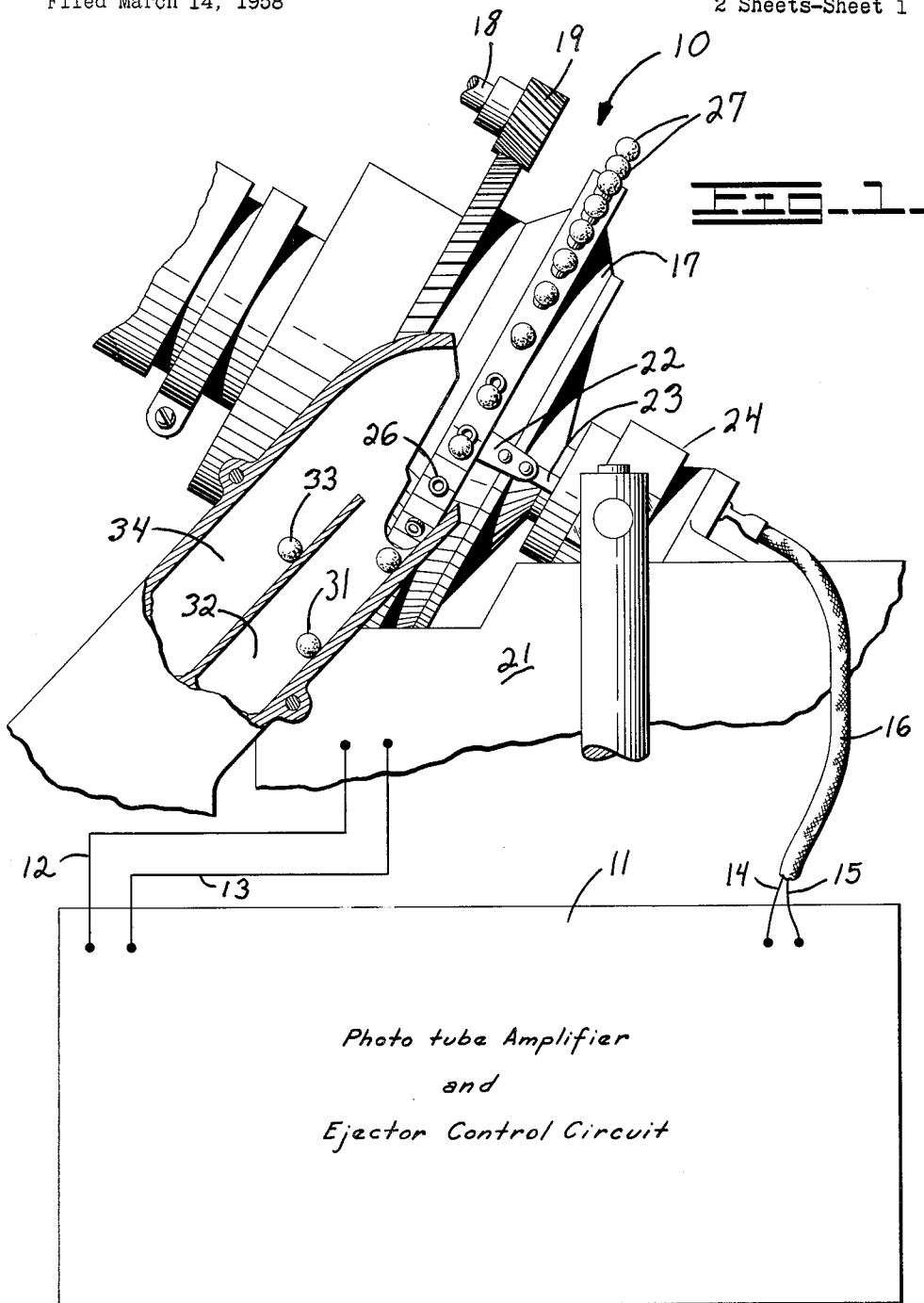
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SOLENOID ACTUATED MECHANISM

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Filed March 14, 1958

2 Sheets-Sheet 1



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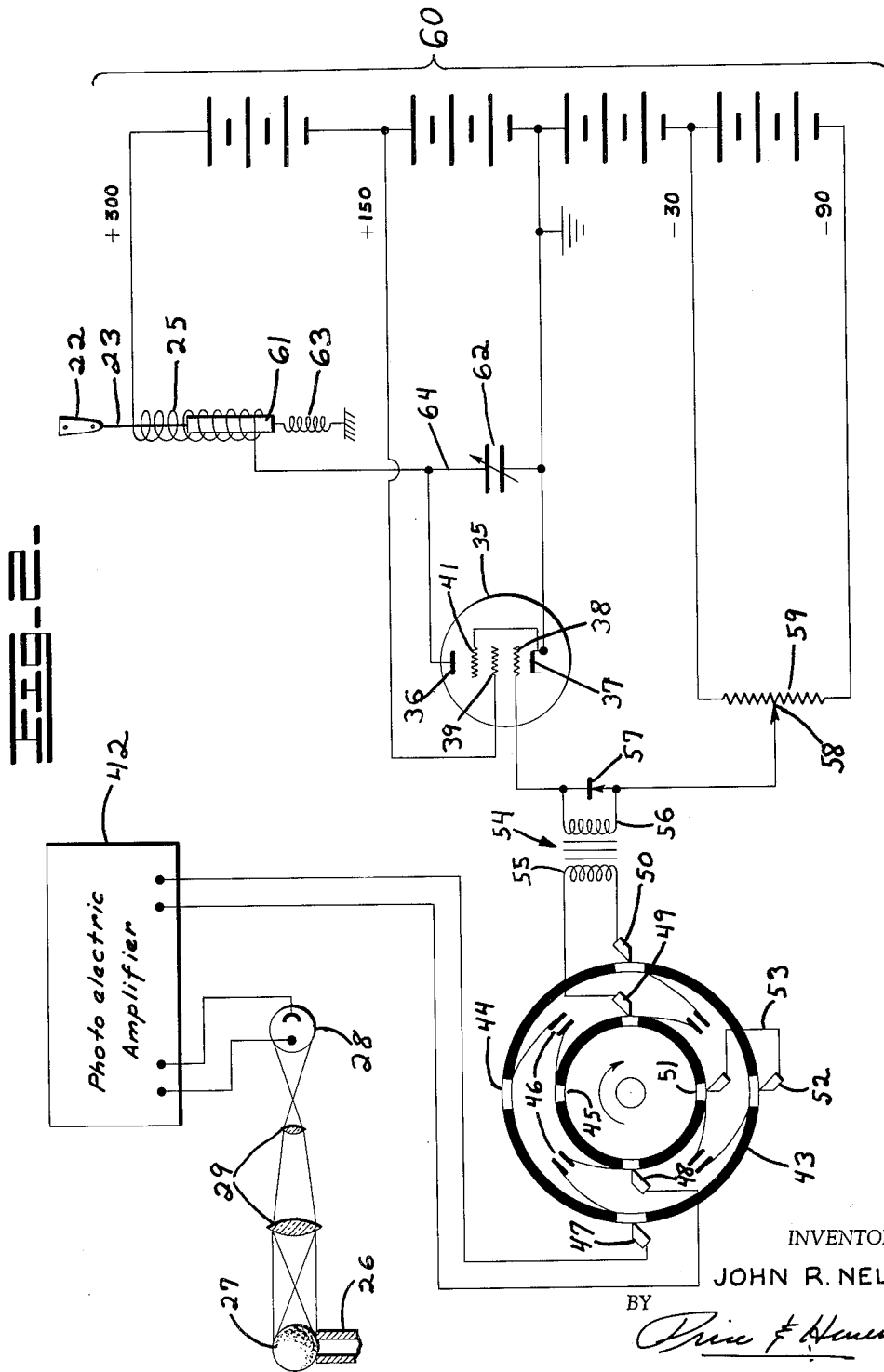
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VACUUM TUBE GATE CONTROL CIRCUIT FOR SOLENOID ACTUATED MECHANISM

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Filed Mar. 14, 1958, Ser. No. 721,425
6 Claims. (Cl. 317-123)

This invention relates to control circuits and particularly a vacuum tube gate control circuit for actuation of inductance devices such as movable-armature solenoids.

Prior control circuits for solenoid actuated devices generally have employed gaseous discharge tubes requiring timed control mechanisms, surge arrestors and other undesirable controls. Further, these prior devices are limited in speed of operation since the gaseous tubes cannot rapidly reestablish their condition required before each discharge. Also, no such control circuits have means for adjusting the power and dwell period of the solenoid actuator.

An object of this invention is to accomplish high speed of the order of hundreds of operations per second of a movable armature such as the ejector plunger of a photoelectric sorting machine.

Another object is to achieve random speed operation of such apparatus.

Still another object of this invention is to eliminate the requirement in solenoid actuated devices of de-energizing switch mechanism for the gate tube.

Further objects are to enable both the power applied to the armature and the length of dwell of the armature in a predetermined position away from the rest position to be adjusted and held precisely at the adjusted value.

Another additional object is to fix the time duration of the dwell of the armature by the resonant frequency of an electric circuit.

Other and further objects, features and advantages will become apparent from the following description made in conjunction with the accompanying drawings wherein:

FIG. 1 is a side elevational, fragmentary view of an electric sorting equipment with which the ejector control circuit of this invention (shown in block form) is adapted for use.

FIG. 2 is an electric circuit diagram of the apparatus of FIG. 1.

Briefly this invention employs a high-current capacity electronic vacuum tube which has its anode-cathode circuit in series with the movable-armature solenoid, the dwell and power of actuation of which are to be controlled. An energy storage condenser is connected in shunt with the tube to its anode and cathode. The power output is adjusted by adjusting grid bias and the dwell is determined by selection of electrical constants to obtain a period of time duration of a half-cycle of an oscillating circuit representing the desired dwell.

Like reference characters are utilized throughout to designate like parts.

Referring to FIG. 1, reference numeral 10 designates a sorting apparatus to which a phototube amplifier and the ejector control circuit 11 of this invention is connected by leads 14 and 15 carried in a cable 16. The sorting apparatus 10 includes a rotating vacuum conveyor wheel or drum 17 which may be of the type employed, for example, in the apparatus disclosed in Patent 2,316,375 for Van Haffton. In such electric sorting machines, suitable means such as a motor driven shaft 18, for example, with gearing 19 are provided for continuously rotating the drum 17 through a viewing chamber and lamp housing or photoelectric sorting head, not shown, concealed within the casing 21. This apparatus

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includes an ejector hammer or striker 22 secured to a plunger rod 23 forming a part of the armature of an electromagnet 24 having a solenoid winding 25 (FIG. 2). The vacuum drum 17 is provided with a plurality of ferrules 26 around the periphery thereof, each adapted to hold an object to be sorted, such as a bean or pea 27. Means, not shown, are provided for supplying the articles 27 to the suction tips of the ferrules 26. As the drum periphery revolves through the lamp housing, light reflected from the article 27 is directed upon a photoelectric tube 28 through a suitable optical system, represented in FIG. 2 by lenses 29.

An amplifier in the ejector control circuit 11 is provided for supplying current impulses to the electromagnet 24, such impulses being dependent upon the reflectivity of the object 27 and, therefore, upon the response of the photoelectric tube 28. The response is adjusted for permitting articles 31 of certain reflectivity to fall into a chute 32 upon interruption of the suction at the ferrule by means, not shown, and for causing other articles of greater or less reflectivity to be struck by the hammer 22 and thereby directed into a second chute 34. In this manner a separation is effected between articles having reflectivity above and below a certain predetermined value for which the apparatus is adjusted. It will be understood that one or the other of the chutes 32 and 34 is a cull chute and other is the pass chute, depending on the manner in which it is desired to operate the apparatus.

As shown in FIG. 2, the solenoid coil 25 of the electromagnet 24 is connected in series with a gating valve comprising a vacuum tube 35 which is preferably a high current electronic vacuum tube such as one of the Retna type 6CD6G, 6CD6GA, or 6CB5. As illustrated the high current vacuum tube 35 has an anode 36, a cathode 37, a control electrode or grid 38, and one or more additional grids or electrodes such as the screen grid 39 and a suppressor grid 41.

A suitable pre-amplifying circuit or photoelectric amplifier 42, a detainer or time delay mechanism 43 are provided for impressing signals upon the control electrode 38 which, in this case, represent impulses in the output of the photoelectric tube 28 resulting from momentary passage of an article 27 through the field of view of the photoelectric tube 28. The impulses or signals are of exceedingly short duration, for example, about 1.5 milliseconds, in order that the conveyor drum 17 may rotate at a high rate of speed and a large number of articles 27 may be sorted in any given period of time. This invention is not limited to the use of a photoelectric pre-amplifier or any particular pre-amplifier circuit. Examples of photoelectric amplifier circuits which may be employed are disclosed in Cox Patents 2,264,621, 2,256,923 or 2,690,258 and copending applications Serial No. 294,427, filed June 19, 1952, now Patent No. 2,833,937, and Serial No. 325,586, filed December 12, 1952, now Patent No. 3,012,666.

The detainer 43 itself does not constitute a novel feature of the present invention. It may be mounted on the shaft of the drum 17 and correspond in construction and arrangement to that of the aforesaid Van Haffton patent, operating in a manner described more fully in Patents 2,244,826 and 2,625,265 to Cox. Briefly the detainer comprises an insulating drum or commutator in which are embedded a plurality of positive conductor segments 44 and negative conductor segments 45, each pair of segments having a signal-storing condenser 46 connected between them. "Writer" brushes 47 and 48 connected to the output of the photoelectric amplifier 42 are provided for contacting the segments 44 and 45, respectively. "Reader" brushes 49 and 50 also are pro-

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vided for contacting the segments 44 and 45, respectively. There are also "eraser" brushes 51 and 52 connected by a conductor 53.

For coupling the "reader" brushes 49 and 50 to the central electrode 38 of the tube 35, a coupling transformer 54 is provided. The latter has a primary winding 55 connected to the "reader" brushes 49 and 50 and a secondary winding 56 shunted by a damping diode 57. The winding 56 is connected between the control electrode 38 and a point 58 of an adjustable negative bias voltage. As shown, the point 58 consists of a sliding tap on a potentiometer 59 connected between two negative voltage points of a power supply 60 shown by way of illustration as a battery.

For obtaining fast powerful action of the operation of the solenoid 25 rendering it responsive to short duration impulses from a photoelectric tube 28, a condenser 62 is connected in the circuit of the solenoid 25. As shown, the condenser 62 is connected between the anode 36 and the cathode 37, thus shunting the high current tube 35. For enabling the dwell of the solenoid armature 61 to be adjusted the condenser 62 is made either in the form of a variable condenser or consists of adjustable or interchangeable elements for adjusting the capacity shunting the tube 35.

Operation

In the operation of the apparatus with a test article 27 of standard reflectivity in the field of view of the photoelectric tube 28 so that no signal is produced, or with a standard background exposed to the photoelectric tube 28 so that no signal is being applied to the control grid 38 of the high current tube 35, the grid bias of the tube 35 is adjusted by manipulation of the tap 58 to produce an anode current in the tube 35 through the solenoid 25 limited to a level below that which will hold the ejector 22 in extended position against the force of a biasing spring 63. The anode supply voltage 60 then charges the energy-storage condenser 62 through the ejector solenoid 25 to a voltage approximately equal to the voltage of the anode supply 60. The actual value of this voltage is equal to the anode supply voltage (300 v. as shown) less the voltage drop across the ejector solenoid 25 due to its electrical resistance with the idling anode current of the tube 35 flowing through the solenoid 25.

When an article 27 comes into the field of view of the photoelectric cell 28 of greater reflectivity it impresses a voltage upon the brushes 47—48 and thereby charges one of the condensers 46. Subsequently the charged condenser 46 is discharged applying positive voltage signal to the control grid 38 of the high current tube 35 through the transformer 54. Since the anode current is a function of the voltage impressed on control grid 38, a large anode current is made to flow at substantially the same rate as the impulse from the detector condenser 46. This anode current demand, which is not satisfied by the power supply because of the blocking effect of the high inductive reactance of the solenoid, discharges condenser 62 through the tube 35. Another way of stating this operation is that the positive impulse on the control grid 38 abruptly reduces the impedance of tube 35 causing a heavy anode current to flow through the tube 35 discharging the energy storage capacitor 62. The potential across the capacitor 62 falls to a value determined by the signal on the control electrode 38, the bias voltage of the grid 38, and the combined reactance of the inductance of the ejector solenoid 25 and the energy storage capacitor 62 at the wave shape and signal frequency of the signal applied to the control electrode 38. As a result of the use of the damping diode 57 the signal is a sharp peak with a vertical front dying to zero within 1.5 milliseconds.

With a signal of such short time duration the opposition to flow of current through the solenoid 25 is very high so that initially it is unresponsive to the reduced impedance of the tube 35 and would resist a change in the anode

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current through the tube 35. Since, however, the energy storage capacitor 62 has very low capacitive reactance, current flow through the tube 35 will build up very rapidly discharging the condenser 62. The positive terminal 64 of the capacitor 62 is driven negative with respect to the anode voltage supply 60 by the opposition to current flow through the solenoid 25 and a large voltage exists across the solenoid 25 after the condenser 62 has been discharged. The current through the tube 35 falls to its idling value due to the ending of the positive signal on the control grid 38. Nevertheless, the high voltage across the ejector solenoid 25 causes a current to flow in the solenoid during the process of recharging the energy storage capacitor 62. This charging current creates a magnetic field which causes the ejector armature 61 to move during the required instant.

The time dwell of armature 61 depends upon the time required to recharge the capacitor 62 which in turn is dependent on the resonant frequency of the ejector solenoid 25 and capacitor 62. The series resistance of the circuit is sufficient to damp the circuit preventing any tendency for it to oscillate. Since the time dwell is so dependent on the above factors, adjustment of the magnitude of the capacity of the condenser 62 determines the resonant frequency and as a result capacitor adjustment serves to adjust the dwell of the armature 61.

The arrangement described is capable of a very wide speed range of operation from a few operations per second up into hundreds of operations per second. Moreover, the arrangement is not limited to a regular repetitive rate of operation as it may be operated at random or at random speeds.

Owing to the fact that only one commutator is required, no synchronization of the incoming control signal mechanical commutator 43 with its brushes is required. Moreover it is unnecessary to provide a surge arrestor system tuned for the particular speed of operation in order to protect the commutator and brushes. Furthermore it is unnecessary to provide a commutator brush for de-energizing a surge arrestor. Since a thyatron or gaseous discharge type of tube is not employed for controlling the solenoid 25 it is unnecessary to employ a power supply decay network tuned for the particular speed of operation in order to assist the counter-electromotive force of the ejector in de-ionizing a thyatron.

This invention is not limited to the use of specific numerical values for the dimensions of the electrical circuit elements. However, satisfactory results have been obtained and articles have been accurately sorted at speeds of the order of 120 to 150 articles per second utilizing a Retna (Radio Electronics Television Manufacturers' Association) 6DC6GA vacuum pentode power tube as the tube 35, with 0.02-microfarad condensers at the signal storage condensers 46 charged to approximately 130 volts. With these values the coupling transformer 54 may be a 3 to 1 stepdown transformer producing a peak voltage of approximately 40 volts across a type 1N34A damping diode. With a 300 volt power supply for the high current tube 35, the energy storage condenser 62 is charged to very nearly 300 volts. For the 150 cycle operation, the energy storage capacitor 62 may have a capacity in the range between .35 and 1.25 microfarads for adjustment of dwell control. The potentiometer 59 may be connected between —30 and —90 volt points on the power supply unit 60. Adjustment of the tap 58 serves for adjustment of power output; and the selection of the larger values of capacity for energy storage condenser 62 also makes possible the delivery of greater power.

The distance through which the armature 61 moves and the point from which it starts its stroke is controlled primarily by the magnitude of the bias level adjusted by the tap 58, which determines the idle anode current of the tube 35 and, therefore, the energy discharge voltage across the energy storage capacitor 62. In this manner the adjustment of the tap 58; that is, the adjustment of the

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magnitude of the negative bias of the control electrode 38 serves as the control of the power output of the solenoid 25.

While this invention has been described as embodied in concrete form and as operating in a specific manner, it should be understood that the invention is not expressly limited thereto, since various modifications and alterations can be made by those skilled in the art without departing from the spirit of the invention. This invention should be only limited as expressly set forth by the language of the following claims.

I claim:

1. A magnetic armature control circuit comprising in combination a high current non-gaseous electronic discharge device whose conductivity is fully controllable by its control grid potential, an actuating solenoid connected in series with said discharge device; a power source connected across said discharge device and solenoid; an energy-storage condenser connected in shunt with said electronic device and thereby in series with said solenoid across said power source; an impulse control voltage source connected to said discharge device and at a predetermined value of its impulse being adapted to make said discharge device highly conductive to an extent such that said condenser will discharge through said device during said impulse; said condenser being recharged by said power source through said solenoid to energize it and actuate its armature.

2. A control circuit as in claim 1 wherein the magnitude of the condenser is adjustable for adjusting the armature dwell of said solenoid by adjusting the oscillation frequency of the solenoid and condenser.

3. A control circuit as in claim 1, in which the power of said solenoid armature can be varied by providing a variable negative bias on the control grid of said discharge device to adjust the level of conductivity of said discharge device in response to said impulse control voltage.

4. A magnetic armature control circuit comprising in combination a high current non-gaseous electronic discharge device, a pair of terminals for connection to a source of plate current, an armature actuating solenoid connected in series with the discharge device to said terminals, an energy-storage condenser connected in shunt with said electronic discharge device, a pair of terminals at which control voltage signals appear, and means for maintaining an idling current through said discharge device in the absence of said signals, said idling current being small as compared to the maximum charging current of said condenser flowing through said solenoid.

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5. A magnetic armature control circuit comprising in combination a high current non-gaseous electronic discharge device, a first pair of terminals for connection to a source of plate current, an armature actuating solenoid connected to said terminals in series with the discharge device, a second pair of terminals at which control voltage pulses of extremely short duration appear, means connected to said second terminals and to said discharge device responsive to said pulses for exciting said electronic discharge device and causing it to become highly conducting for the duration of said control voltage pulses, and an energy-storage condenser connected in shunt with said electronic discharge device, said condenser having a sufficiently low impedance to become substantially completely discharged through said discharge device during the duration of one of said pulses, and said solenoid having a sufficiently high inductive reactance to substantially prevent a change in current flow through said solenoid prior to the termination of the discharge of said condenser.

6. A magnetic armature control circuit comprising in combination a high current electronic discharge device, a first pair of terminals for connection to a source of plate current, an armature actuating solenoid connected to said terminals in series with the discharge device, a second pair of terminals at which control voltage pulses of extremely short duration appear, means connected to said second terminals and to said discharge device responsive to said pulses for exciting said electronic discharge device and causing it to become highly conducting instantaneously upon occurrence of one of said control voltage pulses, and an energy-storage condenser connected in shunt with said electronic discharge device, said condenser having a sufficiently low impedance to become substantially completely discharged through said discharge device during the duration of one of said pulses, and said solenoid having a sufficiently high inductive reactance to substantially prevent a change in current flow through said solenoid prior to the termination of the discharge of said condenser.

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