

May 23, 1950

C. E. SMITH
ENERGIZING AND TIMING CIRCUITS
FOR ELECTROMAGNETIC DEVICES
Original Filed April 10, 1943

2,508,973

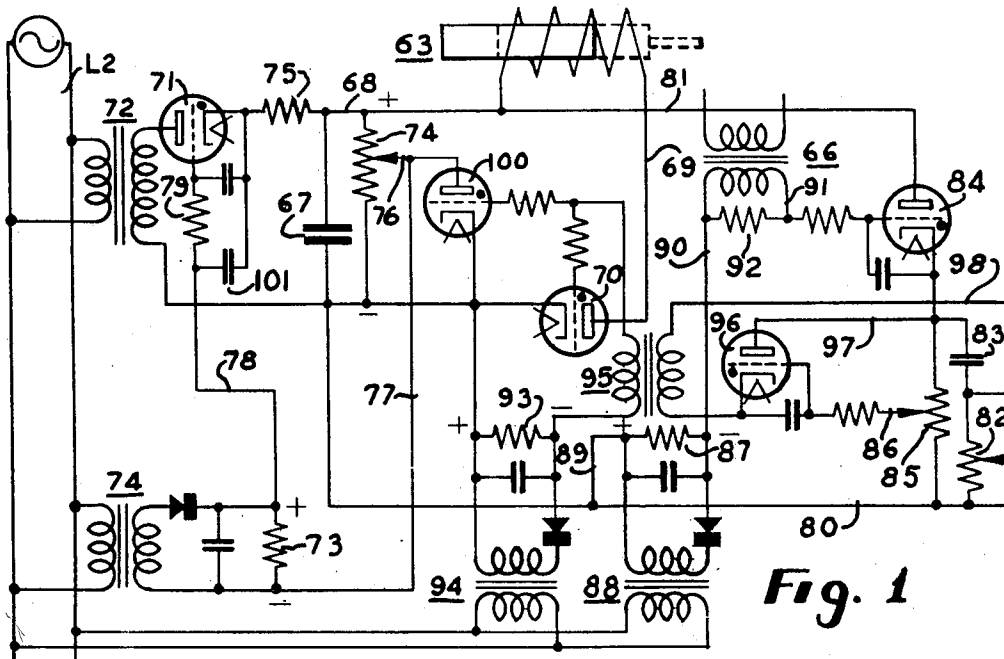
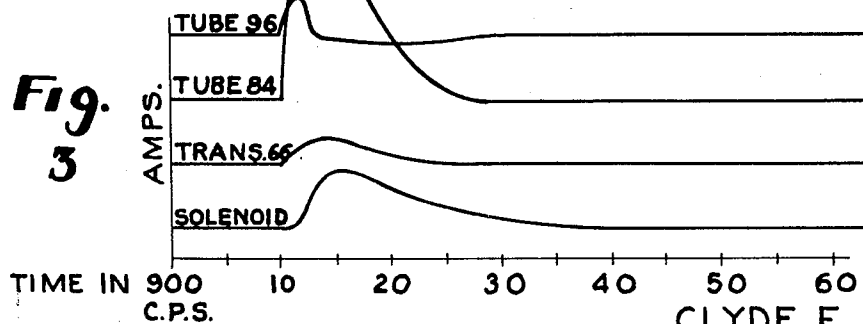
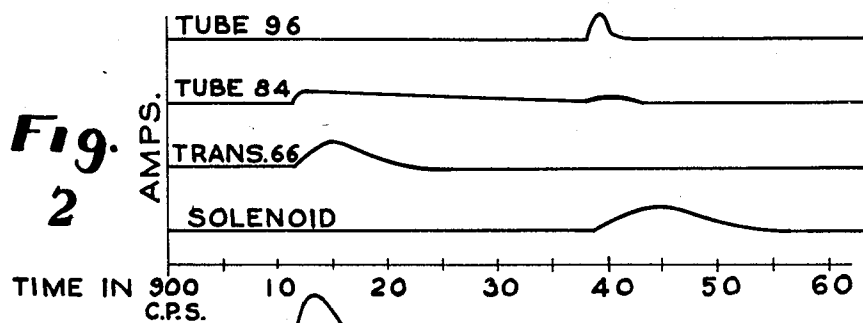


Fig. 1



CLYDE E. SMITH

By

Francis J. Klemm
Attorney

UNITED STATES PATENT OFFICE

2,508,973

ENERGIZING AND TIMING CIRCUITS FOR
ELECTROMAGNETIC DEVICESClyde E. Smith, Warren, Ohio, assignor to The
Taylor-Winfield Corporation, Warren, Ohio, a
corporation of OhioOriginal application April 10, 1943, Serial No.
482,630. Divided and this application June 16,
1944, Serial No. 540,651

3 Claims. (Cl. 175-335)

1

2

This invention, which is a division of the inventions disclosed in the copending application of Melvin M. A. Seeloff and Clyde E. Smith, Serial No. 482,630, filed April 10, 1943, now U. S. Patent No. 2,363,753, relates to energizing circuits for electromagnetic devices and to energizing circuits for such devices utilizing timing means to effect complete actuation of the electromagnetically operated devices in precisely timed relation with respect to the occurrence of an initiating or reference condition.

More particularly, the invention relates to timed energizing circuits for solenoids which may be employed in the actuation of valves, for example, and the primary object of the invention is the provision of such electrical systems which will insure the completion of the actuating strokes of the armatures of the solenoids in an accurately timed and recurrently consistent manner in response to the occurrence of initiating or reference electrical impulses or other reference conditions.

Another object of the invention is the provision of improved energizing circuits for electromagnetic devices whereby the design and construction of complete systems utilizing such devices may be materially simplified while their operation is dependable and uniform in successive cycles of operation. This general object is obtained, through employment of the principles of the invention, by delivering consistent waves of energy to the electromagnetic device in successive operations and by adjusting or controlling the nature of the wave so that movement of the armature of the device follows the pattern required for optimum mode of operation of the complete system utilizing the device. Thus, in solenoid actuation of valves, for example, it may be desirable to insure the full opening of the valves in a predetermined number of milliseconds following the initiation of the flow of energizing current and to hold the valves open for a predetermined interval of time to allow the opening of the valve to accomplish fully its intended function.

Further and more specific objects of the invention include the provision of solenoid energizing and timing circuits having the general characteristics outlined above which are operative irrespective of the nature of the primary current source used in the operation thereof and in which the critical characteristics of the electronic tubes employed are not relied on for proper functioning thereof either in their energizing or timing aspects.

The above and other objects and advantages of the invention will become apparent upon consideration of the following detailed specification and the accompanying drawing wherein:

Figure 1 is a schematic diagram of a timed energizing circuit for a solenoid having an operating armature, the circuit being constructed in accordance with the principles of the invention; and

Figures 2 and 3 are sets of characteristic curves illustrating the operation of the system of Figure 1, the sets representing characteristics under long and short periods of timing, respectively.

Referring to the drawing, L2 is an alternating current supply line leading from any suitable source while reference numeral 63 designates a solenoid which is to be energized by electrical energy derived initially from line L2. In accordance with the principles of the present invention, the solenoid 63 is arranged to be energized by the discharge of a capacitor 67, this capacitor being shown as being connected to the solenoid through the conductors 68 and 69 in the latter of which is positioned a circuit controlling device preferably a thyatron 70. The value of capacitor 67 is chosen with regard to the total amount of energy required to effect the initial actuation of the solenoid armature and any element connected therewith and to maintain such armature and element in their actuated positions for a predetermined length of time. Having determined the value of capacitor 67 solenoid 63 is so designed that its operating circuit will have the following characteristics. First, the inductance of the coil when the armature is in retracted position is so chosen with respect to the value of capacitor 67 that an oscillatory circuit is effected in which the frequency is such that the current passes almost through the first one-half cycle thereof during the time that the armature moves to outer position. Thus positive and high speed operation is attained and the interval between the start of conduction in the device 70 and the full actuation of the armature and connected element is definitely predetermined. Secondly, solenoid 63 is so constructed that its inductance at the time the armature is in actuated position is sufficiently increased to shift the circuit constants beyond critical damping so that upon the armature reaching its actuated position and its operated element being fully opened the current in the coil is unidirectional with a rate of decay low enough to hold the armature in outer position for the required or desired period of time. Upon

the current decaying below a predetermined value the action of the plunger returning spring, not shown, returns the parts to their initial starting positions. Another important advantage of the presently described operating system is that the armature of the solenoid is first allowed to pick up speed before engaging the operating elements. Moreover, this desirable mode of operation is accomplished without variation in the time interval between the start of the flow of energizing current and the full actuation of the connected element or elements.

Capacitor 67 is arranged to be charged by a grid-controlled rectifier 71 deriving energy through a transformer 72 from an alternating current source—the line L2. Rectifier 71 is normally positively biased by a fixed voltage source 73 deriving energy from the line L2 through transformer 74'. This biasing circuit includes the positive end portion of a resistance 74 connected across the capacitor 67 and the biasing circuit may be traced from a cathode of rectifier 71 through the current limiting resistance 75, the positive end portion of resistance 74, adjustable tap 76 on resistance 74, conductor 77, resistance 73, conductor 78, and grid resistor 79 to the grid of the rectifier. As the charge on capacitor 67 approaches the value for which the tap 76 is adjusted the potential on tap 76 and conductor 77 will have become negative with respect to the cathode thus driving the grid negative in opposition to the potential of the source 73. The rectifier 71 will be extinguished but upon a drop of voltage across the capacitor 67 the rectifier will again conduct to maintain the selected charge on the capacitor. Connected in series across the capacitor 67 through the conductors 68, 81 and 80 is a variable resistance 82, a timing capacitor 83, and a thyatron 84. A resistance 85 having an adjustable tap 86 is in parallel with the series connected resistance 82 and capacitor 83 between the cathode of the thyatron 84 and the negative terminal of capacitor 67 through the conductor 80. Thyatron 84 is normally biased to cut-off by the potential developed across resistance 87 by a rectifier drawing energy from the line L2 through transformer 88. This biasing circuit may be traced from the cathode of thyatron 84 through resistance 85, a portion of conductor 80, conductor 89, resistance 87, conductor 90, the secondary of transformer 66, and conductor 91 to the grid of thyatron 84. While any suitable means, as a switch for example, may be employed to initiate operation of the timed energizing circuit, I have shown an impulse transformer 66 the primary of which is intended to be supplied with an impulse of current by the system with which the timed energizing circuit is associated. Transformer 66 is of the current type and connected across the secondary thereof is a resistor 92 across which a voltage is developed upon the flow of current in the transformer. This transformer is so phased that the polarity of its output as developed across the resistor 92 is in opposition to the voltage developed across the resistance 87. Since the voltage across the resistor 92 is considerably greater than that of the fixed bias 87 the thyatron 84 will be rendered conductive immediately upon initiation of the flow of welding current in the primary winding of transformer 66. Conduction in thyatron 84 places a major portion of the voltage across capacitor 67 across the resistance 85 and across the series connected timing capacitor 83 and potentiometer 82. Con-

sequently capacitor 83 begins to charge at a rate determined by the setting of potentiometer 82.

Thyatron 70 which controls the discharge of capacitor 67 through the solenoid 63 is normally biased to cut-off by rectified potential developed across resistance 93 and derived from line L2 through transformer 94. In series with the grid biasing circuit of the tube 70 is the secondary winding of an impulse transformer 95 which has the characteristic of inducing a voltage of steep wave front in its secondary winding as will be well understood. Transformer 95 is arranged to be energized under the control of the electronic valve 96 by the flow of current through tube 84 and potentiometer 82 aided by the discharge of capacitor 83 whereby an impulse of steep wave front is impressed on the primary of the transformer. It will be observed that the anode of valve 96 is connected to the cathode of thyatron 84 as well as to the positive terminal of the capacitor 83 by means of the conductor 97 while the cathode thereof is connected through the primary of transformer 95 and conductor 98 to the negative terminal of capacitor 83 and also to the negative terminal of capacitor 67 through potentiometer 82 and conductor 80. Grid potential for valve 96 is derived from tap 86 of resistance 85. Before conduction in thyatron 84 capacitor 83 has no voltage appearing across it and therefore at the start of conduction the potential on conductor 98 and consequently on the cathode of valve 96 is more positive than the potential at the tap 86. Consequently the valve 96 will be held non-conducting until capacitor 83 is charged to a predetermined voltage at a rate determined by the setting of the potentiometer 82. Upon the capacitor 83 attaining a predetermined charge the potential on its cathode as derived through conductor 98 will become sufficiently negative with respect to the grid to start conduction in the valve 96. Current will then flow through conductors 68 and 81, thyatron 84, conductor 97, valve 96, primary of transformer 95, conductor 98, resistance 82, and through conductor 80 to the opposite side of capacitor 67. More important, however, is the discharge of capacitor 83 through conductor 97, valve 96, primary of transformer 95, and through conductor 98 to the negative terminal of capacitor 83. While the timing of the initiation of conduction in valve 96 is of critical importance for the proper and accurate functioning of the system, the relatively small total energy handled by this valve allows the use of a small tube having negligible temperature characteristics and a low impedance timing capacitor discharge circuit whereby any timing error resulting from the tube characteristics is kept within immeasurable limits.

Transformer 95 is so phased that the steep wave front impulse furnished by its secondary has a polarity opposite to the voltage developed across resistance 93 and the appearance of this impulse consequently results in instantaneous conduction in thyatron 70 to discharge capacitor 67 through the solenoid 63. Having its anode connected to the slide 76 of resistance 74 and its cathode connected to the negative terminal of capacitor 67 is a gas-filled discharge device 100, the grid of which is connected into the grid biasing circuit of the thyatron 70. Consequently tube 100 conducts when tube 70 conducts and causes the potential of slide 76 and of conductor 77 to drop down substantially to the potential of the negative terminal of capacitor 67. This action drives the control grid of rectifier 71 high-

ly negative and the rectifier remains blocked until conduction ceases in tube 70 and 100. At a later time, depending on the time constant of the capacitor 101 which is connected across conductor 78 and the cathode of rectifier 71, rectifier 71 resumes conduction to charge capacitor 67 in preparation for the next succeeding cycle of operation. Since rectifier 71 is held non-conductive for a short interval even after the decrease of voltage across capacitor 67 to a value insufficient to sustain conduction in thyatron 70 the thyatron 84 and valve 96 are extinguished. It should be observed that the dead short characteristic of the discharge circuit for the capacitor 83 involving the valve 96 insures the complete discharge of the capacitor during each cycle of operation making it ready to accurately time the next succeeding operation.

The operating characteristics of the elements of the timing circuit are represented by the curves in Figures 2 and 3, the former dealing with a medium time setting while the latter is concerned with a very short timing period. The abscissae are laid off in time quantities represented by cycles having a frequency of 900 cycles per second after the period. It will be observed that in either case conduction in tube 84 is initiated within one to two milliseconds from the start of the voltage impulse from transformer 66 and that this delay is substantially constant. Upon the elapse of a predetermined interval as determined by the setting of the potentiometer 82 the tube 96 conducts and within one or two milliseconds the valve 70 begins to conduct to dump the energy stored in capacitor 67 into the coil 63. The sharp wave form of the current passed by tube 96 upon the timing out of the capacitor 83 should be particularly noted. This current passing through the primary of the transformer 95 results in a voltage wave in the secondary thereof of substantially identical form and it will be therefore understood that the time of firing of the tube 70 is substantially independent of the inherent characteristics of the tube. Thus extreme accuracy in timing is possible and the system illustrated has been proven to carry an accuracy of plus or minus 1.5% at normal timing intervals.

Figures 2 and 3 also show the correlation of operation of transformer 66 and tubes 84 and 96 with the discharge of the capacitor 67, the curves of the latter being labeled "solenoid." The peak values of the solenoid current curve represent the instants at which movement of the solenoid armature is completed and it will be observed that the time interval between the energization or start of conduction in tube 70 (initiation of discharge of capacitor 67 and the instant when the solenoid armature reaches its full actuated position is short and is substantially constant. This follows from the tuned nature of the solenoid energizing circuit as explained above.

It will be understood that any suitable means may be employed to charge the solenoid energizing capacitor and that insofar as the tuned nature of the energizing circuit is concerned other tripping means than that specifically disclosed may be employed to initiate discharge of the capacitor in timed sequence following the appearance of any desired reference condition.

Since the features of the invention disclosed herein are susceptible of widely varying embodiments the scope of the invention is not to be

limited except as necessitated by the prior state of the art and the scope of the appended claims.

What I claim is:

1. A timing and energizing circuit comprising in combination a capacitor, means to charge said capacitor, a gas discharge device having a control grid in control of the discharge of said capacitor a timing capacitor, means comprising a grid-controlled discharge device to charge said timing capacitor by energy derived from said first mentioned capacitor, and means operative upon said timing capacitor attaining a predetermined charge to discharge said timing capacitor through an impulsing device, said impulsing device being connected to said first mentioned control grid to initiate conduction in said gas discharge device.

2. A timing and energizing circuit comprising in combination a capacitor, means to charge said capacitor, means comprising a grid-controlled gas discharge device to discharge said capacitor a timing capacitor, an adjustable charging circuit for said timing capacitor including a circuit controlling device arranged to be rendered conductive upon the appearance of a reference condition, and means operative upon said timing capacitor attaining a predetermined charge to impress a voltage impulse on the grid of said gas discharge device to initiate discharge of said capacitor.

3. Electrical apparatus comprising an armature, an actuating coil therefor, a timed energizing circuit for said actuating coil comprising a capacitor, means comprising an impulse operated circuit controlling device to discharge said capacitor through said coil, a timing device, means to initiate operation of said timing device in response to the appearance of a reference condition, and means operative upon said timing device timing out its predetermined period to impress an impulse on said circuit controlling device to initiate discharge of said capacitor through said coil, the inductance of said coil being so related to the capacity and charge of said capacitor that said armature is moved from fully retracted position to fully actuated position during the rising portion of the current wave through said coil resulting from the discharge of said capacitor.

CLYDE E. SMITH.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,762,811	Charlton	June 10, 1930
1,819,868	Carter	Aug. 18, 1931
1,970,455	Humphries	Aug. 14, 1934
2,024,019	Wright	Dec. 10, 1935
2,040,677	Suits	May 12, 1936
2,082,644	Lord	June 1, 1937
2,127,080	Barker	Aug. 16, 1938
2,249,488	Nickle	July 15, 1941
2,296,580	Smiley	Sept. 22, 1942
2,299,941	Townsend	Oct. 27, 1942
2,356,765	Klemperer	Aug. 29, 1944

FOREIGN PATENTS

Number	Country	Date
318,316	Great Britain	Sept. 5, 1929
551,058	Great Britain	Feb. 5, 1943