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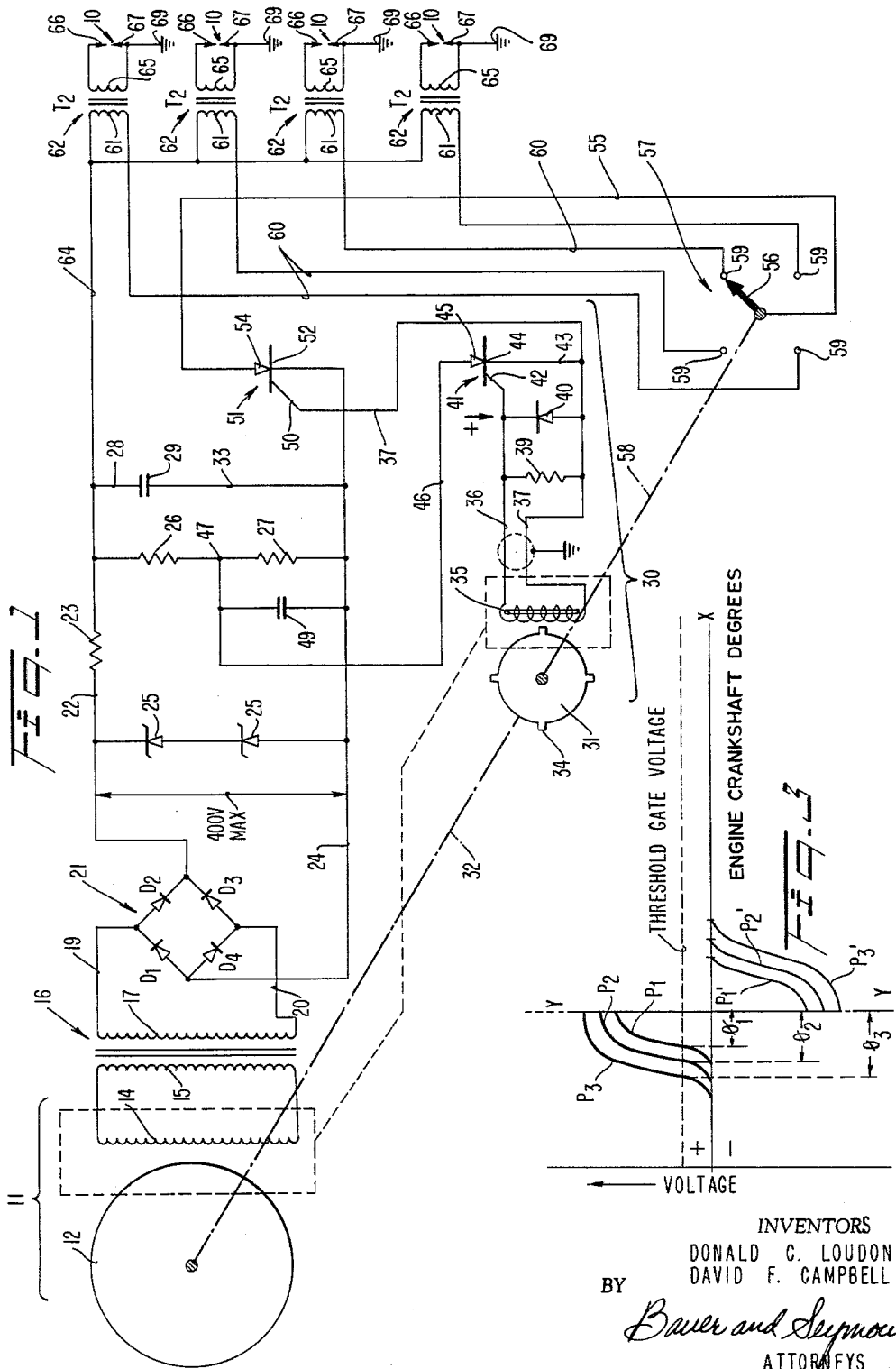
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ELECTRICAL APPARATUS

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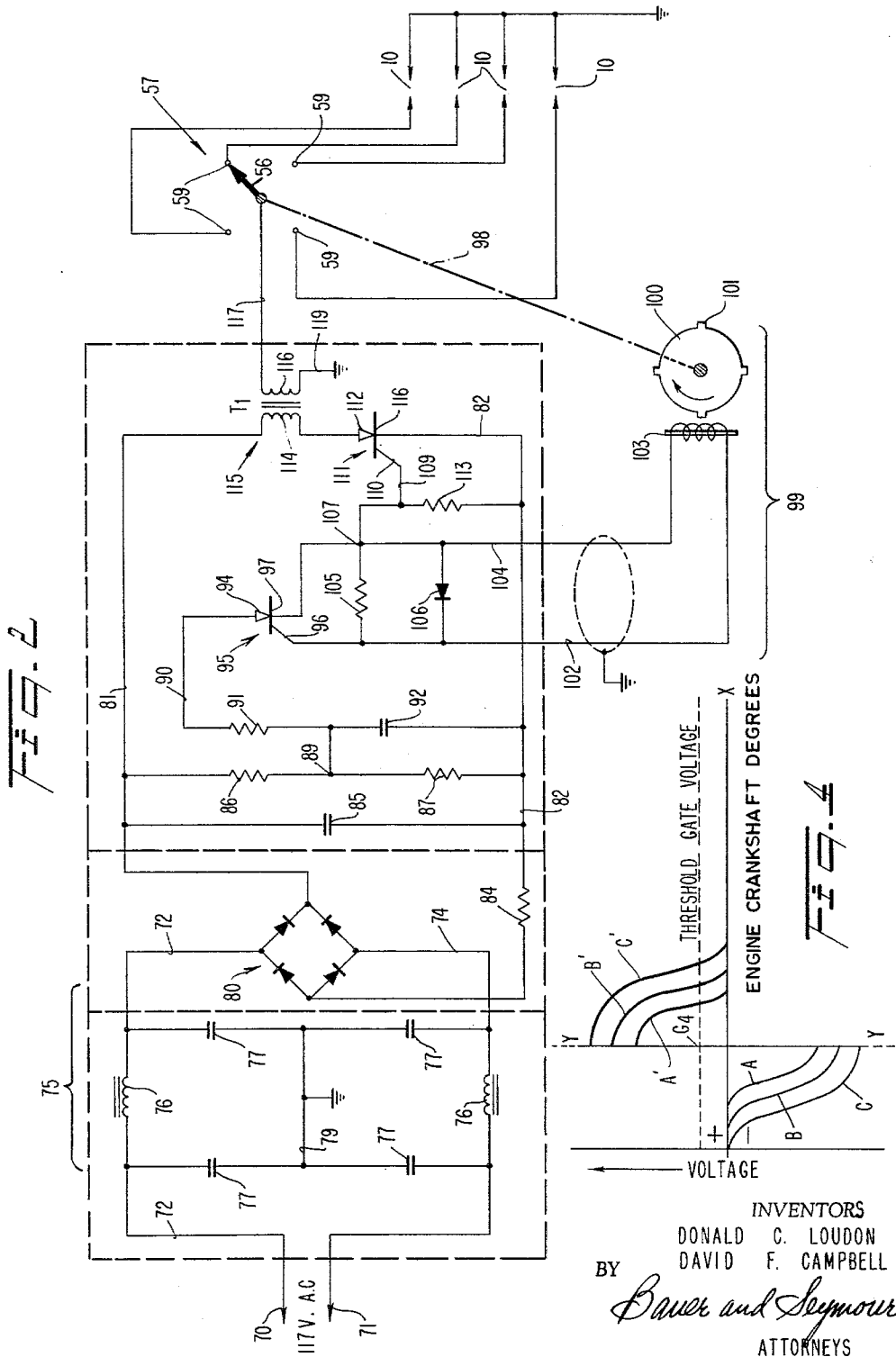
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ELECTRICAL APPARATUS

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This invention relates to electrical apparatus, and more particularly relates to a system for generating timed pulses. The apparatus of the invention may be employed, for example, in an ignition system for an internal combustion engine.

The invention has among its objects the provision of a novel pulse generating system.

A further object of the invention resides in the provision of a pulse generating system which does not require the use of a mechanically operated breaker or contacts.

Another object of the invention lies in the provision of a breakerless pulse generating system which is particularly well adapted for use in ignition systems for internal combustion engines.

A still further object of the invention lies in the provision of a pulse generating system which is particularly characterized by its simplicity, its economy of manufacture and maintenance, and its long life.

Yet another object of the invention lies in the provision, in a specific preferred embodiment of pulse generating apparatus in accordance with the invention, of novel means for securing an advance in the timing of the generated pulses upon an increase in speed of a triggering means associated with the system.

Still another object of the invention lies in the provision of a novel method of timing generated electrical pulses, and of automatically varying the timing of such pulses.

The above and further objects and novel features of the invention will more fully appear from the following description when the same is read in connection with the accompanying drawings. It is to be expressly understood, however, that the drawings are for the purpose of illustration only, and are not intended as a definition of the limits of the invention.

In the drawings, wherein like reference characters refer to like parts throughout the several views,

FIG. 1 is a wiring diagram of a first illustrative embodiment of pulse generating apparatus in accordance with the invention, such apparatus being shown employed for providing ignition spark discharges for an internal combustion engine;

FIG. 2 is a wiring diagram of a second illustrative embodiment of pulse generating apparatus in accordance with the invention, such apparatus being also shown employed as an ignition system for an engine;

FIG. 3 is a graph illustrating the manner in which the apparatus of both FIGS. 1 and 2 operates to yield an automatic advance of the spark discharges upon an increase in speed of the internal combustion engine; and

FIG. 4 is a graph illustrating the manner of operation of the system of the invention when it is modified so that the timing of the spark discharges is fixed regardless of speed of the engine.

As above indicated, the apparatus of the present invention is particularly advantageous when employed to supply ignition spark discharges for an internal combustion engine. It is to be understood, however, that the apparatus of the invention is capable of a number of different applications wherein timed electrical pulses or discharges are required. The apparatus is particularly characterized by the fact that it requires no mechanically operated breaker or contacts and thus is free from the maintenance

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problems which the use of such breakers entail. The apparatus of the invention may derive its primary power in a number of ways, of which the magneto in the system of FIG. 1 and the domestic alternating current source in the system of FIG. 2 are illustrative. In the illustrative embodiments the apparatus includes pulse triggering means in the form of a rotating triggering wheel and a pickup coil. The distributor may be a conventional distributor of the automotive type. The switching functions in the system are performed by solid state switching devices which have no moving parts. As a consequence, the apparatus of the invention will operate for long periods without the necessity of attention.

In FIG. 1 there is shown an ignition system for supplying timed spark discharges to the four spark plugs 10 of an internal combustion engine. The main power for the system is supplied by a magneto or small generator, generally designated 11, which has a pole-carrying rotor 12 driven in timed relationship with the engine. Rotor 12 is disposed close to a field coil 14 so as to induce alternating voltage therein as the rotor travels therepast. Connected to the output leads of winding 14 is the primary winding 15 of a step-up transformer 16. Wires 19 and 20, connected to the opposite ends of secondary winding 17 of transformer 16, are connected to a full wave rectifier 21 which, in the embodiment shown, is made up of four bridge-connected diodes.

Magneto or generator 11, step-up transformer 16, and the rectifier 21 form the main source of power for the ignition system shown. Such power is delivered from rectifier 21 through wires 22 and 24, the potential difference between wires 22 and 24 being preferably regulated to a maximum value, for example, 400 volts, by the provision of one or more zener or break-down diodes connected therebetween. In the embodiment shown two such zener diodes 25, connected in series, are connected between wires 22 and 24.

Connected to wires 22 and 24, so as to be charged thereby, is a storage condenser 29 of substantial capacity. Such condenser may have a capacity, for example, of 5 μ f. Condenser 29 is periodically charged and discharged, the discharge from the condenser being directed to the appropriate spark plug of the engine in timed relationship to the engine by a triggering means to be described and by a distributor shown generally at 57. Condenser 29 has one terminal thereof connected by a wire 28 to wire 22 and its other terminal connected by a wire 33 to wire 24. The rate of charging of condenser 29 from the circuit 22, 24 is governed by the resistor 23.

Discharge of condenser 29 at desired timed intervals is effected by a triggering circuit generally designated 30, such triggering circuit controlling a triggered switching means 51 in the form of a silicon controlled rectifier, which is interposed in the condenser discharge circuit between the condenser and the distributor 57. The triggering circuit includes a second condenser 49 of appreciably smaller capacity than that of condenser 29, condenser 49 having a capacity, for example, of 0.1 μ f. Condenser 49 is connected in paralleled circuit relationship with condenser 29, one terminal of condenser 49 being connected to wire 24 and the other terminal thereof being connected to a junction 47 between two serially connected resistors 26 and 27 connected across wires 22 and 24. Condenser 49 is charged at the same time as condenser 29, and serves as the main source of power for the triggering circuit 30.

A trigger wheel 31 is driven in synchronism with rotor 12 of the magneto by means such as a shaft 32 schematically indicated. Wheel 31 carries a plurality of projections or vanes 34 on its periphery, the number of vanes and the speed of wheel 31 being such that one vane passes the pickup coil 35 of circuit 30 at each time that a spark

discharge is required at a spark plug 10. Coil 35 is provided with a core in the form of a permanent magnet; the vanes 34 are made of magnetic metal so that the passage of each vane through the lines of flux of the core of coil 35 causes voltage to be induced in the coil. The ends of coil 35 are connected through shielded wires 36, 37 to the gate and cathode 42 and 44, respectively, of a controlled switch 41 which may, for example, be a silicon controlled rectifier. The anode 45 of device 41 is connected by a wire 46 to the terminal of condenser 49 which is connected to junction 47. A zener diode 40 is connected across wires 36 and 37 so as to dissipate the negative portion of the wave form from coil 35 and also to limit the maximum positive voltage applied to gate 42. Thus the maximum positive voltage applied to the gate can not reach a value sufficient to damage device 41. Also connected across wires 36 and 37 is a resistor 39 which may, for example, have a resistance on the order of 4.7K ohms. Resistance 39 functions to equalize the potential of wires 36 and 37 during the interval between pulses from coil 35.

Triggered switching device 41 serves, in turn, to trigger the switching device 51. Cathode 44 of device 41 is connected by means of wires 43 and 37 to the gate 50 of device 51. The anode 54 of device 51 is connected by a wire 55 to the rotatable central contactor 56 of distributor 57. The cathode 52 of device 51 is connected to the aforesaid wire 33 which connects one terminal of condenser 29 to wire 24. The distributor 57, in this instance, has four equally angularly spaced terminals 59 which successively cooperate with rotor 56 of the distributor as the rotor travels therepast. Rotor 56 is driven in timed relationship with triggering wheel 31 as by a shaft schematically indicated at 58.

In the system shown in FIG. 1, each of spark plugs 10 is provided with its individual voltage step-up coil 62. One end of the primary 61 of each of coils 62 is connected to a wire 64 which extends to one terminal of condenser 29. The other end of each of primaries 61 is connected by a wire 60 which extends to the respective terminal 59 of the distributor. Each of coils 62 has a secondary winding 65, one end of which is connected to a first electrode 66 and the other end of which is connected to another electrode 67 of the respective spark plug 10. Electrode 67 is connected to ground, as shown at 69.

The above-described apparatus functions as follows: The charging circuit for condensers 29 and 49 is such that both condensers are fully charged between successive passes of a vane 34 through the field of pickup coil 35. The passage of each of vanes 34 through the field of coil 35 produces in coil 35 a voltage pulse having a wave form such as shown in FIG. 3, successive pulses being separated by substantial time intervals. When the gate 42 of device 41 reaches the threshold voltage, which may be on the order of +0.5 volt, device 41 becomes conductive. Thereupon, condenser 49 discharges through device 41 so as to raise gate 50 of device 51 above its threshold voltage. Condenser 29 now discharges in a circuit including device 51, the distributor 57, and the primary winding of the respective coil 62. The discharge of current through primary 61 induces a high voltage in secondary winding 65, thereby causing a spark discharge to occur at the respective spark plug 10.

In FIG. 2 there is shown a second illustrative embodiment of apparatus in accordance with the invention. In general, the apparatus of FIG. 2 differs from that of FIG. 1 as to the character of the main source of electrical power employed for the circuit, the specific disposition of the elements in the triggering circuit, and the manner in which the final portion of the discharge circuit is coupled to the storage condenser and the portion of the discharge circuit immediately associated therewith. The apparatus of FIG. 2 is particularly well adapted for use with stationary engines located close to a source of domestic alternating current.

Supply terminals 70 and 71 of the circuit of FIG. 2 are adapted to be connected to a source of 117 volts, 60 cycle alternating current. From terminals 70 and 71 there extend wires 72 and 74, respectively, which are connected to a filter generally designated 75 and to a full wave rectifier 80. Filter 75 includes two choke coils 76 interposed in wires 72 and 74, respectively, and a shunt connected network having four condensers 77 connected as shown, each set of two serially connected condensers being center tapped and connected to ground by a wire 79. Filter 75 functions to prevent the transmission of disturbances in the circuit caused by the periodic charging and discharging of the storage condenser outwardly of the circuit to the supply line and also acts to prevent the transmission of disturbances external of the ignition circuit in such circuit.

Storage condenser 85, which is similar to condenser 29 in the circuit of FIG. 1, is connected across delivery wires 81 and 82 extending from rectifier 80. A resistor 84 interposed in wire 82 governs the rate of charging of condenser 85. In view of the close regulation of the voltage of domestic alternating current, no voltage regulator is necessary in this circuit.

The triggering circuit includes serially connected resistors 86 and 87 which are disposed across wires 81 and 82. A smaller, parallel circuit connected condenser 92 has one terminal thereof connected to wire 82 and the other terminal connected to junction 89 between resistors 86 and 87. Such second terminal of condenser 92 is connected by wire 90 through a series connected resistor 91 to the anode 94 of a switching device 95 which may be in the form of a silicon controlled switch. The gate 96 of device 95 is connected by a wire 102 to one end of a pickup coil 103. The other end of coil 103 is connected by a wire 104 to the cathode 97 of device 95. A diode 106 is connected across wires 102 and 104 so as to dissipate the negative portions of the pulses generated by coil 103. A resistor 105 is also connected across wires 102 and 104 as shown. A triggering wheel 100 having vanes 101 thereon is mounted similarly to wheel 31 in FIG. 1, wheel 100 and the distributor 57 of the engine being connected by a shaft 98 so as to rotate in timed relationship and in synchronism with the engine.

A wire 109 extends from junction 107 with wire 104 to the gate 110 of a second switching device 111, which may be a silicon controlled rectifier. Wire 82 extends to the cathode 116 of device 111. A resistor 113 is connected across wires 109 and 82 in advance of device 111. Wire 81 is connected to a first terminal of the primary winding 114 of a voltage step-up transformer 115, the other terminal of primary winding 114 being connected to anode 112 of device 111.

Step-up transformer 115 has a secondary winding 116, one terminal of which is connected by a wire 117 to the rotor 56 of distributor 57, the other terminal of the secondary winding being connected to the ground by a wire 119. The distributor 57 is the same as and is connected to the spark plugs 10 in the same manner as in the apparatus of FIG. 1.

The operation of the apparatus of FIG. 2 will be readily apparent from the above. Condensers 85 and 92 are fully charged between successive triggering pulses of the triggering circuit. A triggering pulse renders switching device 95 active, thereby discharging condenser 92 there-through. Such discharge of condenser 92 renders device 111 conductive so that the storage condenser 85 then discharges through wire 81, primary winding 114, and wire 82. The resulting rush of current through primary winding 114 induces a high voltage in secondary winding 116 so that an electrical pulse of discharge energy is delivered to rotor 56 of the distributor and thence to the respective spark plug.

The ignition systems shown in both of FIGS. 1 and 2 are further advantageous because of their inherent property of automatically advancing the time of the spark upon

an increase in the speed of the engine. This property of the circuit of the invention will be more readily apparent upon consideration of FIG. 3. In such figure, wherein crankshaft degrees are plotted horizontally and voltage vertically, there are shown three voltage wave forms from the magnetic pickup (35 in FIG. 1; 103 in FIG. 2). All of such wave forms have similar but reversed portions in the fourth and second quadrants of the graph, the voltage dropping off steeply at the upper ends of the curves in the fourth quadrant so that the mid-portion of each of the wave forms substantially coincides with the vertical line Y—Y. The innermost smallest wave form, designated P_1 , P_1' corresponds to an engine speed of S_1 . The intermediate wave form P_2 , P_2' corresponds to an engine speed of S_2 . The largest wave form P_3 , P_3' corresponds to an engine speed of S_3 , where $S_1 < S_2$ and $S_2 < S_3$. It will thus be seen that as engine speed increases not only does the pickup voltage generated by the magnetic pickup coil increase, but the wave form becomes substantially broader at the base of the positive and negative halves of the pulse.

The first switching device (41 in FIG. 1; 95 in FIG. 2) does not become conductive until the potential of its gate reaches a certain minimum or threshold positive value, for example, 0.5 volts. Such threshold voltage is indicated by the horizontal dash line in FIG. 3. Because of the broadening of the base of the positive half of the pulse, the threshold voltage of the first switching device is reached earlier in the engine cycle as engine speed increases. Thus the point of intersection of the threshold gate voltage in FIG. 3 with wave form P_2 lies to the left of or in advance of its intersection with wave form P_1 , and the intersection of the threshold gate voltage line with wave form P_3 lies further in advance of that with wave form P_2 , or in other words, as shown $\theta_1 < \theta_2 < \theta_3$, where θ designates the degree of ignition advance for a given engine speed.

The system of the present invention can readily be altered so that the timing of the discharges is fixed regardless of changes in engine speed. This may be done in systems of FIGS. 1 and 2 simply by reversing the polarity of the pickup coils 35 (FIG. 1) and 103 (FIG. 2) as by reversing the connection of lead wires 36, 37 and 102, 104, respectively. When this is done, the pulses presented to the gate of the first switching devices 41 (FIG. 1) and 95 (FIG. 2) have wave forms such as shown in FIG. 4, wherein A, A' is the wave form of a triggering pulse for an engine speed of S_1 , B, B' is the wave form for an engine speed of S_2 , and C, C' is the wave form for an engine speed of S_3 , where $S_1 < S_2 < S_3$. It will be seen that the first half of each of such pulses lies in the third quadrant, and that each wave form rises from a maximum negative voltage substantially along the vertical line Y—Y to a maximum positive voltage, from which the voltage decreases in the portion of wave form in the first quadrant of the graph.

The first switching devices 41 (FIG. 1) and 95 (FIG. 2) do not become conductive until a positive voltage equalling or exceeding the threshold voltage of the switching device is impressed upon the gate of such device. Thus the switching device is not conductive during the negative half of any of the wave forms in FIG. 4, and does not become conductive until upon rising substantially along the line Y—Y the voltage equals that at the intersection G_4 between the line Y—Y and the dash line representing the threshold voltage of the switching device. Accordingly, with the alternative arrangement here described the timing of the discharge pulses remains the same regardless of engine speed.

Although only two illustrative embodiments of apparatus and method for generating a succession of electrical pulses in accordance with the invention have been illustrated in the accompanying drawings and described in the foregoing specification, it is to be expressly understood that various changes, such as in the relative dimen-

sions of the parts, materials used, and the like, as well as the suggested manner of use of the apparatus of the invention, may be made therein without departing from the spirit and scope of the invention as will now be apparent to those skilled in the art.

What is claimed is:

1. Apparatus for generating a succession of electrical pulses, comprising a storage condenser, a charging circuit for the condenser, a circuit for periodically discharging the condenser, said discharging circuit including a solid state electronic switching device selectively rendered electrically conductive and non-conductive, said switching device having an anode, a cathode and a control electrode, and triggering means for controlling the switching device, said triggering means comprising a coil winding connected in parallel with a voltage breakdown diode across the cathode and control electrode of said switching device and means for generating a succession of electrical triggering pulses in said winding to render the anode-cathode path of said switching device electrically conductive to the charge on said storage condenser.

2. Apparatus as defined in claim 1 wherein said triggering pulses are of voltage wave form having a positive and a negative excursion for each pulse, the same being such that the positive excursion of each pulse precedes the negative excursion thereof and said switching device is triggered when the triggering pulse voltage rises to a predetermined positive value.

3. Apparatus as defined in claim 1 wherein said triggering pulses are of voltage wave form having a positive and a negative excursion for each pulse, the same being such that the negative excursion of each pulse precedes the positive excursion thereof and the reversal from maximum negative value to maximum positive value is substantially instantaneous, and wherein the switching device is triggered when the triggering pulse voltage rises to a predetermined positive value during such reversal.

4. Apparatus for generating a succession of timed electrical pulses, comprising a storage condenser, a charging circuit for the condenser, a circuit for periodically discharging the condenser, said discharging circuit including a solid state switching device selectively rendered electrically conductive and non-conductive and triggering means for periodically energizing the switching device to render it electrically conductive, said triggering means including a second condenser connected to be charged simultaneously with the storage condenser and means periodically to discharge the second condenser and to deliver the discharge from the second condenser to the switching device to render it electrically conductive, said last-named means including a second solid state switching device, a discharge circuit for the second condenser, the second switching device being interposed in the discharge circuit for the second condenser, wherein the second switching device is selectively rendered electrically conductive and non-conductive, and means for generating a succession of timed electrical triggering pulses and for delivering such timed triggering pulses to the second switching device to render it electrically conductive upon the reception of each triggering pulse.

5. A system for generating a succession of timed electrical pulses, comprising a storage condenser, a charging circuit for the condenser, a circuit for periodically discharging the condenser, an output circuit connected to be energized by the discharge of the storage condenser, the output circuit including at least one discharge gap, a solid state switching device selectively rendered electrically conductive and non-conductive in said discharging circuit, said switching device including a control means which when raised to a predetermined minimum positive potential renders the switching device electrically conductive, said switching device being electrically non-conductive unless the control means is raised to said minimum potential, and triggering means for controlling the switching device including means for generating a suc-

cession of timed positive electrical pulses and for delivering such timed pulses to the control means of the switching device, said triggering means further including rotatable means driven at a selectively variable speed for generating electrical triggering pulses in synchronism with the speed of said driven means, the first portion of the voltage wave form of each triggering pulse plotted against degrees of rotation of said driven means being generally in the shape of the first portion of the positive half of a sine wave and the amplitude of such voltage wave form and the length of its base along the zero voltage axis of the wave form vary in the same direction as the speed of said driven means, whereby the storage condenser begins to discharge and the discharge gap is energized earlier in the cycle of the driven means as the speed of the driven means increases.

6. In an engine ignition system a storage condenser, a triggering condenser, rectifier means, means for repetitively charging said condensers through said rectifier means, a normally non-conductive solid state controlled rectifier for controlling the discharging of said storage condenser, said rectifier having an anode and a cathode in the discharge circuit of said storage condenser and a gate electrode, means connecting said triggering condenser across said gate electrode and cathode to render said controlled rectifier unidirectionally conductive to the charge on said storage condenser, said last-named means including a normally non-conductive solid state electronically controlled switching device for controlling the discharging of said triggering condenser, said switching device having an anode and a cathode in the discharging circuit of said triggering condenser and a gate electrode, and means for cyclically generating electrical pulses and for imposing said pulses upon said second-named gate electrode to render said switching device unidirectionally conductive to the charge on said triggering condenser in timed relation with the operating cycle of the engine.

7. An engine ignition system as defined in claim 6 comprising a transformer having the primary winding thereof in the discharging circuit of said storage condenser, and an igniter gap connected in series with the secondary winding of the transformer.

8. An engine ignition system as defined in claim 6 wherein said switching device is adapted to be rendered conductive to the charge on the triggering condenser when a predetermined voltage is imposed on said second-named gate electrode and wherein the pulses generated by said pulse generating means attain said predetermined voltage earlier in the operating cycle of the engine as the frequency of said pulses increases.

9. An engine ignition system as defined in claim 6 wherein said switching device is adapted to be rendered conductive to the charge on the triggering condenser when a voltage of preselected value is imposed upon said second-named gate electrode and wherein the voltage of the pulses generated by said pulse generating means attains said preselected value at substantially the same time in the operating cycle of the engine throughout a wide range of frequencies of the pulses.

10. Apparatus as defined in claim 2 wherein said triggering means includes a rotating member and said triggering pulses attain said predetermined positive value earlier in the cycle of rotation of said member as the speed of said member increases.

11. An ignition system for an internal combustion engine having at least one cylinder, comprising a storage condenser, a charging circuit for the condenser, a circuit for periodically discharging the condenser, an output circuit connected to be energized by the discharge of the storage condenser, the output circuit including at least one igniter gap and said discharging circuit including a solid state electronically controlled switching device selectively rendered electrically conductive and non-conductive, said switching device including a control means

which when raised to a predetermined minimum positive potential renders the switching device electrically conductive and being electrically non-conductive unless the control means is raised to said minimum potential, and triggering means including means driven in synchronism with the engine for generating electrical triggering pulses and means for generating a succession of timed positive electrical pulses and for delivering such timed pulses to the control means of the switching device, the first portion of the voltage wave form of each of said triggering pulses plotted against engine crankshaft degrees being generally in the shape of the first portion of the positive half of a sine wave and the amplitude of such voltage wave form and the length of its base along the zero voltage axis of the wave form being variable in the same direction as the speed of the engine, whereby the storage condenser begins to discharge and the igniter gap is energized earlier in the engine cycle as the speed of the engine increases.

12. An ignition system as claimed in claim 11, wherein the triggering means includes a pickup coil and the means driven in synchronism with the engine is a triggering wheel mounted to rotate close to the coil.

13. An ignition system for an internal combustion engine having at least one cylinder, comprising a storage condenser, a charging circuit for the condenser, a circuit for periodically discharging the condenser, an output circuit connected to be energized by the discharge of the storage condenser, the output circuit including at least one igniter gap and said discharging circuit including a solid state electronically controlled switching device selectively rendered electrically conductive and non-conductive, said switching device including a control means which when raised to a predetermined minimum positive potential renders the switching device electrically conductive and being electrically non-conductive unless the control means is raised to said minimum potential, and triggering means including means driven in synchronism with the engine for generating a succession of timed positive electrical pulses and for delivering such timed pulses to the control means of the switching device, the first portion of the voltage wave form of each of said triggering pulses being negative, such wave form thereafter rising almost instantaneously to a maximum positive voltage value and thereafter descending to zero, said wave form attaining the threshold voltage of the control means of the switching device at substantially the same time in each engine cycle, whereby the storage condenser begins to discharge and the igniter gap is energized at substantially the same time in the engine cycle regardless of changes in the speed of the engine.

14. An ignition system as claimed in claim 13, wherein the triggering means includes a pickup coil and the means driven in synchronism with the engine is a triggering wheel mounted to rotate close to the coil.

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