

[54] **IGNITION SYSTEM FOR INTERNAL
COMBUSTION ENGINES**

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[58] Field of Search 123/148 E

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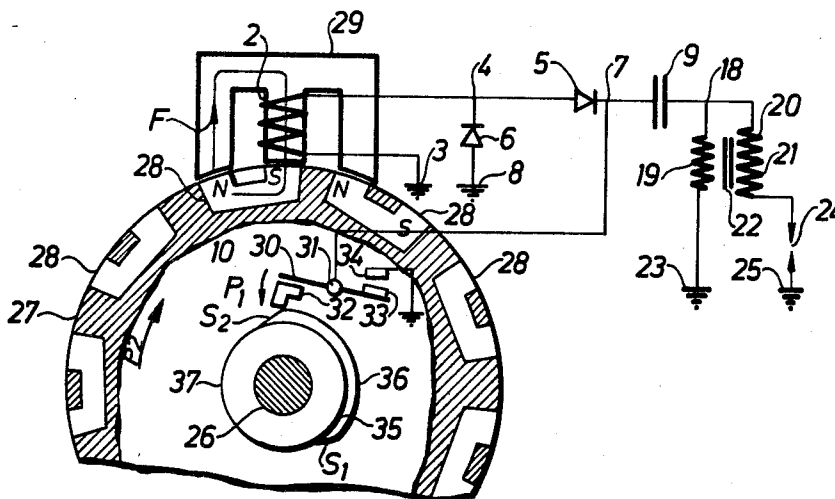
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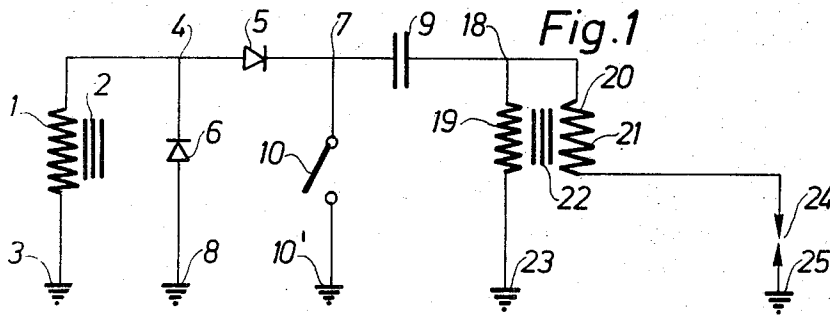
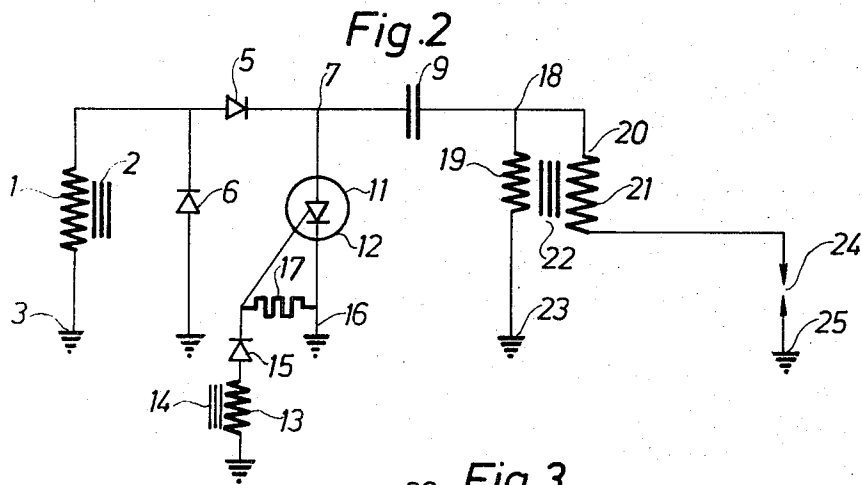
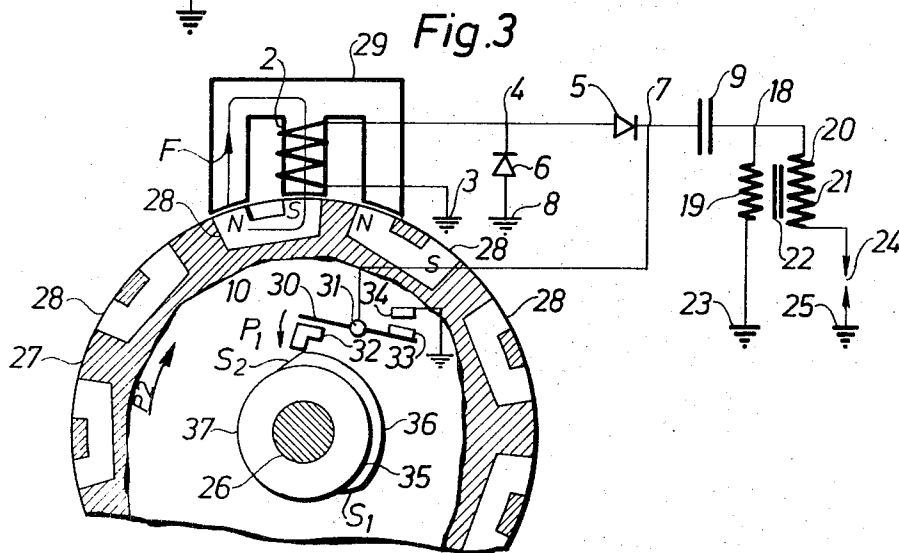
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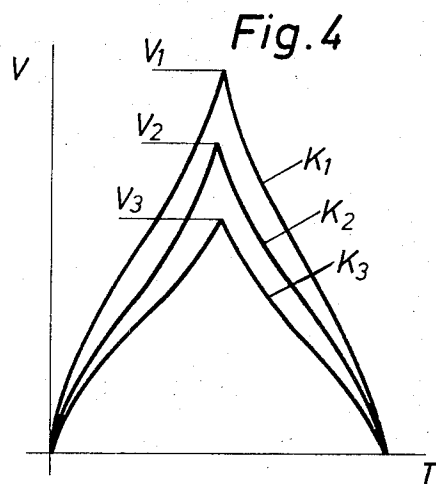
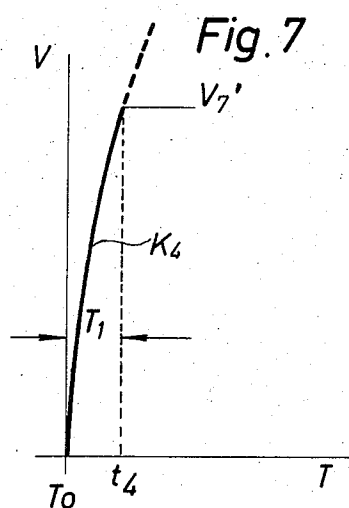
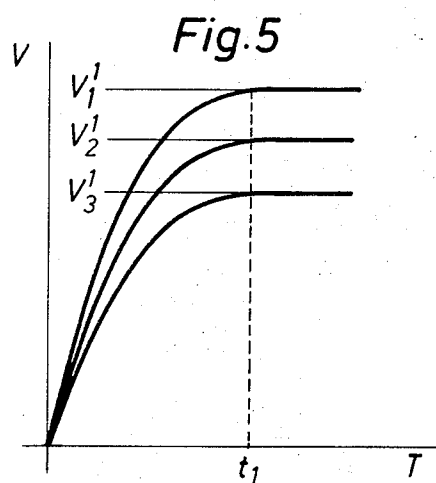
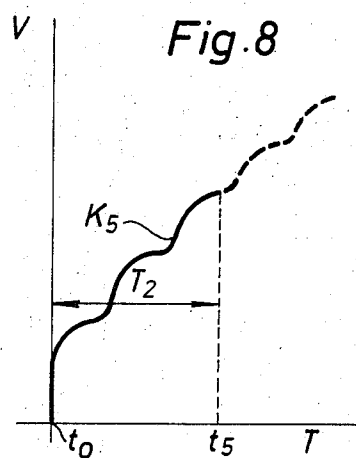
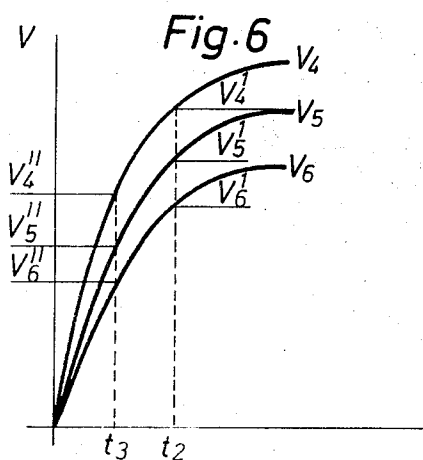
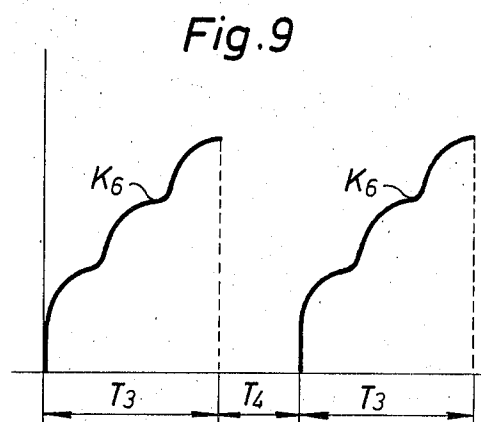
[57] **ABSTRACT**

An ignition system has a capacitor charged by a magneto, and switch means responsive to magneto rotation and connected across said magneto for terminating charging of the capacitor before the capacitor is fully charged.

4 Claims, 9 Drawing Figures







IGNITION SYSTEM FOR INTERNAL COMBUSTION ENGINES

The present invention relates to an arrangement for controlling the capacitor charging pulse of a capacitive ignition system, particularly with flywheel magneto ignition apparatus.

In the operation of capacitive ignition systems for internal combustion engines, a capacitor is charged with a DC current pulse of suitably adjusted voltage, whereafter the capacitor is discharged over the primary winding of an ignition coil, in the secondary winding of which is induced the high DC voltage required to produce a spark on the engine spark plug, resulting in ignition of the fuel mixture. With flywheel magneto ignition apparatus operating with a capacitive system, the capacitor charging pulse is produced by a special charging coil having an iron core arranged in a rotating magnetic field generated by permanent magnets arranged in the rotating portion of the flywheel and having inwardly or outwardly, normally radially directed poles. Each time the permanent magnet passes the iron core of the charging coil an AC current is generated in the coil winding with a negative and a positive half wave of approximately the same magnitude. A diode adapted to permit the current to pass through in only the positive direction is connected in series between the charging coil and the capacitor. In order to relieve the first diode of excessively high blocking voltages, it is normal to provide a second diode connected in parallel over the winding of the charging coil, so that the negative half wave causes current to flow through the charging coil via the second diode, energy being consumed as a result of the inductance in the coil.

The time taken to charge the capacitor with these known systems corresponds to the time required for the positive half wave to reach its maximum value from zero voltage. The capacitor has then taken up the charging voltage which the positive half wave can give. The moment of capacitor discharge, i.e., sparking on the spark plug with subsequent ignition, is determined by a control means, which may comprise a mechanical switch or a thyristor arranged to open and close in response to a pulse from a trigger coil for example.

Certain basic values have been established for capacitive systems in flywheel magneto ignition apparatus in connection with known techniques in the component field of such apparatus. Thus, the capacitor charging voltage should not exceed 500 V if reliable diode and thyristor operation (when such components are included) is to be obtained at acceptable component costs. With certain types of engine, the ignition voltage applied to the spark plug at engine starting speeds should not be less than 16 kV and at maximum engine rotational speeds should be 18 kV. However the ignition voltage may rise to 30 kV at normal engine operating speed.

These values embody requirements which may be difficult to fulfil in practice, especially if an attempt is made at the same time to satisfy the desire of providing for very low starting engine speeds and idling speeds. On the other hand, it is possible to construct a combined charging coil-capacitor-ignition coil which at a charging voltage of 450 V, for example, at normal operational engine speeds provides an ignition voltage of 30 kV. For physical reasons, mainly due to a rapidly falling voltage for the positive half wave at decreasing engine speeds, such a combination cannot provide the

desired ignition voltage of approximately 16 kV at starting engine speeds of the low magnitude desired.

If, on the other hand, the combined charging coil — capacitor — ignition coil is constructed to obtain an ignition voltage of 16 kV at the desired low engine starting speed, for example 200 revolutions per minute, which can of course be effected, the voltage from the charging coil to the capacitor at operational engine speed is so high that it may exceed substantially the desired maximum value, i.e., 500 V. In such a case, there is a grave risk that the apparatus components will be quickly rendered unserviceable.

The present invention provides an arrangement for circumventing the aforementioned difficulties, by controlling the length of the charging pulse to the capacitor, simultaneously affording selection of pulse curves which are not dependent on the maximum value of the charging pulse.

Accordingly, the present invention is mainly characterized in that the capacitor is charged by a voltage pulse emanating from at least one voltage impulse from a charging circuit and that said pulse is interrupted by a control means when the capacitor charging voltage has reached a value beneath the impulse peak voltage value, said value being sufficiently low as to exclude damage in circuits and/or the electronic components of said control means but which is sufficiently high to produce the necessary spark on the spark plug upon subsequent discharge of the capacitor through the ignition circuits.

The arrangement of the present invention comprises means for producing a rotating magnetic field and at least one iron co-acting with said field carrying at least one charging coil which, via a diode, supplies a respective capacitor of an ignition system, said capacitor being connected with a mechanical or electronic ignition control means which is synchronously connected to the arrangement to provide the rotating magnetic field. The inventive arrangement is mainly characterized in that the control means is mechanical and comprises a switch having a switch arm, a first, stationary contact, a second contact mounted on one free end of said arm, a sliding block mounted on the other free end of said arm, and a switch cam having a higher portion and a low portion and fixedly mounted on an engine shaft, the arrangement being such that when the sliding block slides over the high portion the contacts are moved apart, while when said block is located above the low portion the contacts are in mutual abutting relationship, and is further characterized in that the angle ranges of the high and the low cam portions are so adapted and the cam so arranged on the engine shaft that an opening point between the contacts is obtained when a unidirectional charging pulse begins, and a terminal point is obtained after a point of the time when at least one unidirectional charging pulse has transmitted a predetermined charging voltage to the capacitor.

The invention will now be described in more detail with respect to embodiments thereof illustrated in the accompanying drawings, in which

FIG. 1 shows a circuit diagram for a flywheel magnet ignition apparatus according to the invention provided with a charging pulse control means in the form of a mechanical switch.

FIG. 2 illustrates the same circuit diagram as that shown in FIG. 1, but in which the charging pulse con-

tol means has the form of a trigger-coil controlled thyristor.

FIG. 3 illustrates diagrammatically a rotor mounted on an engine shaft and having permanent magnets and the mechanical switch shown in FIG. 1, together with an iron core provided with a charging coil and arranged externally of the rotor.

FIGS. 4 and 5 illustrate different curves for the voltage pulse from the charging coil and the capacitor discharge voltage at different rotational speeds.

FIGS. 6 and 7 illustrate graphically the different effects obtained by the inventive method of regulating the length of the charging pulse.

FIGS. 8 and 9 illustrate graphically an alternative method of discharging the capacitor through a sequence of voltage pulses.

FIGS. 1 and 2 illustrate in principal the same circuit diagram for a capacitive ignition system in a flywheel magneto ignition apparatus according to the invention, although embodying alternative means for controlling the length of the charging pulse. The reference numerals used in the two figures are the same for like components. Referring to FIGS. 1 and 2, a charging coil 1 with an iron core 2 has an output line connected to ground 3 and an output line connected to a connecting point 4, to which a first diode 5 and a second diode 6 are also connected. A further output line from the first diode 5 is connected to a connecting point 7 and another output line from the second diode 6 is connected to ground at 8.

Connected to the connecting point 7 is also an output line from a capacitor 9 and an output line from a control means, which in the circuit of FIG. 1 comprises a mechanical switch generally indicated by the reference numeral 10, and in the circuit of FIG. 2 comprises an electronic switch, generally shown by the reference numeral number 11. An output line from the mechanical switch 10 is grounded at 10'.

The electronic switch 11 comprises a thyristor 12, a trigger coil 13 having an iron core 14 and a diode 15 connected in series between these elements. Connected in parallel between a grounded output line 16 from the thyristor 13 and the connecting point between the thyristor and the diode 15 is a shunt system 17 having a fixed resistance and optionally also a capacitor (not shown) adapted to the magnitude of the capacitive system.

An output line from the capacitor 9 is connected to a connecting point 18, to which is also connected an output line from a primary winding 19 and from a secondary winding 20 of an ignition coil, generally identified at 21 and having an iron core 22. An output line from the primary winding 19 is connected to ground at 23 and an output line from the secondary winding 20 is connected to an insulated electrode on a spark plug 24, the other electrode of which is grounded at 25.

FIG. 3 illustrates diagrammatically an arrangement for producing a charging pulse in the charging coil 1. Firmly mounted on an engine shaft 26 of an engine (not shown) to be served by the ignition apparatus is a rotor 27 of non-magnetic material, e.g., aluminium, zinc, reinforced plastics or the like, with permanent magnets 28 enclosed around the periphery thereof and having outwardly directed poles N, S. Fixedly mounted externally of the periphery of the rotor 27 is a preferably laminated iron core 29 having the shape of an E for example the one arm of which E forms the core 2 of the

charging coil 1. When a permanent magnet 28 passes the arm of the iron core 29 as a result of rotation of the engine shaft 26 and the rotor 27 synchronously carried thereby, an AC voltage with a positive and a negative half wave is produced in the charging coil 1. FIG. 3 illustrates a momentary position with a maximum flux in the direction of arrow F at that point of time when the poles N, S on a permanent magnet 28 are located opposite the two left arms on the iron core 29.

FIG. 3 also shows diagrammatically the manner in which the different components of the circuit diagram of FIG. 1 are electrically connected, i.e., the manner in which they are coupled to a mechanical control means having the form of switch 10 with a switch arm 30 pivotally mounted on a pin 31 and provided at one free end thereof with a sliding block or cam follower 32 and which carries at its other free end a contact 33. A grounded contact 34 is so arranged in connection with the contact 33 that when the arm 30 is rotated sufficiently in the direction of arrow P1 an electrical connection is obtained between the contact 33, 34.

A switch cam 35 having a high portion 36 and a low portion 37 is firmly connected with the engine shaft 26 and the rotor 27 respectively, the switch 10 and the cam 35 being so arranged in relation to each other that the electrical connection between the contact 33, 34 is broken when the sliding block or cam follower 32 is located on the high portion 36, and is closed when the block or cam follower is located above the lower portion 37.

The negative half wave of each AC cycle generated in the charging coil 1 produces current movement through the action of diode 6, substantially while being converted to heat in the charging coil 1. Each positive half wave passes to the capacitor 9 via the diode 5 and causes a discharge to take place. The switch 10 controlled by the cam 35 operates in a manner such that the electrical connection between the contact 33, 34 is broken during the moment of charging, whereafter closure of contacts takes place at just that moment when the capacitor has been charged and a spark is about to occur on the spark plug 24. This is indicated in FIG. 3 by the fact that the block or cam follower 32 is shown located precisely at the junction of the high cam portion 36 and the low cam portion 37, at the same time as a permanent magnet 28 is located opposite two arms of the core 29. Subsequent to slight, further rotation of the rotor 27 in the direction of arrow P2, the capacitor 9 becomes fully charged at the same time as the block or cam follower 32 leaves the high portion of the cam 35, whereupon the contacts 33, 34 are closed.

The voltage sequence for the positive half wave each time a permanent magnet 28 passes the iron core 29 is shown graphically in FIG. 4, in which the voltage is given on a y-axis and the time on an x-axis. The voltage sequence is dependent on the magnetic field, i.e., on the strength of permanent magnets 28, the air gap between the rotor 27 and the iron core 29, dimensioning of charging coil 1 etc., and on the speed at which the rotor 27 rotates. FIG. 4 shows three different curves K1, K2 and K3 representing the voltage sequence with three different combinations of permanent magnets, charging coil, air gap etc. at one and the same speed of revolution, it being assumed that the illustrated positive half waves are produced without influence of the control means 10 and 11. While the voltages are building up to amplitude V1, V2 and V3, the capacitor 9 is

charged for respective curve examples to a voltage $V1'$, $V2'$ and $V3'$, as shown in the diagram of FIG. 5, in which an x-axis and a y-axis denote the same magnitude as those in FIG. 4. As previously mentioned, the switch 10 is open during charging of the capacitor 9. At an accurately determined point of time $t1$, FIG. 5, when ignition is to take place, the switch 10 closes and the capacitor 9 is discharged over the primary winding on the ignition coil 21.

It will be evident herefrom that a combination of permanent magnets - charging coil - air gap etc. can be selected at which a high charging voltage is also provided with low speed of revolution. Such a combination, however, would produce at high rotary speeds voltage peaks of such magnitude as to risk damaging the diodes 5, 6.

In accordance with the invention this risk is totally eliminated by arranging for the switch 10 to be closed at a point on the positive half wave when sufficient charging current has been given to the capacitor 9 but when the voltage maximum for the positive half wave is still not reached.

FIG. 6 illustrates this condition in graph form, through two different closing points $t2$, $t3$ and three different curves $V4$, $V5$ and $V6$ for the charging voltage, the curves representing three different combinations of permanent magnets/charging coil etc, at one and the same speed of revolution. If the closure point $t2$ is applied to the voltage curve $V4$ the charging voltage is obviously restricted to a value $V4'$. In the same manner, the charging voltage $V4''$ is obtained when applying the breaking point $t3$ on the voltage curve $V4$. In an analogous manner, charging voltages $V5'$, $V6'$ and $V5''$, $V6''$ are obtained when applying a closing point $t2$, $t3$ on the other two curves $V5$, $V6$.

With the present invention, it is thus possible to select a combination of permanent magnets/charging coil which presents a steep and high voltage curve, i.e., which also produces high charging voltages at low speeds of revolution, and to utilize only that portion of the positive half wave required to supply the capacitor with a sufficient, and with respect to the wear and tear on the components, a maximum permitted charging voltage.

This is exemplified in the graph shown in FIG. 7, in which the same magnitudes as those shown in FIGS. 4 - 6 are given on the x-axis and y-axis respectively. A curve $K4$ in FIG. 7 shows a very rapidly rising charging voltage, which, however, owing to a prematurely placed breaking point $t4$ does not reach a higher voltage than voltage $V7'$, which can never exceed a predetermined value, for example 500 V and which even at low starting speeds, for example 200 r.p.m., is sufficiently high to provide an ignition voltage of, for example, 16 kV on the spark plug.

As previously mentioned, the switch 10 shall be open during the capacitor charging period, i.e., for a period of time indicated with $T1$ in FIG. 7. This period of time extending between the moment of opening the switch 10 to the moment of closing the same is determined by two points on the cam 35, these points being shown in FIG. 3 as an opening point $S1$ and a closing point $S2$. The angular distance between points $S1$, $S2$ corresponds to the time $T1$. It will be evident that the position of opening point $S1$ is determined by a time $T0$. FIG. 7, at which build up of charging voltage begins, and that the position of closure point $S2$ in dependence

on the course taken by the charging curve according to the invention shall be selected so that a requisite, but noncritical charging voltage $V7'$, FIG. 7, is obtained when the engine is running at full speed.

As previously mentioned, the switch 10 of the control means may be replaced with a thyristor 11, as shown in FIG. 2. The trigger coil 13 with iron core 14 is so arranged in relation to one or more permanent magnets 28 in the rotor 27 and so adjusted by means of resistance 17 and other means (not shown) that the triggering pulses to the thyristor 11 provide exactly the same opening and closing sequences as those described above with reference to the switch 10 and the cam 35.

It is also possible in accordance with the invention to charge the capacitor 9 by means of several sequential positive half wave pulses from the charging coil 1. With this arrangement, which is illustrated in FIG. 3 with relatively closely arranged permanent magnets 28, there is generated a continuous AC current in the charging coil 1. If the high portion 36 on the cam 35 is given greater extension and the closing point $S1$ is caused to lie at a greater angular distance from the opening point $S1$, there is obtained for the capacitor 9 a charging sequence illustrated in graph form in FIG. 8, in which the voltage V is given along the y-axis and the time T along the x-axis. In this instance, a charging curve $K5$ obtains a stepwise configuration, each step representing the charging pulse transmitted by the charging coil as a permanent magnet 28 passes the iron core 29. A time point t_0 and a further time point $t5$, when the switch 10 opens and closes respectively, limits the time $T2$ during which the switch 10 is open. With respect to the cam 35, this time may mean that the angle between the opening point $S1$ and the closing point $S2$ may be, for example, 150° . In turn, this means a considerable reduction in the sensitivity of the arrangement in respect to the position of special closing point $S2$ and may afford considerable advantages in certain practical applications.

This alternative application of the inventive concept is further illustrated in FIG. 9, which shows a graph in which the x-axis and the y-axis represent the same magnitudes as in FIG. 8. FIG. 9 shows two identical curves $K6$ for the charging voltages and a charging time $T3$, when the switch 10 is open, and a time period $T4$ when the switch is closed. It will be understood that the total time $T3$ plus $T4$ in the case of a single cylinder engine corresponds to one revolution, with a two-cylinder engine with uniform cylinder orientation a half revolution etc. In other words, the invention can be applied irrespective of the number of cylinders in the engine and the described embodiments together with variations thereon within the scope of the invention can be selected in accordance with their suitability for different types of engines. It will also be apparent from the foregoing that the alternative employing the electronic switch can also be applied to the charging sequence described with reference to FIGS. 8 and 9.

What I claim is:

1. An ignition system for an internal combustion engine, comprising:
 - a. an ignition coil having primary and secondary windings, said secondary winding being arranged to be connected in circuit with a spark plug;
 - b. a magneto for generating unidirectional charging pulses in response to engine rotation;

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c. a discharge capacitor connected in series between said magneto and said primary winding;
 d. each charging pulse having a peak value of voltage at least equal to the charging voltage of said capacitor at the slowest engine operating speed; and
 e. switch means responsive to magneto rotation and connected across said magneto for terminating charging of said capacitor during higher operating speeds before said capacitor is fully charged.
 2. An ignition system according to claim 1 in which said magneto has a series of permanent magnets successively operative to produce pulse increments which jointly comprise one of said charging pulses, each such increment having a peak voltage below said charging

voltage of said capacitor.

3. An ignition system according to claim 1 in which said switch means comprise a pair of relatively movable electrical contacts, and a cam arranged to be rotated with the rotatable portion of said magneto by a shaft on the magneto for controlling opening and closing of said contacts.

4. An ignition system according to claim 1 in which said switch means comprise a normally non-conductive thyristor connected directly between said capacitor and the low-voltage side of said magneto, and a trigger coil in said magneto connected to render said thyristor conductive.

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