

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

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[22] Filed: **Oct. 30, 1970**
[21] Appl. No.: **85,554**

[30] **Foreign Application Priority Data**

Nov. 4, 1969 Japan..... 44/87568
Jan. 26, 1970 Japan..... 45/6295

[52] U.S. Cl..... 123/148 E, 315/209 CD
[51] Int. Cl..... F02p 3/06
[58] Field of Search 123/148 E;
315/209 CD

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Assistant Examiner—Cort Flint
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[57] **ABSTRACT**

An ignition system for internal combustion engines wherein an ignition coil is provided, in addition to a first winding having a switching element in series and a second winding provided a discharging gap in series, with a third winding magnetically coupled with the first and second windings, a capacitor which is connected across the terminals of the third winding by way of a rectifier has the relation of a parallel connection with a series circuit of the first winding and the switching element, and the series circuit is energized by a power source having a reverse current blocking element, whereby the capacitor is charged by the power source by way of the first and third windings and at the same time the capacitor is discharged, when desired, through the first winding to produce a high voltage across the terminals of the second winding.

2 Claims, 8 Drawing Figures

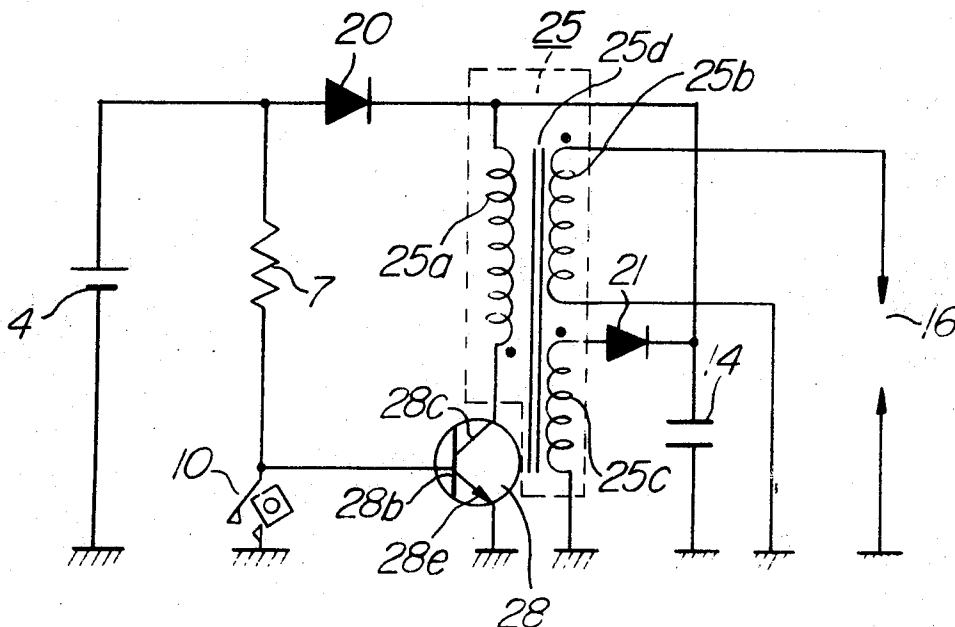


FIG. 1

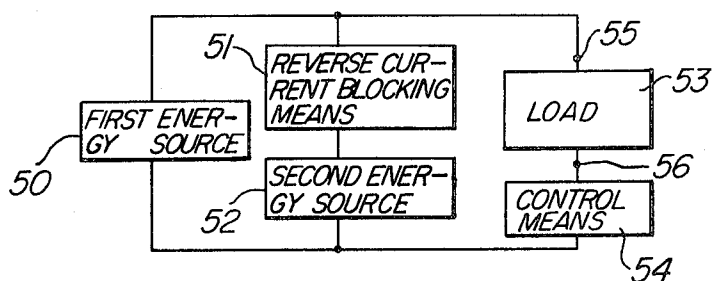


FIG. 2

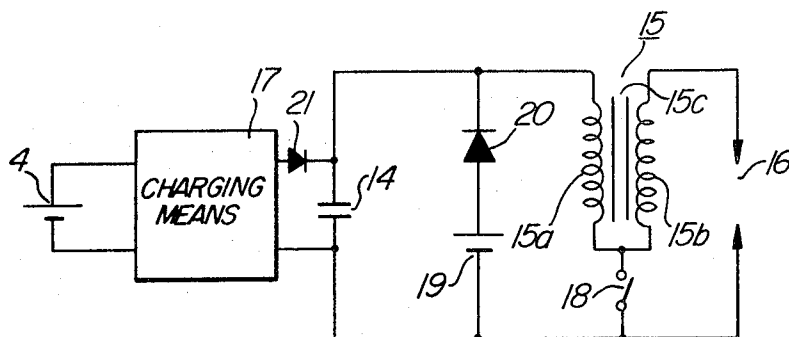
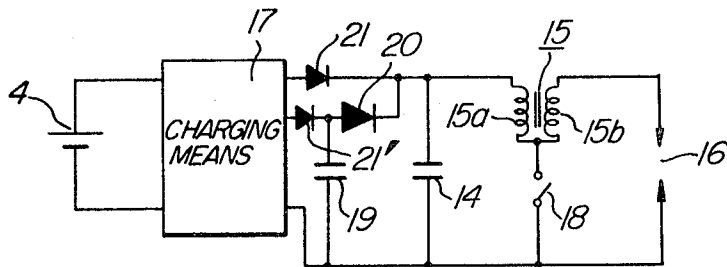


FIG. 3



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FIG. 4

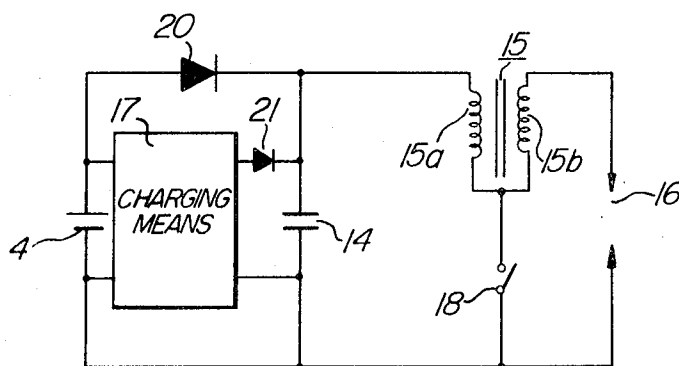
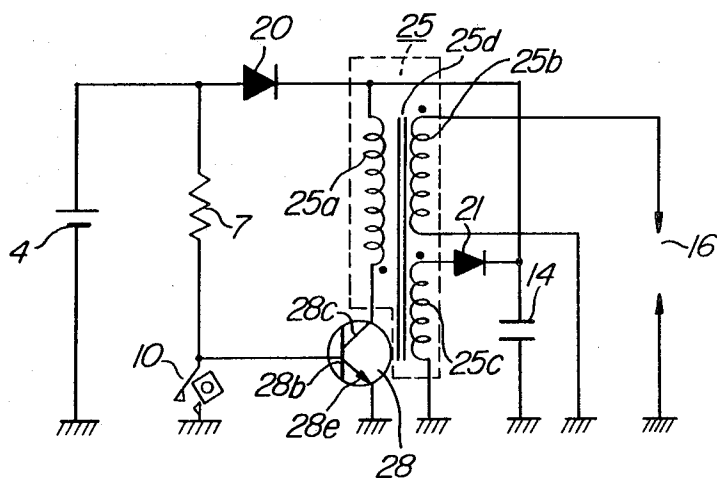


FIG. 5

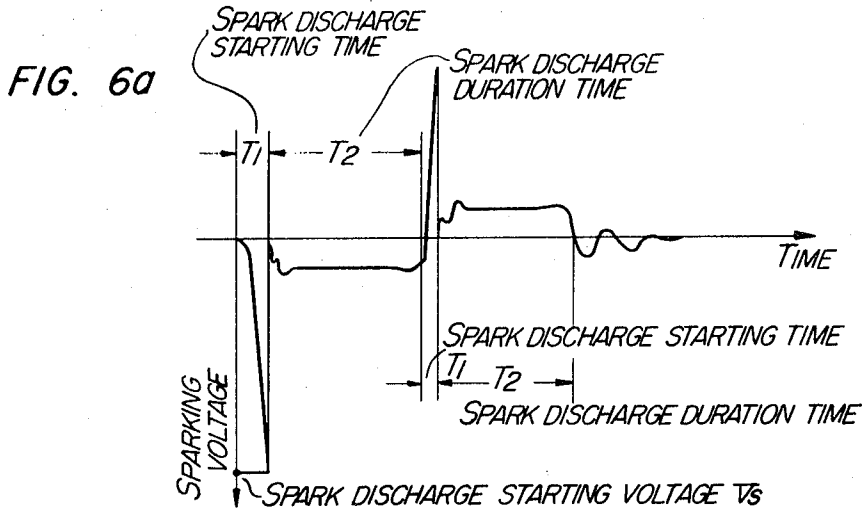
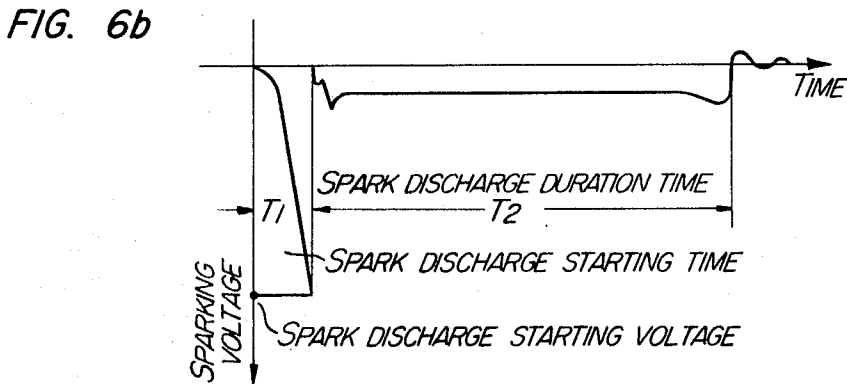
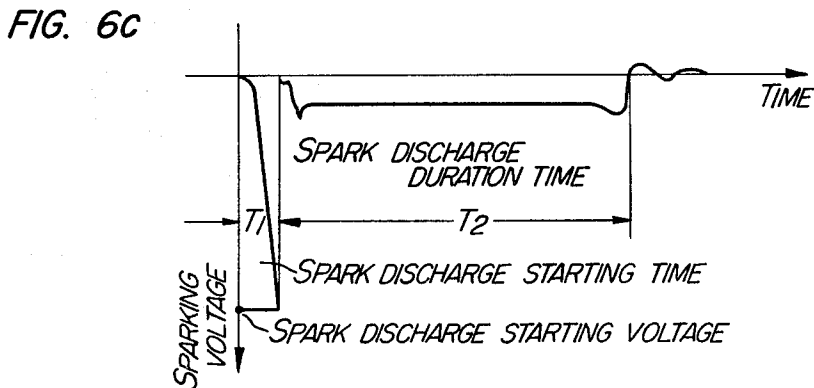


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IGNITION SYSTEM FOR INTERNAL COMBUSTION ENGINE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an ignition system for internal combustion engines.

2. Brief Description of the Prior Art

With the development of high speed vehicles, there has been an increasing demand for improvement in the performance of an ignition system when the vehicle is running at high speeds.

One of the various attempts hitherto made to this end consists of a so-called capacitor discharging type ignition system wherein a low battery voltage or the like is stepped up to a medium voltage by means of a transformer and this medium voltage is then applied to a capacitor so that the stored charge in the capacitor is discharged through the ignition coil at the time of ignition to produce a high voltage across the discharging gap.

However, the conventionally used capacitor discharging type ignition system such as disclosed in U.S. Pat. Nos. 3,331,986 and 3,338,172 employs an inverter transformer or the like transformer to step up a low voltage and moreover such a transformer must be provided in addition to an ignition coil. Thus, the conventional system of the type described has the following deficiencies, although it has some important features.

1. The essential defect of the conventional capacitor discharging type ignition system resides in that since the duration of the spark is short, it is impossible to provide a sufficient time to establish an explosion within the cylinder in spite of the high density of the spark energy and thus there is the danger of the incomplete combustion of fuel for the same stored energy when compared with an ordinary so-called battery-ignition system.

As is well known in the art, the rise time of the discharging gap voltage is faster and the spark lag is shorter in the capacitor discharging type ignition system than in the battery ignition system and consequently the former system may prove to be very effective in starting the engine and in the like operations, since the effect of the leakage resistance on the secondary circuit is reduced and ignition can readily take place even if the spark plug is wet or stained with fuel cinders. However, owing to the fact that the spark current flowing into the secondary winding tends to vary in the same phase relation with the resonance current flow in the primary winding (the polarity of the spark discharge voltage is reversed after the half period of the primary winding resonance cycle so that the spark discharge may be maintained during one period of the primary current on the whole), a faster rise time of the discharging gap voltage may result in an increase in the resonance frequency of the primary winding and this prohibits the spark duration time from being made longer. On the contrary, in order that the duration of a spark may be long enough, the resonant cycle of the primary circuit must be made longer and this will retard the rise time of the discharging gap voltage with the resultant diminishing of the aforesaid effect on the leakage resistance.

2. Since the output voltage is substantially proportional to the input voltage in the oscillatory inverter transformer employed in the conventional system, a voltage decreasing in a DC power source results in a

decrease in the voltage stored across a capacitor so that when this voltage is discharged there will be a corresponding decrease in the actual amount of voltage developed across the discharging gap thus reducing the lighting performance of the system. Such a voltage decreasing in the DC power source may frequently occur when starting the engine, since large power is consumed for starting a starter motor, and this will in turn cause an ignition failure on the ignition system.

3. Since the required semiconductor components include at least two transistors, one SCR and four diodes and at the same time the oscillation period of an inverter transformer must be several times as large as the discharging period of a capacitor, a high-frequency low-loss core must be used and this makes the manufacturing cost very high.

4. Since the oscillatory inverter used in the conventional system is always kept in operation when the engine is running, its oscillating operation is continued even when the engine is idling, so that the amount of power consumed by the transistors is large and the heat loss is also large, resulting in low efficiency. In addition, there is an offensive noise caused by the operation of the system and this impairs the merits of the quiet engine.

5. Since, as is well known, the SCR is a bistable element, it may be inadvertently rendered conductive when its gate is triggered by some noise signal at a time other than the ignition time after it has been turned off. In such a case, the SCR cannot be turned off with the result that not only the ignition system fails to function effectively, but also the output of the inverter transformer is short-circuited, thus causing an excessive current flow to the transistors to thereby cause breakdown. Particularly, when the conventional ignition system is installed in a vehicle, those noise signals which may trigger the SCR gate include the spark discharge from the ignition system itself as well as the sparks produced between the contacts of relays used with the horn, direction indicator and the like and the sparks produced at the brushes of rotary machines. It is difficult to provide complete protection against these noise signals and a large sum of money will be required to do so.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a new and novel ignition system having a very high energy conversion efficiency and combining the features of both the battery-ignition system and the capacitor discharging type ignition system.

Another object of the present invention is to provide an ideal ignition system which comprises the minimum number of components and is very low in cost and which has at the same time an excellent performance as compared with conventional systems.

A further object of the present invention is to provide a highly stable ignition system in which a drop in the battery voltage may not cause a decrease in the voltage induced in the ignition coil secondary winding.

A still further object of the present invention is to provide a highly reliable ignition system which will not be caused to misoperate by any externally applied noise signals.

Other objects of the present invention will be apparent from the detailed descriptions of the preferred em-

bodiments taken in conjunction with the accompanying drawings.

A feature of the present invention resides in that a power source with a high energy density and a power source with a relatively low energy density are provided such that these power sources are controlled by control means to selectively apply their respective energies to the load when desired by the load. In other words, these power sources are controlled such that during the initial period of development of an igniting spark, that is, during the rising time of a spark discharge voltage, a spark discharge voltage with a faster rise time is produced by virtue of a change in the magnetic flux caused by the high energy density power source and then, after the decay of the stored energy in the high energy density power source, a spark discharge voltage of long duration is produced by virtue of a change in the magnetic flux caused by the relatively low energy density power source.

Another feature of the present invention resides in that a power source having a reverse current blocking element, a discharging capacitor and an ignition coil having a switching element connected in series therewith are connected in parallel with one another such that the switching element is closed at a desired time to discharge through the low-tension side of the ignition coil the stored energy in the capacitor previously charged from the power source and then the energy from the power source is discharged through the low-tension side of the ignition coil when the energy in the capacitor decays below the energy level of the power source.

Other features of the present invention will be more apparent from the following descriptions of the preferred embodiments of the invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is an electrical block diagram showing the ignition system of the present invention.

FIG. 2 is an electrical circuit diagram of the ignition system according to the present invention.

FIG. 3 is another electrical circuit diagram of the ignition system according to the present invention.

FIG. 4 is still another electrical circuit diagram of the ignition system according to the present invention.

FIG. 5 is an electrical circuit diagram showing an embodiment of the ignition system according to the present invention.

FIG. 6a is a diagram showing the waveform of the spark discharge voltage produced by the conventional capacitor discharging type ignition system.

FIG. 6b is a diagram showing the waveform of the spark discharge voltage produced by the conventional battery-ignition system.

FIG. 6c is a diagram showing the waveform of the spark discharge voltage produced by the ignition system of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, numeral 50 designates a first energy source forming a closed circuit with a load 53, and a second energy source 52 having reverse current blocking means 51 connected in series therewith is connected in parallel with both the first energy source 50 and the load 53. Control means 54 for controlling

the energy supply from the first and second energy sources is provided in the load circuit.

The circuit constructed as described above operates in the manner which will be explained hereunder.

In this circuit, the first energy source 50 consists of an energy source of very high energy density such as a charged capacitor and it is also an energy source having a decaying property and capable of temporarily discharging a higher energy than the second energy source 52.

The second energy source 52 consists of an energy source of relatively low energy density such as a battery and it is provided with the reverse current blocking means 51 connected in series therewith to prevent the energy in the first energy source 50 from flowing back into the second energy source 52.

When the circuit is established by the control means 54 so that the energy is supplied to the load, a rapid transfer of the energy to the load first takes place from the first energy source 50 whose energy density as well as its absolute quantity are high and as the energy in the first energy source 50 decays it is consumed by the load, so that with the lapse of a certain time, it becomes less than the energy in the second energy source 52. The instant this occurs, the energy in the second energy source 52 is gradually transferred to the load by way of the reverse current blocking element 51.

In the discussion to follow, explanation will be made of the manner of operation of the above described energy supply means of the present invention as applied to the concrete electrical circuit shown in FIG. 2, that is, the circuit comprising a first energy source composed of a capacitor 14 charged by means of a battery 4 through charging means 17 and a diode 21, reverse current blocking means composed of a diode 20, a second energy source consisting of another battery 19, a load consisting of an ignition coil 15 provided with a discharging gap 16 at the output terminal of the secondary winding thereof, and a control means of the energy supply consisting of a switching element 18.

When the switching element 18 in the circuit is rendered conductive, the capacitor 14 previously charged by the battery 4 quickly transfers its energy to the primary winding 15a of the ignition coil 15 from which the energy is delivered to the secondary winding 15b by way of the core 15c. In this case, the current energy is first changed into a magnetic flux energy and the resultant magnetic flux energy is then delivered by way of the core 15c to the secondary winding 15b where the energy is further changed into the form of an induced voltage which is applied across the discharging gap 16. In the discharging gap 16 the energy is converted into heat energy in the form of a spark discharge and it is consumed there as such.

In this case, the voltage induced by the discharge from the capacitor 14 is first applied across the discharging gap 16 by way of the ignition coil 15 to thereby initiate a spark discharge. At the same time that the spark discharge is initiated, the stored energy in the capacitor 14 is used up so that when this energy becomes smaller than the energy stored in the battery 19, the energy supply to the ignition coil 15 is gradually started from the battery 19 by way of the diode 20. Whereupon, the spark discharge is continued for a relatively long period.

Generally, the waveform of an ideal spark discharge voltage in the ignition systems is one in which the rise

of the waveform is very steep and the duration of the discharge after starting the discharge is sufficiently long.

FIG. 6c illustrates the waveform of the spark discharge voltage produced by the system of the present invention.

FIGS. 6a and 6b illustrate the waveforms of the spark discharge voltages produced by the conventional capacitor discharging type ignition system and the conventional battery-ignition system, respectively. Now a comparative study of these waveforms shows that the waveform of the capacitor discharging type rises quickly, but its duration after the start of the discharge is short, while the waveform of the battery-ignition system has a sufficiently long duration, but it does not rise so quickly, and they have their own advantages as well as disadvantages. According to the present invention, however, the waveform of the spark discharge voltage obtained is very close to the previously mentioned ideal waveform in that since the advantages of the two systems are utilized to compensate for their respective disadvantages by smoothing the waveform of the present invention has a rise time which is slower than that of the waveform of the conventional capacitor discharging type but sufficiently faster than that of the conventional battery-ignition system and similarly its duration is shorter than that of the battery-ignition system but sufficiently longer than that of the conventional capacitor discharging type. The reason for this resides only in the fact that the capacitive discharging component of the spark discharge voltage waveform, i.e., the discharge during the rising time of the spark discharge voltage and the inductive discharge component of the spark discharge voltage, i.e., the discharge during the continued discharge of the spark discharge voltage are obtained by means of the separate power sources having different energy densities, respectively.

FIGS. 3 and 4 are electrical circuit diagrams of the concrete circuits illustrating modifications of the electric circuit of the system of the present invention. In FIG. 3, a first power source consists of a capacitor 14 adapted to be charged from a battery 4 by way of charging means 17 and a diode 21, and a second power source is composed of a capacitor 19 charged from the same battery 4 by way of the center tap provided in the charging means 17 and a diode 21'.

In FIG. 4, a first power source consists of a capacitor 14 adapted to be charged from a DC power source 4 by way of charging means 17 and a diode 21 and a second power source consists of the DC power source or battery 4 used to charge the capacitor 14. The manner of operation of each of the circuits described is identical with that of the circuit shown in FIG. 2.

Next, an embodiment of the present invention will be explained in detail with reference to FIG. 5. (The same reference numerals as used in the afore-mentioned figures designate equivalent component parts and therefore will not be explained in detail.)

In FIG. 5, numeral 7 designates a resistor having one end connected to the positive terminal of a battery 4 and the other end connected to the ungrounded terminal of breaker points 10, 20 a diode having its anode terminal connected to the positive terminal of the battery 4, 25 an ignition coil in which a primary winding 25a has one end connected to the cathode terminal of the diode 20 and the other end connected to the ground by way of a collector electrode 28c and an emit-

ter electrode 28e of an NPN transistor 28; one secondary winding 25b has one end grounded and the other end connected to the ground by way of a discharging gap 16 and the other secondary winding 25c has one end grounded and the other end connected to the anode terminal of a diode 21. A base electrode 28b of the transistor 28 is connected in the present embodiment to the ungrounded terminal of the breaker points 10 to receive trigger signals synchronized with the rotation of the engine. Numeral 14 designates a capacitor having one end grounded and the other end connected to the cathode terminal of a diode 22 and to the cathode of the diode 20 and the capacitor 14 constitutes an essential element in the ignition systems of this type. Numeral 25d is a core of the ignition coil 25.

With the construction described above, the operation of the system of this embodiment will be explained hereunder.

With the breaker points 10 open, there is a current flow between the base electrode 28b and the emitter electrode 28e of the transistor 28 from the battery 4 by way of the resistor 7, so that the transistor 28 is rendered conductive and a current is supplied from the battery 4 through the diode 20 to the ignition coil primary winding 25a connected to the collector electrode 28c of the transistor 28.

On the other hand, with the breaker points 10 closed the transistor 28 is cut off as the breaker points 10 cause a short-circuit between the base electrode 28b and the emitter electrode 28e. When this happens, the current flowing through the primary winding 25a is suddenly cut off and this results in a change of the magnetic flux in each of the windings by way of the core 25d thus inducing a voltage having a negative polarity in the direction of the black mark. In this case, the induced voltage in the secondary winding 25c charges the capacitor 14 with such a polarity that its ungrounded terminal becomes positive and its grounded terminal negative. Even though the stored voltage across the capacitor 14 is allowed to get higher than the voltage of the battery 4, this stored voltage may be maintained at its peak value by means of the diode 20 and the transistor 28 in its cutoff state.

When the breaker points 10 open again, the transistor 28 is rendered conductive. Whereupon, the stored voltage across the capacitor 14 is applied to the primary winding 25a so that a voltage is induced again by way of the core 25d with the positive polarity being in the direction of the black mark.

Then, if the value of the capacitor 14 is so chosen that its stored energy may be completely used up when the capacitor 14 abruptly discharges through the primary winding 25a to produce a spark across the discharging gap, at the same time that the capacitor 14 completes its discharge, that is, the energy in the capacitor 14 becomes less than the energy in the battery 4, the battery 4 supplies through the diode 20 a current which rises at the L/R time constant (where L is the inductance of the primary winding 25a and R is the resistance of the primary circuit) so that the electromotive force induced in the other winding 25c by the flux change caused by this current, is supplied as long as the flux change is maintained so as to be used as the energy for maintaining the discharge across the discharging gap 16 following the ignition caused by the stored energy in the capacitor 14.

When the breaker points 10 close again, the transistor 28 is cut off again to recharge the capacitor 14.

Thereafter, repetitions of the similar process operate the ignition system.

It is now evident from the foregoing that according to the present invention a spark discharge voltage with a faster rise time is produced by virtue of a change in the magnetic flux caused by the discharge current of a capacitor and then, after the completion of the discharge by the capacitor, a spark discharge voltage of long duration is produced by virtue of a change in the magnetic flux caused by a current supplied from the battery.

This prevents the decay of the output which may be caused by the reduced leakage resistance of the high-tension circuit and at the same time the energy conversion efficiency can be improved to thereby eliminate the problem of incompletely burned fuel. Furthermore, while the present invention has such remarkable effects, the circuit according to the present invention can still be constructed with very few component elements and at a cost much lower compared to that of the ignition system shown in FIG. 1. Thus, the effects achieved by the present invention have excellent practical utility.

It should be understood that the electrical and mechanical component parts used in the embodiment described above may be replaced with other component parts which are functionally the same, and many modifications are possible without departing from the scope and spirit of the technical concept of the present invention.

Therefore, the scope of protection of the present invention is in no way limited to the above described embodiment.

I claim:

1. An ignition system for an internal combustion engine comprising:

- a first energy source having a high energy density and a very short decay time;
- a second energy source having an energy density and a decay time which are respectively lower and longer than the energy density and decay time of said first energy source;

means, connected between said first and second energy sources, for preventing the flow of current from said first energy source to said second energy source while permitting the flow of current from said second energy source;

an ignition coil, coupled to said first and second energy sources, to be energized by the energy therein; and

means, coupled to said ignition coil, for controlling the supply of energy to said ignition coil from said first and second energy sources in synchronism with the rotation of the engine, by effecting the application of the energy in said first energy source to said ignition coil at each point in time when said engine is to be ignited and then successively applying the energy in said second energy source to said ignition coil at the instant when the energy in said first energy source becomes less than the energy in said second energy source, wherein

said first energy source comprises a capacitor, said current flow preventing means comprises a first diode and said controlling means comprises a transistor circuit connected between the primary winding provided in said ignition coil and said second energy source, said ignition coil further including first and second secondary windings, the first of which is connected to the discharge gap in said engine, and the second secondary winding of which is connected through a second diode to said capacitor.

2. An ignition system for internal combustion engines characterized in that an ignition coil is provided, in addition to a first winding having a switching element in series and a second winding provided a discharging gap across the terminals thereof, with a third winding magnetically coupled with said first and second windings, a capacitor connected across the terminals of said third winding by way of a rectifier has the relation of a parallel connection with a series circuit of said first winding and said switching element, and said series circuit is energized by a power source having a reverse current blocking element.

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