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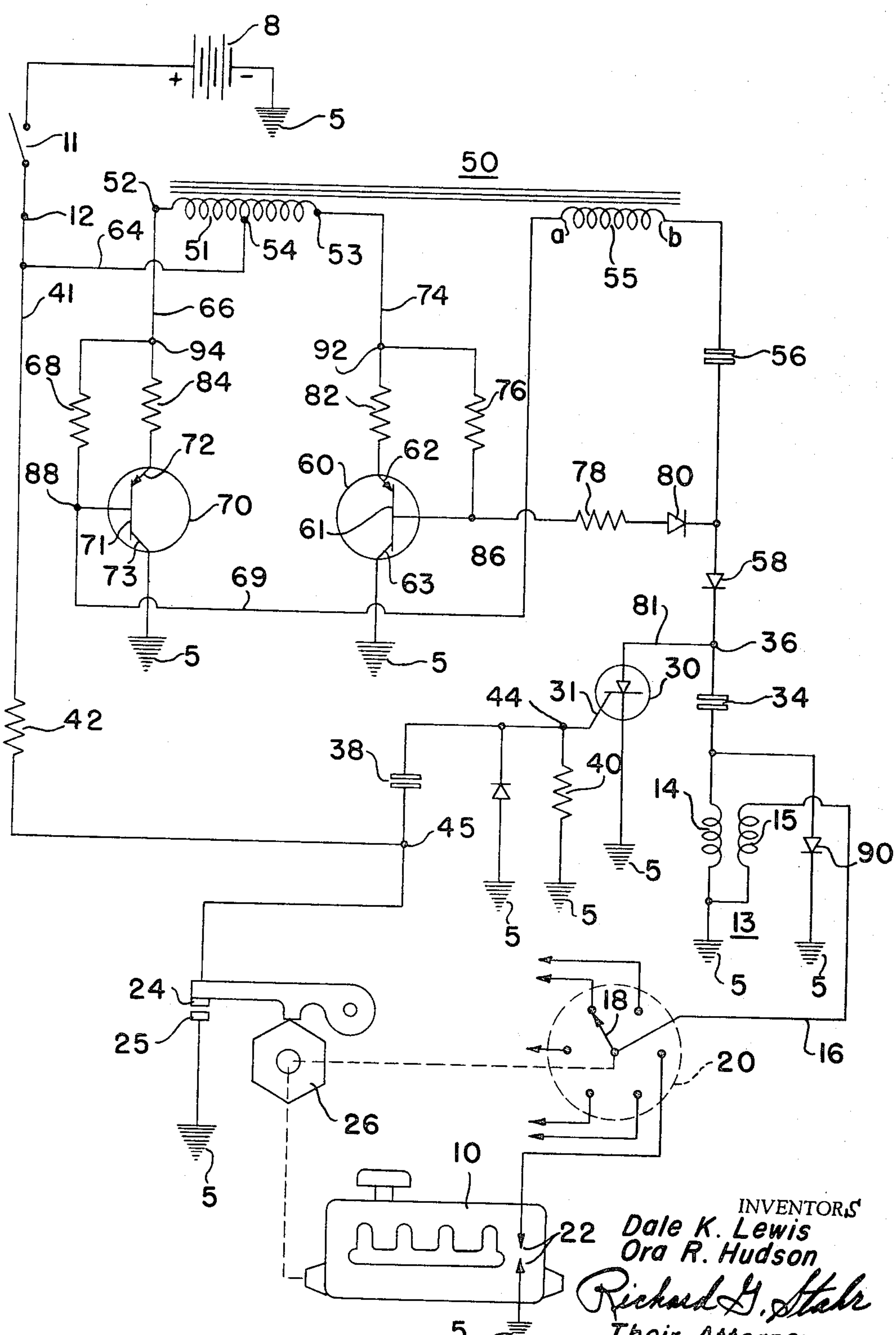

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IGNITION SYSTEM FOR INTERNAL COMBUSTION ENGINES

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ABSTRACT OF THE DISCLOSURE

A capacitor discharge ignition system including an ignition capacitor, a step-up transformer having a center tapped primary winding and a high voltage secondary winding and a switching silicon controlled rectifier for establishing a discharge path for the ignition capacitor through the primary winding of the ignition coil. The center tap of the primary winding is connected to battery potential and the end terminals thereof are connected to ground through respective normally "off" transistors. In response to current flow from the battery through the switching silicon controlled rectifier as it is switched conductive in timed relationship with the engine, one of these transistors is biased conductive to complete an energizing circuit for one-half of the center tapped primary winding. The magnetic flux produced by this current flow induces a high potential in the secondary winding of the transformer for charging the ignition capacitor.

The present invention relates to ignition systems for internal combustion engines and, more specifically, to a capacitor discharge ignition system for internal combustion engines.

Capacitor discharge, transistorized ignition systems are becoming increasingly popular, particularly in the automotive field. For this reason, an ignition system of this type which provides for high speed operation, low system storarge battery drain, low ignition breaker point current and voltage, which may be used with conventional ignition timing equipment, is independent of ignition point dwell time when used with breaker contact type ignition timing equipment and which employs conventional ignition system coils, is a highly desirable system.

It is, therefore, an object of this invention to provide an improved ignition system for internal combustion engines.

It is another object of this invention to provide an improved capacitor discharge ignition system for internal combustion engines.

It is another object of this invention to provide an improved capacitor discharge ignition system for internal combustion engines which may be employed with a wide variety of types of ignition timing equipment.

In accordance with this invention, an improved capacitor discharge ignition system for internal combustion engines is provided wherein an ignition potential is produced in response to conduction through the controllable switching device which establishes a discharge path for the ignition capacitor through the primary winding of the ignition coil.

For a better understanding of the present invention, together with additional objects, advantages and features thereof, reference is made to the following description and accompanying single figure drawing wherein the point of reference or ground potential, since it is the same point electrically throughout the system, has been schematically illustrated by the accepted symbol and referenced by the numeral 5.

Referring to the figure, the novel capacitor discharge ignition system of this invention is set forth in schematic

form in combination with a source of direct current system potential, which may be a conventional storage type battery 8, and an internal combustion engine 10. Battery 8 may be selectively connected to and disconnected from the circuit by a conventional single pole, single throw switch 11.

The ignition system of this invention may be connected across the source of system potential through electrical circuitry including terminal 12 and point of reference or ground potential 5. It is to be specifically understood that circuitry suitable for connecting the ignition system of this invention across battery 8 may be of any type well known in the art and is not to be construed as limited to the specific connections and circuitry set forth in the figure.

To produce the high potentials necessary to fire the spark plugs included in engine 10, an ignition coil 13, which may be a conventional ignition coil well known in the automotive art, having a primary winding 14 and a secondary winding 15 is provided. The high sparking potential induced in secondary winding 15 may be conducted, through lead 16, to movable contact 18 of a conventional automotive type distributor 20 which directs the sparking potential to the proper spark plug of engine 10 as this contact is driven in timed relationship with engine 10, in a manner well known in the automotive art. One of the spark plugs included in engines 10 is schematically represented by opposed arrowheads 22. It is to be specifically understood, that one spark plug is required for each cylinder of engine 10.

To produce ignition synchronizing signal pulses in timed relationship with engine 10, a pair of breaker contacts 24 and 25, which are opened and closed in timed relationship with engine 10 as engine 10 rotates distributor cam 26 in a manner well known in the automotive art, may be employed. The function of the ignition synchronizing pulses produced upon the opening of breaker contacts 24 and 25 will be explained in detail later in this specification.

Connected across the circuitry suitable for connection across battery 8, through a circuit to be later described in detail, is a controllable switching device having two current carrying electrodes and a control electrode and being of the type which may be triggered to conduction upon the application of a control potential signal across the control electrode and one of the current carrying electrodes thereof. In the figure, this controllable switching device is shown to be a silicon controlled rectifier 30 having two current carrying electrodes and a control electrode 31. It is to be specifically understood, that alternate controllable switching devices having similar electrical characteristics may be substituted for silicon controlled rectifier 30 without departing from the spirit of the invention.

The silicon controlled rectifier is a semiconductor device having a control electrode, generally termed the gate electrode, and two current carrying electrodes, generally termed the anode and cathode electrodes, which is designed to normally block current flow in either direction. With the anode and cathode electrodes forward poled, anode positive and cathode negative, the silicon controlled rectifier may be triggered to conduction upon the application, to the control electrode, of a control potential signal of a polarity which is positive in respect to the potential present upon the cathode electrode and of sufficient magnitude to produce control electrode-cathode, or gate, current. Upon being triggered to conduction, however, the control electrode is no longer capable of affecting the device which will remain in the conducting state until either the anode-cathode circuit is interrupted or the polarity of the potential applied across the anode-cathode electrodes is reversed.

Connected across the current carrying electrodes, the anode-cathode electrodes, of silicon controlled rectifier

30, is the series combination of a capacitor 34 and primary winding 14 of ignition coil 13 between junction 36 and point of reference or ground potential 5.

To apply the ignition synchronizing signal pulses produced upon the opening of breaker contacts 24 and 25 across the control electrode 31 and the cathode electrode of silicon controlled rectifier 30, a capacitor 38 and a resistor 40, is provided. Capacitor 38 and resistor 40 are connected across the circuitry suitable for connection across battery 8 through lead 41, and resistor 42 and point of reference or ground potential 5. Junction 44, between capacitor 38 and resistor 40, is connected to control electrode 31 of silicon controlled rectifier 30 and breaker contacts 24 and 25 are connected in shunt with the series combination of capacitor 38 and resistor 40 between junction 45 and point of reference or ground potential 5. Resistor 42 may be included in series with the series combination of capacitor 38 and resistor 40 to limit current flow, and thereby reduce battery drain, between the positive and negative polarity terminals of battery 8 when points 24 and 25 are closed.

To produce the required ignition potential to charge capacitor 34, circuitry which is responsive to conduction through silicon controlled rectifier 30 is provided. This circuitry includes a "step-up" transformer 50 having a primary winding 51 and a secondary winding 55, magnetically coupled to primary winding 51. Primary winding 51 has two end terminals 52 and 53 and a center terminal 54.

To establish an energizing circuit for that portion of primary winding 51 between center terminal 54 and end terminal 53, a first controllable switching device responsive to conduction through silicon controlled rectifier 30 is provided and to establish an energizing circuit for that portion of primary winding 51 between center terminal 54 and end terminal 52, a second controllable switching device which is responsive to current flow through secondary winding 55, is provided. In the figure, these controllable switching devices have been illustrated as type PNP transistors 60 and 70, respectively, having the usual base, emitter and collector electrodes. Although these switching devices have been shown in the figure to be type PNP transistors, it is to be specifically understood that alternate switching devices having similar electrical characteristics may be substituted therefor without departing from the spirit of the invention.

To place a charge upon capacitor 34, charging circuitry for connecting secondary winding 55 across capacitor 34 is provided and may be traced from end *b* of secondary winding 55, through capacitor 56, diode 58, capacitor 34, primary winding 14, point of reference or ground potential 5, battery 8, switch 11, terminal 12, lead 64, that portion of primary winding 51 between center terminal 54 and end terminal 52, lead 66, resistor 68 and lead 69 to the opposite end *a* of secondary winding 55.

The anode-cathode electrodes, or current carrying electrodes, of silicon controlled rectifier 30 are connected across the circuitry suitable for connection to battery 8 through electrical circuitry including terminal 12, lead 64, that portion of primary winding 51 between center terminal 54 and end terminal 53, lead 74, resistor 76, resistor 78, diode 80, diode 58, junction 36 and lead 81 and point of reference or ground potential 5. As the anode electrode of silicon controlled rectifier 30 is connected to the positive polarity terminal of battery 8, through terminal 12 and switch 11, and the cathode electrode of silicon controlled rectifier 30 is connected to the negative polarity terminal of battery 8, through point of reference or ground potential 5, this device is forward poled.

The emitter electrodes 62 and 72 of respective transistors 60 and 70 are connected to the positive polarity terminal of battery 8 through respective resistors 82 and 84, respective leads 74 and 66, the respective end terminals 53 and 52 of primary winding 51, center terminal 54 of primary winding 51, lead 64, terminal 12 and switch 11. The collector electrodes 63 and 73 of respective transistors 60 and 70 are connected to the negative polarity terminal of battery 8 through point of reference or ground potential 5. Therefore, the emitter-collector electrodes of these type PNP transistors 60 and 70 are forward poled.

As the base electrode 61 of transistor 60 is connected to junction 86 between resistors 76 and 78, transistor 60 is responsive to current flow through silicon controlled rectifier 30 and the circuit which may be traced from positive polarity terminal of battery 8, through switch 11, terminal 12, lead 64, center terminal 54 and end terminal 53 of primary winding 51, lead 74, resistors 76 and 78, diodes 80 and 58, lead 81, the anode-cathode electrodes of silicon controlled rectifier 30 and point of reference or ground potential 5 to the negative polarity terminal of battery 8.

As the base electrode 71 of transistor 70 is connected to junction 88 between secondary winding 55 and resistor 68, this device is responsive to current flow through secondary winding 55 and the circuit connected thereacross which may be traced from end *b* of secondary winding 55, through capacitor 56, diode 58, capacitor 34, diode 90, point of reference or ground potential 5, battery 8, switch 11, terminal 12, lead 64, center terminal 54 and end terminal 52 of primary winding 51, lead 66, resistor 68, and lead 69 to the opposite end *a* of secondary winding 55.

Upon each opening of breaker contacts 24 and 25 with switch 11 closed, current flows from the positive polarity terminal of battery 8, through switch 11, terminal 12, lead 41, resistor 42, capacitor 38 and resistor 40, point of reference or ground potential 5 to the negative polarity terminal of battery 8. As the potential drop produced by this current flow through resistor 40 is of a positive polarity at junction 44 in respect to point of reference or ground potential 5, this control potential signal produces gate current flow through silicon controlled rectifier 30 and triggers this device to conduction. When capacitor 38 has become charged, this control potential signal is removed from control electrode 31 of silicon controlled rectifier 30 as current no longer flows through resistor 40.

With silicon controlled rectifier 30 conducting, the cathode electrode of diode 58 is essentially grounded and the circuit previously described is established for current flow from the positive polarity terminal of battery 8, through switch 11, terminal 12, lead 64, center terminal 54 and end terminal 53 of primary winding 51, lead 74, resistors 76 and 78, diodes 80 and 58, lead 81, silicon controlled rectifier 30 and ground 5 to the negative polarity terminal of battery 8. This current flowing though resistor 76 produces a potential drop thereacross which is of a polarity at junction 86 more neagtive than that at junction 92. As this is the proper emitter-base potential relationship to produce emitter-base current flow through a type PNP transistor, transistor 60 saturates.

Upon the saturation of transistor 60, the instantaneous potential drop across that portion of primary winding 51 between center terminal 54 and end terminal 53 is stepped up by the turns ratio of transformer 50 and appears across secondary winding 55 as a much higher potential which is of a positive polarity at end *a* of secondary winding 55 in respect to end *b* of secondary winding 55. As transformer 50 has a large step-up ratio, end *b* of secondary winding 55 is of a negative polarity in respect to point of reference potential or ground 5.

This fully induced potential is applied through capacitor 56 to the anode electrode of diode 58 and the cathode electrode of diode 80. As the cathode electrode of diode 58 is at susbtantially ground potential, it is of a positive polarity with respect to the anode electrode and, therefore, diode 58 reverse biased. With diode 58 reverse biased and not conducting, the circuit, previously described, through which holding current for silicon controlled rectifier 30 is supplied is interrupted. With the circuit for holding current through silicon controlled rectifier **30** interrupted by reverse biased diode **58** in response to the potential induced in secondary winding **55** upon the saturation of transistor **60**, silicon controlled rectifier **30** extinguishes.

The potential induced in secondary winding **55** produces a charging current flow for capacitor **56** which may be traced from end *a* of secondary winding **55**, through lead **69**, resistor **68**, lead **66**, primary winding **51**, lead **74**, the parallel combination of resistor **76** and resistor **82** and the emitter-base junction of transistor **60**, resistor **78**, diode **80**, capacitor **56** to end *b* of secondary winding **55**. This charging current maintains transistor **60** conducting until capacitor **56** is charged to substantially the full potential induced across secondary winding **55**. When transistor **56** has become fully charged, this charging current flow ceases and, therefore, transistor **60** extinguishes.

When transistor **60** extinguishes, the collapse of current flow through that portion of primary winding **51** between center terminal **54** and end terminal **53** induces a second potential across secondary winding **55** which is of a polarity opposed to that induced upon the saturation of transistor **60**. That is, end *b* of secondary winding **55** is positive in respect to end *a* thereof.

The positive potential of end *b* of secondary winding **55** is applied through capacitor **56** to the cathode electrode of diode **80** and the anode electrode of diode **58**, thereby reverse biasing diode **80** and forward biasing diode **58**.

Upon the conduction of diode **58**, the charging circuit for capacitor **34**, previously described, is again established for current flow from capacitor **56**, through diode **58**, capacitor **34**, diode **90**, point of reference or ground potential **5**, battery **8**, switch **11**, that portion of primary winding **51** between center terminal **54** and end terminal **52**, lead **66**, resistor **68**, lead **69**, through secondary winding **55** to the opposite plate of capacitor **56**.

This current flow through resistor **68** produces a potential drop thereacross which is of a negative polarity at junction **88** in respect to junction **94**. As this is the proper emitter-base potential relationship to produce emitter-base current flow through a type PNP transistor, transistor **70** saturates.

The instantaneous potential drop across that portion of primary winding **51** between center terminal **54** and end terminal **52** upon the saturation of transistor **70** is stepped up by the turns ratio of transformer **50** and appears as a potential of much higher magnitude across secondary winding **55** with end *b* thereof being of a positive polarity in respect to end *a*.

This potential adds to the charge upon capacitor **56** and capacitor **34** charges through the charging circuit previously described to a potential substantially equal to the peak to peak excursion of the potential of end *b* of secondary winding **55** as capacitor **56** is much larger than capacitor **34**.

When capacitor **34** becomes charged, charge current ceases to flow through the charging circuit and transistor **70** extinguishes.

As transistor **70** extinguishes, current ceases to flow though the primary windings of transformer **50** and the potential across secondary winding **55** returns to zero. As silicon controlled rectifier **30** is nonconductive at this time, having been extinguished in a manner previously explained, and diode **58** is reverse biased by the charge upon capacitor **34**, capacitor **34** maintains this charge until silicon controlled rectifier **30** is again triggered conductive upon the next opening of breaker contacts **24** and **25**.

Upon the next opening of points **24** and **25**, silicon controlled rectifier **30** is triggered to conduction in a manner previously explained, and capacitor **34** discharges through primary winding **14** of ignition coil **13** through a circuit which may be traced from capacitor **34**, through junction **36**, lead **81**, the anode-cathode electrodes of silicon controlled rectifier **30**, point of reference or ground potential **5** and primary winding **14** of coil **13** to the opposite plate of capacitor **34**.

As silicon controlled rectifier **30** is now conducting, the sequence of events to produce the next ignition potential as hereinabove described is repeated.

In a practical application of the novel ignition system of this invention, the cycle of events hereinabove described required approximately one millisecond, thereby providing a capacitor discharge ignition system which is capable of producing 1000 firings per second.

The novel ignition system of this invention has been described in combination with breaker contact type ignition timing equipment and specific semiconductor devices and electrical polarities have been set forth in the specification for purposes of clearly illustrating the novel features. It is to be specifically understood that this ignition system may be used in combination with other types of ignition timing equipment and that alternate semiconductor devices and compatible electrical polarities may be employed without departing from the spirit of the invention.

While a preferred embodiment of the present invention has been shown and described, it will be obvious to those skilled in the art that various modifications and substitutions may be made without departing from the spirit of the invention which is to be limited only within the scope of the appended claims.

What is claimed is as follows:

1. A capacitor discharge ignition system for internal combustion engines comprising in combination with a source of direct current system potential, circuit means suitable for connection across said source of system potential, an ignition coil having at least a primary winding, means for producing ignition synchronizing signal pulses in timed relationship with said engine, a capacitor, a controllable switching device having two current carrying electrodes and a control electrode and being of the type which may be triggered to conduction upon the application of a control signal across said control electrode and one of said current carrying electrodes, means for connecting said current carrying electrodes of said controllable switching device across said circuit means, means for connecting the series combination of said primary winding of said ignition coil and said capacitor across said current carrying electrodes of said controllable switching device, means for applying said ignition synchronizing signal pulses across said control electrode and one of said current carrying electrodes of said controllable switching device for switching said device to conduction in timed relationship with said engine, a transformer having a primary winding including first and second end terminals and a center terminal and a secondary winding, first switching means responsive to conduction through said controllable switching device for establishing an energizing circuit across said circuit means for that portion of said primary winding between said center terminal and one of said first and second end terminals, second switching means responsive to current flow through said secondary winding for establishing an energizing circuit across said circuit means for that portion of said primary winding between said center terminal and the other one of said first and second end terminals and charging circuit means for connecting said secondary winding across said capacitor.

2. A capacitor discharge ignition system as defined in claim **1** wherein said controllable switching device is a silicon controlled rectifier.

3. A capacitor discharge ignition system as defined in claim **1** wherein said means for producing ignition synchronizing signal pulses in timed relationship with said engine comprises a second capacitor, a resistor, means for connecting said second capacitor and said resistor in series across said circuit means, means for connecting the junction between said second capacitor and said resistor to said control electrode of said controllable switching device, a pair of breaker contacts which are open and closed in timed relationship with said engine and means for connecting said breaker contacts in shunt with the series combination of said second capacitor and said resistor.

4. A capacitor discharge ignition system as defined in claim 3 wherein said means for producing ignition synchronizing pulses in timed relationship with said engine further includes a second resistor, means for connecting said second resistor in series with said series combination of said second capacitor and said resistor and means for connecting said breaker contacts in shunt with only said series combination of said second capacitor and said resistor.

5. A capacitor discharge ignition system as defined in claim 1 wherein said means responsive to conduction through said controllable switching device for producing an ignition potential comprises a transformer having a primary winding including first and second end terminals and a center terminal and a secondary winding, a first circuit means connected across said secondary winding, first switching means responsive to conduction through said controllable switching device for establishing an energizing circuit across said circuit means for that portion of said primary winding between said center terminal and one of said first and second end terminals whereby a potential is induced in said secondary winding, second switching means responsive to the current flow produced by said potential induced in said secondary winding through said first circuit means for establishing an energizing circuit

across said circuit means for that portion of said primary winding between said center terminal and the other one of said first and second end terminals whereby an ignition potential is induced in said secondary winding and charging circuit means for applying said ignition potential induced in said secondary winding across said capacitor.

6. A capacitor discharge ignition system as defined in claim 5 wherein said first and second switching means are transistors.

7. A capacitor discharge ignition system as defined in claim 6 wherein said charging circuit means includes a polarity sensitive circuit element responsive to said first potential induced in said secondary winding for interrupting said charging circuit and said first circuit means connected across said secondary winding includes a polarity sensitive circuit element which is responsive to said ignition potential for interrupting said first circuit means.

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