March 17, 1959 L. J. GIACOLETTO 2,878,298

IGNITION SYSTEM

Filed Dec. 30, 1953 2 Sheets-Sheet 1

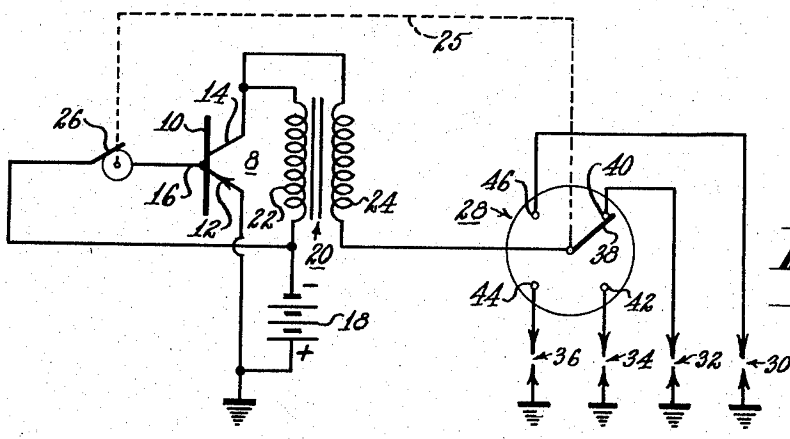

FIG. 1.

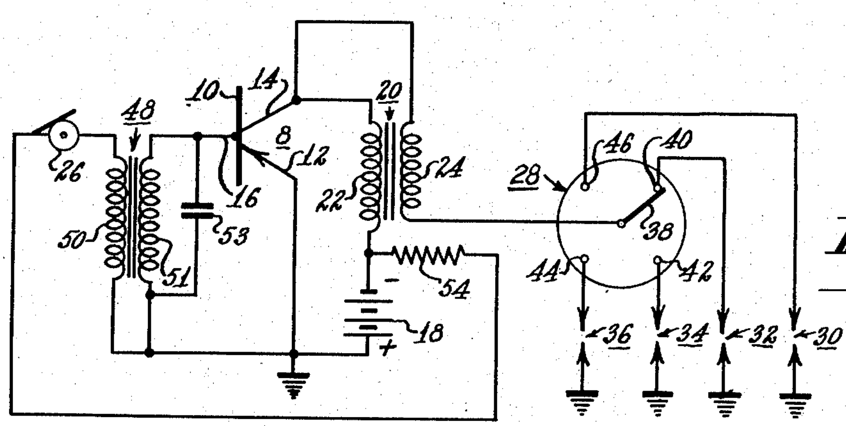

FIG. 2.

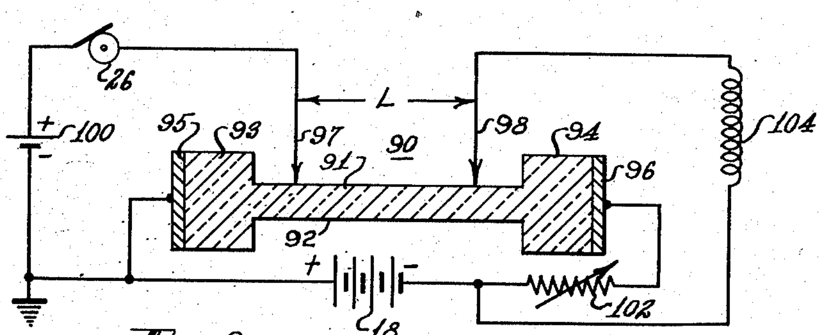

FIG. 6.

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IGNITION SYSTEM

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2 Sheets-Sheet 2

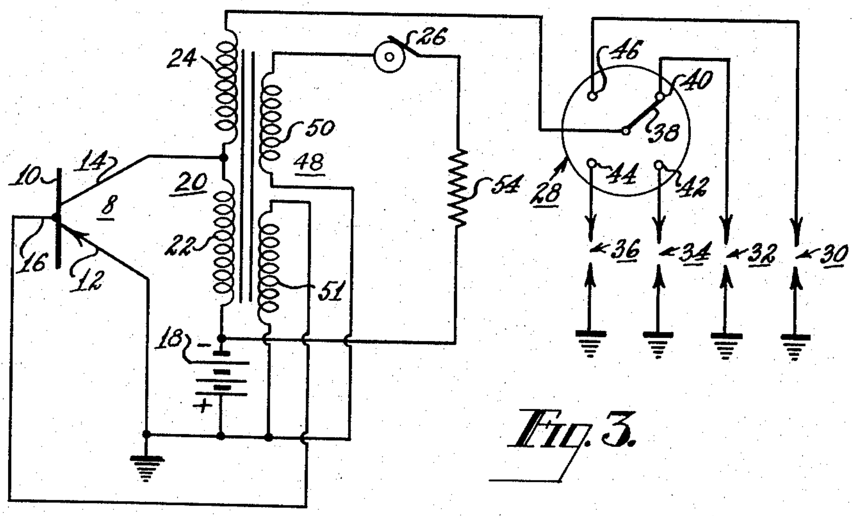
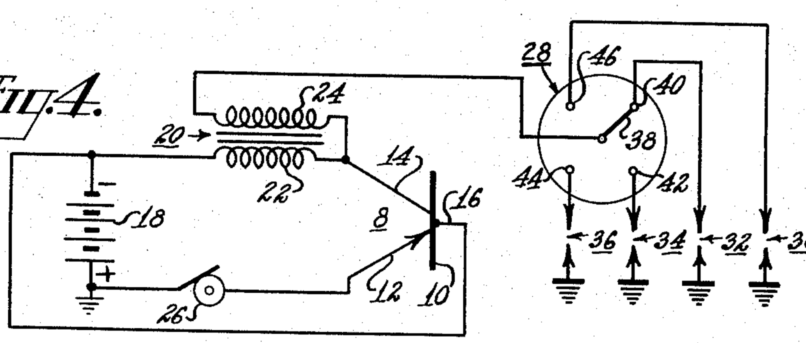


Fig. 3.

Fig. 4.



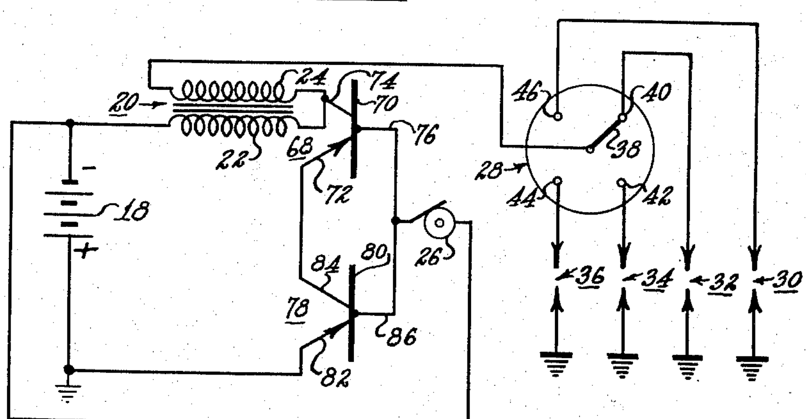


Fig. 5.

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IGNITION SYSTEM

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10 Claims. (Cl. 123—148)

This invention relates to ignition systems for internal combustion engines and the like and in particular to systems of the type referred to utilizing semi-conductor devices.

In the typical ignition system for internal combustion engines, a direct current source of electrical energy such as a storage battery which is charged by a generator is connected through an ignition switch to one terminal of the primary winding of an ignition coil. Generally the battery also serves to operate the starting motor and supplies electrical energy for the lights and other accessories. Batteries having voltage ratings of six to twelve volts are generally used for these purposes.

The other terminal of the primary winding is conventionally connected to the cam-actuated movable contact point of an ignition circuit breaker. The movable contact point of the circuit breaker may be opened and closed under the influence of the cam to control the current in the primary winding of the ignition coil.

The secondary winding of the ignition coil is connected to a central contact of a distributor, which is, in essence, a rotary switch whose function is to connect the secondary winding alternately to each of the several spark plugs in their firing sequence. Generally, the distributor assembly is a double unit comprising a rotary switch and a circuit breaker.

In operation, the ignition coil is energized when the breaker contact points are closed, establishing a magnetic field through the core of the coil. This field rapidly collapses when the contacts open, and a high voltage is induced in the secondary winding. The current in the secondary flows to the distributor which selects the proper spark plug for firing. The rotary switch of the distributor is mounted in phase with the circuit breaker cam so that the secondary winding is connected with one of the spark plugs at the instant the breaker contact points open. When the cam opens the breaker points, the distributor has advanced to a contact which is connected to the next spark plug in the firing sequence. In a typical eight cylinder, four cycle engine, for example, this process may have a repetition rate of approximately 350 times a second.

One of the problems encountered in ignition systems induced by certain electrical effects, in large measure the voltage which is established by self-inductance when the primary circuit of the coil is broken, is the tendency of the contact surfaces or points in the circuit breaker to burn and pit due to arcing and the subsequent oxidation of the points. This difficulty is increased as the compression ratio of the engine is increased. To keep these effects at a minimum, a capacitor is usually connected across the points to by-pass this voltage back through the primary winding of the coil. Although burning and pitting is thus reduced, it is not eliminated and the contact points often need to be replaced. In addition, the provision of a capacitor establishes a resonant condition in the primary winding at low frequencies, thus requir-

ing more turns in the secondary to obtain a high enough voltage.

Ignition failures and the expense of replacing contact points due to pitting and burning are problems which it would be desirable to eliminate. There have, however, unfortunately been no commercially successful substitutes for the conventional circuit breaker. One alternative to the conventional ignition system which has been proposed, and is the subject of several U. S. patents, is the use of vacuum tubes or gas tubes acting as control elements or valves to replace the mechanical circuit breaker of the conventional ignition systems. In using electron tubes for this purpose, for example, mechanical switches may be used to change the bias on an electrode of the tube. Such switches do not carry the working current of the ignition system and are, therefore, not subject to burning and pitting. While avoiding some of the difficulties associated with the conventional circuit breaker, electron tubes have a relatively short useful life and need frequent replacing. In addition, the plate energization and heater voltages required for the proper operation of an electron tube are generally considerably higher than the six to twelve volts normally required for an ignition system. Thus, a separate or larger battery is required to provide sufficient operating potentials for the tubes of an ignition system for a typical contemporary automobile. Other disadvantages of this alternative include the fragile nature of tubes, their relatively large size and the delay between the time the tubes are energized and begin operating.

Changes in both the engine speed and the load change the optimum point in the engine cycle at which the ignition spark should occur. Thus, an earlier timing of the spark is needed at higher speeds. The charge in the cylinder also ignites more readily at heavy load conditions than at light loads, because of the higher pressure and temperature and relatively less dilution with exhaust gas from previous cycles at heavy loads. Thus, it is desirable to retard the timing of the spark for increasing loads and advance the spark timing at light loads. This advance of the spark timing is generally accomplished, in the conventional ignition system, by mechanical means incorporated in the distributor assembly. Moving mechanical parts are, of course, subject to wear and require frequent accurate adjustment for efficient engine performance. Hence, it would be desirable to provide electronic spark advance means which is not subject to wear of a mechanical nature and requires a minimum amount of adjustment.

The present invention utilizes the characteristics peculiar to semi-conductor devices such as transistors to overcome the foregoing and other defects and disadvantages of the conventional internal-combustion ignition systems. Transistors, as is well known, have among others, the advantages of small size, durability, low power requirements, instant starting and a long useful life. While these benefits of transistors recommend their use in many types of equipment in which vacuum tubes have been almost exclusively used heretofore, the characteristics of transistors which differ from those of vacuum tubes have made it usually necessary either to adapt the external circuits of the equipment or construct completely new circuits to accommodate the peculiar characteristics of transistors.

Accordingly, it is an object of the present invention to provide an ignition system for internal combustion engines and the like which utilizes semi-conductor devices for simplified and improved construction and operation.

It is another object of the present invention to provide an ignition system for engines of the internal combustion type which utilizes semi-conductor devices to control and regulate the operation thereof.

It is yet another object of the present invention to provide a semi-conductor ignition system of the type referred to, the parts of which are characterized by reliability, durability and a long useful life.

A still further object of the present invention is to provide a transistorized ignition system for high compression internal combustion engines wherein the conventional ignition circuit breaker is eliminated.

Another object of the present invention is to provide an improved ignition system for automobile internal combustion engines wherein transistors are utilized for simplifying the construction and wherein the conventional automobile storage battery may be utilized as the biasing source for the transistors.

It is still another object of the present invention to provide an improved ignition system for internal combustion engines, the spark advance of which utilizes a semi-conductor device.

These and further objects and advantages of the present invention are achieved, in general, by connecting one of the electrodes of a semi-conductor device such as a transistor with the primary winding of a standard ignition coil, and connecting another of the electrodes of the transistor to suitable switching means adapted to open and close the circuit associated with this latter electrode in synchronism with the ignition distributor. Thus, the transistor is alternately conductive and non-conductive and a current will be alternately supplied to the primary winding of the ignition coil. The current through the primary induces a high enough voltage in the secondary to produce a spark across the terminals of the appropriate spark plug for ignition purposes. In another aspect of the present invention a filamentary type semi-conductor device is used as a spark-advance means.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawing, in which:

Figures 1, 2, 3 and 4 are schematic circuit diagrams of ignition systems utilizing semi-conductor devices in accordance with the invention;

Figure 5 is a schematic circuit diagram of an ignition system utilizing a pair of series transistors further in accordance with the invention; and

Figure 6 is a schematic circuit diagram of spark-advance means for an ignition system utilizing a semi-conductor device in accordance with the invention.

Referring now to the drawing, wherein like elements are designated by like reference numerals throughout the figures, and referring particularly to Figure 1, an ignition system in accordance with the invention includes a semi-conductor device such as a transistor **8** having a semi-conductive body **10** and three contacting electrodes which are designated as an emitter **12**, a collector **14** and a base **16**. The semi-conductive body **10** is of the P–N–P junction variety, although it should be understood that throughout the description the use of P–N–P junction transistors is merely for the purpose of illustration and other suitable types may be used, such as N–P–N junction transistors. For the latter type, the polarity of the biasing battery would have to be reversed.

To properly bias the electrodes of transistor **8**, a direct current source of voltage such as a conventional storage battery **18** has its positive terminal connected to a source of fixed reference potential or ground for the system. This may be accomplished, for example, by connecting the positive terminal to the frame of the engine. The negative terminal of battery **18** is connected through the primary winding **22** of a standard ignition coil or step-up transformer **20** to the collector **14** of transistor **8**. The base **16** of transistor **8** is connected through a switching device **26** to the negative terminal of battery **18**. The biasing will thus be recognized as being proper for a junction transistor of the P–N–P type.

One end of the high voltage secondary winding **24** of the step-up transformer **20** is connected to the junction of collector **14** and the primary winding **22** of the transformer. The other end of secondary winding **24** is connected to a rotary contact **38** of the ignition distributor **28**. For the purposes of illustrating the present invention, and by way of example only, the transistorized ignition system embodying the present invention has been illustrated in conjunction with a four-cylinder internal combustion engine. Thus, four spark plugs **30**, **32**, **34** and **36** are provided, each being connected between ground and respective distributor terminals **46**, **40**, **42** and **44** of the ignition distributor **28**. The rotary contact **38**, as is well known, is adapted to contact each of the outer terminals or contacts **40**, **42**, **44** and **46** in proper firing sequence. In the position shown, the rotor **38** is connected with terminals **40**, which is, in turn, connected to the spark plug **32**. Thus, the secondary circuit of ignition coil **20** is connected to spark plug **32** and the combustible mixture in the cylinder associated with this plug will fire.

The switching device **26** may comprise a cam-operated switch of the make-break type. The timer cam which operates this switch is synchronized with the engine speed as by being connected with the crankshaft of the internal combustion engine for example. The switching device **26** is also synchronized with the ignition distributor **28** as shown by the dotted line **25**.

In operation closing of the switching device will complete or close the base circuit of transistor **8**. Accordingly, the collector **14** will conduct current. Current flowing in the collector **14** will also flow through the primary winding **22** of the step-up transformer or ignition coil **20**. When the switch **26** is opened by the cam, the base circuit of transistor **8** will be opened and the transistor **8** will be non-conductive. Thus, the magnetic field through the primary winding will rapidly collapse inducing a potential across the secondary winding **24** of transformer **20** which will be sufficiently high to induce a spark across the electrodes of the appropriate spark plug. The rotary contact **38** will then move to contact the next outside terminal of the distributor and the base circuit will again be closed under the action of switch **26**.

Thus, an ignition system which utilizes transistors in accordance with the invention fulfills the requirements for proper ignition and, at the same time, is characterized by the advantages for which transistors are well known, such as small size, durability and a long useful life. In addition to these advantages the bias requirements of the transistor are seen to be ideally suited for operation in the conventional ignition system. Furthermore, the conventional circuit breaker and the disadvantages thereof is eliminated from the system and a simpler and smaller switch which does not carry the working current of the circuit is utilized. As a result, an ignition system in accordance with the invention is subjected to a minimum of mechanical and electrical failures. In addition, because of the on-off switching operation performed by the transistor, ambient temperature variations are not of a detrimental nature. If necessary, however, the transistor operating temperature can be stabilized by connecting the transistor thermally to the automobile cooling system.

In the circuit illustrated in Figure 1, the time the transistor **8** is conductive is dependent on and will vary with the engine speed. Thus, if the cam-driven switch **26** is closed at the moment the ignition is turned on, the transistor will conduct maximum current until the engine starts and the switch **26** is opened. To avoid this possibility, a circuit of the type illustrated in Figure 2 may be utilized which includes a second or auxiliary transformer **48** having a primary winding **50** and a secondary winding 51, one end of which is connected with the base 16 of the transistor 8 and the other end of which is grounded as shown. Thus, the secondary winding 51 provides a direct current path to ground. A capacitor 53 is connected in shunt with the secondary winding 51.

To complete the primary circuit of the auxiliary transformer 48 and provide a conductive path between the collector 14 and the base 16, one end of the primary winding 50 is returned through the cam-driven switch 26 and a resistor 54 to the negative terminal of the battery 18. In other respects the circuit illustrated in Figure 2 is identical with the one illustrated in Figure 1.

In operation, closing the switch 26 will cause a current to flow from the collector 14 through the primary winding 22 of the ignition coil 20, the resistor 54 and the primary winding 50 of the auxiliary transformer 48. This current will increase until it reaches a steady state maximum condition as determined by the bias on transistor 8. When the switch 26 is opened, however, the magnetic field of transformer 48 will collapse rapidly and a voltage will be induced in the secondary winding 51 of a sufficient magnitude and proper polarity when applied to the base 16 to trigger the transistor 8 into a maximum current conduction condition. The period of this voltage will be determined by the L-C time the contact switch is closed. Thus, the collector current through the primary winding 22 of the ignition coil 20 will induce a voltage in the secondary winding 24, which because of the autotransformer action will be of sufficient magnitude to cause a spark across the appropriate spark plug. In the position shown, the rotary contact 38 of the distributor 28 is connected with spark plug 32.

In addition to insuring that the transistor 8 will not carry maximum current until the engine starts, the circuit illustrated in Figure 2 has the added advantage that more than one transistor may be operated in series if desired, with a separate transformer used to trigger each of the transistors.

By coupling the secondary winding 51 of the auxiliary transformer 48 with the primary winding 22 of the ignition coil or transformer 20, regeneration may be provided, thus making it possible to trigger the transistor 8 into a maximum conduction condition with a smaller control pulse. This has been done in the circuit illustrated in Figure 3, where the auxiliary transformer 48 and the ignition coil or transformer 20 have a common core, thus saving the use of one core. Because of the regenerative feedback arrangement, care must be taken to prevent the circuit breaking into continuous oscillation. This can be done by choosing the circuit parameters so that the auxiliary transformer is not resonant at the same frequency as the output circuit of the transistor.

It is also possible to open and close the emitter circuit of the transistor for proper timing of the ignition spark. Thus in Figure 4, the cam-operated switch 26 is serially connected between the emitter 12 of transistor 8 and the biasing battery 18, the negative terminal of which is connected to the primary winding 22 of ignition coil 20. The other end of the primary winding 22 is connected to the collector 14. Opening and closing of the switch 26 will have the same effect as in Figure 1, causing a current to flow through the primary winding 22 when closed and rendering transistor 8 non-conductive when open. While the peak voltage obtainable is thus increased by an arrangement of the type illustrated in Figure 4, the contact points of the switch 26 will carry the full operating current of the transistor, tending thereby to increase burning and pitting.

In Figure 5, the available peak voltage may be increased by operating two or more transistors such as transistors 68 and 78 in series. To this end, the base electrodes 76 and 86 are connected together and the switch 26 is connected from the junction of the respective base electrodes 76 and 86 to one end of the primary winding 22 of the ignition coil 20, the other end of which is connected to the collector 74 of transistor 68. The positive terminal of the battery 18 is, in this case, connected to the emitter 82 of the transistor 78, and its negative terminal is connected to the junction of the switch 26 and the primary winding 22. The battery is thus seen to provide proper bias for both transistors, which in this case are both of the P-N-P type.

In Figure 6, spark advance means comprise a filamentary type transistor 90 such as disclosed in the Patent No. 2,502,479 to G. L. Pearson and W. Shockley.

The filamentary transistor 90 includes a semi-conducting body 91 having an elongated attenuated portion 92. The attenuated intermediate portion may be provided with the enlarged end portions 93 and 94, although it should be noted that the entire semiconducting body 91 may have the same cross section throughout its length. The electrodes 95 and 96 are provided in low resistance contact with the enlarged end portions 93 and 94, respectively. Another pair of electrodes 97 and 98 is provided in rectifying contact with the attenuated portion 92. The electrodes 97 and 98 are preferably spaced apart an appreciable distance as indicated.

Operating potentials are applied to the electrodes in such a manner that the electrodes 95 and 96 form bases, the electrode 97 an emitter and the electrode 98 a collector. It will be assumed that the semi-conducting body 91 is of the N-type. A voltage in the forward direction is applied between the base 95 and the emitter 97. To this end, a battery 100 has its positive terminal connected through the cam-driven switch 26 to the emitter 97 and has its negative terminal grounded.

A voltage in the reverse direction is applied between the low resistance electrode 95 and the collector 98. To this end, the supply battery 18 has its negative terminal connected through a variable resistor or rheostat 102 to the electrode 96, while the collector 98 is connected through the inductor 104, which may be the primary winding of the auxiliary control transformer 48 illustrated in Figures 2 and 3, to the negative terminal of the battery 18. The positive terminal of the battery 18 is connected to the base 95 and accordingly, the electrodes 96 and 98 will be negative with respect to the base 95.

It should be understood that if semi-conducting body 91 is of the P-type, the polarity of the biasing batteries would have to be reversed.

As shown, the emitter 97 will inject holes, that is, electrical particles which behave as if they had a positive charge. It is well known that the transit time, t, required for charge carriers (here holes) to travel a distance, L, through a semi-conducting material (i. e., from emitter to collector) is given by the formula:

$$t=L/\mu E$$

where μ is the hole mobility and E is the electric field which is applied by the battery 18 between the electrodes 95 and 96, and is linearly related to the voltage developed between the electrodes 95 and 96.

The voltage between the electrodes 95 and 96 can be controlled by adjusting the resistance of the resistor 102. Thus, by adjusting the resistance of the resistor 102 the electric field between the electrodes 95 and 96 may be changed which in turn will vary the time for the holes to travel from the emitter 97 to the collector 98. By mechanically connecting the control means for the resistor 102 to the engine crankshaft or the engine manifold, the engine speed or the vacuum in the manifold can be used to control the voltage between the electrodes 95 and 96. Accordingly, the time the holes travel from the emitter 97 to the collector 98 can be controlled by either the engine speed or the manifold vacuum and a single electronic spark advance means is possible. The amount of spark required for most efficient operation at all speeds can be obtained by suitably tapering the rheostat 102.

Thus, by coupling the inductor **104** with the base of the transistor in the same manner as illustrated in Figure 1 or Figures 2 and 3, spark advance of such ignition systems may be achieved. By relating the time it takes holes to travel from the emitter **97** to the collector **98** to engine speed or the manifold vacuum, the timing of the current pulses through the inductor **104** can be varied in accordance with engine speed or the vacuum. Thus, the transistor will be triggered on and off and the spark will be timed precisely with the cycle of the engine and the spark will occur at the optimum point of the engine cycle.

As described herein an ignition system utilizing semi-conductor devices is characterized by simplicity as well as reliability. Furthermore, a minimum number of mechanical parts are necessary for proper operation of the system and the conventional circuit breaker is eliminated. In addition, the biasing requirements of semi-conductors are on the order of the voltage ratings of conventional automobile batteries. An electronic spark advance is also provided which further reduces the need for mechanical moving parts.

What is claimed is:

1. In combination with an ignition system for an internal combustion engine having voltage distribution means and including a first transformer having a primary and a secondary winding, a semi-conductor device having an emitter electrode, a collector electrode, and a base electrode, a source of potential including a pair of terminals, means directly connecting said primary winding between said collector electrode and one terminal of said source, means connecting said emitter electrode to the other terminal of said source, a second transformer having a primary and a secondary winding, means connecting the secondary winding of said second transformer between said base electrode and the other terminal of said source, switching means serially and direct current conductively connected between the primary windings of said second and first transformers and operative in synchronism with said engine to alter the current conducting condition of said semi-conductor device to provide a high voltage intermittently across the secondary winding of said first transformer in response to the speed of said engine, and means connecting the secondary winding of said first transformer directly between said collector and said voltage distribution means for applying said high voltage to said voltage distribution means.

2. In combination with an ignition system for an internal combustion engine including voltage distribution means and a high voltage transformer having a primary and a secondary winding, a semi-conductor device having a collector electrode, a base electrode and an emitter electrode, a source of potential including a pair of terminals, means connecting said emitter electrode to one of said terminals, means directly connecting said primary winding between said collector electrode and the other terminal of said source, triggering means including a second transformer and timing means responsive to the speed of said engine connected with said base electrode and operative in synchronism with said engine to alter the current conducting condition of said semi-conductor device for intermittently providing a high voltage across said secondary winding, and means connecting said secondary winding directly between said collector and said voltage distribution means for applying said high voltage to said voltage distribution means.

3. In an ignition system for an internal combustion engine having voltage distribution means the combination comprising, a semi-conductor device including a semi-conductive body having emitter, collector and base electrodes, a first transformer having a primary and a secondary winding, a source of potential including a pair of terminals one of which is connected to a point of fixed reference potential for said system, means directly connecting said primary winding between said collector electrode and the other terminal of said source, a second transformer coupled with said first transformer and having a primary and a secondary winding, means connecting said emitter electrode with said point of reference potential, means connecting the secondary winding of said second transformer in series between said point of reference potential and said base electrode, switching means responsive to the speed of said engine serially and direct-current conductively connected between the respective primary windings of said first and second transformer and operative to control the current flow through the primary winding of said first transformer for intermittently obtaining a high voltage across the secondary winding of said first transformer, and means connecting the secondary winding of said first transformer directly between said collector and said voltage distribution means for applying said high voltage to said voltage distribution means.

4. In an ignition system for an internal combustion engine having sparking means associated with the cylinders thereof, the combination comprising, a semi-conductor device including a semi-conductive body having emitter, collector and base electrodes, transformer means including a primary and a secondary winding directly connected with said collector electrode, switching means responsive to the speed of said engine direct-current conductively connected between said base electrode and the low voltage end of said primary winding and operative to open and close the circuit connections for said base electrode in synchronism with said engine, said switching means being operative to control the current flow through said primary winding, means providing a point of fixed reference potential for said system, means connecting said emitter electrode with said point, a source of direct current energization means connected between said point and the low voltage end of said primary winding, and voltage distribution means connected between said secondary winding and said sparking means and operative in synchronism with said switching means to cyclically energize said sparking means.

5. In an ignition system for an internal combustion engine having sparking means associated with the cylinders thereof, the combination comprising, a first and a second semi-conductor device each including a semi-conductive body having emitter, collector and base electrodes, means connecting the base electrode of said first device with the base electrode of said second device, means connecting the collector electrode of said first device with the emitter electrode of said second device, a high voltage transformer including a primary and a secondary winding, a source of potential including a pair of terminals, means directly connecting said primary winding between the collector electrode of said second device and one terminal of said source, means connecting the emitter electrode of said first device with the other terminal of said source, switching means responsive to the speed of said engine direct-current conductively connected from the junction of said base electrodes to the junction of said primary winding and said one terminal of said source to open and close the circuit connections for said base electrode in synchronism with said engine for controlling the current flow through said transformer means and for intermittently obtaining a high voltage across said secondary winding, means directly connecting said secondary winding with said collector electrode, and voltage distribution means connected between said secondary winding and said sparking means and operative in synchronism with said switching means to cyclically energize said sparking means.

6. In combination with an ignition system for an internal combustion engine including a high voltage transformer having a primary and a secondary winding, a semi-conductor device having a collector electrode, a base

electrode and an emitter electrode, means connecting the high voltage end of said primary winding directly with the collector electrode, voltage distribution means, means connecting said secondary winding in series between the junction of said collector electrode and the high voltage end of said primary winding and said voltage distribution means, means providing a point of fixed reference potential for said system, means connecting said emitter electrode with said point, a direct current source of biasing potential serially connected between the low voltage end of said primary winding and said point, and timing switch means serially and direct-current conductively connected between said base electrode and the low voltage end of said primary winding and operative in synchronism with said engine to open and close the circuit connections for said base electrode and to alter the current conducting condition of said semi-conductor device whereby a high voltage is intermittently produced across said secondary winding in response to the speed of said engine.

7. In combination with an ignition system for an internal combustion engine including a high voltage transformer having a primary and a secondary winding, a semi-conductor device having a collector electrode, a base electrode and an emitter electrode, means directly connecting said primary winding between said collector and base electrodes, voltage distribution means, means directly connecting said secondary winding in series from the junction of said collector electrode and the high voltage end of said primary winding to said voltage distribution means, means providing a source of potential having a pair of terminals, means connecting one of said terminals to the junction of said primary winding and said base electrode, and switching means direct-current conductively connected between said emitter electrode and the other terminal of said source and operative in synchronism with said engine to alter the current conducting conditions of said semi-conductor device to intermittently provide a high voltage across said secondary winding in response to the speed of said engine.

8. In an ignition system for an internal combustion engine having voltage distribution means, the combination comprising, at least one transistor including base, emitter, and collector electrodes, a high voltage transformer including a primary and a secondary winding, a direct current supply and switching circuit including a source of potential having a pair of terminals and switching means responsive to the speed of said engine connected between said base and emitter electrodes, said base electrode being connected to one of said terminals and said emitter electrode being connected to the other of said terminals, said switching means being operative to open and close the circuit connections of said supply and switching circuit in synchronism with said engine to control the collector current of said transistor to intermittently produce a high voltage across said secondary winding, means directly connecting said primary winding between said collector electrode and said one terminal of said source, and means connecting said secondary winding directly between said collector and said voltage distribution means for applying said high voltage to said voltage distribution means.

9. In an ignition system for an internal combustion engine having voltage distribution means, the combination comprising, at least one transistor including base, emitter and collector electrodes, a high voltage transformer including a primary and a secondary winding, a source of potential including a pair of terminals one of which is connected to a point of ground potential, means directly connecting said primary winding between said collector electrode and the other terminal of said source, means connecting said emitter electrode to said point of ground potential, switching means responsive to the speed of said engine direct-current conductively connected between said base electrode and the junction of said primary winding and said source of potential for opening and closing the circuit connection for said base in synchronism with said engine to control the collector current of said transistor and for intermittently obtaining a high voltage across said secondary winding, and means connecting said secondary winding directly between said collector and said voltage distribution means for applying said high voltage to said voltage distribution means.

10. In an ignition system for an internal combustion engine having voltage distribution means, the combination comprising, at least one transistor including base, emitter and collector electrodes, a high voltage transformer including a primary and a secondary winding, a source of potential including a pair of terminals, means directly connecting said primary winding between said collector electrode and one terminal of said source, means connecting said emitter electrode to the other terminal of said source, switching means responsive to the speed of said engine direct-current conductively connected between said base electrode and the junction of said primary winding and said source of potential for opening and closing the circuit connection for said base in synchronism with said engine to control the collector current of said transistor and for intermittently obtaining a high voltage across said secondary winding, and means connecting said secondary winding directly between said collector and said voltage distribution means for applying said high voltage to said voltage distribution means.

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