March 29, 1966 J. COUFAL 3,242,916

IGNITION SYSTEM FOR INTERNAL COMBUSTION ENGINE

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Fig. 1.

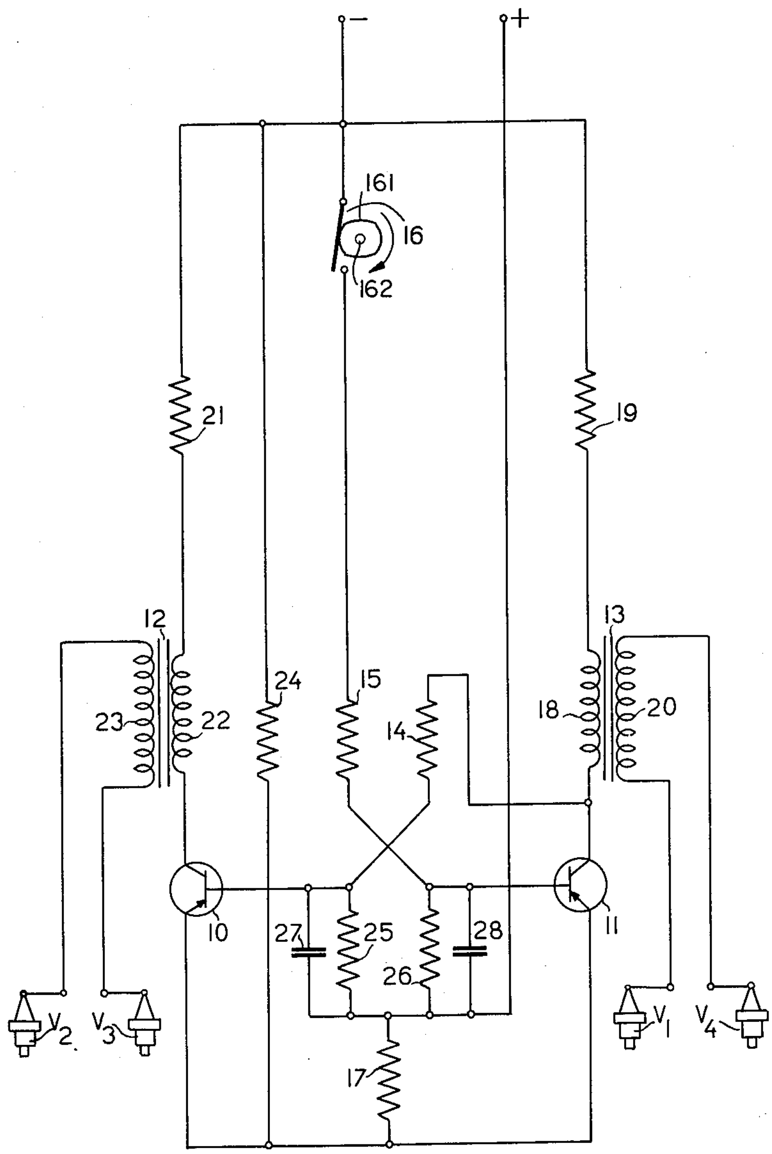

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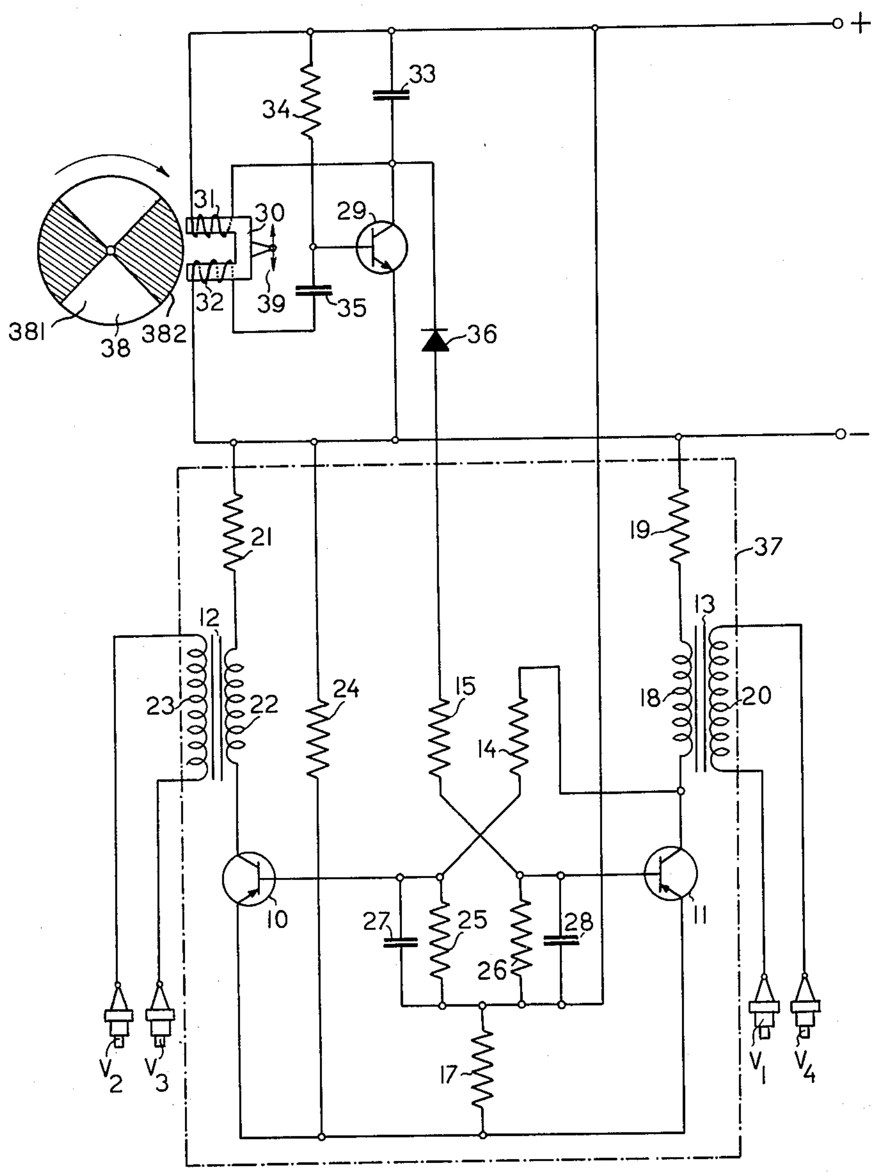
Fig. 2.



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IGNITION SYSTEM FOR INTERNAL COMBUSTION ENGINE

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Fig. 3.

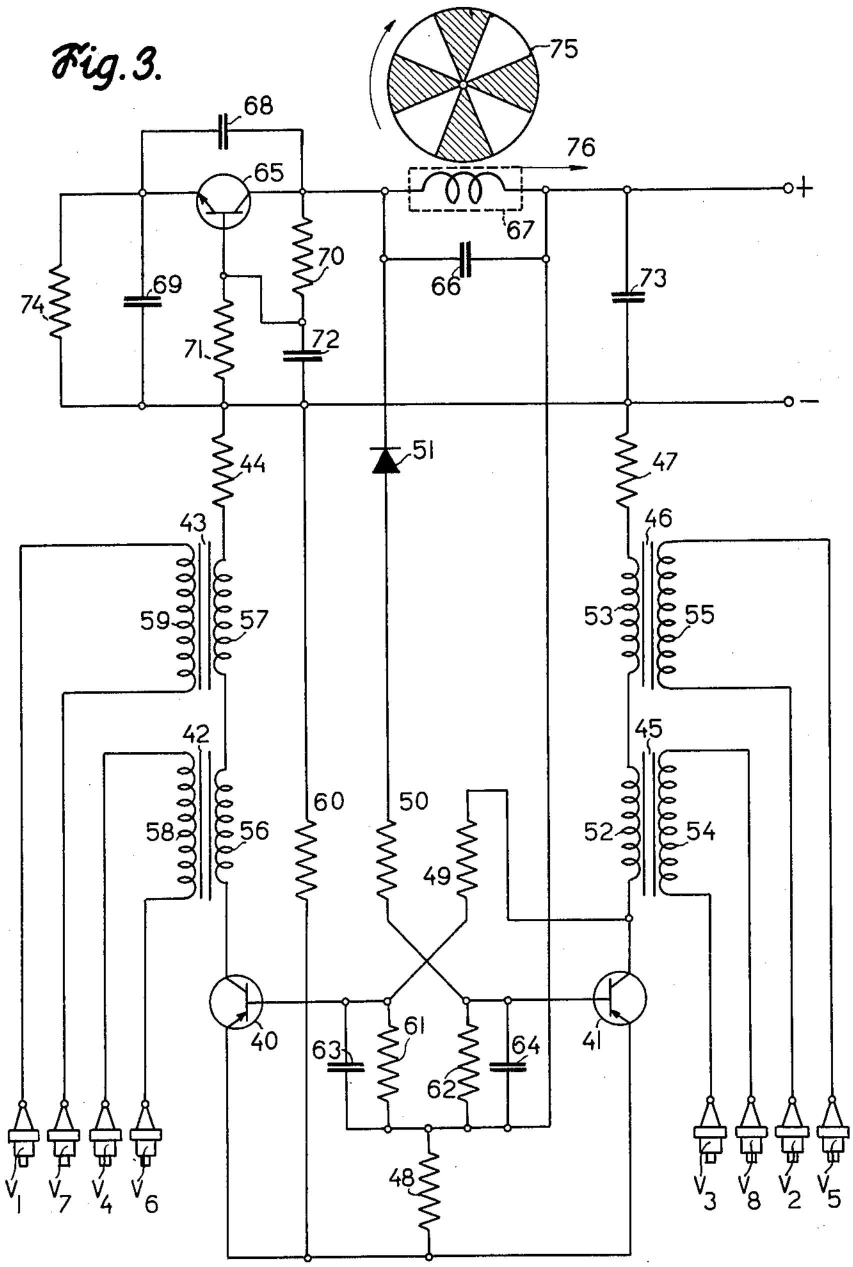

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Fig. 4.

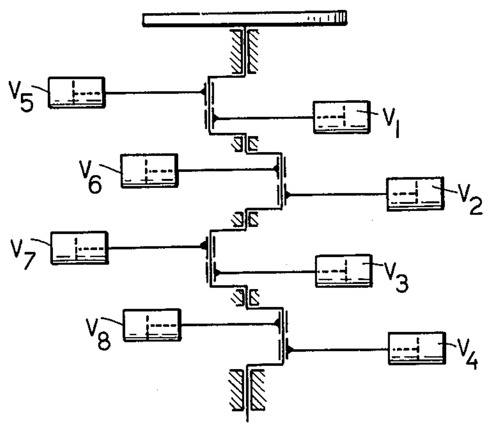
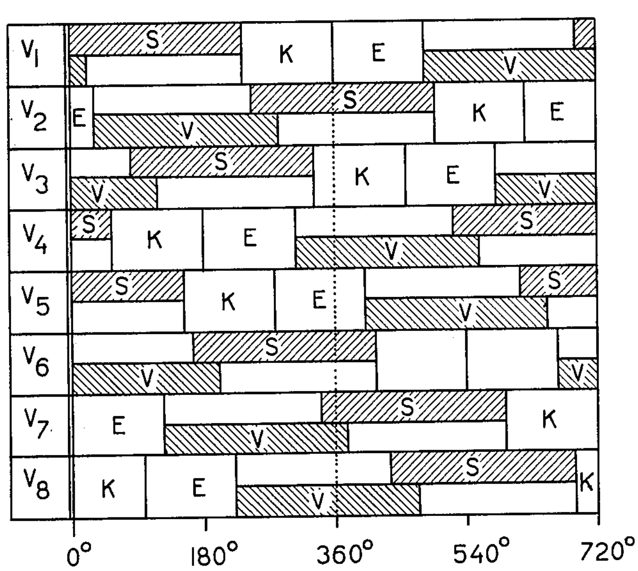


Fig. 5.



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IGNITION SYSTEM FOR INTERNAL COMBUSTION ENGINE

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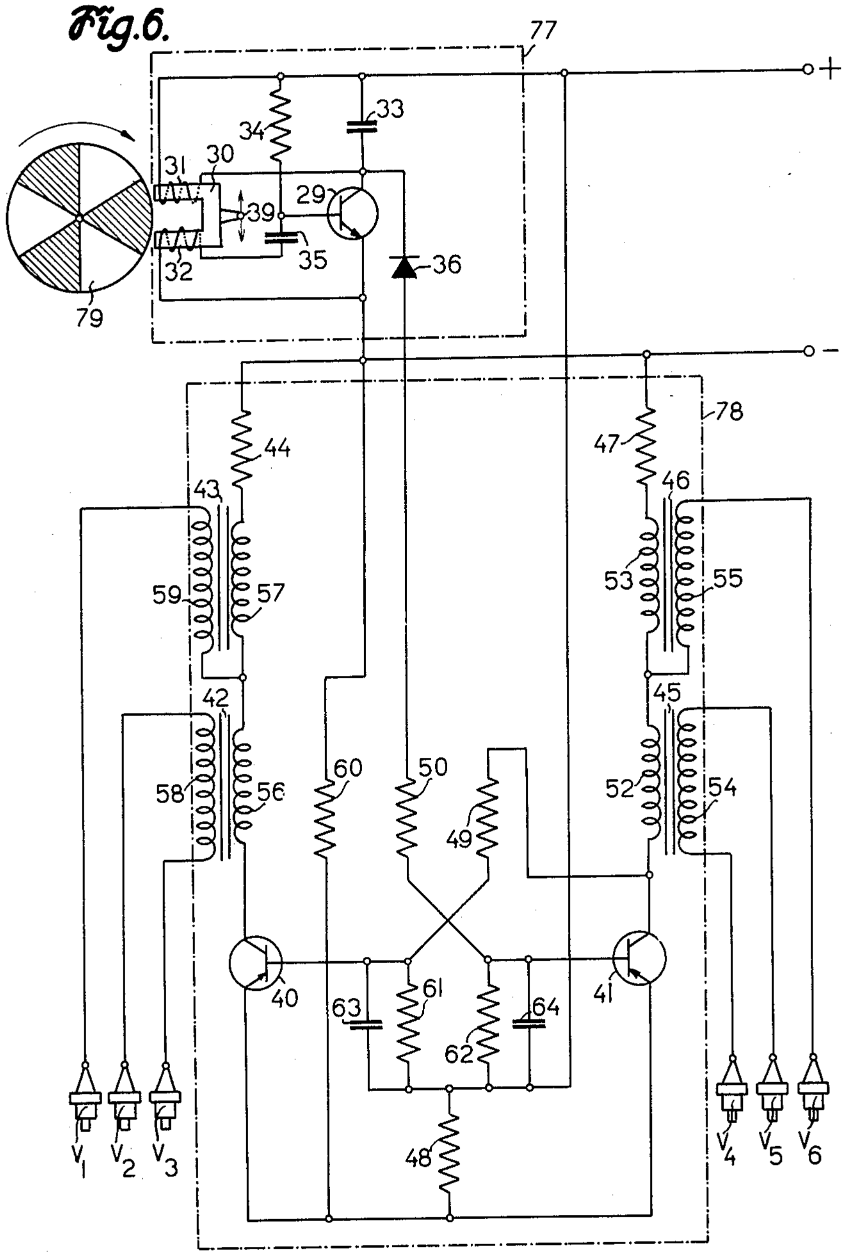
Fig. 6.



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United States Patent Office

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IGNITION SYSTEM FOR INTERNAL COMBUSTION ENGINE

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Claims priority, application Czechoslovakia, Sept. 4, 1962, 5,104/62

7 Claims. (Cl. 123—148)

This invention relates to ignition systems for internal combustion engines, and particularly to a system for energizing spark plugs in a multi-cylinder engine.

In its more specific aspects the invention is concerned with a spark ignition system which avoids the use of a distributor and associated problems. Transistor circuits have heretofore been employed in ignition systems to overcome the difficulties inherent in the mechanically moved contacts of more conventional distributors, but the known transistor ignition systems have been rather complex and costly.

An object of this invention is the provision of a simple ignition system without distributor which is adaptable to exacting requirements, and whose timing can be made very precise.

The invention contemplate the use of two power circuits each of which includes the primary winding of a transformer and a switch means capable of assuming a conductive and a non-conductive condition, and conductively connected to a source of electric current for passage of current from the source through the associated transformer winding in the conductive condition of the switch means. Switch actuating means are connected to a source of a sequence of electric timing pulses and the switch means of each power circuit for putting one of the switch means into its conductive condition and the other switch means into the non-conductive condition in response to a first pulse of the sequence, and for reversing the conditions of the switch means in response to a second timing pulse of the sequence. The secondary windings of the transformers are respectively connected to spark plugs.

The exact nature of this invention as well as other objects and advantages thereof will be readily apparent from consideration of the following specification relating to the annexed drawing in which:

FIG. 1 is the circuit diagram of an ignition system according to this invention for a four-cylinder internal combustion engine;

FIG. 2 shows a modification of the circuit of FIG. 1;

FIG. 3 is the circuit diagram of an ignition circuit for an eight-cylinder engine;

FIG. 4 shows the arrangement of the cylinders in the engine connected to the ignition system of FIG. 3 in conventional representation;

FIG. 5 is a valve timing diagram for the engine of FIG. 4; and

FIG. 6 is the circuit diagram of an ignition system of the invention for a six-cylinder engine.

Referring now to the drawing in detail, and initially to FIG. 1, there is shown the wiring diagram of an ignition system having two power circuits. A P-N-P transistor 10 and a step-up transformer 12 are the principal elements of the first power circuit, and a P-N-P transistor 11 and step-up transformer 13 in the second circuit. The primary windings 22, 18 of the transformers 12, 13, and current limiting resistors 21, 19 are respectively arranged in series between the collectors of the transistors and the negative terminal of a direct current source.

The base of the transistor 10 is connected to the collector of the transistor 11 through a resistor 14 and the base of the transistor 11 is connected to the negative terminal of the current source through a resistor 15 and a timing switch 16 whose contacts are alternatingly opened and closed by a rotating cam 161 having two lobes and mounted on a drive shaft 162.

The emitters of the transistors are connected by a common biasing resistor 17 to the positive terminal of the current source. This arrangement permits current flow through the resistor 11 and the primary winding 18 of the transformer 13 when the switch 16 is closed, whereas current flow through the transistor 10 is practically zero because the voltage between the emitter and collector of the transistor 11 is insignificant, the base of the transistor 10 being connected to the collector of the transistor 11 through the resistor 14.

When the switch 16 is opened, the transistor 11 blocks current flow to the primary winding 18 of transformer 13, and the magnetic field of the primary winding is rapidly reduced to zero, thereby producing a current pulse in the secondary winding 20. Because of the increased potential at the collector of the transistor 11, the transistor 10 simultaneously permits current flow through the primary winding 22 of the transformer 12 within the limits set by the resistor 21, and a magnetic field is induced in the winding 22 of the transformer 12. When the switch 16 is again closed, the magnetic field of the winding 22 collapses, and a current pulse is induced in the winding 23.

A resistor 24 interposed between the negative terminal of the current source and the emitters of both transistors 10, 11 is selected in such a manner that a suitable positive potential is applied to the bases of the transistors 10, 11 from the positive terminal of the source through respective resistors 25, 26. Capacitors 27, 28 are arranged in parallel with the resistors 25, 26 to control the instantaneous base potential when the conductivity of the transistors changes.

The spark plugs of two cylinders V_2, V_3 of a four cylinder engine are connected to the secondary winding 23 of the transformer 12 in the first power circuit, and the spark plugs of the other two cylinders V_1, V_4 are connected to the secondary winding 20 of the transformer 13, in the second power circuit. The firing order of the cylinders is 1–3–4–2. Their operation during two crankshaft revolutions in indicated in the following table.

Piston stroke	V_1	V_2	V_3	V_4
I	Expansion	Exhaust	Compression	Intake.
II	Exhaust	Intake	Expansion	Compression.
III	Intake	Compression	Exhaust	Expansion.
IV	Compression	Expansion	Intake	Exhaust.

If the firing order is 1–4–3–2 or 1–2–3–4, the spark plugs of the cylinders V_1 and V_3 are connected with one power circuit, and those of the cylinders V_2 and V_4 with the other power circuit. The illustrated connection is also employed for the firing order 1–2–3–4.

The ignition system shown in FIG. 1 is operated as follows:

At the moment at which the switch 16 opens, sparks are produced in the cylinders V_1 and V_4. Assuming that ignition is timed to occur several degrees ahead of the TDC (top dead center) position of the piston in the cylinder, the spark in the cylinder V_4 passes through a spent fuel mixture since the inlet valve opens approximately at 13° ahead of TDC, as is conventional. There is no ignitable mixture in cylinder V_4 at the time of the spark. Normal ignition and explosion takes place in the cylinder V_1.

The cam 161 is connected to the camshaft of the engine in such a manner that the switch 16 is closed again after the camshaft turns 90°. Sparks are generated hereby in the cylinders V_2 and V_3, and ignition takes place in the cylinder V_3 only for the reasons set forth above. The further ignition cycle will be evident from the above table.

The ignition system shown in FIG. 1 generates a spark alternatingly in the two power circuits upon closing and opening of the timing switch **16**. The switch may be driven by the illustrated cam having two lobes and driven by the camshaft or by a single lobe cam driven by the crankshaft. The ignition system does not rely for operativeness on a critical cam configuration. The engine revolutions at which oscillations set in at the switch are much higher than at the contact of a conventional ignition system, and the ignition system is capable of operating at higher engine speed and higher engine output than an otherwise comparable conventional system.

Only a control or timing current flows through the switch **16**, and the power circuit for the spark current is switched by the transistors **10**, **11**. Sparks are generated upon opening and closing of the switch **16** at 90° intervals if the switch cam **161** is coupled to the camshaft, or at 180° intervals if the cam is coupled to the crankshaft.

The ignition system illustrated in FIG. 2 is similar to that shown in FIG. 1 and operates basically in the same manner. It does not rely on a switch even for opening and closing a control or timing circuit. The elements of the ignition system of FIG. 1 other than the switch **16** are again employed in the ignition system of FIG. 2, and are shown within a chain-dotted rectangular frame **37**. They are identified by the same reference numerals as in FIG. 1 and will not be described again.

The system of FIG. 2 employs as a source of timing signals an oscillator whose main elements are an N-P-N transistor **29** and a transformer **30**. The primary winding **31** of the transformer is arranged in series between the collector of the transistor and the positive terminal of the direct current source, and the secondary winding **32** of the transformer **30** is arranged in feed-back circuit connecting the transistor base to the negative source terminal. The frequency of oscillation is determined by the inductivity of the primary winding **31** and the capacity of a capacitor **33** arranged in parallel circuit with the winding **31**.

A resistor **34** connects the base of the transistor **29** to the positive source terminal to provide positive bias voltage, and a capacitor **35** in the feedback circuit blocks the flow of direct current into the latter circuit. The oscillations produced are rectified by a rectifier **36**, and the rectified output of the oscillator is employed to switch the power circuits.

The rectifier output is controlled by a timing disk **38** which is composed by two quadrants **381** of metallic material and two non-metallic quadrants which sequentially pass the transformer **30** during rotation of the disc **382**. The disk is coupled to the engine cam shaft in a manner not further illustrated, and may be replaced by a disk consisting of one metallic 180° sector and a similar nonmetallic sector, and coupled to the crankshaft. The parameters of the oscillator circuit are selected in such a manner as to permit oscillation when one type of quadrant is aligned with the transformer **30**, and to suppress oscillations when the other type of quadrant is near the transformer. The non-metallic quadrants may be constituted by cut-outs.

Current thus flows through the recifier **36** to the switching circuits in pulses whose timing is controlled by the rotation of the disk **38**. Flow of current from the positive terminal of the direct current source to the base of the transistor **11** is prevented by the rectifier **36** during the periods in which the oscillator is inoperative.

The precise ignition timing is determined by the angular position of the transformer **30** relative to the axis of the disk **38**, and therefore relative to the TDC position of each piston. Spark advance may be controlled automatically in response to engine load by a diagrammatically illustrated linkage **39** which is connected by a spring and a pull rod actuated by the vacuum in the intake manifold, and shifts the transformer **30** as indicated by the double arrow. Spark advance in response to engine speed is achieved by turning the disk **38** relative to the driving camshaft by means of a centrifugal governor.

FIG. 3 shows an ignition system of the invention for an eight-cylinder internal combustion engine. The ignition system illustrated is intended for the Tatra, type 603, eight-cylinder engine whose firing order is 1–3–5–2–7–8–4–5, whose cylinders are arranged in two banks of four at right angles to each other, and whose crankshaft has four cranks that are offset 90°.

The manner in which the eight pistons are connected to the four cranks of the engine is evident from FIG. 4 in which the pistons are labelled V_1 to V_8. The valve diagram in FIG. 5 shows the condition of the eight cylinders during two revolutions (720°) of the crankshaft. The four phases of the engine cycle are indicated in FIG. 5 by capital letters. S is intake, K is compression, E is expansion, and V is exhaust.

The engine cycle illustrated in FIG. 5 permits the spark plugs of cylinders V_1, V_7, V_4, and V_6 to be connected to one power circuit, and these of cylinder V_3, V_8, V_2, and V_5 to be connected to the other power circuit shown in FIG. 3 as will be described in more detail hereinafter. If the firing order were 1–6–2–5–8–3–7–4, the spark plugs in one power circuit would be V_1, V_8, V_2, V_7, and those in the other circuit would be V_3, V_6, V_4, and V_5. A firing order 1–2–7–3–6–8–4–5 would call for connecting V_1, V_6, V_4, and V_7 to one circuit, and V_2, V_8, V_3, V_5 to the other circuit.

Ignition occurs in cylinder V_1 near the end of compression stroke K at 8° before the TDC position of the piston. A spark is simultaneously generated in the cylinder V_7 whose intake valve opens approximately 15° before TDC, and whose exhaust valve is open until approximately 20° after TDC. There is nothing in the cylinder V_7 that could be ignited.

Sparks are simultaneously also generated in cylinders V_4 and V_6. As is seen in FIG. 5, the cylinder V_4 is at the end of its expansion phase and its exhaust valve is already open, opening of the valve being timed at 50° before BDC (bottom dead center). The cylinder V_6 is at the end of its intake stroke S. Since the intake valve remains open until 55° after BDC, compression has not started yet. Neither the cylinder V_4 nor the cylinder V_6 contains an explosive mixture at the time of ignition in the cylinder V_1.

It has been found that the position of the crankshaft is not proportional to the amount of fuel mixture drawn into the cylinder. The fuel mixture does not ingite until it is compressed to a certain minimum pressure, the limiting pressure decreasing with the intensity of the spark. Both last-mentioned factors militate against ignition in cylinder V_6 under the conditions shown in FIG. 5 at the moment discussed.

When the contents of cylinder V_3 are ignited next near the end of the compression phase K in that cylinder, the simultaneously produced sparks in the cylinders V_8, V_5, and V_2 do not cause ignition, and no sparks are generated in the other four cylinders. It is readily apparent from FIG. 5, that all eight cylinders fire in the desired order at intervals of 90° of crankshaft portion.

The ignition system illustrated in FIG. 3 which operates an eight-cylinder engine in the manner described above is basically closely similar to that shown in FIG. 2, and therefore also to that illustrated in FIG. 1, provisions for the greater number of cylinders being made by use of additional transformers and of a modified timing circuit.

The diagram of FIG. 3 shows two power circuits respectively employing P-N-P transistors **40**, **41**. The primary windings **56**, **57** of two step-up transformers **42**, **43** and a current limiting resistor **44** are arranged in series in the collector circuit of the transistor **40** which leads to the negative terminal of a source of direct current. The primary windings **52, 53** of two transformers **45, 46** and a current limiting resistor **47** are similarly arranged in the collector circuit of the transistor **41**. The emitters of the transistors **40, 41** are connected to each other and to a bias resistor **48** which links them to the positive terminal of the direct current source. The elements described so far constitute the two power circuits which energize the eight spark plugs connected in pairs to the secondary windings **58, 59, 54, 55** of the transformers **42, 43, 45, 46**.

The base of the transistor **40** is connected through a resistor **49** to the collector of the transistor **41**, and the base of the latter is connected through a resistor **50** and rectifier **51** to a control oscillator, the power circuit of the transistor **41** being open to the flow of current as long as the oscillator generates alternating current by oscillating. Flowing current includes magnetic fields about the primary windings **52, 53**. Upon interruption of that current, as described hereinabove with reference to FIG. 1, the transistor **40** controlling the other power circuit becomes conductive in an analogous manner, not requiring further description.

A resistor **60** interposed between the negative terminal of the direct current source and the emitters of the two ransistors **40, 41**, resistors **61, 62**, respectively arranged between the bases of the transistors **40, 41** and the positive terminal of the current source, and capacitors **63, 64** arranged in parallel circuit with the resistors **61, 62** are the equivalents of the corresponding elements **24** and **28** in the ignition system of FIG. 1.

A timing signal is delivered to the transistors **40, 41** by an oscillator whose basic element is an N-P-N transistor **65**, and whose oscillating circuit consists of a capacitor **66** and a coil **67** arranged in parallel circuit between the positive terminal of the principal current source and the collector of the transistor **65**. The parameters of the capacitor **66** and the coil **67** determine the oscillator frequency.

The collector of the transistor **65** is connected to the emitter by a capacitor **68**, and the emitter is connected to the negative terminal of the principal power source by a capacitor **69**, the capacitors **68, 69** forming a capacitative divider for supplying feedback to the emitter. Two resistors **70, 71** arranged in series to form a voltage divider connected to collector of the transistor **65** to the negative terminal of the current source. A tap between the rsistors **70, 71** is connected to the transistor base to provide bias voltage. Capacitors **72, 73** respectively connect the negative terminal of the source to the aforementioned tap and the positive terminal to allow passage of alternating current. A resistor **74** connecting the emitter of the transistor **65** to the negative terminal of the current source stabilizes the working point of the transistor.

A timing or control signal is drawn from the oscillator circuit by the rectifier **51** at the emitter of the transistor **65**, but may also be taken from a tap of the coil **67**.

A timing disk **75** is rotatably mounted close to the coil **67**. It differs from the disk **38** shown in FIG. 2 by being composed of four metallic and four non-metallic sectors, each sector extending over 45°, and is connected to camshaft of the engine in a manner not further shown. Because of the influence of the disk **75** on the parameters of the oscillating circuit **66, 67**, the oscillator operates intermittently, and current passes through the rectifier **51** in control pulses each of which has a duration corresponding to a 45° rotation of the disk and is separated from the next pulse by a period of oscillator inoperativeness of equal duration.

Spark timing is achieved as described hereinabove with reference to FIG. 2. Primary spark advance is controlled by the position of the coil **67** relative to the disk **75**, and to the TDC positions of the pistons. Automatic timing control in response to engine load is obtained by a link **76** conventionally shown in FIG. 3, and connected to a diaphragm actuated by the vacuum in the intake manifold. A centrifugal governor, not itself shown, may be employed in a basically conventional manner for shifting the angular position of the disk **75** relative to the camshaft in order to make the ignition advance responsive to the instantaneous engine speed.

The power circuits illustrated in FIG. 3 can be controlled by a cam-operated single switch in the manner evident from FIG. 1, and a cam having four lobes may be employed instead of the eight lobe cam used in conventional distributors.

FIG. 6 shows an ignition system of the invention for a six-cylinder internal combustion engine. Its power circuits **78** differ from those shown in FIG. 3 only by connections between one terminal of each of the secondary windings **55, 59** and a terminal of the corresponding primary windings **53, 57**. The oscillator circuit **77** which provides control pulses through a rectifier **36** is identical with that shown in FIG. 2 except for a timing disk **79** which cooperates with the transformer **30** and in which 60° sectors of metallic and non-metallic material alternate in a circumferential direction. The disk **79** is coupled to the camshaft of the non-illustrated six-cylinder engine. It will be appreciated that the oscillator arrangement may be replaced by a switch operated by a three-lobed cam in the manner shown in FIG. 1.

An engine having a firing order 1–5–3–6–2–4 and a crankshaft equipped with six cranks offset 120° from each other can be operated by the ignition system illustrated in FIG. 6 with the spark plugs of the cylinders V_1, V_2 and V_3 connected to one power circuit, and the remaining spark plugs connected to the other circuit in a manner obvious from the preceding descriptions of the operation and four- and eight-cylinder engines, and from FIG. 5.

The ignition system of the invention is thus readily adapted to engines having any desired number of cylinders. It can be simply modified for engines having even more cylinders than eight by inserting additional transformers into the collector leads of the transistors in the power circuits. The advantages of the ignition systems of the invention over conventional systems increase with the number of cylinders because of the complexity of rotary ignition distributor arrangements which increases with an increasing number of cylinders.

The invention is not limited to the specific circuits illustrated and described. The N-P-N transistors shown may be replaced by N-P-N transistors and vice versa, and those skilled in the art will have no difficulty in suitably modifying other circuit features for this purpose. Either terminal of the principal current source may be grounded as desired, and as consistent with the circuit employed. The transistors may be replaced by other semi-conductor elements or by electronic tubes having characteristics consistent with the described functions.

It is therefore to be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

What I claim is:

1. An ignition system for an internal combustion engine comprising, in combination

(a) a source of electric current;

(b) two power circuits connected to said source, each circuit including

  (1) a primary winding, and

  (2) switch means having a conductive and a non-conductive condition and being conductively connected to said source and to said winding for serial passage of current from said source through said winding and said switch means in said conductive condition of said switch means;

(c) a source of a sequence of electric triming pulses;

(d) switch actuating means connected to said source of timing pulses and to only a single selected one of said switch means of said power circuits.

(1) coupling circuitry connecting said selected one of said switch means to the switch means of the other power circuit in a dependent mutual coupling manner,

(2) means for biasing said selected switch means to its nonconductive condition in the absence of the application thereto of a timing pulse,

(3) so that the energization of the selected switch means in response to the application thereto of a single timing pulse is effective to simultaneously de-energize the switch means of said other power circuit and so that the de-energization of the selected switch means in response to the absence of the application thereto of a timing pulse is effective to energize the switch means of said other power circuit,

(e) two secondary windings inductively coupled to said primary windings respectively and constituting respective transformers therein; and

(f) a spark plug in circuit with each secondary winding.

2. An ignition system as set forth in claim **1**, wherein each switch means includes a transistor having three electrodes, a first electrode being conductively connected to said source, and a second electrode being conductively connected to the associated primary winding; said switch actuating means including a resistor conductively interposed between the third electrode of one of said transistors and the second electrode of the other transistor; and said source of timing pulses being connected to the third electrode of said other transistor.

3. An ignition system as set forth in claim **1**, wherein said engine has a camshaft and a crankshaft, and said source of pulses includes pulse generating means, and motion transmitting means for connecting pulse said generating means to one of said shafts for synchronizing the timing of said pulses to the movement of said one shaft.

4. An ignition system as set forth in claim **3**, wherein said pulse generating means include a switch and a source of electric current in circuit with said switch, the starting and the interruption of said current by said switch constituting said pulses.

5. An ignition system as set forth in claim **3**, wherein said pulse generating means include an oscillator and timing means movable for shifting said oscillator between an operative and an inoperative condition, said timing means being connected to said motion transmitting means for movement thereby.

6. An ignition system as set forth in claim **5**, wherein said oscillator includes an oscillator circuit, and said timing means include means for cyclically varying a parameter of said oscillating circuit.

7. An ignition circuit as set forth in claim **6**, wherein said oscillator circuit includes an inductor, and said means for varying said parameter include a metallic member and means for cyclically moving said metallic member relative to said inductor.

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