

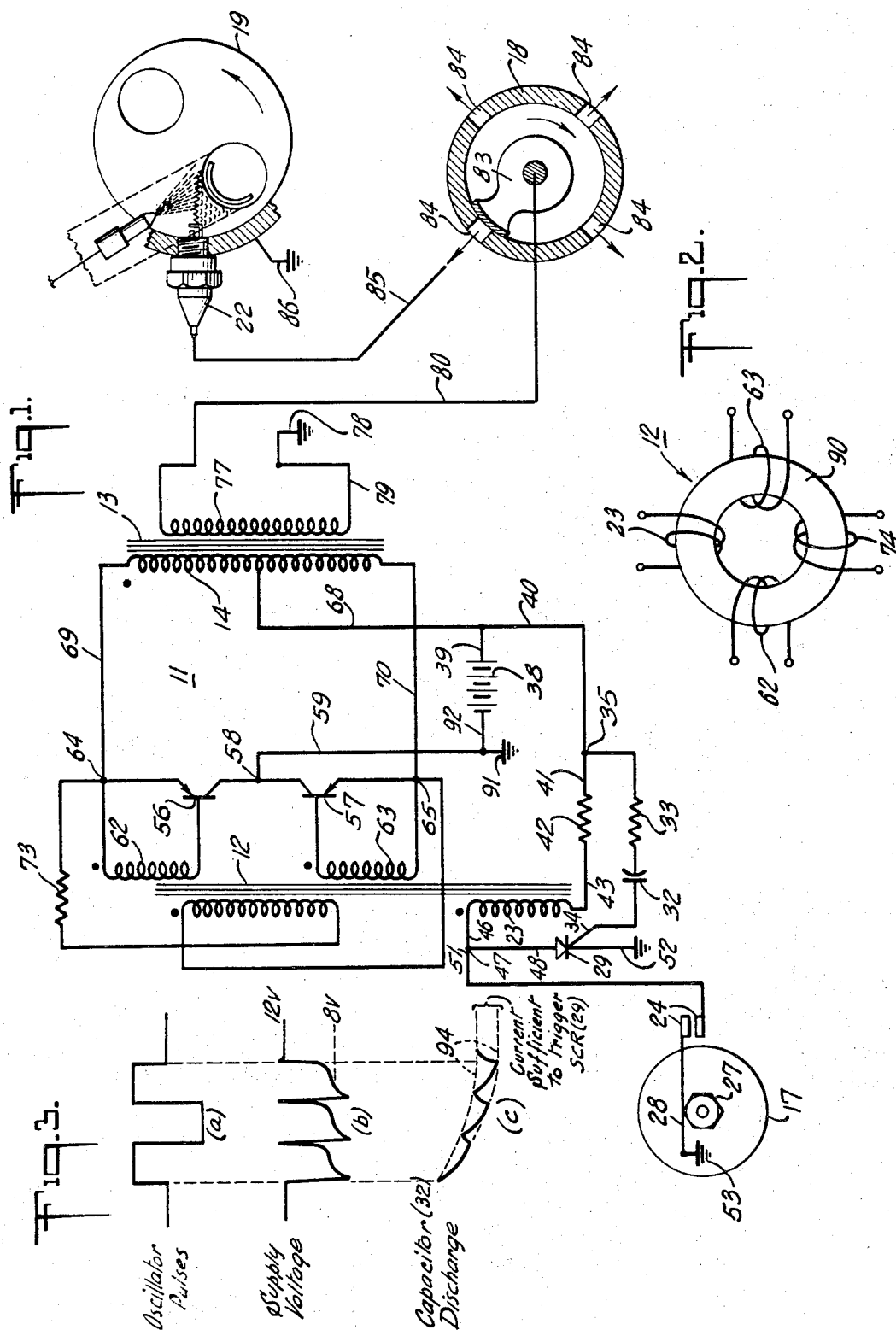
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IGNITION SYSTEM FOR INTERNAL COMBUSTION ENGINES

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IGNITION SYSTEM FOR INTERNAL COMBUSTION ENGINES

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ABSTRACT OF THE DISCLOSURE

An electrical ignition system for internal combustion engines. The circuit includes a Jensen oscillator. Starting and stopping of the oscillator is controlled by engine breaker points plus an electric timing circuit.

This invention concerns ignition systems in general, and more particularly relates to an ignition system that is applicable to internal combustion engines. While the system was developed particularly for use with internal combustion engines of the type described in U.S. patent to Barber No. 2,484,009 issued Oct. 11, 1949, it is an ignition system that also is applicable to internal combustion engines generally.

Special arrangements for ignition systems have been developed to meet some of the problems relating to the type of internal combustion engine described in the aforementioned U.S. patent to Barber (No. 2,484,009). These were particularly related to the timing in relation to fuel injection, and some of these ignition systems are indicated by issued U.S. patents, e.g., Taylor No. 2,718,883 and Davis No. 2,960,973. However, practical difficulties were found, particularly when attempt was made to employ a sufficiently simplified system that would be practical from a cost standpoint. Thus, one need was to provide a single spark generation circuit with distributor, for applying the spark from a central timed control to each one of multiple cylinders such as are found in the ordinary internal combustion engine.

It was discovered that a relatively high frequency AC source was to be preferred over DC, since the latter erodes the spark plug terminals too fast. It was also discovered that the needed ignition spark system should provide a spark having energy content that lies within specific minimum boundaries of both voltage amplitude and time duration. In order to meet those minimums without attendant difficulties either from extra high voltage energy in the spark or from extra long duration energy in the spark, a system according to this invention was developed. It provides an intermediate spark control having adequate voltage without undue duration and thus provides optimum ignition conditions.

Consequently, an object of this invention is to provide an ignition system for internal combustion engines, that employs an AC voltage and enables a spark to be energized for a predetermined fixed duration commencing with an interval of time as determined by a single mechanical timer or otherwise independently of the speed of operation of the engine. Of course, each spark interval must be commenced with a definite mechanical relationship relative to the engine operation, and the time duration of a spark interval may be chosen such that it varies with speed only so long as the speed is greater than a predetermined value.

Another object of the invention is to provide an ignition system for giving optimum spark ignition that will produce a maximum efficiency by providing complete burning of the combustion products over a full range of operating speed, from starting to maximum r.p.m.

Briefly, the invention concerns an ignition system for

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use with an internal combustion engine having breaker points associated therewith for mechanically determining the timing of the initiation of an ignition spark for a cylinder of said engine. The system comprises in combination a source of relatively high frequency electrical energy having continuing duration, means for rapid starting of said high frequency energy under control of said breaker points to reach full amplitude without delay, and means for instantaneously stopping said high frequency energy after a predetermined time duration commencing with said starting time. The combination is such that optimum spark energy is applied to said engine cylinder irrespective of speed of operation thereof.

The foregoing objects and benefits of the invention will be described in greater detail below in connection with a preferred embodiment thereof, and relating to the figures of the drawings wherein:

FIG. 1 shows a circuit diagram including schematically the output connection to a spark plug;

FIG. 2 shows a schematic illustration of a toroidal type transformer with four windings thereon that is employed as the feedback transformer in the FIG. 1 system; and

FIG. 3 is a set of voltage characteristic curves illustrating circuit conditions when the breaker points open.

Referring to FIG. 1 it will be noted that this ignition system is shown as applied to the type of internal combustion engine described in the Davis patent mentioned above, i.e., No. 2,960,973. However, the ignition system shown and described in that patent had the drawbacks mentioned above, including variation of the duration of spark energy depending upon speed of operation of the engine. In the subject invention, however, variation in the spark duration may be controlled so that it only depends upon speed of the engine's operation at high speeds; and so that at low speeds no variation in duration exists since the initiation of each spark energy pulse is time controlled but the duration thereafter is independent of the action of breaker points which initiated such spark. This will be described more fully hereafter, but it may be noted that there is great advantage in the ability to hold the maximum spark duration to an optimum constant at engine speeds down to and including starting speeds where otherwise a continuous spark would burn up the electrical system at one or more points.

The system includes an oscillator 11, which in turn includes a feedback transformer 12 and an output transformer 13. The latter has a center tapped primary winding 14 in the oscillator circuit.

There is a distributor 17 that controls the starting of oscillator 11 in a manner to be described below. On the output side of oscillator 11, i.e., from the secondary of transformer 13 there is a connection as illustrated which leads to a commutator 18 that determines which cylinder of a multi-cylinder engine is having the spark energy applied thereto at a given point in an operating cycle of the engine. There is only one cylinder 19 schematically indicated in the drawing since all of the others are substantially identical thereto. It may be observed that the illustration shows a spark plug 22 appropriately mounted in connection with each cylinder 19. This will control the ignition of the flame front for the special type combustion system of the engine shown.

The spark energy is in the form of a high frequency AC potential supplied by the oscillator via its output transformer 13. For controlling the starting and stopping of the oscillator 11, there is a saturating winding 23 on the transformer 12. Current flow in this saturating winding 23 is controlled by a set of breaker points 24. Points 24 have the opening and closing thereof controlled mechanically by the lobes on a cam 27 against which rides the follower (not shown) that actuates movement of an arm

28 which carries one of the points 24 thereon and completes an electrical circuit to ground, as indicated.

Connected electrically across the points 24 there is a silicon controlled rectifier 29 that acts as a shunt for the points 24 when the rectifier is conducting. Triggering of the rectifier 29 to a conductive state is controlled by the illustrated circuit. This includes a capacitor 32 and a resistor 33 connected in series between a control electrode 34 of rectifier 29 and a circuit connection 35, from which there is a direct circuit connection (as shown) to the positive side of a DC potential or battery 38. Thus current flow through saturating winding 23 may be maintained over the path from the positive terminal of battery 38, either through the rectifier 29 or across the points 24 when they are closed. The path of current flow will be completed to ground in either case.

The foregoing path for transformer saturating current flow may be traced as follows. Beginning at the positive side of battery 38, the circuit is completed via a circuit connection 39, and another circuit connection 40 to the circuit connection point 35. Then the circuit continues via a wire 41 to one end of a resistor 42 and from the other end of the resistor over a wire 43 to one end of the winding 23. From the other end of winding 23 the circuit continues over a wire 46 to a circuit connection point 47, and from there there is a parallel pair of circuits via either a wire 48 to one side of the silicon controlled rectifier 29 or via another wire 51 to the fixed one of breaker points 24. Then in either case the circuit is alternatively completed to ground as shown, i.e., either from the other side of rectifier 29 via a wire 52 to ground or from the fixed one of points 24 via the movable one of the points and the arm 28 to a ground connection 53. It will be observed that with these circuits the winding 23 will be carrying current (and consequently be causing saturation of transformer 12) whenever the points 24 are closed or the silicon controlled rectifier 29 is conducting.

The oscillator 11 that is illustrated is a known circuit, per se, and it includes among the elements thereof a pair of transistors 56 and 57 that are connected as shown with the collector of each both connected to a point 58 and from there via a wire 59 to ground as illustrated. There is also a connection to the negative side of the battery 38 as shown.

This type of oscillator is known as a Jensen circuit. The base of each transistor 56 and 57 is connected to one end of a winding 62 and 63 respectively, both of which are located on the transformer 12. The other end of each winding 62 and 63 is connected to a circuit junction point 64 and 65 respectively to which the emitter of each transistor 56 and 57 respectively is also connected as shown.

Power is supplied to the transistors 56 and 57 in common from the battery 38 via a circuit wire 68 which goes to a center tap on winding 14 of the output transformer 13. The ends of winding 14 are each connected via a wire 69 and another wire 70 respectively, to the circuit junction points 64 and 65, again respectively.

A feedback connection for providing oscillation, includes the circuit which has a resistor 73 connected in series with a feedback winding 74 of the transformer 12. These two elements are connected between the junction points 64 and 65 to provide direct feedback as shown.

Operation of the foregoing Jensen oscillator may be explained as follows. When the supply voltage from battery 38 is applied to the circuit, either the transistor 56 or 57 starts to conduct and thereby develops a voltage across one-half of the primary winding 14 of transformer 13. Since the other transistor (56 or 57) is cut-off, a voltage is induced in the other half of the primary winding 14 that is approximately equal to the voltage across the conducting half of the primary. Consequently, the whole winding 14 has a voltage thereacross that is approximately twice the supply voltage of battery 38. This same voltage is applied to the series circuit of resistor 73 and

primary winding 74 of the transformer 12 which is a saturable core device. As the transformer 12 starts into saturation it demands more and more current which in turn causes a voltage drop across the resistor 73 to increase and thereby reduce the drive voltage available to the primary, i.e., winding 74 of the transformer 12. This concurrently is reducing the voltage applied to the base of the conducting one of the transistors 56 or 57, and this trend continues until the available voltage is no longer sufficient to maintain that transistor in a conducting state. When this happens, that transistor cuts off and the energy stored in the inductive components of the circuit causes voltages of opposite polarity to appear. These in turn trigger the other transistor into a conducting state and the oscillator thus reverses itself and goes through a similar cycle with the opposite transistor conducting. Such oscillation will continue so long as the supply voltage is applied. However, as will be more fully pointed out below control of this oscillation may be had by controlling the saturation of transformer 12.

The output of the ignition system is taken from the secondary of the transformer 13. Thus, a secondary winding 77 has an alternating high voltage signal generated therein that is applied to cause the desired spark at the electrodes of the spark plug 22. The circuit for this output signal is clearly shown schematically and may be traced from a ground connection 78 to one side of the secondary winding 77 via a wire 79. The other side of winding 77 is connected via a circuit wire 80 to a rotor member 83 of the commutator 18. There are a plurality of output electrodes 84 situated around the periphery of the commutator 18 in a standard manner, and as the rotor 83 is located adjacent each of these electrodes a circuit may be completed from a circuit wire, e.g., wire 85 which leads to a corresponding spark plug, e.g., spark plug 22 illustrated. The circuit from the spark plug to ground is completed in a conventional manner, e.g., via the grounded one of the electrodes in the spark plug 22. Such electrical ground return circuit is indicated by a ground wire connection 86 in the drawing.

FIG. 2 merely illustrates in a schematic manner the physical structure for transformer 12. This transformer is, as explained above, a saturable core device and consequently is constructed with a torodial core structure 90 having the four windings 23, 62, 63 and 74 wound thereon as schematically indicated. A specific example of the actual size of the windings employed with a toroidal transformer for an ignition system according to the invention and the preferred embodiment illustrated in FIG. 1, is as follows: winding 23—forty-eight turns—wire size No. 20 AWG; windings 62 and 63—twenty turns—wire size No. 22 AWG; winding 74—two hundred turns—wire size No. 30 AWG.

Operation

Referring to FIG. 1, operation of the ignition system will be described for one firing of a given spark plug in a multiple cylinder internal combustion engine. It will be appreciated that this is substantially duplicated for each firing of successive spark plugs as the commutator moves from one to the next of the plurality of circuits for the given cylinders. Also, it will be understood that timing of the breaker point operation is a matter of mechanical design and adjustment. If desired in particular instances such as with special type internal combustion engines, e.g., a special fuel injection type engine as described in connection with the above mentioned patents; there might be a control of the breaker points with relation to fuel injection rather than strictly from the drive shaft connection as with the standard type internal combustion engine.

However, in either case the advantages of an ignition system according to this invention will be those already mentioned including the fact that the maximum duration of the ignition spark is fixed by design constants in the electrical circuit, and therefore the principal adjustment

under control of the mechanical timing is that of setting the instant where the breaker points open for any given cylinder firing. In other words, in the range of speeds below high speed operation for the engine, it does not matter how long the breaker points stay open. It is the control gained by the arrangement including silicon controlled rectifier 29 that determines the length of time of the high voltage AC pulse type output which causes firing of the spark plug.

During engine operation, commencing with the time before firing of a given spark plug (when breaker points 24 are closed), it will be observed that the saturating winding 23 is then carrying its full current. This causes saturation of the magnetic circuit which includes toroidal transformer 12. The saturating current flow path may be traced from the positive terminal of battery 38 over wire 39, wire 40, wire 41 to resistor 42 and then via wire 43 through winding 23 over wire 46 to circuit junction point 47. From point 47 the circuit continues over wire 51, the closed breaker points 24, arm 28 to ground connection 53. And then it continues from another ground connection 91 via a wire 92 to the negative terminal of battery 38. It may be noted that under these conditions, there is substantially no voltage applied across the silicon controlled rectifier 29 and consequently it is non-conducting.

When the breaker points 24 open, the saturating current in winding 23 ceases and the resulting decay in the magnetic field in transformer 12 produces a transient voltage pulse which effectively aids the instantaneous starting of the oscillator 11. Thus, whichever of the transistors 56 or 57 tends to conduct first, it will be pushed into its initial conducting state immediately and rapidly upon the commencing of the magnetic field decay just described. This is an important feature in that the instantaneous and sure starting of the oscillations to provide an ignition voltage pulse is very accurate and will take place even under adverse conditions. An additional benefit is realized with such rapid starting of the oscillations in the oscillator circuit 11, in that the energy dissipated in the transistors 56 and 57 during the build up of the oscillations, is reduced to a minimum and consequently the heating and related losses are materially reduced.

As soon as the breaker points 24 open, the oscillator 11 commences to oscillate, and capacitor 32 which had been charged to full battery voltage, e.g., +12 volts, during the time when the points were closed begins to incrementally discharge. This action results from the large current draw of the oscillator which produces transients on the battery 38 supply to capacitor 32—see FIGURE 3b. This effective drop in supply voltage to capacitor 32 causes it to discharge thru the gate cathode diode of SCR 29 until the oscillator 11 reverses itself, at which time the capacitor attempts to recharge itself since the supply voltage has now gone back up to +12 volts. However, the other transistor now begins conducting and the capacitor 32 begins to discharge again (FIGURE 3c). As can be seen from FIGURE 3c the potential difference between the capacitor 32 and supply voltage at each reversal is increasing (see dashed lines 94), until such point is reached whereat the potential difference becomes large enough to cause the gate-cathode current during the charge period to be sufficient to trigger the SCR 29, into conduction, which then remains conducting until the voltage thereacross is reduced to some value below the sustaining level of the SCR 29. This condition of conduction in rectifier 29 acts like closed breaker points 24, i.e., it will draw full current through saturating winding 23 so that the oscillator is thus cut off. This means that the duration of spark energy from the output of oscillator 11 is definitely controlled to be no more than a predetermined time duration commencing with the opening of breaker points 24.

It will be understood that once the points 24 have been closed, this creates substantially zero potential across the rectifier 29 and thus causes it to cease conducting or

never to start if it was not already in a conducting state. Consequently, a preferable adjustment of the system is to design the dwell time of the cam 27 for the breaker points 24 to provide an optimum spark width or time period at maximum speed for the engine. Then, by choosing the desired values for the circuit constants, i.e., in connection with resistor 33, capacitor 32 and SCR rectifier 29, to provide for the desired maximum time duration of spark pulse at lesser speeds. The latter pulse duration will be a constant irrespective of how slow the engine is running.

In this manner, the time duration for a spark energy pulse may be shorter at higher speeds in direct relationship to the speed of the engine by reason of the timing created by the mechanical actuation of breaker points 24. Thus, after the beginning of a pulse, if the breaker points 24 close again before the charging circuit for capacitor 32 has had sufficient oscillator cycles operating to build the charge high enough to cause conduction of rectifier 29, the oscillator 11 will be cut off when breaker points 24 close because of the saturating current which will then flow in winding 23.

A clear illustration of one of the benefits of an ignition system according to this invention relates to the starting speed for an internal combustion engine. Such speed is obviously extremely slow and during starting time a system according to the prior art would tend to subject an oscillator, such as that employed here, to extremely long periods of energization such that the transistors would become burned out. On the other hand with a system according to this invention, the spark will remain properly and accurately timed but each spark will only last for the predetermined maximum time that is adequate for ignition but without waste or difficulties.

Also, it may be noted that the arrangement according to the invention is advantageous in having an inherent protection against a short circuit on the output circuit for oscillator 11. Thus, with such a system, a short circuit on the output of transformer 13 will cause the oscillator to be unable to achieve oscillation, since the loop gain will not go above unity. Consequently, the oscillating circuit remains shut down under such conditions and no harmful effects are felt.

While a particular embodiment of the invention has been described in considerable detail above in accordance with the applicable statutes, this is not to be taken as in any way limiting the invention but merely as being descriptive thereof

We claim:

1. An ignition system for use with an internal combustion engine having breaker points associated therewith for mechanically determining the timing of initiation of an ignition spark for a cylinder of said engine, comprising in combination
 - a) an oscillator employing electromagnetic feedback, coupling and providing relatively high frequency electrical energy having continuing duration during oscillation thereof,
 - b) means for saturating said feedback coupling with steady state magnetic flux to stop said oscillator,
 - c) and means for cutting off said steady state magnetic flux in order to cause rapid starting of said high frequency energy,
 - d) said last named means being under control of said breaker points.
2. An ignition system according to claim 1 wherein said electromagnetic feedback coupling comprises a transformer having a saturable core.
3. An ignition system according to claim 2 wherein said means for saturating said feedback coupling comprises a winding on said saturable core, and a DC energizing circuit for said winding including said breaker points therein.
4. An ignition system according to claim 3 further including electronically controlled shunt means across said

breaker points for energizing said winding after a pre-determined number of cycles of oscillation of said oscillator.

5. An ignition system for use with an internal combustion engine having breaker points associated therewith for mechanically determining the timing of initiation of ignition spark for a cylinder of said engine, comprising in combination

- (a) a Jensen type oscillator having a saturable core transformer incorporated therein,
 - a feedback winding in said oscillator on said saturable core transformer for sustaining oscillations when said core is not saturated, and
 - an output transformer having an input winding connected to said oscillator and an output winding connected to supply said spark,
- (b) a saturating winding located on said saturable transformer for positive and rapid starting and for instantaneously stopping said oscillations depending upon current flow conditions therein,
- (c) a source of DC potential and circuit means for energizing said oscillator and for supplying current flow to said saturating winding,
- (d) second circuit means for connecting said breaker points in series with said DC potential and said saturating winding,

- (e) a silicon controlled rectifier,
- (f) third circuit means for connecting said silicon controlled rectifier in shunt with said breaker points, and
- (g) fourth circuit means including a capacitor for controlling conduction of said silicon controlled rectifier,

all whereby said ignition spark initiation is positive and rapid upon opening of said breaker points and termination is instantaneous upon either closing of said breaker points or conduction of said rectifier which ever occurs first.

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