June 7, 1960 A. C. LEGEAY ET AL 2,940,014

ELECTRONIC IGNITION SYSTEM

Filed June 28, 1955

Fig. 1.

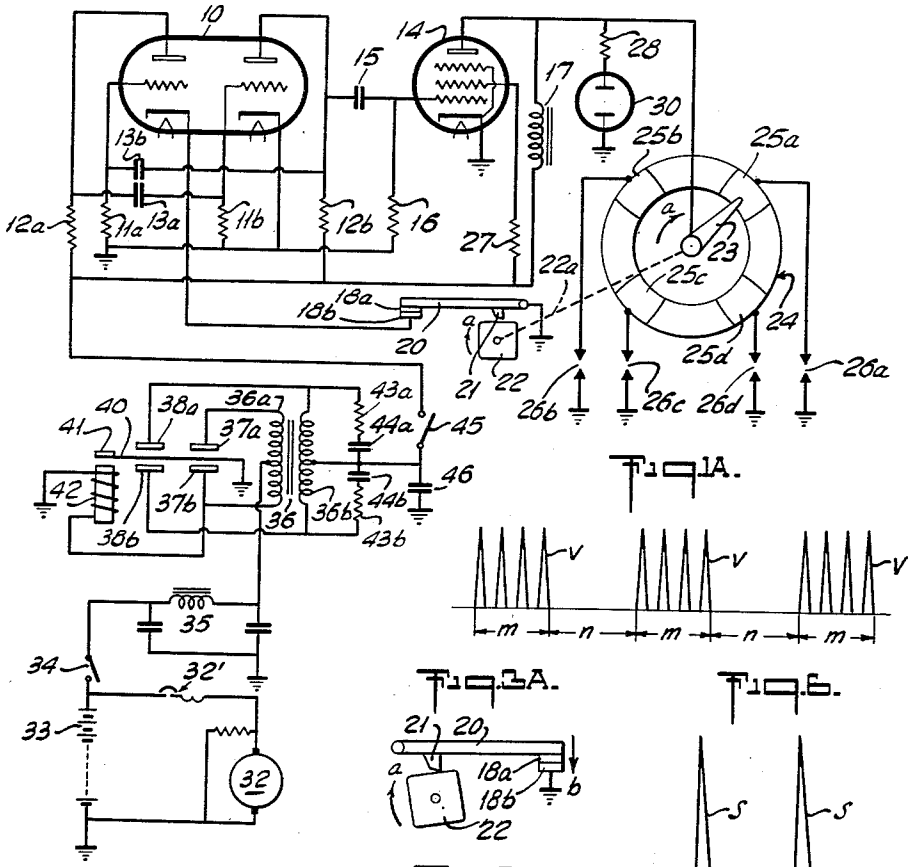


Fig. 1A.

Fig. 2.

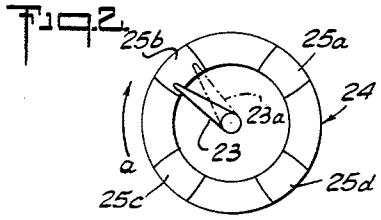


Fig. 3A.

Fig. 3B.

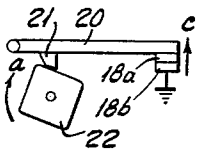


Fig. 4.

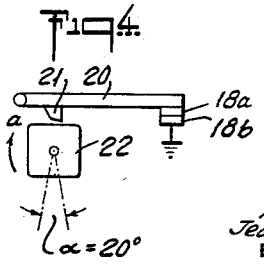


Fig. 5.

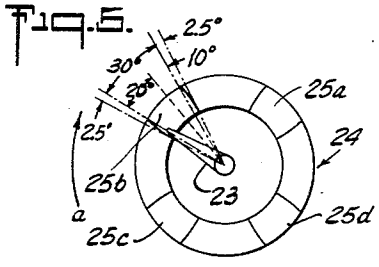
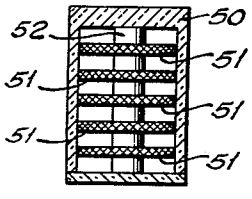


Fig. 6.

Fig. 7.



INVENTORS
Andre Camille Legeay
Jean Emilien Chauvineau
BY
ATTORNEY

United States Patent Office 2,940,014 Patented June 7, 1960

2,940,014

ELECTRONIC IGNITION SYSTEM

Andre Camille Legeay, Paris, and Jean Emilien Chauvineau, Lozere, France, assignors to F. Alexander, New York, N.Y.

Filed June 28, 1955, Ser. No. 518,434

6 Claims. (Cl. 315—209)

The present invention relates to electronic ignition systems for use in internal combustion engines and the like, including reciprocating engines, gas turbines, jet and turbo-jet engines, and the like prime movers or motors utilizing an explosive or inflammable fluid or gaseous mixture as operating fuel.

Among the more general objects of the invention is the provision of an improved ignition system which will enable a more exact timing and more efficient ignition and combustion and which furthermore provides a new and more efficient method of firing the explosive mixture in the cylinder or combustion chamber of an internal combustion engine.

Among the more specific objects of the invention is the provision of a new and improved ignition system which will reduce or eliminate sparking or arcing between the ignition control contacts, frequently occurring in conventional ignition systems as a result of fouling or disabling of one or more spark gaps, and other defects.

Another object is to reduce the wear on the igition control or distributor contacts by the elimination of any interrupting currents between the contacts.

Still a further object is the provision of an ignition device of light weight and reduced bulk which can be readily substituted for the conventional igintion coil and condenser as used in standard engines, such as for motorcars, etc., substantially without requiring any essential change in the circuit connections of the electrical system.

A further object is the provision of an ignition system capable of operating equally well at different altitudes and independently of atmospheric pressure changes.

Other objects are to avoid misfiring, eliminate the usual troublesome contact points and to generally increase the efficiency or reduce the fuel consumption of internal combustion engines, in particular of motorcar engines.

Still another object of the invention is the provision of a novel electronic ignition system for internal combustion engines utilizing the effects of high frequency ionizing the combustible fuel mixture, to readily initiate the ignition and to improve the over-all efficiency of the combustion, substantially without the drawbacks and defects of the conventional high frequency discharge ignition systems known in the prior art.

The foregoing and ancillary objects, as well as novel aspects of the invention, will be better understood from the following detailed description taken in conjunction with the accompanying drawing, forming part of this specification and wherein:

Fig. 1 is an electrical circuit diagram of an improved electronic ignition system for internal combustion engines embodying the principles of the invention;

Fig. 1A illustrates a series of ignition pulse voltage trains utilized by the invention;

Fig. 2 and Figs. 3A and 3B are partial views of the interrupter or ignition control contact mechanism of Fig. 1, illustrating a preferred design thereof according to the invention;

Figs. 4 and 5 are further partial views of the ignition control mechanism and distributor, illustrating in greater detail the design and operation according to the invention;

Fig. 6 is a graph illustrating a series of high voltage ignition sparks; and

Fig. 7 is a cross-section through a preferred construction of a peaking transformer used in the peak voltage generator of Fig. 1 forming part of the invention.

Like reference characters identify like parts in the different views of the drawing.

With the foregoing objects in view, the invention involves generally the provision of means for and a method of producing a series of low-frequency high voltage impulses or ignition sparks during a single ignition period having a predetermined recurrence frequency, in such a manner that during high engine speeds a sufficient number of discrete sparks is available to insure ignition and efficient combustion of the explosive mixture, while during idling or low engine speeds, the period of the peak voltage trains or number of discrete sparks increases in proportion to the reduced engine speed, providing thereby, in addition to improved all-over efficiency, the advantage of easy and ready starting and more efficient operation of the engine at idling and low speed operation.

In order to carry the invention into effect there is utilized an electronic system generating a peaked voltage wave being constituted by a series of high voltage pulses at relatively low frequency and having a steep-fronted shape, such as square or triangular, to insure a sufficient number of harmonics and to provide the equivalent of a high frequency wave without the use of any high frequency generator or circuits. As a result, the pulses or voltage peaks behave from the point of view of ionization of the combustible gas or mixture in the manner similar to a continuous high frequency wave or voltage applied to a spark gap, such as the spark plug of the type as used in conventional internal combustion engines.

In other words, the invention utilizes a series of discrete high voltage sparks in place of a single ignition spark during a single ignition period, resulting in improved efficiency of the combustion of the explosive mixture and, in turn, in increased thermal efficiency of the engine. As a result, replacement of a conventional ignition system by the improved system according to the present invention will result in a substantial increase of output power for a given fuel consumption, or vice versa, in reduced fuel consumption for a given output power. The train or series of sparks during a single ignition period consists of elementary sparks having substantially the same power, independently of the operating condition of the engine, such as starting, idling or operation, thus insuring reliability of operation and optimum efficiency at all times. Furthermore, by the use of multiple spark ignition according to the invention, interference with or interruption of the ignition as a result of fouling of the spark plugs, moisture and other causes is greatly reduced or minimized.

Referring to Fig. 1, there is shown a pulse voltage generator connected to the distributor of a reciprocating internal combustion engine as used in motorcars or the like and assumed to be of the four cylinder type in the example illustrated. The pulse voltage generator, in the example shown, consists of a square wave oscillator or multivibrator comprised of a twin-triode amplifier tube 10 having two triode sections mounted in a common envelope and each comprising a cathode, grid and plate electrode of conventional design. The cathodes of both triode sections, which may be in the form of separate tubes, are connected directly to ground or other potential reference point, such as the metal chassis or frame

of the engine, while the grid electrodes are grounded through grid leak resistors **11***a* and **11***b* and the plates are connected to the positive terminal of a suitable high voltage supply source indicated by the plus sign through load resistors **12***a* and **12***b*, respectively. Each of the plates of one section is furthermore connected to the grid of the other section through a coupling capacitor **13***a* and **13***b*, respectively, whereby to cause the circuit to operate as a self-running bi-stable relaxation oscillator by alternately passing current through the triode sections at a frequency determined by the circuit constants, that is, the grid leak resistances **11***a* and **11***b* and feedback capacitors **13***a* and **13***b*.

The square wave output voltage produced by the multi-vibrator is applied to the grid of a pentode power amplifier and peak voltage generator **14** by way of a grid coupling capacitor **15** and grid leak resistance **16**, to produce high voltage peaks or pulses in the output or plate circuit of the amplifier by the action of a special plate peaking inductance **17**. More specifically, during the positive half cycles of the impressed square wave voltage or conducting periods of the tube **14**, magnetic energy will be stored in the coil or inductance **17** which energy, at the starting of the negative half-cycles of the impressed voltage or interruption of the current through the tube, collapses suddenly in such a manner as to generate a series of steep-fronted peak voltages or pulses at the anode of tube **14**, as shown at V, Fig. 1A. These pulse trains or peak voltages are applied to the contacts **25***a*, **25***b*, **25***c* and **25***d* of a distributor **24** by way of a movable or rotary contact arm or finger **23**, to ignite or fire the spark plugs **26***a*, **26***b*, **26***c*, **26***d* connected to said contacts, respectively, in the manner shown and readily understood.

In order to produce and apply ignition pulses only during the time of connection of a spark plug to its respective distributor contact, or in other words to provide a series of discrete pulse trains during successive time periods *m* separated by suitable time intervals *n*, Fig. 1A, there is further provided a make and break device periodic interrupter inserted, in the example shown, in the ground circuit of one of the cathodes of the multi-vibrator **10** and comprised of a spring-biased pivoted contact arm **20** having a projection **21** cooperating with a rotating cam **22** synchronized with the movable distributor contact **23**, as indicated by the curved arrows *a* and dot-dash line **22***a* in the drawing. Contact arm **20** being grounded carries a first contact **18***a* which cooperates with a second stationary contact **18***b*, said contacts being inserted in the ground lead of one of the cathodes of the multi-vibrator, to effect a control of the multi-vibrator to produce a train or series of discrete peak voltages or pulses in synchronism with the connecting periods of the spark plugs **26***a* to **26***d* to the output of the amplifier **14**. The number of voltage pulses or sparks during each ignition period may be suitably chosen to insure a sufficient number of discrete ignitions or sparks at maximum operating speed of the engine and to cause the number of sparks to increase as the speed is reduced for the purpose further understood from the following.

In the case of conventional engines for motorcars, a pulse or spark repetition frequency of from 1000 to 5000 pulses per second has been found to provide satisfactory results, although the optimum number of sparks for each ignition period varies according to different engines and can be determined by experiment.

In order to prevent arcing or sparking between the distributor contacts as a result of excess voltages due to unsatisfactory operation or fouling of one or more of the spark plugs, there is advantageously provided an excess voltage arrester connected between the plate of the amplifier **14** and ground and comprising, in the example shown, a resistor **28** and gaseous discharge tube **30**. Any equivalent means or device may be provided for this purpose, as will be understood. The value of resistor **28** should be suitably selected, too high a value resulting in inefficient by-passing or excess voltage suppression and too low value causing a reduction of the amplitude of the pulse voltage and decreased efficiency of the ignition by the spark gaps **26***a* to **26***d*.

In place of the multi-vibrator type peak voltage generator, it is understood that any other equivalent square wave or peak voltage generator known in the art may be used for the purpose of the invention.

In the case of a motorcar, the direct current high voltage for the operation of the multi-vibrator and power amplifier may be derived from the low voltage generator or battery by the aid of any suitable direct current voltage transformer, such as a vibrator power supply of the type commonly used in connection with automobile radio sets. In the example illustrated, there is shown for this purpose a vibrator type direct current transformer connected to the standard electric supply system, comprising the generator **32**, storage battery **33** and automatic cut-out **32'**, by way of a switch **34** and interference filter **35** of known construction. The vibrator shown is of the synchronous interrupter and mechanical rectifier type and comprises a grounded vibrating element or reed **40** carrying a contact **41** which cooperates with a magnet core having a winding **42** connected to the circuit to cause continuous vibration of the element **40** by automatic interrupter action, in a manner well known and understood by those skilled in the art.

Cooperating with the element **40** are a first pair of interrupting contacts **37***a* and **37***b* connected to the opposite ends of the primary winding **36***a* of a voltage step-up transformer **36**, the center point of said winding being connected to the low voltage source, that is, the generator **32** or battery **33**. The element **40** is furthermore arranged to cooperate with a pair of synchronous rectifying contacts **38***a* and **38***b* connected to the opposite ends of the transformer secondary **36***b*, whereby to provide a stepped-up direct current output voltage between the center point of winding **36***b* and ground. This output voltage serves to supply the pulse generator through a further switch or circuit breaker **45**. Resistors **43***a* and **43***b* and capacitors **44***a* and **46** connected to the winding **36***b* act as a filter to smoothen or steady the direct current output voltage, in a manner well known in connection with vibrator type power supply devices of this type. The output voltage of the vibrator may have a sufficient value for energizing the multi-vibrator or other pulse voltage generator, depending upon the type of tubes or circuits used.

According to a preferred embodiment, the switch **45** may be of the mercury type, to interrupt or disconnect the pulse voltage generator in case of extreme shock to which the motor or vehicle may be subjected and to avoid interference with or undesirable operation of the ignition system.

There is thus provided by the invention a new and improved ignition system which while using peaked or pulsed voltage of relatively low frequency provides all the benefits of a high frequency ignition system, substantially without the drawbacks and defects of the latter. By choosing a suitable pulse recurrence frequency of the voltage peaks V, that is, such as to provide a sufficient number of discrete peaks or pulses during maximum engine speed, there will be insured a sufficient content of high harmonics of adequate amplitudes to cause high frequency ionization of the gaseous mixture, resulting both in reliable starting of the ignition and in increased combustion efficiency.

Assuming, by way of example, a maximum engine speed of 3000 revolutions per minute, that is, 50 revolutions per second, and a contact angle $\alpha=18°$ (see Fig. 4), the period of one revolution will be equal to $\frac{1}{50}$ sec. while a single contact closing period will be equal to

$$\frac{18}{50 \cdot 360} = \frac{1}{1000} \text{ sec.}$$

Assuming further a peak voltage recurring frequency of 5000 pulses per second, the number of pulses per single ignition at maximum engine speed will be 5 pulses and 50 pulses at an engine speed of 300 revolutions per minute. Provided the instantaneous or peak value of the pulses is of a sufficient magnitude, say from 3000 to 5000 volts, there is insured in this manner an adequate amount of high harmonic frequencies of sufficient intensity to cause ionization of the gaseous mixture and, in turn, insure ready starting of the ignition and other desirable effects.

In order, according to an improved feature of the invention, to avoid arcing or sparking between the distributor contacts, the interrupter and the distributor are designed in such a manner as to cause the movable or rotary contact **23** of the distributor to engage a stationary contact **25***a*—**25***d* prior to the starting of a train or series of voltage peaks and to interrupt the train of voltage pulses before the rotary contact **23** leaves or becomes disengaged from the stationary contacts of the distributor. This design and operation will be further understood by reference to Figs. 2, 3A and 3B.

Referring to Fig. 3A, there is shown the instant when the contacts **18***a* and **19***b* become closed or engaged as indicated by the arrow *b* showing the movement of the contact arm **20**, thus starting the operation of the multi-vibrator or other pulse generator to produce a series of trains of pulses or peak voltages V, as shown in Fig. 1A. This instant corresponds to a position of the rotary contact of the distributor having already engaged one of the stationary contacts such as **25***b* as shown at **23** in Fig. 2. Fig. 3B shows the position of the cam **22** at the instant when the contacts **18***a* and **18***b* become again separated or disengaged, as indicated by the arrow *c* in the drawing. The corresponding position of the contact arm **23***a*, shown in dotted lines in Fig. 2, is such as to still engage the stationary contact **25***b*. As a result the contact arm **23** engages and disengages the stationary contacts **25***a*—**25***d* of the distributor in a substantially currentless condition, thus avoiding arcing or sparking and deterioration or wear of the contacts of the distributor. Furthermore, since the periodic interrupter or contactor **20** actuated by the cam **22** carries only the relatively weak space discharge current of the multi-vibrator, arcing of the interrupter contacts is practically negligible, whereby to result in high operating stability and long life of both the interrupter and distributor. It will be understood that the control of the multi-vibrator or pulse generator by interrupting the ground return of one of the tubes or sections is by way of example only, many other ways to start and stop the pulses V, such as by interruption of the grid circuit of either of the multi-vibrator sections or tubes or of the power amplifier, being possible and suggesting themselves to those skilled in the art.

If the ignition system according to the invention is used in connection with engines of the type provided with the automatic ignition advance with increasing engine speeds by means of centrifugal advance weights or equivalent means, further provision should be made according to the invention in the design and/or adjustment of the distributor and pulse train interrupter, to take care of any manual or automatic advance adjusting range by the proper dimensioning of the distributor contacts in relation to the angular operating range of the interrupter, in the manner shown and more clearly understood by reference to Figs. 4 and 5.

Fig. 4 shows the position of the cam **22** in the center of the closing period of contacts **18***a* and **18***b* assumed to have an angular operating range equal to 20°. In this case the contacts of the distributor, as shown in Fig. 5, may have an angular width of 35°, this including a range of 2.5° at each end to avoid arcing or sparking as explained in reference to Figs. 2, 3A and 3B, and an additional 10° to take care of the manual and/or automatic advance adjustment of the ignition, depending on the type or design of the engine, as will be readily understood.

Fig. 6 shows the shape of a pair of elementary sparks S produced by the high voltage pulses V which behave in the manner of a high frequency wave as a result of its high harmonic content, in the manner pointed out hereinabove.

In order to obtain sharp-pointed or peaked voltage pulses V at the output of the pulse voltage generator, it is advantageous to use a special low-leakage type of peaking transformer **17**, as shown in Fig. 7. In the latter, the inductance comprises a hollow cylindrical housing **50** consisting of a suitable insulating material capable of withstanding high voltage such as Plexiglas or an equivalent synthetic insulating material and having mounted therein a number of pancake-shaped induction coils **51** spaced from each other and supported by a center magnetic core **52** of high permeability.

For practical purposes, it is possible to use a standard distributor for the purpose of the invention, with slight modification to comply with the requirements of the invention, as pointed out, and using a high grade insulating material, such as nylon or Teflon as a base member in which are mounted by directly molding or otherwise securing the fixed contacts **25***a*—**25***d* for cooperation with the rotary contact **23**.

In the foregoing the invention has been described with specific reference to an illustrative device. It will be evident, however, that numerous variations and modifications, as well as the substitution of equivalent parts and elements for those shown and described for illustration, may be made without departing from the broader scope and spirit of the invention as set forth in the appended claims. The specification and drawing are accordingly to be regarded in an illustrative rather than in a limiting sense.

We claim:

1. In an internal combustion engine having a plurality of spark plugs and a spark plug distributor; an ignition system comprising a source producing a peaked voltage wave constituted by a series of spaced discrete and unidirectional high voltage pulses having a substantially constant pulse recurrence frequency independent of the engine speed, said distributor periodically connecting the spark plugs to said source, a periodic make and break device synchronized with said distributor and connected to said source, to control the spark plug firing periods, said recurrence frequency having a value to provide a multiplicity of high voltage pulses during each spark plug firing period having a predetermined minimum at maximum engine speed and increasing in number in proportion as the engine speed decreases, said pulses being separated from each other by spacing intervals to effect a corresponding number of discrete ignition sparks during each spark plug firing period.

2. An ignition system as claimed in claim 1, said source being comprised of a square voltage generator and an amplifier having an input circuit controlled thereby and including a peaking inductance in its output circuit, to convert the square wave generated into a series of discrete unidirectional high voltage pulses.

3. In an ignition system as claimed in claim 2, said generator consisting of a pair of amplifier devices connected to form a multi-vibrator and said make and break device being connected in the input circuit of one of said amplifier devices.

4. In an ignition system as claimed in claim 1, including excess voltage arresting means connected in parallel with said source and distributor.

5. In an internal combustion engine comprising a plurality of spark plugs and a spark plug distributor having stationary contacts connected to said spark plugs and a cooperating rotating contact synchronized with said engine; an ignition system comprising a source connected

to said rotating contact and producing a peaked voltage wave being constituted by a series of spaced unidirectional high voltage pulses having a substantially constant pulse recurrence frequency independent of the engine speed, a make and break device connected to said source and synchronized with said distributor, said make and break device having a ratio of closing to opening periods related to the ratio of spark plug firing closing to opening periods of said distributor, to cause a substantially currentless connection and disconnection of the distributor contacts by said rotating contact, said pulse recurrence frequency having a value to provide a multiplicity of high voltage pulses during each spark plug firing period being a predetermined minimum at maximum engine speed and increasing in number in proportion as the engine speed decreases, said pulses being separated from each other by spacng intervals to effect a corresponding number of discrete ignition sparks during each spark plug firing period.

6. An ignition system for internal combustion engines as claimed in claim 4, including ignition advance and retarding means associated with said distributor, the relative closing and opening periods of said make and break device and of said distributor, respectively, designed to maintain a currentless connection and disconnection of the distributor contacts throughout the full ignition advance and retard operating range of said engine.

References Cited in the file of this patent

UNITED STATES PATENTS

1,207,193	Mason	Dec. 5, 1916
1,334,095	Hill	Mar. 16, 1920
1,589,489	Snook	June 22, 1926
1,605,724	Heaton	Nov. 2, 1926
1,968,930	Cotter et al.	Aug. 7, 1934
2,353,527	Touceda et al.	July 11, 1944
2,389,637	Ruben	Nov. 27, 1945
2,392,192	Robinson	Jan. 1, 1946
2,447,377	Tognola et al.	Aug. 17, 1948
2,632,133	McNulty	Mar. 17, 1953
2,833,963	Tognola	May 6, 1958

FOREIGN PATENTS

509,801	Belgium	Mar. 31, 1952