Nov. 22, 1960 J. D. HARNDEN, JR 2,961,580

IGNITION SYSTEM

Filed Dec. 27, 1957 3 Sheets-Sheet 1

Fig. 1.

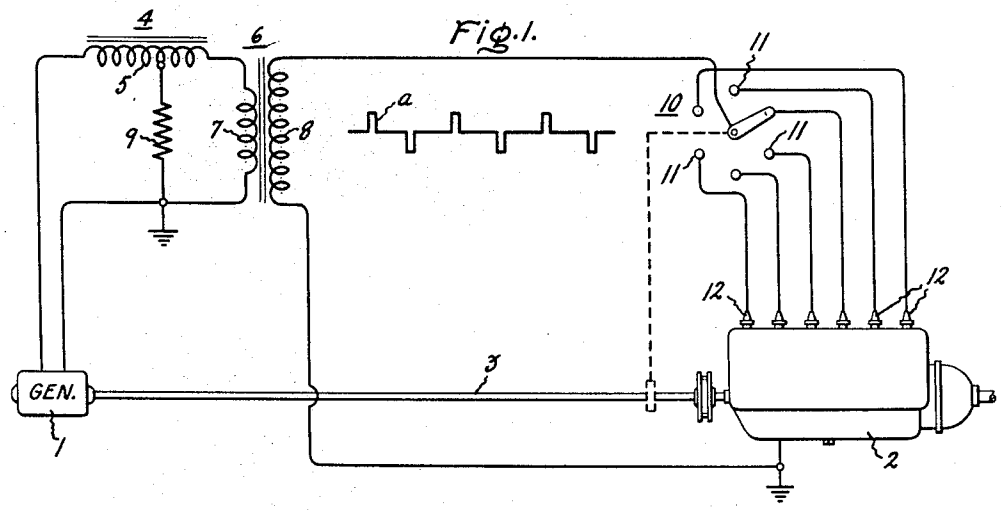


Fig. 2a

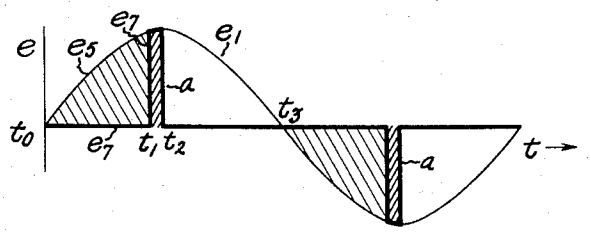


Fig. 2b.

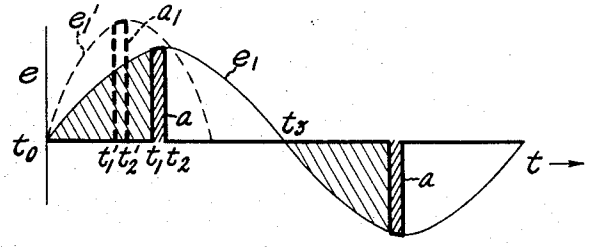
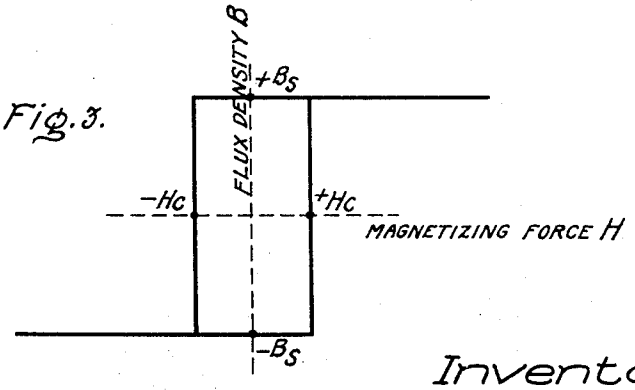


Fig. 3.



Inventor:
John D. Harnden, Jr.;
by Merton D Morse
His Attorney.

Nov. 22, 1960 J. D. HARNDEN, JR 2,961,580

IGNITION SYSTEM

Filed Dec. 27, 1957 3 Sheets-Sheet 2

Fig. 4.

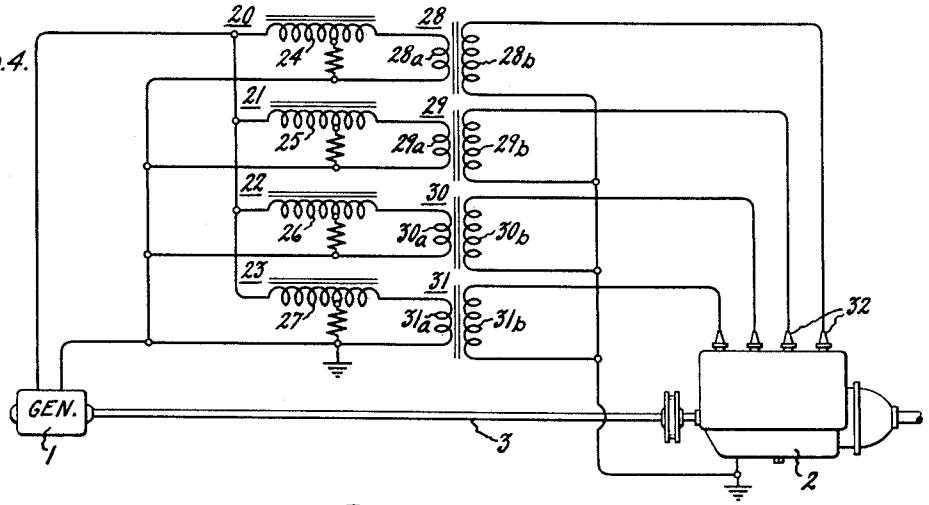


Fig. 5a.

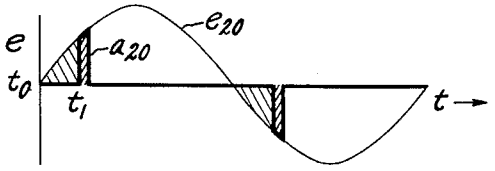


Fig. 5b.

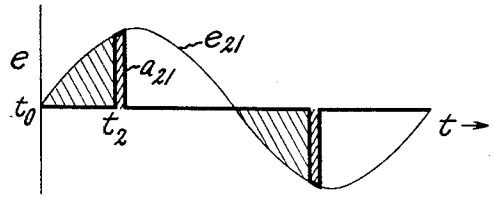


Fig. 5c.

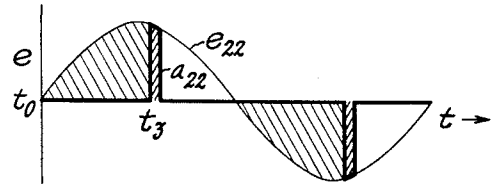


Fig. 5d.

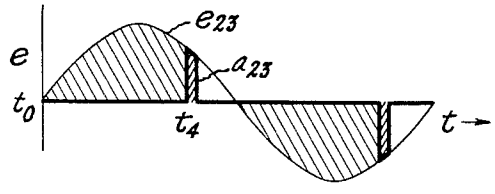
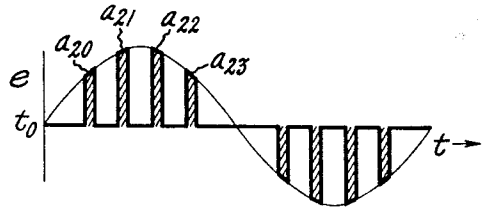


Fig. 5e.



Inventor:
John D. Harnden, Jr.;
by Morton D. Rose
His Attorney.

Nov. 22, 1960 J. D. HARNDEN, JR 2,961,580

IGNITION SYSTEM

Filed Dec. 27, 1957 3 Sheets-Sheet 3

Fig. 6.

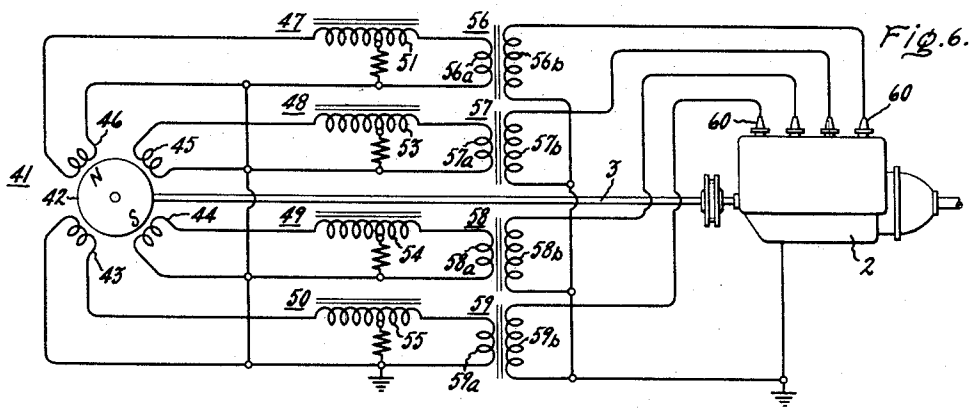


Fig. 7a.

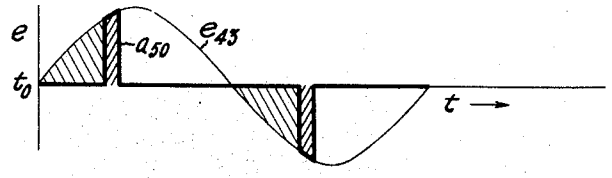


Fig. 7b.

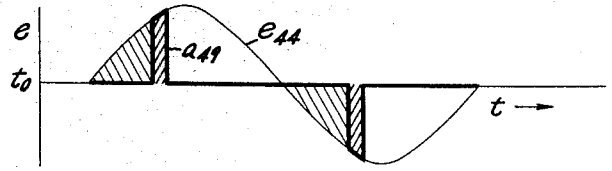


Fig. 7c.

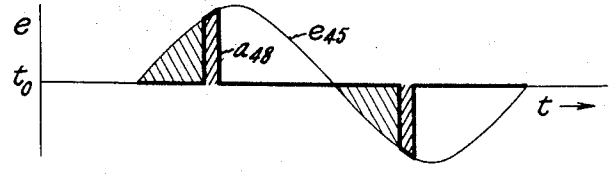


Fig. 7d.

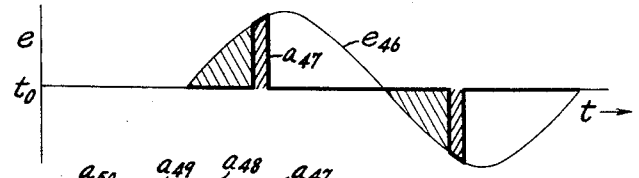
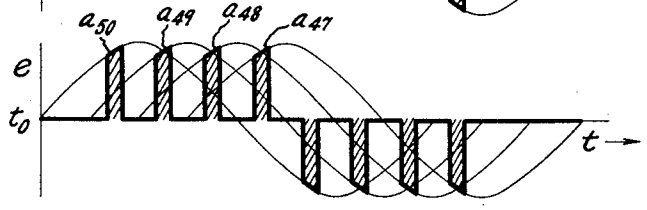


Fig. 7e.



Inventor:
John D. Harnden, Jr.,
by Merton D Morse
His Attorney.

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2,961,580

IGNITION SYSTEM

John D. Harnden, Jr., Schenectady, N.Y., assignor to General Electric Company, a corporation of New York

Filed Dec. 27, 1957, Ser. No. 705,551

14 Claims. (Cl. 315—254)

This invention relates to an ignition system for internal combustion processes and, more particularly, to an ignition system utilizing a pulse generator for producing ignition impulses constructed from saturable impedance devices.

One of the objects of my invention is to provide an ignition system which eliminates the use of mechanical breaker point assemblies. Conventional ignition systems as utilized in today's internal combustion engines comprise a spark coil having a low voltage primary energized from a unidirectional source, such as the car battery, and a high voltage secondary connected through the mechanical distributor to the spark plugs. The high voltage ignition impulses for breaking down the spark gap in the plugs are produced by a breaker assembly connected in the primary of a spark coil. This breaker assembly is actuated periodically to interrupt the circuit, thereby producing rapid change in flux in the spark coil and inducing high voltage impulses in the secondary of the coil.

Such ignition systems leave much to be desired from the standpoint of effectiveness, reliability and efficiency.

It is quite clear that the current interrupting breaker points place an inherent limitation upon the entire system, since these points must carry the entire primary current for firing the cylinders in the engine, causing severe wear and ultimate destruction of breaker point surfaces. In addition to the necessary periodic replacement of the points, a continuous deterioration of engine performance results, since the rapidity with which the primary circuit can be interrupted and consequently the sharpness of the impulses decreases as the breaker point surfaces are destroyed. Because of the degeneration of these impulses, proper ignition is hindered, resulting in poor engine performance and increased fuel consumption.

Furthermore, conventional ignition systems are inherently inefficient, since a major portion of the system power is dissipated across the breaker points rather than in the spark discharge.

Modern engine design leading towards increased horsepower and compression ratios intensify all of the problems resulting from the use of mechanical interrupting means since higher power levels at the spark discharge gaps are required and thus the breaker points must interrupt higher currents accelerating the destruction of the breaker point surfaces. A limit has thus been reached in the application of presently available ignition systems and an entire new approach and philosophy is required.

One solution to this problem, disclosed in patent specification Serial No. 705,669 entitled "Ignition Systems" by E. D. Cook, filed December 27, 1957, assigned to the General Electric Company, utilizes a saturable magnetic device to release power periodically from an alternating current source to the spark plugs. The saturable magnetic device includes a direct current control winding incorporating a breaker point assembly actuated in synchronism with the engine to control the saturation of the magnetic device. Thus, the breaker points act as the synchronizing means in the control winding circuit to supply

electrical power to the spark plugs and do not interrupt the primary current. Hence, the load on the breaker points is reduced with the consequent reduction of the breaker point surface attrition. However, the elimination of the breaker points by utilizing an entirely static magnetic pulse generator to supply the ignition impulses is desirable.

One of the advantages of such a system is that a low power alternating voltage source may be utilized. Furthermore, spark advance and retard may be achieved without utilizing mechanical movements. In addition, it is also possible to eliminate the mechanical distributor entirely.

It is another object of this invention, therefore, to provide an ignition system utilizing completely static magnetic ignition pulse generating means.

A further object of this invention is to provide an ignition system utilizing electrical spark advance and retard control.

Still another object of this invention is to provide an ignition system utilizing contactless distributing means.

Other objects and advantages of the invention will become apparent as the description of the invention proceeds.

The above objects are achieved by means of a static saturating magnetic pulse generator energized from an alternating voltage source driven from the engine. The self-saturating magnetic pulse generator produces a steep wave front impulse during each alternation of the voltage by the successive saturation of a pair of saturable impedances.

In alternative embodiments, a multiplicity of pulse generating networks is provided for producing a multiplicity of time-displaced ignition impulses during each alternation of the alternating voltage, the pulses from the individual networks being coupled to different ones of the engine spark plugs, eliminating the mechanical distributor.

The novel features which are believed to be 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 together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the accompanying drawing in which:

Figure 1 is a schematic diagram of one embodiment of the invention;

Figures 2*a*–2*b* are waveforms useful in illustrating the operation of the circuit of Figure 1;

Figure 3 is a graph illustrating an idealized rectangular hysteresis loop useful in explaining the operation of the saturable devices of Figure 1;

Figure 4 is a schematic diagram of an alternative embodiment of the invention utilizing contactless distribution;

Figures 5*a*–5*e* are waveforms useful in illustrating the operation of the circuit of Figure 4;

Figure 6 is yet another embodiment of the invention; and

Figures 7*a*–7*e* are waveforms useful in illustrating the operation of the circuits shown in Figure 6.

Referring now to Figure 1, the ignition system includes an alternating voltage source driven by the engine and a pair of saturable magnetic devices adapted to saturate at different times during each voltage alternation to produce an ignition impulse during each alternation. Thus, a source of alternating voltage **1**, such as a tachometer generator or the like, is driven by the internal combustion engine **2** through the medium of the timing shaft **3**, such as the camshaft which operates in fixed time relation to the movement of the reciprocating engine elements, to produce an output voltage, the frequency of which is pro-

portional to the engine speed. Coupled to the generator 1 is a static magnetic pulse generator 4 comprising a saturable reactor 5 and a saturable transformer 6, the primary winding 7 of which is connected in series with the reactor 5 across the generator terminals. A high leakage resistance 9 is connected between a point on the saturable reactor 5 and one terminal of the voltage source 1 to provide a path for a portion of the reactor 5 exciting current. The saturable devices 5 and 6 are so constructed that they saturate during different points during each voltage alternation to produce the ignition impulse. The secondary high voltage winding 8 of the saturable transformer 6 has one end thereof connected to ground and the other end to a distributor 10 to distribute ignition impulses through distributor contacts 11 sequentially to the appropriate spark plugs 12 of the internal combustion engine.

The saturable devices of pulse generator 4 have their cores formed of rectangular hysteresis loop material. Such material, as is well known to those skilled in the art, has a sharp transition point between conditions of saturation and non-saturation, so that their impedance can change almost instantaneously from a high value to substantially zero; an idealized hysteresis characteristic of this type being illustrated in Figure 3. Reactor 5 acts essentially as a hold-off reactor so that, in its unsaturated condition, substantially all of the voltage appears across it, blocking voltage from the saturable transformer 6. However, reactor 5 saturates at time t_1 during each alternation with its impedance dropping substantially to zero, supplying full voltage across the primary winding 7 of transformer 6. However, the saturable transformer 6 saturates soon after at a time t_2 so that voltage is coupled into the secondary and through the distributor to the respective spark plugs during the interval t_1 to t_2.

To compehend the operation of the pulse generator 4 of Figure 1 completely, it would be well to examine the underlying theoretical considerations governing the operation of saturable impedance devices such as 5 and 6. The flux change in inductors such as 5 and 6 is, as is well known, proportional to the voltage time integral of the inductive component and is defined by the equation:

$$\phi=\frac{K}{N}\int e dt$$

where

N=the number of turns of wire in the winding of the inductor.
K=a constant determined by the core material.
e=instantaneous voltage.
t=time in seconds.
ϕ=the magnetic flux.

It is also known that the flux density in a core is defined by the equation:

$$B=\phi/A$$

where

B=flux density/sq. unit of area.
A=cross sectional area of core of the inductor.

Thus, the volt integral equation can be rewritten to read:

$$B=\frac{K}{NA}\int e dt$$

It is obvious from the above equation that the time required for saturation may be varied by varying any one of the factors defined in the above equations. However, once all of the parameters for a given inductor are settled; i.e., N, A, K, the volt-seconds $\int e dt$ are fixed for that particular saturable device.

Keeping this in mind, the operation of the ignition system of Figure 1 may best be understood by reference to Figures 2*a* and 2*b*. Initially, both the saturable reactor 5 and saturable transformer 6 are unsaturated; however, the impedance of the reactor 5 is such that substantially all of the voltage during the illustrated positive alternation appears across the reactor 5 as e_1, shown in Figure 2*a*, and none across winding 7. At time t_1 determined by its parameters, the necessary volt-seconds, illustrated by means of the shaded portion, cause the reactor 5 to saturate and its impedance drops substantially to zero. Therefore, after t_1 substantially all of the generator voltage appears across the primary 7 of the saturable transformer 6 as the voltage e_7. However, the parameters of the saturable reactor 6 are such that it holds off only a very small volt-second area and shortly after, at time t_2, it saturates, its impedance dropping substantially to zero, removing voltage across the secondary 8 terminating the ignition impulse. At time t_3 the core has returned to $+B_s$ and is in condition to traverse the reverse side of the loop during the negative alternation.

During the negative alternation the same reactor saturation sequence occurs producing a negative impulse. Thus, an ignition impulse is produced during each alternation of the voltage produced by the voltage generator 1 with successive pulses having opposite polarities.

After t_2 until the end of each alternation at t_3 the current is limited only by the circuit resistances of the saturable reactors 5 and 6. Although this value of resistance is small, overheating will not result since the tachometer generator 1 utilized as the alternating voltage supply for the circuit contains reactance which limits the current flow. Leakage resistance 9 is of very high value and, as has been pointed out previously, merely provides a path for the exciting current of the saturable reactor 5.

From an examination of Figure 2*a* it becomes apparent that such an ignition system requires a generator having a small power output because the average power requirement is low and the efficiency is high. During the interval t_0–t_1 essentially the only current flowing is the small exciting current reactor 5, determined by the coercive force H_c, illustrated in Figure 3, so that the power dissipation is negligible. Similarly, from T_1–T_2 substantially all the power goes into spark energy, less small copper and core losses. This is in striking contrast to present day ignition systems where approximately twice as much power is dissipated in the system as is delivered to spark plugs.

It is apparent in considering the ignition system of Figure 1 that changes in engine speed affect the output frequency of the tachometer generator 1 since it is driven from the engine cam shaft 3. Figure 2*b* illustrates the relationship between the alternating voltage output of the generator 1 for different engine speeds. The solid curve e_1 represents the generator output for one speed and broken curve e_1' that for a higher speed. It is clear that the time t_1' and t_2' when reactors 5 and 6 saturate for voltage e_1' occurs earlier than t_1 and t_2 for the voltage wave e_1. Hence, output pulses a' and a are produced which are time displaced. That is, assuming that the tachometer generator 1 has a linear voltage versus frequency characteristic, at higher frequencies the amplitude increases and hence the volt-seconds to saturate the reactors are achieved earlier in time, preserving the electrical firing angle. That is, although the pulses a' and a occur at different times they occur at the same position in electrical degrees of their respective voltages e_1' and e_1.

In describing the functioning of pulse generator 4 with reference to Figure 2*b* for various engine speeds and generator frequencies, it was assumed, for simplicity of explanation, that the ignition impulses are produced with their electrical firing angle preserved. However, in actuality, as engine speed varies it is necessary to provide steady state spark advance or retard with variations in engine speed to insure proper operation. This is achieved by varying the point in electrical degrees at which the reactors saturate. For the small amount of spark advance required, one effective approach is to utilize a tachometer the output of which has a linear voltage vs.

frequency characteristic. The output voltage is connected to a bias winding having a capacitor connected in series therewith which thus provides a frequency sensitive circuit element having high impedance at low and low impedance at high frequencies. The bias winding is wound on the core of the reactor **5** and provide a bias varying with frequency and thus speed, producing saturation earlier in the alternation (in advance of t_1) with increasing speed.

Another approach contemplates using control and bias windings with the saturable reactor **5** that are energized from the tachometer generator voltage, the magnitude of which is varied by a potentiometer arrangement understood to be both static and contact in response to the engine throttle movement to compensate for transient advances.

Yet a third alternative for controlling the advance or retard of the spark is to use a saturable reactor element **5** of the variac type having a variable number of turns which may be selectively changed to control the volt-seconds necessary for saturation. In this manner the electrical angle of the pulse may be advanced or retarded selectively from the throttle mechanism of the engine.

In addition it is, of course, possible to change the position of the tachometer generator stator directly from throttle with changes in speed to maintain spark control in a manner analogous to that utilized to control breaker point advance in present day ignition systems.

All of these various methods of controlling the spark conditions have been described, to illustrate briefly, the various techniques that may be utilized to enhance performance.

The output frequency per camshaft revolution of the tachometer generator **1** of Figure 1 is, of course, determined by the number of cylinders in the engine. That is, for example, in most six or eight cylinder engines it takes two camshaft revolutions to fire all the spark plugs in the engine. Since the pulse generator **4** produces two output pulses for each cycle of the alternating voltage, it becomes obvious that the construction of the tachometer generator and the relationship of the output frequency to each camshaft revolution is determined from these various parameters to produce an adequate number of ignition impulses to fire the engine.

In the ignition system illustrated in Figure 1, a single magnetic pulse generator is utilzed to produce a series of ignition impulses, whcih are applied to selected ones of the engine spark plugs by means of a mechanical distributor driven from the camshaft. Such a mechanical distributor means is subject to surface attrition of the distributor points since a mechanical wiper and contact arrangement transmits the ignition impulses. It is desirable, in order to achieve the utmost in reliability, to eliminate the mechanical distributor and Figure 4 illustrates an embodiment of such an ignition system. A multiplicity of pulse-generating networks of the type illustrated in Figure 1 are coupled to a source of alternating voltage driven from the engine. Each of the (n) individual pulse generating networks are directly and permanently coupled to one of the engine spark plugs.

An alternating voltage source, such as a tachometer generator **1**, is driven from the engine **2** by means of a camshaft **3** and has a pair of output terminals, one of which is grounded. The output voltage from the tachometer generator **1** is coupled to a multiplicity of pulse-generating networks **20**, **21**, **22** and **23**, connected in parallel across the generator terminals. The respective networks include saturable hold-off reactors **24**, **25**, **26** and **27**, and saturable transformers **28**, **29**, **30** and **31** having, respectively, primary windings **28***a*, **29***a*, **30***a* and **31***a*, and secondary high voltage windings **28***b*, **29***b*, **30***b*, and **31***b*. Each of the saturable hold-off reactors is connected in series with the primary winding of its respective saturable transformer across the output terminals of the tachometer generator **1**. Thus, each of the pulse generating networks **20**, **21**, etc., produces an output pulse during each alternation of the voltage from the generator **1**. Each of the secondary windings **28***b*, **29***b*, etc. are grounded at one end and connected at the other to an individual one of the spark plugs **32**. In this manner the output from the individual pulse generating means is continuously connected to a given one of the engine spark plugs **32**.

To achieve the proper spark plug firing sequence it is, of course, necessary that the output pulses produced by the individual pulse generators be displaced in time. To this end the individual hold-off reactors **24**, **25**, etc. of each of the pulse generating networks has a different volt-second characteristic and, as a consequence, saturates at different points during each voltage alternation. This may be seen most clearly with reference to Figures 5*a*–5*e*. Figure5*a* illustrates the characteristics of the pulse generator **20** and, as can be seen there, its hold-off reactor **24** has a volt-second characteristic such that it saturates at time t_1 to produce the pulse a_{20}. In Figure 5b, representing the operation of pulse generator **21**, the hold-off reactor **25** of this network is such that its volt-second characteristic causes it to saturate at time t_2 to produce a time displaced output pulse a_{21}. In a similar fashion, Figures 5*c* and 5*d* illustrate the characteristics of the remaining networks **22** and **23** which are so constructed as to produce the time displaced pulses a_{22} and a_{23}. As a consequence, a pulse train a_{20}, a_{21}, etc., such as is illustrated in Figure 5*e*, is produced during each voltage alternation from the tachometer generator **1** which pulses are directly coupled to one of the spark plugs.

For the sake of simplicity, the ignition system of Figure 4 has been illustrated as a four cylinder engine. It is obvious, of course, that this system is clearly applicable to engines of six or eight cylinder engines or, in fact, engines having any number of cylinders. Four cylinders were illustrated in order to simplify the drawing by minimizing the number of circuits shown; but it is apparent that pulse trains having any number of pulses may be produced by utilizing separate pulse-forming networks having different volt-second characteristics, eliminating the necessity for a mechanical distributor and thus greatly improving the reliability of the ignition system.

As can be seen from Figures 5*a*–5*e*, the individual pulses of the pulse train vary in amplitude depending on the position during each alternation at which they occur. It is obvious, of course, that the magnitude of the smallest pulse in the train must be sufficiently high to cause a breakdown of the gap of its individual spark plug. Hence, the minimum condition as far as sparking voltage is established by the smallest amplitude pulse in the pulse train.

In the ignition system of Figure 4 a multiplicity of networks, each having different saturation characteristics, are provided to generate the individual pulses of the train. However, it may be much more desirable in certain circumstances to utilize identical networks to avoid having to produce and utilize so many different ones. Figure 6 illustrates an alternative embodiment of the ignition system of Figure 4 wherein a multiplicity (n) of networks having the same saturation characteristics are provided which networks have applied thereto one of a multiplicity (n) of phase displaced alternating voltages to generate the required pulse train.

A multiphase alternating voltage source **41** such as a tachometer generator produces a multiplicity of phase displaced alternating voltages and is driven from an internal combustion engine **2** by means of the familiar camshaft **3**. The tachometer generator **41** is of the permanent magnet type, having a permanent magnet rotor **42** mounted on the camshaft, and n-spaced armature winding pairs **43**, **44**, **45** and **46** positioned around the periphery of the rotor so that n-phase displaced voltages are induced therein by each rotation of the permanent magnet rotor **42**. Each of the armature windings **43**, **44**,

etc. illustrated as a single coil for the sake of simplicity, of course, comprises a pair of coils. Since the individual armature windings are displaced in space about the periphery of the permanent magnet rotor, the voltages induced in the respective windings are phase displaced as illustrated in Figures 7*a*–7*d*. Each of the armature windings 43, 44, etc. is connected to an individual one of *n*-pulse generating networks 47, 48, 49 and 50. Each of these pulse networks include saturable hold-off reactors 51, 53, 54, and 55 and saturable transformers 56, 57, 58 and 59 having, respectively, primary windings 56*a*, 57*a*, 58*a* and 59*a*, and high voltage secondary windings 56*b*, 57*b*, 58*b* and 59*b*. The individual saturable hold-off reactors 51, etc. of the individual pulse networks are connected in series with the primary windings 56*a*, etc. of the saturable transformers across the armature windings 46, etc. Each network thus has applied thereto one of the phase displaced voltages from the generator 41.

The hold-off reactors 51, etc. of each network have identical volt-second characteristics whereby they saturate at the same point during each alternation. However, as the applied alternating voltages are phase displaced, each of these networks produce an output pulse displaced in time by a similar amount. Hence, as can be seen in Figure 7*e*, a multiplicity of output pulses a_{50}, a_{49}, a_{48}, and a_{47} are produced which are applied to individual ones of the spark plugs 60 through the respective secondary windings 56*b*, 57*b*, etc. of the individual transformers.

The ignition system of Figure 6 thus provides ignition impulses to the individual spark plugs of an internal combustion engine without utilizing a mechanical distributor system, achieving the utmost in reliability by eliminating all mechanical parts.

Once more, for the sake of simplicity of explanation and illustration, a four cylinder engine has been illustrated but it is obvious, of course, that the ignition system embodying applicant's invention may be utilized with internal combustion engines of any number of cylinders.

In describing the apparatus of Figure 6, a tachometer generator has been utilized which has a multiplicity of spaced armature windings to produce the desired number of phase displaced voltages. It will be apparent that the tachometer generator of Figure 6 may be replaced by a number of single-phase tachometers having permanent magnet rotors which may be positioned on the camshaft with the individual rotors so positioned relative to each other that the proper phase relation among their voltages is achieved.

From the previous description, it can be seen that an ignition system has been provided which utilizes no mechanical breaker points to produce the sparking voltage and which, is alternative embodiments, eliminates the need for mechanical distribution means. Thus, an ignition system of high accuracy, reliability, and efficiency has been provided.

It is apparent that the concept of this invention is not limited to internal combustion engines but may be used wherever electrical detonation is required such as, for example, oil burner ignition systems.

One of the very important advantages accruing is the inherent accuracy and stability of this system which eliminates the need for period adjustment and renewal of timing circuit components, such points, cams, etc., due to mechanical and electrical wear and failures.

In addition, by virtue of using an independent energy source; i.e., the engine driven generator, the system is not directly dependent on battery conditions resulting from numerous extraneous factors such as age, weather, prior history, etc.

While a particular embodiment of this invention has been shown it will, of course, be understood that it is not limited thereto since many modifications both in the circuit arrangements and in the instrumentalities employed may be made. It is contemplated by the appended claims to cover any such modifications as fall within the true spirit and scope of this invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In an engine ignition system, the combination comprising an alternating voltage generator driven from said engine, a completely static pulse generating means coupled to and continuously energized from said generator, said static pulse generating means including a hold off saturable impedance means adapted to block the voltage from said generator until it saturates at a given point during each voltage alternation whereby steep fronted ignition impulses are produced during each alternation.

2. In an engine ignition system, the combination comprising an alternating voltage generator driven from said engine, a magnetic pulse generating means coupled to said generator including a pair of saturable impedance means adapted to saturate at different points during each voltage alternation whereby steep fronted ignition impulses are produced across one of the saturable means during each alternation, and means coupled to said one of said saturable means to apply successive ones of said pulses to selected engine spark plugs.

3. In an engine ignition system, the combination comprising an alternating voltage generator driven from said engine, a magnetic pulse generating means coupled to said generator including a pair of series connected self-saturating impedance means adapted to saturate at different times during each voltage alternation whereby ignition impulses are produced across that impedance which saturates at the later time during each alternation, and means coupled to said last named impedance to apply said impulses to selected engine spark plugs.

4. In an engine ignition system, the combination comprising an alternating voltage generator driven from said engine, a magnetic pulse generating means coupled to said generator including a self-saturating impedance means, a self-saturating transformer means having a primary and secondary windings the primary winding of which is connected in series with said impedance means across said generator, said impedance means having a higher impedance and saturating earlier than said transformer means during each alternation whereby substantially all of said voltage appears across said impedance during its unsaturated condition and across said transformer during its saturated condition initiating a sharp pulse wave front upon saturation of said impedance means and terminating said pulse upon saturation of said transformer, and means coupled to the secondary winding of said transformer to distribute said pulses to engine spark plugs.

5. In an engine ignition system, the combination comprising an alternating voltage generator driven from said engine, a magnetic pulse generating means coupled to said generator including a hold-off saturable impedance having an impedance in its unsaturated condition such that substantially all of the voltage from said generator appears thereacross, a load saturable impedance having said generator voltage applied thereto upon saturation of said hold-off reactor to produce the front edge of an ignition impulse and producing the back edge of the ignition impulse when it saturates, and means coupled to said load impedance to apply said impulses to the engine spark plugs.

6. In an engine ignition system, the combination comprising an alternating voltage generator driven from said engine, magnetic pulse generating means coupled to said generator including a multiplicity of pulse forming means each adapted to produce a pulse during each alternation of said voltage, said pulse forming means comprising at least one saturable impedance means adapted to saturate at given points during each voltage alternation, and means coupled to each of said pulse forming means to apply the pulses therefrom to a selected one of the engine spark plugs.

7. In an engine ignition system, the combination com-

prising an alternating voltage generator driven from said engine, magnetic pulse generating means coupled to said generator including a multiplicity of pulse forming means each adapted to produce a pulse during each alternation of said voltage, said pulse forming means comprising a hold-off saturable impedance and a load saturable impedance, said hold-off impedance in its unsaturated condition holding said voltage off from said load impedance and transferring said voltage thereto upon saturation to produce pulses across said load impedance, and means coupled to the load impedances of each of said pulse forming means to distribute the pulses therefrom to a selected one of said engine spark plugs.

8. An engine ignition system according to claim 7 wherein the saturable load impedances are saturable transformers the primary winding of each being connected in series with its respective hold-off impedance and the secondary winding of each adapted to supply the pulses to one of the engine spark plugs.

9. In an engine ignition system, the combination comprising an alternating voltage generator driven from said engine, magentic pulse generating means coupled to said generator including a multiplicity of pulse forming means each adapted to produce a pulse during each alternation of said voltage, each of said pulse forming means producing a pulse during each voltage alternation which pulse is displaced in time relative to each of those produced by the remaining pulse forming means, and means coupled to each of said pulse forming means to apply the pulses therefrom to one of the engine spark plugs.

10. In an engine ignition system, the combination comprising an alternating voltage generator driven from said engine, magnetic pulse generating means coupled to said generator including a multiplicity of pulse forming means each adapted to produce a pulse driving each alternation of said voltage, each of said pulse forming means comprising two series connected saturable reactors having different volt-second characteristics whereby they saturate at different times during each voltage alternation to produce a pulse, the saturable reactors of each pulse forming means having volt-second characteristics which are different from corresponding reactor pairs of the remaining ones whereby a pulse train is produced during each voltage alternation, and means coupled to each pulse forming means to distribute the pulses to individual engine spark plugs.

11. In an engine ignition system, the combination comprising a multiphase alternating voltage generator driven by said engine producing a multiplicity of phase displaced alternating voltages, a multiplicity of pulse forming networks coupled to said generator and adapted to receive different ones of said phase displaced alternating voltages, each of said networks containing saturable impedance means having identical volt-second saturation characteristics with corresponding one of other networks whereby each network produces a pulse displaced from those of the remaining networks by the same number of electrical degrees as their associated phase displaced alternating voltage, and means coupled to each of said networks to distribute the respective pulses to one of the engine spark plugs.

12. The engine ignition system according to claim 11 wherein each of said networks comprises two series connected saturable impedances having different volt-second characteristics whereby a pulse is produced in each network during each voltage alternation.

13. The engine ignition system according to claim 12 wherein the alternating voltage generator comprises a permanent magnet rotor and n spaced armature windings having n phase displaced voltages induced therein, each of said armature windings being connected to one of n pulse forming networks to apply one of said phase displaced voltages to each.

14. In an engine ignition system, the combination comprising an alternating voltage generator means driven from said engine to generate an alternating voltage wave in fixed time relation to the operation of the engine, a completely static pulse circuit coupled to and continuously energized from said generator including a transformer comprising a primary and secondary winding, a saturable hold off impedance means coupled to one of the windings of said transformer to block the generator voltage from said transformer until said impedance means saturates to produce steep fronted ignition impulses at a fixed time in the period of said wave, and means coupled to said transformer to apply successive ones of said ignition impulses to selected engine spark plugs.

References Cited in the file of this patent

UNITED STATES PATENTS

2,212,404	Robinson	Aug. 20, 1940
2,392,192	Robinson	Jan. 1, 1946
2,456,743	Short	Dec. 21, 1948
2,774,878	Jensen	Dec. 18, 1956
2,791,724	Ekblom et al.	May 7, 1957