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IGNITION SYSTEM FOR INTERNAL COMBUSTION ENGINE

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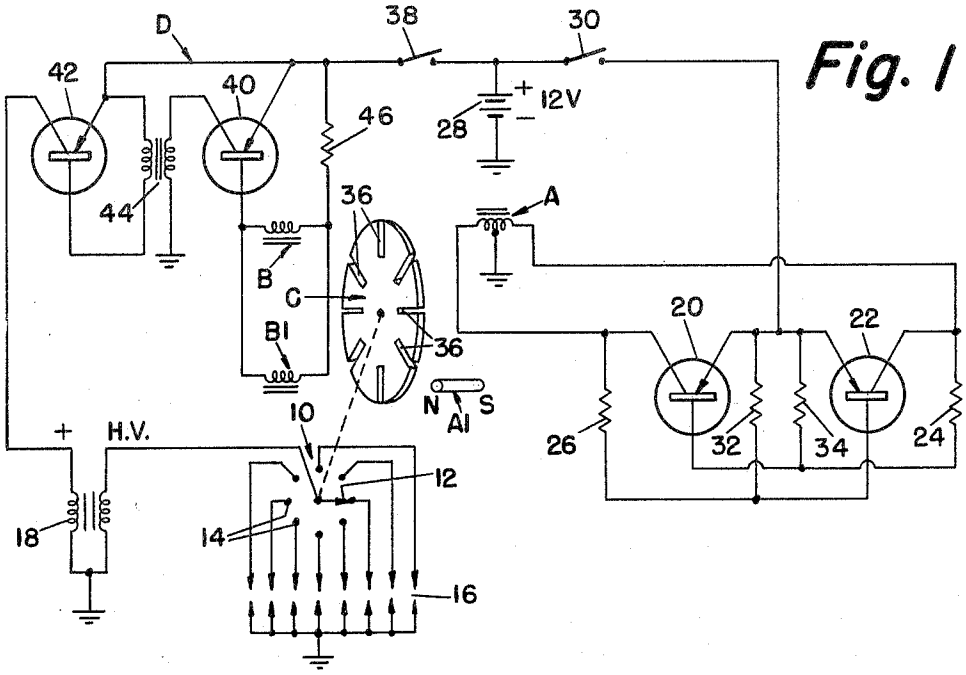
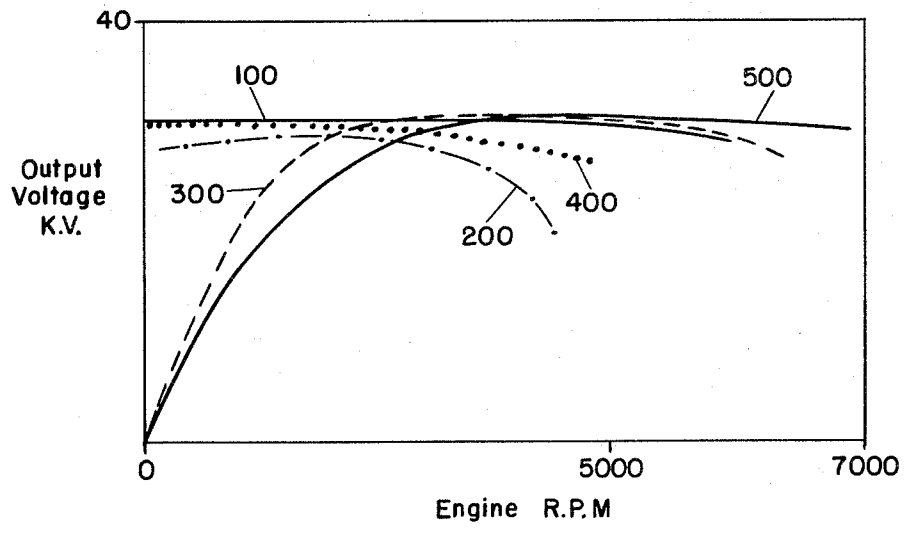


Fig. 1

Fig. 2



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IGNITION SYSTEM FOR INTERNAL COMBUSTION ENGINE

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This invention relates to an ignition system for an internal combustion engine, and more particularly relates to an electrical circuit and device for producing spark discharges in multi-cylinder engines which are subjected to wide ranges of speed, load, and temperature operating conditions.

The conventional ignition system for firing the cylinders of an automotive engine, for example, includes a spark induction coil, a rotary distributor, a cam-operated, make-and-break switch, commonly known as "points," and a condenser in parallel with the points. A battery is connected in series with the primary of the coil and the breaker points, the distributor rotor being connected to the coil secondary while the stator segments of the distributor communicate with the respective spark plugs.

It is well known that the breaker points are an engineering compromise which impose a very serious limitation upon engine operation over the extreme variety of operating conditions even normally encountered. First of all, due to interruption by the points of the large inductive current in the coil primary, a large arc is drawn across the points each time the contacts open. The arcing necessarily results in pitting and burning of the point contacts and is the primary cause of wear together with consequent and frequent replacement. Secondly, when the points close, current flows in the coil primary but builds up only slowly because the induced primary voltage opposes the battery voltage. The greater the number of turns in the primary, the greater is the induced back E.M.F. which accordingly results in deceleration in current build-up. Thirdly, the points must accept the feedback voltage from the secondary which also produces some arcing even though a certain portion of this feedback is absorbed by the condenser. At low r.p.m. when the engine is barely turning over, as for example, starting in cold weather, the points remain in contact much longer than during usual driving speeds. This prolonged contacting condition produces overheating and oxidation of the points and causes them to become "blue" with consequent increased contact resistance, the effect being loss of engine power, generally poor performance and difficult starting.

At high engine speeds, because of the increased size of the magnetic core necessary to produce high self inductance in the spark coil at cranking speeds, there is accordingly a substantial magnetic core loss which is sufficient to effectively decrease the high voltage at the secondary. The proportionate decrease in high voltage results in the frequently encountered high speed misses, and hence, poor fuel combustion, fouled plugs, with consequent engine residue and wear.

Although transistorizing the input to the spark coil by incorporating the points in the base circuit of a current limiting transistor switch and utilizing an ignition coil having a very closely coupled primary and secondary winding with a primary of relatively low inductance (see U.S. Patent No. 2,966,615) improves the foregoing deficiencies to some extent, the points are still subject to the natural vibrational frequency of their spring loading members which resonate at high speeds. That is, at speeds in the order of 5,000 r.p.m. which is quite common in racing engines, the spring loaded points cannot follow the cam actuation, and their resulting tendency to "float" yields a deficiency in current supply to the coil.

The conventional magneto which has been in existence for years and now used as standard equipment in aircraft, has an output curve which is opposite to that of the battery ignition. Thus, the magneto starts out very poorly because of its reliance on a rotating magnet for changes of flux through the coil, the weak output at cranking speeds resulting from a slow rate at which the flux is cut. However, at speeds above 1,000 r.p.m., the magneto becomes more efficient, and its output remains fairly level as the speed increases up to 5,000 r.p.m. In a magneto, when the induced voltage is highest, the magneto points open causing the field through the coil to collapse and thereby making available the voltage from the secondary to the plugs. Nevertheless, in addition to the great size and cost of a conventional magneto ignition, there still exists the inherent inability of the contact points to functionally follow at speeds in excess of 5,000 r.p.m. Thus, it is apparent that the use of contacting interrupter points must necessarily impede the progress in the development of higher speed internal combustion engines.

It is therefore an object of this invention to provide an ignition system for internal combustion engines in which breaker points are completely eliminated.

Another object of my invention is to provide an ignition system in which both the conventional make-and-break switch and electrical condensers may be discarded.

Another object of my invention is to provide an electrical circuit and device for a multi-cylinder ignition system wherein a substantially constant high voltage output is obtained independent of engine speed and load.

Another object of my invention is to provide an ignition system for a multi-cylinder internal combustion engine whereby full voltage, power and maximum efficiency will be afforded under a maximum range of conditions in engine speed, temperature and load.

Another object of this invention is to provide an ignition system in which destructive arcing and overloads are eliminated thereby permitting parts to be specified to greater tolerances.

Another object of this invention is to provide an ignition system of extremely stable characteristics and long-lasting life.

Another object of my invention is to provide an ignition system which is easily adapted to existing electrical systems.

Another object of my invention is to provide a timed interrupter ignition system in which no arcing occurs.

Another object of my invention is to provide an ignition system for an internal combustion engine in which voltage pulses delivered to the spark plugs are precisely timed and of optimum value and duration.

Another object of this invention is to provide an ignition system in which a substantially constant high voltage response is produced regardless of engine speed.

Other objects of this invention are to provide an improved device of the character described that is easily and economically produced, which is sturdy in construction, and which is highly effective and efficient in operation.

With the above and related objects in view, this invention consists of the details of construction and combination of parts as will be more fully understood from the following detailed description when read in conjunction with the accompanying drawing in which:

FIG. 1 is a circuit diagram and schematic representation of an ignition system embodying my invention.

FIG. 2 is a graphic diagram illustrating typical output responses versus engine speeds for various ignition systems including the instant invention.

Referring now in greater detail to the drawing in which similar reference characters refer to similar parts, FIG. 1 shows an ignition system for an internal combustion en-

gine comprising a transistor-energized oscillator coil A, a pick-up coil B air-spaced therefrom but in coupled communication therewith, and a circumferentially-spaced, radially-slit conductive disk C which is rotatable intermediate the oscillator and pick-up coils so as to interrupt the coupling therebetween at regular intervals.

The disk C is mechanically driven by the engine (not shown) together with a conventional distributor **10** preferably by means of a common shaft upon which the distributor rotor **12** is secured as indicated by the broken line in FIG. 1. A gear or pulley drive may also be employed for this purpose. Distributor stator elements **14** are respectively connected to a like plurality of spark plugs **16** in the usual conventional manner. The electrical signal or pulses transmitted to the coil B are first amplified by a booster electronic circuit D which then energizes an induction spark coil **18** to apply the potential for firing the plugs **16** through the distributor rotor **12**.

The transistorized input circuit is essentially a D.C. to A.C. converter and comprises a pair of P-N-P transistors **20** and **22** which operate as a multi-vibrator oscillator generating square waves at a high frequency, preferably above 30 kilocycles per second. A pair of 2N176's or ST20's may be employed for this purpose. The base of transistor **20** is connected to the collector of transistor **22** through a 100 ohm, 20 watt resistor **24** for example. Similarly, the base of transistor **22** is connected to the collector of transistor **20** through a 100 ohm, 20 watt resistor **26**. The emitters of both transistors are coupled together and connected to the positive terminal of a battery **28** through a switch **30**. The bases of the transistors are further coupled to their respective emitters by way of resistors **32** and **34**, each being rated at 15 ohms, 2 watts as an illustration. The ends of the input coil A are connected across the collectors of the two transistors **20** and **22** while the center tap of the coil is returned to the negative terminal of the battery through ground.

Each of the coils A and B are wound on respective soft iron cores which are spaced in air from each other, and a voltage will be induced in the coil B so long as the magnetic flux generated by the high frequency oscillations in coil A is permitted to link the two coils.

The disk C is made of a highly electrically conductive material such as copper and has a plurality of radially-extending, circumferentially-spaced slits or apertures **36** which are equally spaced about the periphery. These slits **36** correspond in number with the cylinders of the engine and are in synchronism with the rotor **12** as it registers with the various stator segments **14**.

Thus, each time a slit **36** is in alignment with the magnetic field generated between the coils A and B, the coils are coupled and the pick-up coil B becomes the seat of oscillations. On the other hand, when a solid segment of the disk C is interposed between the two coils, the flux communication therebetween is interrupted so that coupling of the coils A and B is suppressed. Therefore, as the disk C rotates, a succession of pulses will be transmitted to the amplifier or booster circuit D and further peaked by the spark coil **18** in exact timing for firing the spark plugs independent of engine speed. Since each of the pulses comprise a band of high frequency oscillations, the duration of these pulses is a function of the width of the apertures **36** which are preferably narrow slits.

The booster circuit D comprises a pair of transistors **40** and **42** connected in common emitter configuration to the positive terminal of the battery **28** through a switch **38**, the transistors being cascade coupled by an interstage transformer **44**. The pulses developed in the coil B are applied to the emitter of transistor **40** across resistor **46**, nominally 50,000 ohms.

The output voltage response representative of my invention for a given engine speed is designated by the curve indicated by reference numeral **100** in FIG. 2. A typical performance curve of a conventional "breaker point" battery ignition is indicated by reference numeral **200** and a transistorized "breaker point" ignition by the numeral **400**. The response characteristics of a comparable magneto ignition is designated by the reference numeral **300**.

It is to be noted that the output response of my coupled-coil ignition system has greater linearity than heretofore utilized ignition systems, primarily because of the substitution of the interrupting conductive disk C for the conventional breaker points. In addition, the use of my radially slit disk makes possible an entirely new magneto concept whose design may be employed as an adjunct to the invention described above, or which may be used alone to yield extremely high efficiencies at engine speeds in excess of 5,000 r.p.m.

Referring back to FIG. 1, my improved magneto comprises a stationary permanent magnet A1 made of alnico for example, and which is arranged in co-axially spaced relationship with a coil B1. Again, the disk C is interposed between the coil B1 and the magnet A1 so that the slits **36** moving through the field of the magnet create a change of flux which induces a voltage in the coil B1. The magnet A1 is radially positioned in timed alignment with the distributor so that the magnet substantially registers circumferentially with any one of the stator segments **14**. The coil B1 is connected across the input of the booster amplifier D in parallel with the coil B if desired or with the latter removed from the circuit. The magnetically induced pulses in coil B1 will be peaked in the manner previously described under the coupled-coil ignition system. At low engine speeds, the rate of change of flux between the magnet A1 and the coil B1 will be small, and correspondingly little or no voltage will be induced in the coil B1. However, at high engine r.p.m., there will be no limitation as by breaker points, and therefore a stable, timed and linear response.

The response characteristics of my improved magneto A1–C–B1 is illustrated by the FIG. 2 curve designated by the numeral **500**. As is apparent, increasing the engine speed correspondingly increases the speed of disk C rotation which acts to increase the rate at which the magnetic flux is cut between the magnet A1 and the coil B1. Therefore, the amplitude of the pulses generated in the coil B1 will increase until limited by the rate at which current can build up in said coil. Suitable design of coil B1 with appropriate amplification of the pulses generated therein will result in a substantially linear response above 1,000 engine r.p.m.

It is also to be observed that the magneto A1–B1 system can be used contemporaneously with the coupled oscillation coil pair A–B so long as they are radially spaced from each other in any multiple of 360° divided by the number of engine cylinders. With appropriate advance or retard of timing in each system, one will not interfere with the other even though pulses are generated by each at substantially the same instant and delivered concurrently to the booster circuit D. Note that when the voltage of the oscillating coil pair begins to fall off, the magneto A1–B1 will take over to produce a substantially constant response as represented by curve **100–500** in FIG. 2. In order to conserve battery, switch **30** may be manually or automatically opened at the point when the curves **100** and **500** intersect and thereby discontinue transistor oscillations.

Although my invention has been described in considerable detail, such description is intended as being illustrative rather that limiting, since my invention may be variously embodied, and the scope of the invention is to be determined as claimed.

I claim as my invention:

1. In an ignition system for an internal combustion engine having a plurality of spark plugs and a rotatable distributor communicating therewith, a high voltage pulse generator comprising a conductive disk rotatable with the distributor and having a plurality of circumferentially-spaced slits radially extending therein from a me-

dial annulus to the periphery thereof, magnetic field inducing means laterally spaced from one side of said disk and registering with the annular circle developed by the slits, magnetic pick-up means laterally spaced from the other side of said disk and inductively coupled with said inducing means as each slit is rotated therebetween, and means applying electrical pulses induced in said pick-up means to the distributor, said magnetic field inducing means including both a permanent magnet and independently thereof a coil having high frequency electrical oscillations applied thereto, said electrically oscillating coil acting as a source for supplying voltage at low engine speed and said magnet being operative for supplying voltage at high engine speed, whereby a synchronized high voltage pulse of constant amplitude at all engine speeds will be delivered to the spark plugs at regular intervals without the necessity of breaker points.

2. The invention of claim 1 wherein said magnetic pick-up means comprises a pair of circumferentially-spaced coils, and said magnetic field inducing means comprises the oscillator coil registering with one of said pick-up coils, and the permanent magnet registering with the other of said pick-up coils.

3. An ignition system for an internal combustion engine having a plurality of spark plugs and a rotary distributor communicating therewith comprising a pair of coils air-spaced from each other but arranged in coupled communication when an electromagnetic field is generated by one, generating means for applying an oscillatory voltage to one of said coils, a conductive disk having circumferentially-spaced radially extending slits therein intermediate said coils and being rotatable with said distributor so as to interrupt the coupling between said coils at regular intervals, a permanent magnet on the same side of said disk as the electro-magnetic field generating coil and circumferentially spaced therefrom, a pick-up coil in alignment with said magnet and having a change of flux induced therein as the field of said magnet is cut by said slit disk, and means for applying to the distributor rotor electrical impulses induced in both the pick-up coil for said magnet and the coil coupled with the electro-magnetic field generating coil at a potential of constant amplitude sufficient to fire the spark plugs sequentially and independently of engine speed.

4. The invention of claim 3 wherein said generating means comprises a transistor multivibrator.

5. An ignition system for an internal combustion engine having a rotary distributor sequentially communicating with a plurality of spark plugs comprising a permanent magnet, a coil axially spaced from said magnet but disposed in the field thereof, a conductive disk rotatable with said distributor with the plane of the disk air spaced intermediate said magnet and said coil, said disk having circumferentially spaced radially extending slits therein sequentially registering with the magnetic field so as to produce a rate of change of magnetic flux and thereby induce a voltage at regular intervals in said coil, and amplifying means coupling said coil with said distributor so as to fire the spark plugs at optimum potential at high engine speeds without breaker points, an inducing coil on the same side of said disk as said magnet and having high frequency electrical oscillations applied thereto, and a second coil spaced from the same side of said disk as said first-mentioned coil and coupled with the high frequency oscillations of said inducing coil as the slits of said disk respectively pass therebetween, said amplifying means further coupling said second coil with said distributor so as to fire the spark plugs at optimum potential at low engine speeds.

6. In an ignition system for internal combustion engines including a plurality of spark plugs and a rotatable distributor communicating therewith, a conductive disk rotatable with said distributor and having a plurality of circumferentially-spaced slits radially extending therein, a permanent magnet adjacently spaced laterally from one face of said disk and having a magnetic field cut by the slits during rotation of said disk, a first pick-up coil laterally spaced from the other face of said disk whereby electrical impulses will be induced in said first pick-up coil as each slit passes through the magnetic field, an inducing coil spaced from said magnet on the same side of the disk thereof, a second pick-up coil in alignment with said inducing coil laterally spaced from the other face of said disk, a high frequency oscillator coupled with said inducing coil, the output of said inducing coil being inductively coupled with said second pick-up coil only when the apertures of said disk extend therebetween, and amplifying means coupling said first and second pick-up coils with said distributor so as to deliver high voltage pulses of substantially constant amplitude to said spark plugs at both low and high engine speeds.

7. Means for supplying constant voltage to a load over varying ranges of engine speed comprising a rotatable disk, having a plurality of circumferentially spaced radially extending slits therein, pick-up means spaced from one face of the disk and connected with the load, a coil spaced from the other face of the disk, a frequency oscillator connected with said coil so that the output thereof is inductively coupled with said pick-up means as the slits pass therebetween and supplying a voltage thereto and to the load at low engine speeds, and a permanent magnet spaced from said pick-up means for said disk and having a magnetic field cut by the slits so as to produce a rate of change in magnetic flux to said pick-up means so as to induce a voltage therein and to the load at high engine speeds.

8. An ignition system for an internal combustion engine having a plurality of spark plugs and a rotatable distributor comprising a rotatable conductive disk having a plurality of circumferentially-spaced apertures therein, pick-up means spaced from one face of said disk and sequentially coupled to said spark plugs by said distributor, a coil spaced from the other face of said disk, high frequency electrical oscillation means connected with said coil so that the output thereof is inductively coupled with said pick-up means as the apertures pass therebetween for supplying electrical pulses to said spark plugs at low engine speeds, and a permanent magnet spaced from said pick-up means by said disk and having a magnetic field cut by the apertures thereof so as to produce a change of flux to said pick-up means and induce a voltage therein for supplying electrical pulses to said spark plugs at high engine speeds.

9. The invention of claim 8 wherein the number of apertures in said disk is equal to the number of spark plugs.

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