June 30, 1970 E. JAULMES 3,517,655
CAPACITY-DISCHARGE ELECTRONIC IGNITION APPARATUS FOR INTERNAL COMBUSTION ENGINES
Filed June 12, 1968 2 Sheets-Sheet 1

Fig. 1.

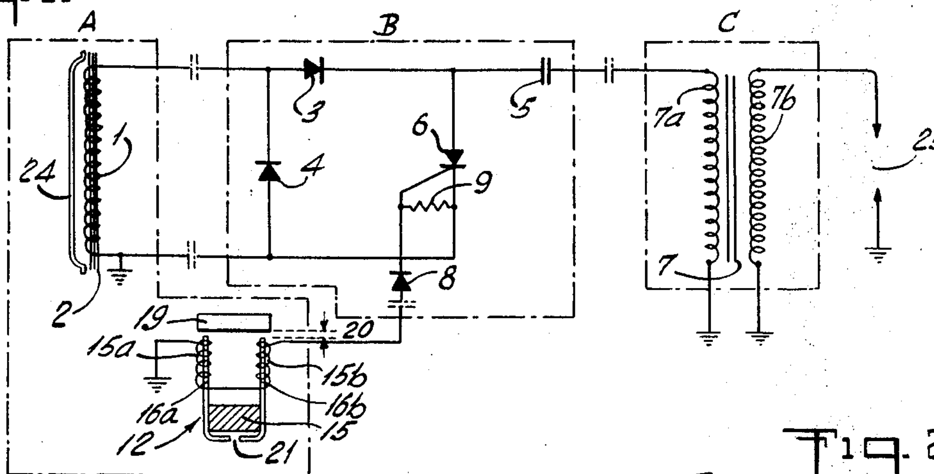

Fig. 2.

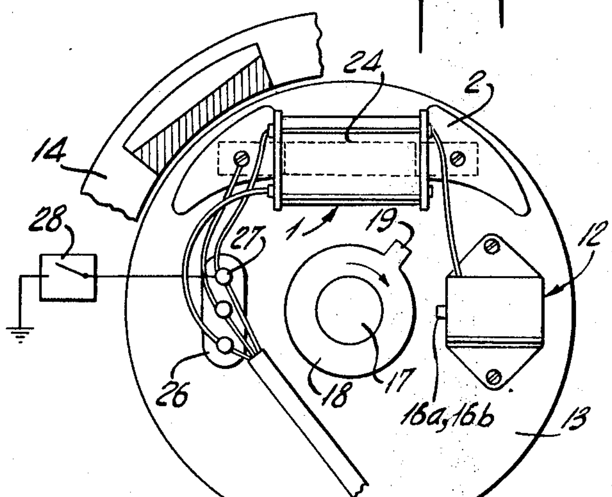

Fig. 3.

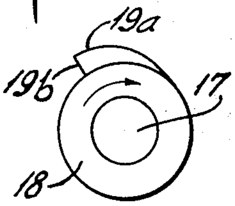

Fig. 6.

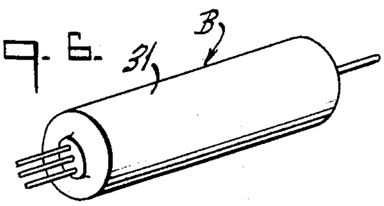

Fig. 5.

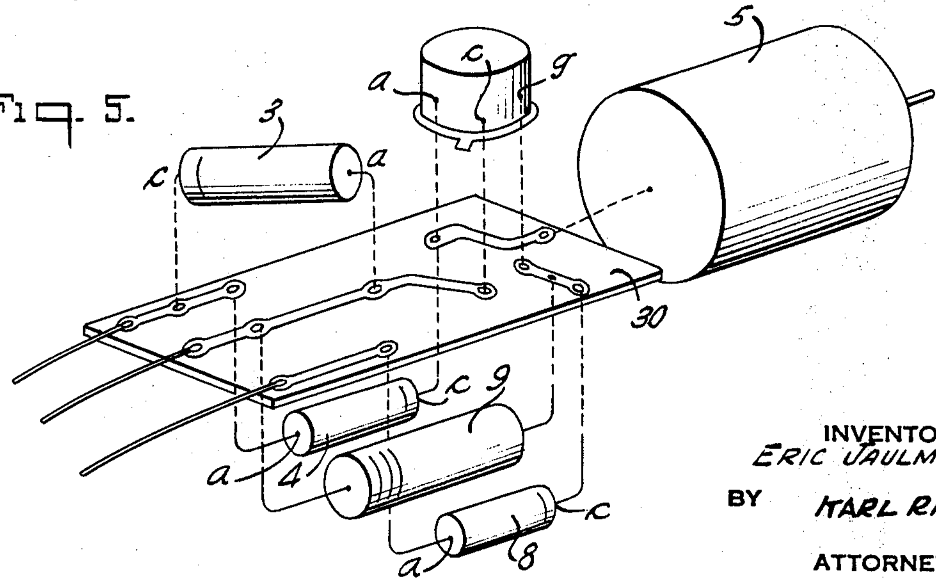

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Fig. 4.

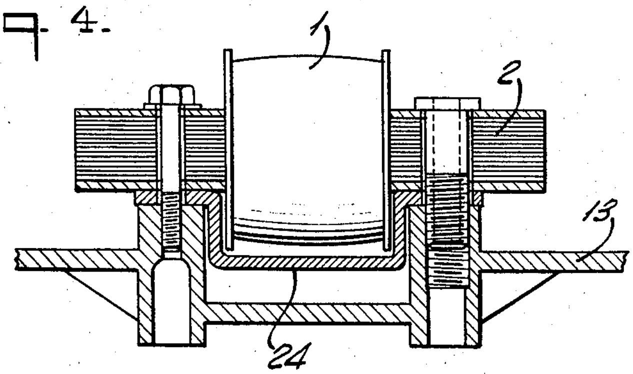


Fig. 7.

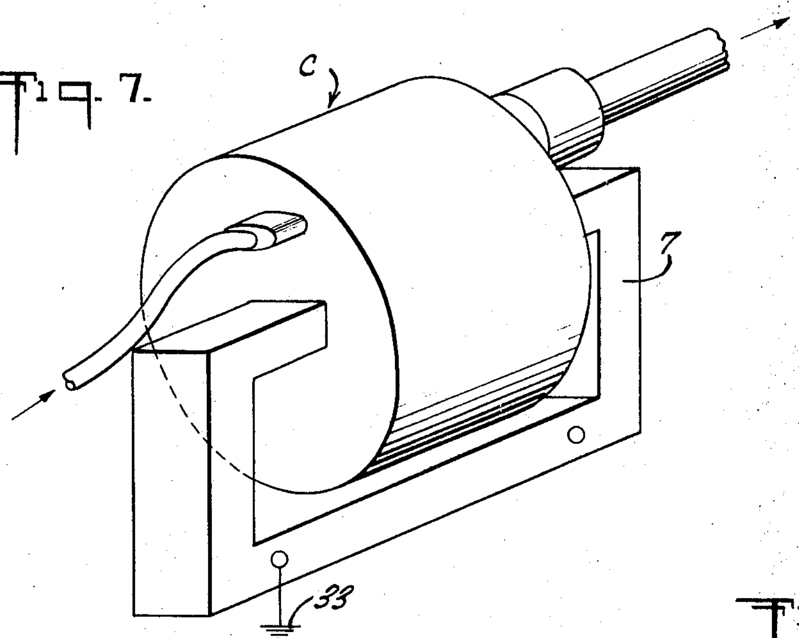
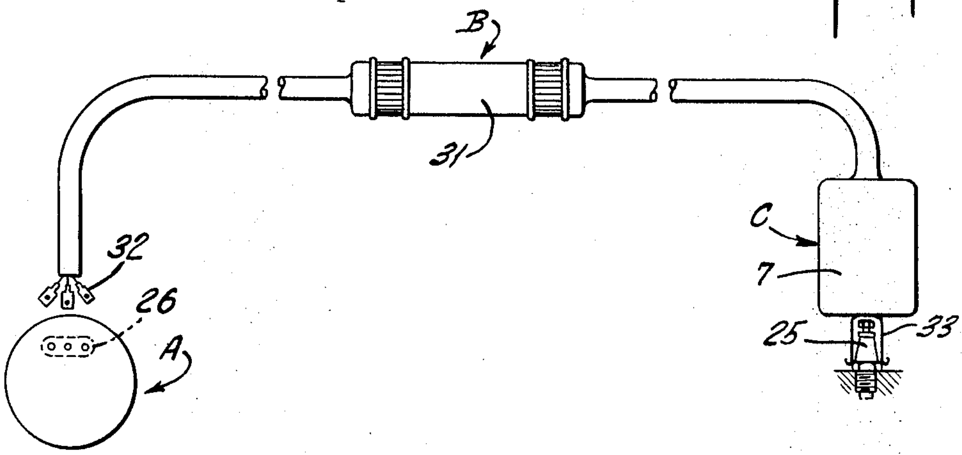


Fig. 8.



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United States Patent Office

3,517,655

Patented June 30, 1970

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3,517,655

CAPACITY-DISCHARGE ELECTRONIC IGNITION APPARATUS FOR INTERNAL COMBUSTION ENGINES

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Filed June 12, 1968, Ser. No. 736,312

Claims priority, application France, June 14, 1967, 110,239

Int. Cl. F02p *1/02*

U.S. Cl. 123—148 8 Claims

ABSTRACT OF THE DISCLOSURE

An electronic ignition system for internal combustion engines comprises an alternator driven by the engine and connected in series with a rectifier, a capacitor and a primary winding of an ignition transformer, to form a charging circuit. An SCR connected in series with the capacitor and the primary winding serves to discharge the capacitor through said winding upon the SCR being fired by a triggering pulse produced by a triggering pulse generator driven by the engine. The alternator includes a stator magnet carrying a generating winding and a rotor cooperating with said magnet. Regulation of the generated voltage is effected, independently of engine speed variations, by a magnetic shunt bypassing said magnet.

The present invention relates to capacity-discharge electronic ignition apparatus or systems for internal combustion engines of automotive vehicles and the like, more particularly, to systems of this type utilizing an alternator driven by the engine in conjunction with one or more electrical rectifiers, to supply the charging voltage for the ignition capacitor.

This invention is more particularly concerned with so-called "breakless" ignition systems of this type which comprise a magnetic triggering pulse generator, consisting of a rotating magnet and stationary pickup coil, also driven by the engine and taking the place of the conventional breaker contacts, to supply triggering pulses for the initiation of the discharge of the capacitor via a solid state relay in the form of a controlled rectifier, commonly known as a thryristor of SCR (silicon-controlled rectifier), as referred to in the following for the purposes of this specification.

Breakless electronic ignition systems of the foregoing type essentially comprise an ignition transformer having a primary winding and a secondary winding connected to a spark plug, or to a plurality of spark plugs through a coventional distributor, in a manner well known. An ignition capacitor in series with said primary winding, a rectifier and the winding of the alternator form a charging circuit for the capacitor, while the SCR or the like solid state relay is connected in series with said primary winding and capacitor, to provide a discharge circuit therefor. In operation, the capacitor is charged to a suitable high voltage supplied by the alternator and rectifier, whereupon application of a triggering pulse, supplied by the pickup coil of the triggering pulse generator, to the gate or control electrode of the SCR causes the latter to be "turned on," whereby to discharge the capacitor through the primary winding of the ignition transformer. This in turn results in a secondary spark voltage being applied to the spark gap in the form of a damped electric oscillation for ignition of the fuel-air mixture in the combustion chamber of the engine, in a manner well known.

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Among the objects of the present invention is the provision of an electronic ignition system of the referred to type for automotive and the like internal combustion engines subject to relatively large changes of operating speed, which system is both simple in design as well as compact in construction; which requires a minimum of component parts or devices; which uses no moving parts except for the alternator producing the charging voltage and the trigger pulse generator; which can be manufactured in the form of compact constructional units or modules for easy and expeditious mounting and installation; and which will enable instant removal for the carrying out of repairs and replacements.

While the use of an alternator in electronic ignition systems for the production of the charging voltage of the capacitor in conjunction with one or more rectifiers has been found to have great advantage of both a practical and economic nature, compared with the supply by the car battery in conjunction with a D.C. transformer, special voltage regulating means are required in systems of this type on account of the alternator voltage varying within substantial limits in proportion to the engine speeds during the widely varying operating or driving conditions of the automotive vehicle.

It has already been proposed to effect a voltage regulation in an electronic ignition system of the referred to type by the provision of a series resistor in the capacitor charging circuit. The resistor is designed in such a manner, in relation to the inductance of the alternator winding, that the capacitor is charged to substantially the full operating voltage during idling and low engine speeds, while with the generated voltage and frequency of the charging and discharging cycles being increased at medium and high engine operating speeds, the capacitor is charged to a fractional portion only of the generated voltage, thus providing an average and substantially constant capacitor charging voltage throughout the range of engine speeds or vehicle operating conditions. A system of this type is described and shown by French Pat. 1,369,469, issued July 2, 1963.

According to one aspect of the present invention, the regulating or charging resistor of the prior system is dispensed with and displaced by a magnetic shunt or by-pass disposed across the magnet armature of the alternator winding. The advantages of such a simplified construction, aside from saving mounting space and reduced cost, will be appreciated in considering that the charging resistor, in the case of a typical practical example, has a value of about 4700 ohms and a heat dissipation rating of about 40 watts, whereby to render the same rather bulky as well as costly and making necessary the provision of special cooling ribs and mounting of the resistor at a point within the engine to ensure efficient heat radiation.

According to another aspect of the invention, being the result of the elimination of the bulky and costly charging resistor, the entire ignition apparatus may now be subdivided into three compact constructional units or modules, in such a manner as to enable an easy and expeditious installment as well as replacement of one or more of the units or parts thereof. The first or electromagnetic unit, being constituted by the stator of the alternator, simply comprises the armature and its winding and the triggering pulse generator. The second or electronic unit comprises the SCR, the necessary diodes, the biasing resistor for the SCR and the capacitor proper. All these elements or devices may be firmly encased in and sealed by a protective mass or body of a suitable insulating plastic, to provide the required protection against mechanical impact (vibration) and humidity, resulting thereby in a small and compact unit of minimum bulk and dimensions. The third or ignition unit of the system is constituted by the ignition transformer, the latter being preferably constructed for mounting in the immediate vicinity of the spark plug or plugs of the engine. Advantageously, this may include suitable mounting means for direct connection to the spark plug.

According to an improved feature of the invention, there may be provided a simple anti-theft switch, in the form of a key or the like being connected to the high-tension output lead of the trigger pulse generator, to short-circuit the same and to prevent unauthorized operation of the engine.

With the subdivision of the entire ignition system into the three constructional units described in the foregoing, only three leads are required to connect the alterator unit with the electronic unit, while a single lead suffices for the connection of the latter with the ignition unit or transformer. The second and third units, together with their connecting leads, may be in turn combined into a common assembly or structure molded in a suitable plastic having an adequate flexibility, to enable its easy installation or mounting upon the engine. As a consequence, the only two connections to be made for the mounting of the entire composite unit are the attachment to the alternator terminals, on the one hand, and to the spark plug, on the other hand, as will become further apparent as the description proceeds in reference to the drawings.

As a matter of fact, the simplicity of the construction described is such as to enable, in the case of multi-cylinder engines, each of the cylinders to be individually fitted with its own ignition system, to dispense with a distributor being highly sensitive to humidity and subject to other drawbacks and defects well known. This in turn results in increased operating safety, mainly on account of the fact that each ignition unit is entirely self-contained and adapted to operate without a battery subject to constant uncertainty and requiring continued supervision.

The complete sealing of the parts or devices renders the system according to the invention especially suitable for the outfitting of marine motors, though being by no means limited thereto. Other advantages are easy and expeditious installment, as well as reduced bulk and cost, making it possible thereby to hold two or more units in stock or reserve for the quick and instant carrying out of repairs or replacements.

The invention, both as to the foregoing and ancillary objects as well as novel aspects thereof, will be better understood from the following detailed description of a preferred practical embodiment, taken in conjunction with the accompanying drawings forming part of this specification and in which:

FIG. 1 is a wiring diagram of a preferred embodiment of the electronic ignition system according to the invention;

FIG. 2 shows the first group or unit of elements embodied in the alternator;

FIG. 3 is a fragmentary view, showing a modification of FIG. 2;

FIG. 4 is a longitudinal cross-section of the magnet winding or armature of the alternator;

FIG. 5 shows, in perspective "exploded" view of the second unit forming part of the ignition system according to the invention;

FIG. 6 shows the unit according to FIG. 5 in its final molded shape;

FIG. 7 shows the ignition transformer forming the third constructional unit according to the invention; and

FIG. 8 illustrates, on a reduced scale, a preferred assembly of the units, forming an operative ignition system according to the invention.

Like reference numerals denote like parts throughout the different views of the drawings.

Referring more particularly to FIG. 1, the numeral **1** denotes the winding upon a magnetic armature **2** mounted upon the stator of the alternator which serves to supply the charging voltage for an ignition capacitor **5**. Further connected in series with the winding **1** and capacitor **5** is the primary winding **7***a* of a conventional ignition transformer **7** having a secondary winding **7***b* connected to a spark plug **25**. The armature **2** is provided with a magnetic shunt **24** for the regulation of the capacitor charging voltage, in a manner as will become more apparent as the description proceeds.

A first diode **3** being in series with the winding **1** and capacitor **5** and acting as a rectifier passes the positive alternations of the output current of the alternator, while a further diode **4** shunting the armature winding **1** serves to short-circuit the negative current alternations.

Alternatively, a bridge-type or equivalent rectifier arrangement may be interposed between the winding **1** and the capacitor **5**, to utilize both alternations of the supply voltage, in a manner readily understood.

The energy stored in the capacitor **5** is discharged through the primary winding **7***a* upon triggering or firing of an SCR or controlled diode **6**, forming a discharge circuit in series with said capacitor and primary winding. The firing or "turning on" of the SCR is effected by a triggering voltage pulse produced by the triggering pulse generator collectively indicated at **12** in the drawing and having its output windings connected to the gate or control electrode of the SCR. The latter is further provided with a biasing resistor **9** connected between its gate and cathode, to provide a definite threshold or response sensitivity, in a manner well known.

A further threshold diode **8** interposed between the triggering pulse generator **12** and the SCR **6** serves to suppress the negative alternation of the triggering voltage induced in the windings of the generator **12** and to fix a minimum response voltage or threshold for the operation of the SCR. As a consequence, spurious and other interfering voltages of a value less than the threshold value will be ineffective in causing undesired firings of the SCR or equivalent solid state relay.

The triggering pulse generator, being mounted upon the stator **13** of the alternator disposed within a rotor **14** driven by the engine, FIG. 2, comprises essentially a permanent magnet **15** and two windings **15***a* and **15***b* mounted upon cores or pole pieces **16***a* and **16***b* extending from the upper side of said magnet. The axes of the cores **16***a* and **16***b* coincide with a plane passing through the rotary axis of the engine shaft **17**, while the hub **18** of the rotor **14**, also driven by said shaft, carries a magnetic bar or armature **19** moving past the cores **16***a* and **16***b* once during each revolution of the shaft, a slight intervening air gap **20** being provided between the ends of the cores and said armature. The opposite ends of the cores **16***a* and **16***b* extending from the lower side of the magnet **15** form a leakage or air gap **21**, the purpose and function of which will be described in greater detail hereafter.

Both windings **15***a* and **15***b* of the triggering pulse generator **12** are connected in the same sense in series, as far as the useful fluxes in the cores **16***a* and **16***b* are concerned, said windings being in effective relatively opposed connection in respect to any external or disturbing flux emanating from the magnetic field of the rotor **14**. It has, however, found to be still necessary to shield the triggering pulse generator against interference caused by assymmetrical flux conditions, in which case the shielding parts or structures advantageously serve as mounting means for the generator **12**, as shown in FIG. 2.

According to the preferred structural embodiment of the invention as shown by FIG. 2, the triggering pulse generator **12** is mounted upon the stator **13** of the inductor-type alternator, said stator being disposed inside the rotor **14** having a number of pole pieces cooperating with the permanent magnetic field of the stationary armature **2** in effecting periodic variations of the magnetic flux linked with said winding, to generate an alternating voltage in the winding **1**, in a manner well known and understood.

In accordance with the present invention, regulation of the generated voltage is effected simply and effectively by the function of the magnetic shunt or by-pass **24** bridging the magnet core **2** between points on the opposite sides of the winding **1**, as more clearly shown in FIG. 4, the effect of said shunt being to divert a portion of the main magnetic flux through the magnet **2** in proportion to the increase of the magnetic reluctance of said magnet with increasing engine speed, and vice versa. In other words, the shunt **24** is so designed as to variably distribute the magnetic flux during different engine speeds, in such a manner as to result in a substantially constant or average voltage induced in the winding **1** independently of vehicle operating conditions.

Expressed in a different way, the magnetic reluctance of the armature **2** is a function of the current through the winding **1** and the varying magnetic saturation of the core **2**, as well as of the frequency of the voltage being generated, with the result that a greater amount of the flux will be by-passed by the shunt **24** as the operating frequency or engine speed are increased, and vice versa. This results in a correspondingly reduced useful flux through the core **1**, and, in turn, a decrease of the voltage induced in the winding **1**.

The bar **19** which cooperates with the cores **16***a* and **16***b* of the triggering pulse generator **12** may have a relatively small thickness as shown in FIG. 2, whereby to cause the generation of a positive pulse having a relatively short rise time necessary for the firing of the SCR or the like solid state control device.

According to a modified construction of the bar **19** as shown by FIG. 3, the same takes the shape of a wedge having a ramp-shaped portion **19***a* of gradually decreasing height towards the hub **18** in the rotating direction, as indicated by the arrow in the drawing, and a radial end face or portion **19***b*. As can be seen, with a construction of this type, the fluctuation of the magnetic flux produced by the bar **19** results in a sharply defined initial pulse, provided the rotation is in the direction as shown by the arrow. On the other hand, rotation in the opposite direction results in a more gradual flux variation and a correspondingly reduced generated voltage unable to fire or trigger the SCR **6**. This particular type of bar or armature **19** thus constitutes a simple and effective means to prevent operation of the motor in the reverse or wrong direction, eliminating thereby a frequently occurring risk, in particular in connection with marine motors equipped with a manually operable ignition advance device.

The triggering pulse generator **12** may be mounted upon the stator **13** of the alternator at the place normally taken by the conventional breaker or interrupter. The mounting is advantageously such as to enable a radial displacement or adjustment for the setting or control of the width of the air gap **20**, FIG. 1. Further mounted upon the stator **13** may be the magnet and winding (not shown) of an auxiliary alternator for the generation of the charging current for the storage battery provided in conventional motor vehicles. Item **26** is an insulating plate carrying the three connecting terminals of the unit of any suitable type known in the art.

As already described, the terminal **27** being in connection with the high-tension output end of the triggering generator **12** may be connected to mass or ground through a safety switch **28**, to disable the engine operation.

As further described in the foregoing, the entire ignition apparatus according to the invention is advantageously subdivided into three constructional subassemblies or units, as indicated by the dot-dash lines in FIG. 1, viz an electromagnetic unit A, an electronic unit B, and an ignition unit C.

More particularly, unit A comprises the alternator magnet **2**, winding **1**, and the triggering pulse generator **12**, all mounted upon the stator **13** in the manner shown by FIG. 2. Unit B, being more clearly shown in FIGS. 5 and 6, comprises all the electronic parts and devices, that is, the diodes **3** and **4**, the capacitor **5**, the SCR **6**, the threshold diode **8**, and the biasing resistor **9**, all being electrically interconnected preferably by means of a printed circuit applied to an insulating base or support **30**, in a manner shown and readily understood. For better understanding, there are shown in FIG. 5 the terminals *a*, *c* and *g* representing the anode, cathode and gate electrodes of the SCR and diodes, respectively. The entire unit is encased in a molded housing consisting of a suitable synthetic resin, such as in the form of a cylindrical unit **31**, FIG. 6, which, according to practical example, may have a length of only about 75 mm. and a diameter of 22 mm. suitable for easy mounting, such as by clamping, upon a part of the engine.

Finally, the third unit, as more clearly shown by FIG. 7, consists of the ignition transformer **7** preferably mounted in close proximity to the spark plug **25**, such as by directly connecting and clamping it to the plug as shown in FIG. 8. Referring to the latter, the high-tension output terminal of the winding **7***b* is in direct contact with the plug, while the connection to the mass is effected by a magnetic shield **33** embracing the hexagonal nut of the plug, the construction shown acting at the same time as a noise suppressor or interference eliminating device.

The operation of the invention as described in the foregoing is as follows.

Whenever the bar **19** passes in front of the cores **16***a* and **16***b* of the triggering pulse generator **12**, the air gap **20** becomes less than the leakage gap **21**, whereby the magnetic flux predominately passes through the bar **19**. As the latter recedes from the cores, the flux again passes through the gap **21**, the resultant flux variations causing the induction of a triggering voltage in the windings **15***a* and **15***b*.

The gap **21** is so designed as to cause a different flux distribution during different engine operating conditions or speeds, in such a manner as to result in an output current regulation of the generator as a function of the engine speed. More particularly, the magnetic reluctance of the cores **16***a* and **16***b* is a function of the frequency and current, with the result that a greater portion of the flux is passed through the gap **21**, as the engine is increased.

If a triggering voltage pulse produced by the generator **12** is applied to the control electrode (gate) of the SCR **6**, the latter is "turned on" and functions as a simple diode, whereby to initiate the discharge of the capacitor **5** through the primary winding **7***a* of the ignition transformer. The discharge circuit is of the oscillatory type, being composed of the capacitance of capacitor **5** and the inductance of the winding **7***a*, the resistance of the circuit being relatively small, whereby to result in a low-damped oscillation of the discharge. The diodes **3** and **4** pass the negative alternations of the oscillatory current, while the SCR **6** passes the positive alternations during its conducting or "ON" condition. There are produced in this manner a number of successive sparks, one during each oscillating period, within a full or single ignition cycle. The oscillations are arrested as soon as the discharge current decreases below the critical minimum amplitude necessary to sustain conduction of the SCR.

Investigations on the ignition of the fuel-air mixture in the combustion chambers of internal combustion engines have shown it advisable, both from the standpoint of ensuring maximum efficiency or energy conversion and to prevent fouling of the spark plug electrodes, to utilize a greater number of discharge oscillating periods, such for instance as to result in at least three discreet sparks during each ignition cycle. A prerequisite for such an operation is that the pulse duration of the triggering pulse generator, at the highest possible engine speed, exceeds the duration or length of the oscillation wave train, that is, three alternations of the oscillating current in the example mentioned.

Referring to FIG. 8, there is shown a preferred construction of the ignition apparatus according to the invention, wherein all the elements with the exception of those of the unit A embodied in the stator **13**, together with their connecting leads or cables, are combined into a single structure or assembly embedded in a suitable insulating plastic and adapted to reduce the installation to the simple and expeditious connection of a pair of cables extending from the unit **31** to the terminal plate **26** upon the stator **13** by way of suitable connectors **32**, on the one hand, and to the spark plug **25**, on the other hand.

The ignition apparatus shown and described herein may also be used in connection with systems utilizing a D.C. source (battery) in conjunction with an A.C. converter in place of an alternator driven by the engine. In such a case, the core **1** is part of a conventional transformer having a primary winding (not shown) connected to the output of the converter, with the coil **1** forming the secondary of the transformer and serving to charge the capacitor **5**, in substantially the same manner as described herein. The same applies where the vehicle already includes an auxiliary (lighting) alternator and the latter is utilized for the charging of the ignition capacitor via a step-up transformer.

As already mentioned, the structural simplicity and compactness of the ignition apparatus according to the invention, especially as shown by FIG. 8, makes it possible to individually equip each cylinder of a multi-cylinder engine with its own and independent ignition system, that is, providing as many units according to FIG. 8 as there are engine cylinders. In such a case, the armatures **19** of the triggering pulse generators, replacing the conventional distributor, must be relatively replaced to result in a proper ignition timing for the various cylinders, in a manner readily understood by those skilled in the art.

In the foregoing, the invention has been described in reference to a specific illustrative and exemplary device. It will be evident, however, that variations and modifications, as well as the substitution of equivalent parts or devices for those shown herein 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 drawings are accordingly to be regarded in an illustrative rather than in a restrictive sense.

I claim:

1. Electronic ignition apparatus for an internal combustion engine comprising in combination:

(1) an ignition transformer having a primary and a secondary ignition winding,

(2) a spark plug connected to said secondary ignition winding,

(3) an electric alternator including

(a) a stator supporting a magnetic armature carrying an armature winding,

(b) a rotor cooperating with said armature and driven by said engine,

(4) a capacitor

(5) a charging circuit for said capacitor including said armature winding, rectifier means, said capacitor and said primary ignition winding in series,

(6) a discharge circuit including said capacitor, a controlled rectifier having a gate and said primary ignition winding,

(7) a magnetic triggering pulse generator synchronized

with the engine and having an output winding connected to said gate, and

(8) a magnetic shunt by-passing said armature between points on the opposite sides of said armature winding and designed to maintain a substantially constant voltage induced in said armature winding, substantially independently of engine speed variations.

2. Electronic ignition apparatus as claimed in claim **1**, said rectifier means comprising a first diode in series with said armature winding and said capacitor, to apply one of the alternations of the generated voltage to said capacitor, and a second diode shunting said armature winding, to suppress the other alternations of said voltage.

3. Electronic ignition apparatus as claimed in claim **1**, said triggering pulse generator comprising a magnet mounted upon said stator and having a pair of magnetic cores extending therefrom, to form pole pieces, a magnetic armature driven by the engine for cooperation with said pole pieces, and a pair of induction windings upon said cores connected in series and to said gate.

4. Electronic ignition apparatus as claimed in claim **3**, including a threshold diode connected between said triggering pulse generator and said gate.

5. Electronic ignition apparatus as claimed in claim **3**, including a biasing resistor shunting the gate and cathode of said controlled rectifier.

6. Electronic ignition apparatus as claimed in claim **1**, said apparatus being subdivided into three self-contained units, viz an electromagnetic unit comprising said stator, said armature winding, and said triggering pulse generator, an electronic unit comprising said capacitor, said rectifier means and said controlled rectifier, and an ignition unit comprised of said ignition transformer.

7. Electronic ignition apparatus as claimed in claim **6**, said electronic unit being hermetically sealed in a body of insulating material with a pair of flexible connecting members projecting from said body for the connection of said unit to said electromagnetic and ignition units, respectively.

8. Electronic ignition apparatus as claimed in claim **1**, including switch means, to short circuit said triggering pulse generator.

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