SMALL ENGINE CAPACITOR DISCHARGE IGNITION SYSTEM

Filed Aug. 23, 1968

Fig. 1.

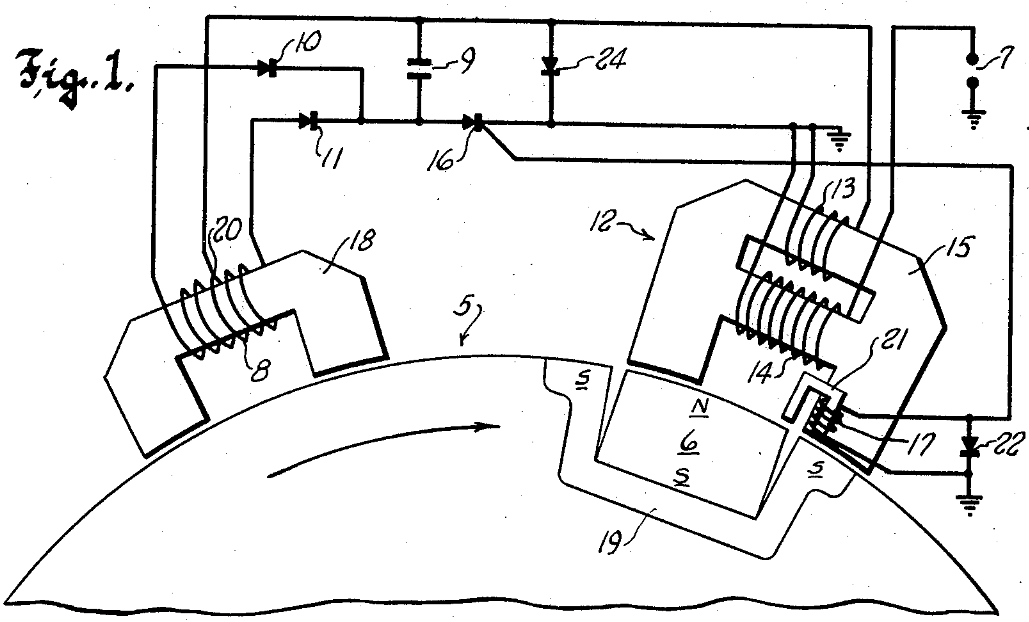
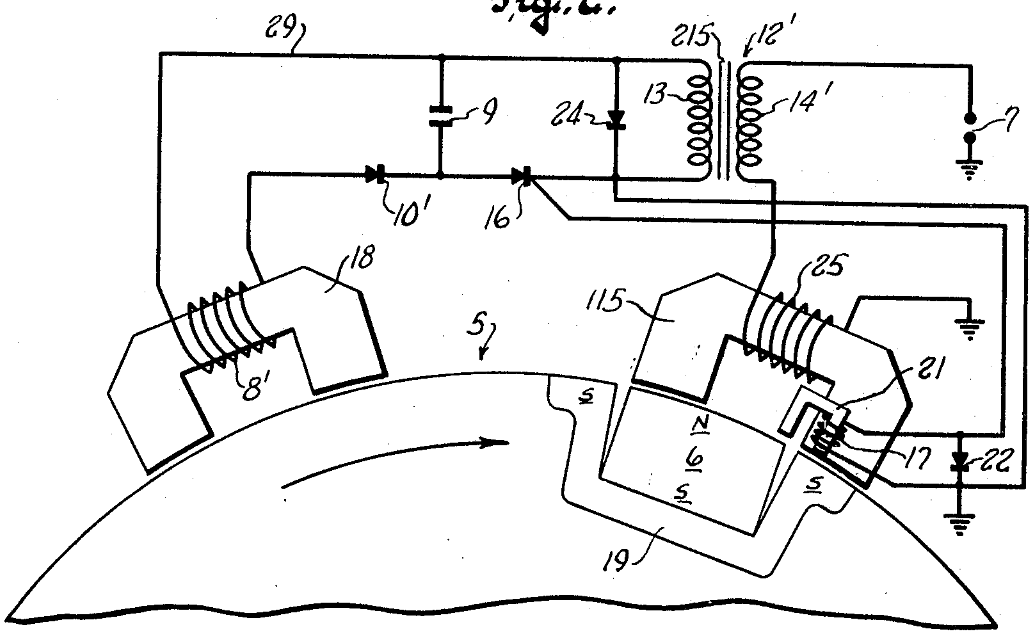


Fig. 2.



Inventor
Joseph R. Harkness
By
Attorney

United States Patent Office 3,498,281
Patented Mar. 3, 1970

1

3,498,281
SMALL ENGINE CAPACITOR DISCHARGE IGNITION SYSTEM

Joseph R. Harkness, Germantown, Wis., assignor to Briggs & Stratton Corporation, Wauwatosa, Wis., a corporation of Delaware

Filed Aug. 23, 1968, Ser. No. 754,874
Int. Cl. F02p *1/02;* H05b *37/02, 39/04*
U.S. Cl. 123—149 8 Claims

ABSTRACT OF THE DISCLOSURE

Poor cold starting of engines results when a capacitor discharge ignition apparatus provides a spark of only brief duration. To prolong the plug firing interval in such a system, the core of the step-up transformer or ignition coil is juxtaposed to the orbit of a flywheel-carried magnet, whereby a current is induced in the secondary that provides for continuance of plug firing after condenser discharge. Alternatively, a separate coil, connected in series with the secondary and the plug, is arranged to cooperate with the magnet in generating such current.

This invention pertains to solid state capacitor discharge ignition systems for reciprocating internal combustion engines, and relates more particularly to a capacitor discharge ignition system which is especially suited for small engines and which performs well under extreme cold starting conditions and when the engine has been choked excessively during cranking.

A capacitor discharge ignition system is one in which the discharge of a previously charged capacitor is relied upon to provide the energy for spark plug firing. The capacitor is charged during a part of each engine cycle which precedes spark plug firing, and its discharge at the time when firing of the spark plug is to be effected is controlled by suitable switching means, usually an electronic switching element such as an SCR. The switching element is connected in series between the capacitor and the primary of a step-up transformer or ignition coil, so that the capacitor discharges into the primary when the switching element becomes conductive. The secondary of the transformer or coil is of course connected with the spark plug.

In small engines of the type with which this invention is concerned, charging of the capacitor can be effected by means of a permanent magnet that is mounted for orbital motion on the engine flywhel or on some other rotating engine part, in cooperation with a charging coil that is wound on a core mounted adjacent to the magnet orbit. During the capacitor charging portion of the engine cycle, the magnet is carried orbitally past the core of the charging coil to thereby induce in the charging coil an E.M.F. by which the capacitor is charged. A suitable rectifier arrangement prevents discharge of the capacitor back into the charging coil.

Where the switching element comprises an SCR or other triode, its triggering current can be produced by means of a triggering coil which is connected with the gate of the triode and is wound on a second core mounted adjacent to the orbit of the flywheel-carried magnet, in a position to be swept by the magnet at the time when firing of the plug is to take place, so that as the magnet moves past the second core a current is induced in the triggering coil that renders the triode conductive.

While prior apparatus of the type just described was highly satisfactory in most respects, engines equipped with such ignition systems were very often hard to start in extremely cold weather, when temperatures were on the order of 0° F. and below. The cause of such starting

2

difficulty resided in the short duration of the spark produced by many heretofore conventional capacitor discharge ignition systems.

Under conditions of extreme cold, a certain amount of fuel is present in the cylinder in liquid form, either as a mist or as a film of condensate on the cold engine parts, or both. The presence of this liquid fuel in the vicinity of the spark plug enables the plug to be fired at a substantially lower voltage than normal, so that the amount of energy put into the fuel-air mixture in the cylinder per microsecond of spark plug arcing is substantially lower than normal. The same thing can occur at warmer temperatures when the engine has been choked excessively during cranking.

Under these conditions more than a normal amount of energy is required to initiate combustion of the mixture inasmuch as the liquid fuel between the spark plug electrodes must first be vaporized and then be brought up to kindling temperature before combustion can begin. A single spark of the short duration produced by many prior capacitor discharge ignition systems could not put enough energy into the fuel-air mixture to effect both the necssary vaporization of the fuel and the elevation of the temperature of the vaporized mixture to the ignition point.

To overcome this problem, some prior capacitor discharge ignition systems provided for the spark plug to be fired with a rapid succession of sparks during each engine cycle, each spark of opposite polarity to its predecessor. Such a series of sparks was produced by discharging the capacitor into an oscillating circuit. While more energy could be put into the fuel air mixture with a multiplicity of sparks in each engine cycle than with only one spark, all of the energy for the succession of sparks had to be generated in the charging coil and stored in the capacitor, so that in a multiple spark system those components were necessarily more expensive than their counterparts in a system that produced only one spark during each engine cycle.

With the foregoing considerations in mind it is a general object of the present invention to provide very inexpensive means in capacitor discharge ignition apparatus for small engines for substantially prolonging the duration of the spark produced by such apparatus, to thereby greatly facilitate the starting of an engine equipped with such an ignition system under severe low temperature conditions and when the engine has been choked excessively during cranking.

More particularly it is an object of this invention to utilize very simple and inexpensive means to prolong the duration of the spark that is produced during each engine cycle by a capacitor discharge type of ignition system, which means can comprise, in one embodiment of the invention, a very simple and inexpensive modification of the step-up transformer heretofore conventional in such a system.

Another object of this invention is to provide a capacitor discharge type of ignition apparatus that is especially suitable for small engines, comprising a magnet which is carried by the engine flywheel for orbital motion in timed relation to the engine cycle, and winding means cooperating with the magnet for generating a first current by which a capacitor is charged, a second current by which a capacitor discharging switching element is triggered, and a third current that can effect a prolongation of spark plug firing after the capacitor is discharged; and wherein the winding means for producing said third current can comprise the secondary of the step-up transformer conventionally used in such apparatus.

Thus it can be said to be another object of this invention to provide an ignition system of the character described wherein a magnet which is carried orbitally by a moving engine part (and which is the only moving part of the ignition apparatus) provides both the energy for charging the capacitor and the energy for effecting a prolongation of spark plug firing, whereby, under cold starting conditions, the interval of plug firing during each engine cycle continues for a substantial time after the capacitor has been discharged.

With these observations and objects in mind, the manner in which the invention achieves its purpose will be appreciated from the following description and the accompanying drawings. This disclosure is intended merely to exemplify the invention. The invention is not limited to the particular structure disclosed, and changes can be made therein which lie within the scope of the appended claims without departing from the invention.

The drawings illustrate two complete examples of physical embodiments of the invention constructed according to the best modes so far devised for the practical application of the principles thereof, and in which:

FIGURE 1 is a more or less diagrammatic view in elevation of ignition apparatus embodying the principles of this invention; and

FIGURE 2 is a similar type of view but illustrating a modified embodiment of the invention.

Referring now more particularly to the accompanying drawings, the numeral **5** designates generally a rotating part of a reciprocating internal combustion engine upon which is mounted a permanent magnet **6** that is moved orbitally in timed relation to the engine cycle. The permanent magnet is the only moving part in an ignition system of this invention, by which firing of a spark plug **7** is effected at the proper time in each engine cycle. The remainder of the ignition apparatus comprises, in general, a charging coil **8**, a capacitor **9** that is connected with the charging coil through rectifiers **10** and **11**, a step-up transformer or ignition coil **12** having a primary winding **13** and a secondary winding **14** on a core **15**, a triode **16** that is connected in series circuit with the capacitor and the primary **13**, and a triggering coil **17** which is connected with the gate element of the triode.

For purposes of example, the rotating part **5** can be assumed to be a crankshaft mounted flywheel, and it will be hereinafter so designated, so that the magnet **6** can be assumed to complete two orbits during each engine cycle if the flywheel is mounted on a four-cycle engine, or one orbit during each engine cycle in the case of a two-stroke engine. The invention is applicable to either type of engine, and in the case of a single cylinder four-cycle engine it will be understood that one unneeded firing of the plug will occur during each engine cycle, as is often the case with simple four-cycle engines.

The charging coil **8** is wound on the bight portion of a U-shaped magnetically permeable core **18** that is mounted adjacent to the orbit of the magnet **6**, in a location to be swept by the magnet during a time in the engine cycle prior to firing of the spark plug. As shown, the magnet **6** is of the flat ceramic type. It is mounted on the flywheel perimeter with one of its poles (illustrated as the north pole) radially outermost and its opposite pole radially innermost and in contact with a broad, U-shaped magnetically permeable pole shoe **19** that has its legs projecting radially outwardly at opposite sides of the magnet, with the extremity of each leg providing (in this case) a south magnetic pole. The legs of the U-shaped core **18** on which the charging coil is wound extend toward the magnet orbit and are spaced apart in the orbital direction by a distance somewhat less than that between the legs of the pole shoe **19**.

It will be apparent that as the magnet sweeps past the core **18**, it charges thereinto a flux which builds to a peak of one polarity, then rapidly reverses to a peak of opposite polarity, and finally diminishes substantially to zero. This pattern of flux change in the core **18** induces in the charging coil **8** current pulses of both polarities.

A center tap **20** of the charging coil is connected with one terminal of the capacitor **9**, while the other terminal of the capacitor is connected, through diode rectifiers **10** and **11**, with the end terminals of the charging coil. The charging coil end terminals are connected with like terminals of the diode rectifiers **10** and **11** so that those rectifiers provide full wave rectification of the A.C. induced in the charging coil to permit both phases of it to be utilized for charging the capacitor **9**. The diodes also prevent the capacitor from discharging back into the charging coil.

The triode **16**, which is preferably an SCR, controls discharge of the capacitor **9** into the primary **13** of the step-up transformer or ignition coil **12** and is in turn controlled by the small triggering coil **17**, which is wound on its own core **21**. The core **21** is U-shaped, and has its legs extending toward the magnet orbit to be swept by the magnet, but its legs are spaced apart by a relatively small distance so that a rapid build-up of flux occurs in the core **21** as a pair of opposite poles of the magnet structure come into alignment with its legs. The core **21** is mounted in a location to be swept by the magnet during a part of the engine cycle that follows charging of the capacitor, at a time when firing of the spark plug is to occur. The flux charged into the core **21** by the moving magnet **6** first builds rapidly to a peak of one polarity, then drops to zero for a short interval while the magnet itself is under both of its legs, then builds rapidly to a peak of opposite polarity, and finally drops back to zero. The current induced in the triggering coil **17** by the first flux peak is utilized to fire the triode **16**. Since the SCR cannot withstand a high back current, a small diode rectifier **22** is connected across the terminals of the triggering coil to short circuit current of the undesired phase that is induced therein.

When the SCR is rendered conductive, the capacitor **9** discharges through it into the primary **13** of the step-up transformer **12**, thus inducing in the secondary **14** a voltage high enough to fire the spark plug **7**. A diode rectifier **24** is connected across the terminals of the primary **13** in the direction to conduct when the voltage across the primary reverses after the capacitor **9** has discharged, so as to prevent charging of the capacitor in the opposite sense and maintain a flow of current through the primary winding for some time, thereby producing a somewhat more prolonged firing of the spark plug than would be obtained without the diode **24**.

The core **15** of the transformer **12** has legs which project toward the magnet orbit to be swept by the magnet at the time the spark plug is to fire. The spacing of said legs in the orbital direction is substantially the same as that between the legs of the core **18** on which the charging coil **8** is wound. Hence as the magnet sweeps past the core **15** it charges thereinto a flux which first builds to a maximum value of one polarity, then rapidly reverses to a maximum value of opposite polarity. Firing of the SCR **16** occurs near the beginning of the flux reversal in core **15**, and for proper timing of condenser discharge the core **21** of the triggering coil can be mounted on that leg of the core **15** which is last swept by the magnet in its orbital motion, the core **21** being slightly offset from said leg in the direction counter to that of flywheel motion but being adjacent to it in the direction of the flywheel axis.

Because the secondary **14** of the transformer **12** is in flux linking relationship with the core **15**, the current induced in the secondary is a function not only of the discharge of the capacitor through the primary **13**, but also of the rapidly changing flux field charged into that core by the orbitally moving permanent magnet, and therefore the voltage across the secondary is somewhat higher than what it would be if it were due to discharge of the capacitor alone. Consequently, when the capacitor discharges there will be a brief but very high voltage "spike" that will assuredly initiate firing of the plug.

Once an arc has been established across the spark plug, the voltage across the secondary that is required to maintain the arc is substantially lower than that which was required to initiate it. Therefore the brief duration of the initial high voltage "spike" is not disadvantageous with respect to continued firing of the plug.

During the time the spark plug is being fired by the energy discharged from the capacitor **9**, the flux charged into the core **15** by the flywheel-carried magnet is undergoing rapid change in the course of reversal so that such flux change contributes to some extent to the energy available for plug firing during this period.

However, the energy for plug firing that is available from discharge of the capacitor **9** is expended before the completion of reversal of the magnet-charged flux in the core. From then on, arcing across the spark plug is maintained solely by the rapid change in magnet-charged flux, by which E.M.F. is induced in the secondary. While the rate of change of such magnet-charged flux would not be high enough so that the voltage induced by it would be capable of initiating plug firing, it is high enough to maintain plug firing once the arc has been initiated by the high voltage "spike" due to discharge of the capacitor; and when the engine is very cold, plug firing can continue through most of the period of magnet-charged flux reversal.

Under some circumstances the arrangement illustrated in FIGURE 1 may not operate with optimum efficiency. Because of the high rates of change of flux encountered in a capacitor discharge ignition apparatus, the step-up transformer **12** comprising the windings **13** and **14** and the core **15** may be somewhat inefficient if the core **15** is made of steel laminations, due to hysteresis effects. On the other hand, if the core **15** is made of the soft ferrite class of core materials which afford good transformer action, the flux density of the core at saturation may be too low for induction of a sufficiently high voltage E.M.F. to sustain plug firing during the part of the cycle when flux charged into the core from the permanent magnet is relied upon to provide the energy for plug firing.

The arrangement illustrated in FIGURE 2 escapes this dilemma by reason of the provision of a separate winding **25**, having its own core **115**, in which is developed the magnet produced energy for the prolongation of plug firing. The primary **13** and secondary **14′** of the step-up transformer or ignition coil **12′** are wound on a separate core **215**, which can be of a material selected solely with regard to its efficiency as a transformer core and situated in any convenient location. The core **115** for the winding **25** is of course mounted adjacent to the orbit of the magnet **6**, in the same relative location as the core **15** in the FIGURE 1 embodiment, to be swept by the magnet during that portion of the engine cycle in which plug firing is to occur. That core can be selected solely on the basis of its efficiency for cooperation with the magnet **6** in generating an E.M.F. in the winding **25**.

The winding **25** is connected in series with the secondary **14′** and the spark plug, so that during that portion of the cycle in which discharge of the capacitor **9** occurs, the voltage across the spark plug is the sum of the voltages across the secondary **14′** and across the winding **25**.

As shown in FIGURE 2, the charging coil **8′** has no center tap and has one of its terminals connected directly with a terminal of the condenser **9** by means of a conductor **29** while its other terminal is connected with the opposite condenser terminal through a diode rectifier **10′**. This arrangement, which provides for half-wave rectification, utilizes for condenser charging only current of one phase that is induced in the charging coil, and may be very satisfactory in some cases. Of course the half-wave rectifier charging arrangement could be used in the FIGURE 1 embodiment in place of the full-wave rectifier charging apparatus there illustrated, and vice versa.

In other particulars the embodiment of the invention illustrated in FIGURE 2 corresponds to that shown in FIGURE 1.

From the foregoing description taken with the accompanying drawings it will be apparent that this invention provides capacitor discharge ignition apparatus which is especially suitable for a single cylinder internal combustion engine and whereby greatly improved engine staring performance is obtained in extremely cold weather and when the engine has been choked excessively, by reason of the fact that the apparatus of this invention provides for spark plug firing during a substantially long portion of each cycle when liquid fuel is present in the combustion chamber.

What is claimed as my invention is:

1. Ignition apparatus for firing a spark plug of a reciprocating internal combustion engine, comprising a magnet that moves orbitally in timed relation to the engine cycle, a capacitor, means for charging the capacitor as the magnet moves through a first part of its orbit, first winding means, and switching means connected in series with the capacitor and the first winding means and arranged to be rendered conductive as the magnet moves through a second part of its orbit to provide for discharge of the capacitor through the first winding means, said ignition apparatus being characterized by:

(A) a core mounted adjacent to said second part of the magnet orbit; and

(B) second winding means which is

  (1) connected across the spark plug,

  (2) at least in part inductively coupled with the first winding means, so that upon discharge of the capacitor a high voltage is induced in the second winding means for initiating spark plug firing, and

  (3) at least in part in flux linking relationship with said core so that movemet of the magnet through said second part of its orbit induces a voltage in said second winding means during a time immediately following discharge of the capacitor by which firing of the spark plug can be prolonged when the voltage required to maintain spark plug firing is low.

2. Ignition apparatus for firing a spark plug of a reciprocating internal combustion engine, of the type comprising a capacitor, first winding means, and a triode that is connected in series between the capacitor and the first winding means and has a gate element to which current can be applied to render the triode conductive so that the capacitor can discharge through the first winding means, said ignition apparatus being characterized by:

(A) a magnet that is carried by a part on the engine for orbital motion in timed relation to the engine cycle;

(B) a charging coil in which a current is induced by the magnet as the same moves through a first part of its orbit, said charging coil being connected with the capacitor for charging the latter;

(C) a triggering coil in which a current is induced by the magnet as the same moves through a second part of its orbit, said triggering coil being connected with the gate element of the triode;

(D) a core mounted to be swept by the magnet as it moves through said second part of its orbit; and

(E) second winding means, said second winding means being

  (1) connected across the spark plug,

  (2) at least in part inductively coupled with the first winding means, so that upon discharge of the capacitor a high voltage is induced in the second winding means for initiating spark plug firing, and

  (3) at least in part in flux linking relationship with said core so that movement of the magnet through said second part of its orbit induces a voltage in said second winding means during a

time immediately following discharge of the capacitor, by which firing of the spark plug can be prolonged when the voltage required to maintain spark plug firing is low.

3. The ignition apparatus of claim **2** further characterized by:

said first winding means and said second winding means respectively comprising the primary and secondary of a step-up transformer, and both being in flux linking relation to said core.

4. The ignition apparatus of claim **2** further characterized by:

(A) said first winding means comprising the primary of a step-up transformer; and

(B) said second winding means having

(1) a first portion which is inductively coupled with the first winding means to provide the secondary of the step-up transformer, and

(2) a second portion which is wound on said core and which is connected in series with the first portion.

5. Ignition apparatus for firing a spark plug of a reciprocating internal combustion engine in a predetermined portion of the engine cycle, of the type comprising a capacitor, means for charging the capacitor during a part of the engine cycle prior to that in which the spark plug is to be fired, inductance means connected with the spark plug, and switching means connected between the capacitor and the inductance means to control the time of discharge of the capacitor into the inductance means and thereby control the initiation of spark plug firing, said ignition apparatus being characterized by:

means for generating a voltage across the inductance means, which voltage exists during a time in each engine cycle immediately following discharge of the capacitor and can prolong spark plug firing beyond the interval of capacitor discharge when the voltage required to maintain spark plug firing is low, said current generating means comprising

(A) a magnet carried by a movable part of the engine for orbital motion in timed relation to the engine cycle;

(B) core means mounted adjacent to the magnet orbit and arranged to have a rapidly changing flux charged thereinto by the magnet during the last mentioned time in each engine cycle; and

(C) winding means in flux linking relationship with said core means and operatively associated with the inductance means.

6. Ignition apparatus for firing a spark plug of a reciprocating internal combustion engine in a predetermined portion of the engine cycle, of the type comprising a capacitor, means for charging the capacitor during a part of the engine cycle which precedes said portion thereof in which spark plug firing occurs, inductance means connected with the spark plug, and switching means connected between the capacitor and the inductance means to control the time of discharge of the capacitor into the inductance means and thereby control the initiation of spark plug firing, said ignition apparatus being characterized by:

(A) a magnet carried by a movable part on the engine for orbital motion in timed relation to the engine cycle; and

(B) a core which cooperates with the magnet and which is in flux linking relationship with the inductance means for generating a voltage in the latter, said core being so arranged with respect to the magnet orbit that such voltage is generated immediately following discharge of the capacitor so that it provides for prolongation of the interval of spark plug firing when the voltage required to maintain spark plug firing is low.

7. The method of improving the cold starting characteristics of a reciprocating internal combustion engine having an ignition system of the type comprising a capacitor, means for charging the capacitor during a time in each engine cycle prior to that at which firing of the spark plug is desired, and inductance having a secondary connected with a spark plug and having a primary connected in series with the capacitor and a switching means, and means for rendering the switching means conductive at said time in each engine cycle when spark plug firing is desired, to permit the capacitor to discharge into the primary, which method is characterized by:

(A) moving a magnet orbitally in timed relation to the engine cycle; and

(B) by means of the moving magnet, inducing a voltage across the secondary of the inductance at a time in each engine cycle immediately following discharge of the capacitor, which voltage is sufficiently high to maintain firing of the spark plug at times when unvaporized fuel is present in the neighborhood of the spark plug electrodes.

8. Ignition apparatus for firing a spark plug of a reciprocating internal combustion engine, comprising a magnet that moves orbitally in timed relation to the engine cycle, a capacitor, means for charging the capacitor as the magnet moves through a first part of its orbit, a step-up transformer having a core, a primary wound on the core and connectable with the capacitor through switching means rendered conductive as the magnet moves through a second part of its orbit, and a secondary connected with a spark plug, said ignition apparatus being characterized by:

magnetically permeable means on the core of the step-up transformer providing a pair of legs that project toward the magnet orbit, said legs being in orbitally spaced relationship and being arranged to be swept by the magnet in said second part of its orbit and to cooperate with it in producing a changing flux in the core by which a voltage is induced in the secondary that can prolong firing of the spark plug beyond discharge of the capacitor when the voltage required to maintain spark plug firing is low.

References Cited

UNITED STATES PATENTS

3,280,809 10/1966 Issler.
3,326,199 6/1967 McMillen ---------- 123—149
3,447,521 6/1969 Piteo.

LAURENCE M. GOODRIDGE, Primary Examiner

U.S. Cl. X.R.

315—209