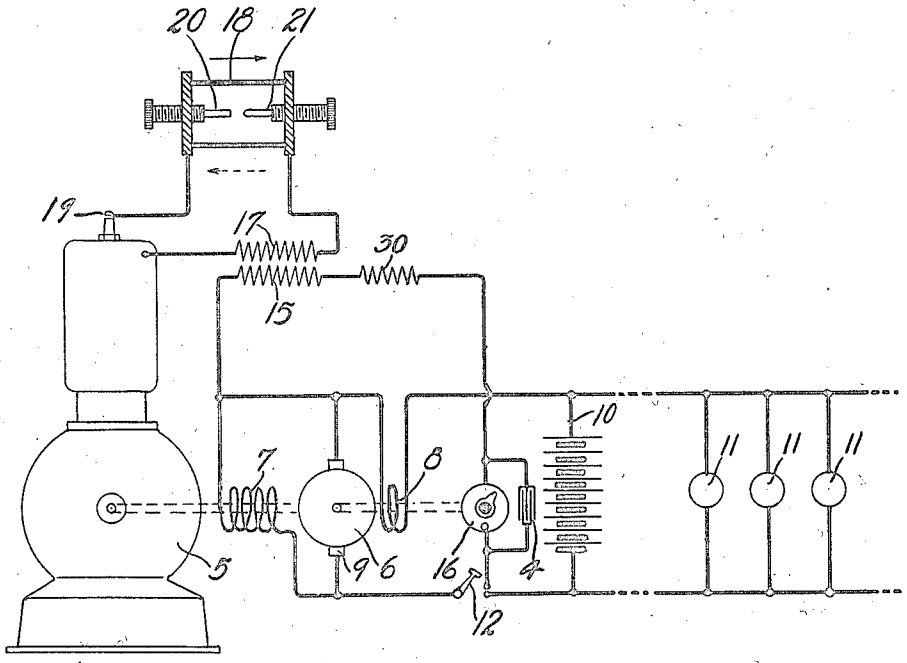
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C. E. REDDIG

ELECTRICAL IGNITION SYSTEM

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Inventor:
Charles E. Reddig
by Hubert A. Patterson
Atty.

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CHARLES E. REDDIG, OF RICHMOND HILL, NEW YORK, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

ELECTRICAL IGNITION SYSTEM.

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To all whom it may concern:

Be it known that I, CHARLES E. REDDIG, a citizen of United States of America, residing at Richmond Hill, Long Island, in the county of Queens, State of New York, have invented certain new and useful Improvements in Electrical Ignition Systems, of which the following is a full, clear, concise, and exact description.

This invention relates to improvements in electrical ignition systems and more particularly to such systems employed for igniting the gaseous charges in internal combustion engines.

One of the objects of the invention is to provide an ignition system, energized by a current of relatively high voltage, which will deliver a spark only when the primary circuit is broken, and will not deliver a spark when the said circuit is closed.

There are now in general use small electric power and light plants comprising an internal combustion engine and a dynamo driven thereby. In order to make the control circuits for such plants as economical and simple as possible, it has been the practice to supply the ignition system of the internal combustion engine with current from the dynamo. The current supplied by such dynamos is generally under a pressure of approximately thirty-six volts or more, and, due to this potential, for reasons hereinafter explained great difficulty has been encountered in preventing a spark being delivered the spark plug of the engine when the primary ignition circuit is made; this spark occurring at a time too early in the cycle of the engine for efficient operation.

In ignition systems employed in such plants which comprise a primary circuit which is made and broken intermittently by an interrupter, and a secondary circuit inductively related to the primary circuit in which the spark plug of the engine is connected, the efficiency and life of the engines have been reduced, due to the presence of what is known in the art as "preignition." In the efficient operation of an internal combustion engine, the gaseous charge should be fully ignited at a time when the piston has about completed its compression stroke and has just begun its working stroke, at which time the connecting rod has just passed dead center. If the charge is fully ignited before the piston has reached this point in its cycle, the force of the explosion will be exerted thereagainst either while it is completing its compression stroke or is on dead center; in both cases lessening the effective working power of the explosion and in the second case placing an undue strain on the connecting rod and crank shaft. Where a gaseous charge is ignited at such a time "preignition" is said to have taken place. Upon careful analysis it has been found that preignition, which has been prevalent in ignition systems of the type above referred to, has been caused by the creation of a spark at the plug when the interrupter closes the primary circuit. In such ignition systems it is desired that a spark take place at the plug at the time when the interrupter breaks the primary circuit, and where such a spark occurs at the plug when the primary circuit is closed by the interrupter, the charge is fired too early in the cycle of the engine. It is the primary object of the invention to provide an ignition system of this type which will prevent any spark occurring at the plug when the interrupter closes the primary circuit, and will not increase to any substantial degree the potential required to be induced in the secondary circuit in order to produce the spark which takes place at the plug when the primary circuit is broken. To accomplish this object, an ignition system made in accordance with the invention includes an impedance in the secondary circuit, the conductance of said impedance being so low as to prevent passage of current therethrough due to voltage induced by the closing of the primary circuit by the interrupter and said impedance consuming but a small portion of the secondary circuit voltage induced at the opening of the primary circuit by the interrupter.

In carrying out the invention, the secondary circuit is provided with an auxiliary series spark gap, the break down voltage of which is lower than the break down voltage

of the gap at the spark plug, its break down voltage being just high enough to prevent the passage of current induced in the secondary circuit when the primary circuit is closed by the interrupter. Since the voltage induced in the secondary circuit by the breaking of the primary circuit is, as is well known, considerably higher than the voltage induced in the said secondary circuit when the primary circuit is closed, an auxiliary spark gap of this character, although preventing the passage of current across the auxiliary gap when the primary circuit is closed, consumes but little of the electromotive force induced in the secondary circuit by the breaking of the primary circuit.

As is well known in the art, the potential required to break down a spark gap is much less at high temperatures and when the gap is located in a gas, such as is formed by the explosive mixture. It is obvious, however, that under starting conditions when the engine is cold and the explosive mixture is imperfectly vaporized that the potential necessary to cause a spark to cross the gap at the spark plug will be very much greater than under running conditions when the engine is warmed up. The result is that the use of an asymmetric conductor of this type prevents ignition which would otherwise occur after the engine has warmed up, but at the same time consumes but a small proportion of the voltage of the secondary circuit which is especially advantageous under the conditions occurring at starting which require the maximum induced voltage in the secondary circuit.

I am aware that auxiliary spark gaps have long been employed in the secondary circuits of ignition systems of the type previously referred to, such auxiliary gaps being known in the art as "intensifiers". Auxiliary spark gaps of this type have, in every case, been employed in order to cause the resumption of sparking in fouled spark plugs, and in order to operate and perform their intended functions must have a break down voltage higher than the break down voltage of the gap at the plug. A very comprehensive analysis of these so-called "intensifiers", together with their functions, construction and results obtained by their use, is set forth in Report No. 57, prepared by the Bureau of Standards of the United States Government for the National Advisory Committee of Aeronautics, the report being entitled, "The subsidiary gap as a means for improving ignition", printed by the Government Printing Office at Washington, 1920. Attention is called to the fact that these "intensifiers" in order to perform their intended functions must have a break down voltage higher than the break down voltage of the gap at the plug, the reasons for which are fully set forth in the report above referred to. Since the break down voltage of the auxiliary gap is higher than the break down voltage of the spark plug, a considerable amount of the induced E. M. F. is consumed by the auxiliary gap so that a smaller amount of E. M. F. is available for breaking down the gap at the plug making the engine difficult to start when cold. However, in the improved ignition system herein disclosed, the break down voltage of the spark gap is less than the break down voltage of the gap at the plug, but is just sufficient to prevent a spark at the plug when the primary circuit is closed, and due to the relatively small impedance offered by the auxiliary gap, the consumption of E. M. F. induced in the secondary circuit when the primary circuit is broken is a minimum so that the engine may be readily started even though cold.

I am also aware that there are ignition systems in use for multiple cylinder internal combustion engines employing a distributor in the secondary circuit which consists of a series of electrodes and a rotating arm which passes in sequence adjacent each electrode, a spark taking place between the rotating arm and the electrode, and a second spark taking place at the spark plug associated with the electrode. A distributor of this type which, in effect, constitutes an auxiliary spark gap, is not employed to prevent preignition when the primary circuit is closed, since in such systems the voltage source is low and as will be hereinafter explained the problem of such preignition is not present, but is used to obviate a wiping contact between the distributor arm and its associated electrodes. In fact there are a number of ignition systems in use employing distributors in which there is a wiping contact between the distributor arm and its associated contacts, the Delco system being one of this type. Another distinction between a system of this type and one to which the present invention is applied resides in the fact that where a distributor is used, the electrodes are movable one relative to the other, whereas in ignition systems where no distributor is employed, the contacts of the auxiliary spark gaps are fixed, and in every system, prior to the present invention, have been separated a distance such that the break down voltage of the auxiliary gap is higher than the break down voltage of the gap at the plug.

Other objects and advantages of the present invention will be definitely indicated in the claims appended hereto, while the features of construction and mode of operation will be best understood by reference to the following description taken in connection with the accompanying drawing which is a diagrammatic illustration showing the improved ignition system applied to a prime

mover dynamo plant in which the prime mover is an internal combustion engine.

Referring now to the drawing in detail, the reference numeral 5 indicates an internal combustion engine, the crank shaft of which is directly connected to the armature 6 of a motor generator having a shunt field 7 and a series field 8, the current output of the said motor generator being under a pressure of approximately 36 volts. The shunt field 7 is connected across the brushes 9, while the series field 8 and said brushes 9 are connected in series with a storage battery 10 and a load 11 by means of a switch 12. To start the set, switch 12 is closed and current is supplied the motor dynamo by the battery 10, the former operating as a motor to crank the engine 5. After the engine is started and the motor generator has come up to speed, it functions as a dynamo to replenish the storage battery 10 and supply the load 11. Since prime mover dynamo plants of this type are well known in the art, a detailed description thereof is thought to be unnecessary.

The improved ignition system comprises a primary circuit consisting of the primary winding 15 of an induction coil and a series resistance 30 which are connected in shunt of the storage battery 10 and motor generator 6 when the switch 12 is closed. In series with the primary winding 15 is an interrupter 16 driven by the engine 5, the contacts of said interrupter being bridged by a condenser 4, the purpose of which is well known to those skilled in the art. A secondary circuit is inductively related to the primary circuit and comprises the secondary winding 17 of the induction coil which is grounded at one end to the engine. Connected in series with the secondary winding 17 is an auxiliary spark gap 18 and the engine spark plug 19. The auxiliary spark gap 18 comprises adjustable electrodes 20 and 21 insulated from each other and electrically connected with the spark plug and secondary winding 17, respectively. Attention is called to the fact that the electrode 20 is provided with a blunt end, while the end of the electrode 21 is pointed, the purpose of which will be hereinafter explained.

When the interrupter 16 closes the primary circuit, current is induced in the secondary winding 17 of the induction coil by the current flowing in the primary winding 15 thereof. Due to the presence of the auxiliary spark gap 18, sufficient impedance is offered to prevent a spark at the plug 19.

If the auxiliary gap were not employed, the impedance in the main gap might not be sufficient to prevent ignition of the explosive mixture after the engine becomes warmed up. The length of the auxiliary gap 18 may be determined from the design of the ignition coil and the voltage of the circuit in the following way:

The voltage equation for the primary ignition circuit is:

$$E = ir + L\frac{di}{dt}$$

At the instant of closure of this circuit, the current is zero, so that the equation becomes

$$E = L\frac{di}{dt}$$

The voltage per turn consumed in the primary winding of the induction coil is thus $\frac{E}{N_p}$, where N_p represents the number of turns in the primary. The voltage per turn in the secondary winding of the induction coil will be substantially the same, but may be slightly less on account of leakage flux. Thus the induced secondary voltage at the instant of closure of the primary circuit will not exceed

$$\frac{EN_s}{N_p}$$

where N_s represents the number of turns in the secondary. This gives data from which the proper length of the auxiliary gap 18 may be determined. For example, it is customary to have approximately 20,000 turns on the secondary winding and approximately 400 turns on the primary winding of a 32 volt ignition coil with an accompanying series resistance such as would be employed in the set to which the present improved ignition circuit is shown applied. The induced voltage in the secondary would therefore be in this case

$$\frac{20{,}000}{400} \times 32 = 1600 \text{ volts.}$$

It is now merely necessary to employ an auxiliary gap just large enough to prevent breakdown by this voltage $\frac{1}{32}''$ auxiliary gap is therefore suitable. It has been found that this voltage without the use of the auxiliary spark gap 18 is sufficient to break down a main gap of $\frac{1}{16}''$ at the spark plug when the engine becomes thoroughly heated, but by inserting the auxiliary gap 18, adjusted to approximately $\frac{1}{32}''$, the preignition is prevented. As has been previously stated, at starting a maximum induced voltage in the secondary circuit is desirable to insure a spark at the plug, and were a greater gap than $\frac{1}{32}''$ employed it would obviously consume an appreciable proportion of the secondary E. M. F. upon the break of the primary circuit, and would therefore interfere with securing a satisfactory spark under starting conditions.

It will be apparent from the foregoing that the use of a circuit employing a resistance in series with the primary greatly in-

creases the voltage induced in the secondary of the ignition coil upon the make of the primary contacts. For example, if resistance 30 had not been employed, and the ignition current supplied from a separate source of 12 volts (which would then be sufficient to produce the same primary current) the voltage induced in the secondary circuit would be as follows:

$$\frac{20{,}000}{400} \times 12 = 600 \text{ volts.}$$

It is thus apparent that in ignition systems where the induced voltage is low the danger of preignition does not exist. The ignition systems for multiple cylinder engines employing distributors, previously referred to, are supplied with current under a pressure of twelve volts or less, and for the reasons just stated are not subject to preignition when the primary circuit is closed, and where in such systems the distributor arm is spaced from its associated electrodes this construction is not to avoid preignition but to save the wear incident with wiping contact between the distributor arm and its associated contacts.

In ignition systems employing high voltage it might appear that preignition could be avoided by employing a proportionately larger number of primary turns in the induction coil. Where a coil of this type is used, it will be found that although preignition is prevented, the inductance of the primary winding is so great that severe sparking occurs at the timer contacts rendering the ignition circuit inoperative after a short time. For this reason in high voltage ignition systems a series resistance is employed in the primary circuit together with a coil of low inductance.

From the foregoing it will be appreciated that the essence of the invention resides in preventing the passage of current in the secondary circuit when the primary circuit is closed by the interrupter, and at the same time consuming but a small part of the voltage induced in the secondary circuit by the opening of the primary circuit by the interrupter, in ignition systems where the primary circuit employs a relatively high voltage and in ignition systems where the electrodes constituting the auxiliary gap are fixed. By the expression "relatively high voltage" I mean to designate a potential in the primary circuit of thirty six volts or more as distinguished from a potential less than this amount. This result can be accentuated by giving the electrodes forming the auxiliary spark gap the proper shape. It is well known in the art that on any charged conductor the density of the charge is greatest where the curvature of the conductor is the greatest. Where the conductor is pointed, the density of the collected electricity may be so great as to produce a continual loss of charge. This phenomenon is made use of in the present invention by providing one of the electrodes 20 with a flat end and the other electrode 21 with a pointed end. These electrodes are so arranged that when the primary circuit is closed, the direction of the induced current in the secondary circuit is from the blunt end electrode 20 to the pointed electrode 21, as is indicated by the full line arrow, and since the charge is substantially evenly distributed on the surface of the blunt end, the air gap has a higher break down voltage than it would have were the end of the electrode 20 pointed. However, when the primary circuit is broken by the interrupter, the direction of the current induced in the secondary circuit is from the pointed electrode 21 to the blunt electrode 20, as is indicated by the dotted line arrow. Since the charge on the electrode 21 becomes so dense on the point thereof that it tends to leak away, the break down voltage of the air gap is much smaller than when the direction of current flow is from 20 to 21.

What is claimed is:

1. In a system for preventing preignition in explosive engines, a low tension circuit including a source of current under pressure of a relatively high voltage and an interrupter, a high tension circuit in inductive relation to the low tension circuit and including a spark gap, and an asymmetric conductor in the secondary circuit for passing currents resulting from the opening of the interrupter contacts.

2. In a prime mover dynamo plant in combination, a single cylinder internal combustion engine, a generator driven by the engine, supply leads from the generator, an induction coil primary and an interrupter connected across the leads of the generator, a secondary in inductive relation to the primary, a spark plug, and an asymmetric conductor in circuit with the secondary to prevent current passing through the spark plug upon the closure of the interrupter contacts.

3. The combination with an internal combustion engine and a dynamo driven thereby, of an ignition system for the engine, comprising a primary circuit supplied with current by said dynamo, an interrupter in said primary circuit, a spark plug and an impedance in said secondary circuit, said impedance having a conductance low enough to prevent the passage of current therethrough due to high voltage induced in the secondary circuit by the closing of the primary circuit by the interrupter, whereby a spark at the plug is prevented, and the said impedance being such as to consume but a small part of the higher voltage induced in the secondary circuit by the opening of the

primary circuit by the interrupter, whereby a current producing spark is supplied the said plug.

4. An ignition system comprising a low tension circuit, a source of current and an interrupter in said circuit, a high tension circuit inductively arranged with relation to said low tension circuit, a main spark gap and an auxiliary spark gap having fixed electrodes in said high tension circuit, the said auxiliary spark gap having a lower break down voltage than the break down voltage of the main spark gap.

5. An ignition system comprising a low tension circuit, a source of current and an interrupter in said circuit, a high tension circuit inductively arranged with relation to said low tension circuit, a main spark gap and an auxiliary spark gap comprising two electrodes, the end of one electrode having a smaller radius of curvature than the other, said electrodes arranged whereby when the primary circuit is closed the direction of the induced current in the secondary circuit is from one electrode to the electrode whose end has the smaller radius of curvature, the said auxiliary spark gap having a lower break down voltage than the break down voltage of the main spark gap.

6. An ignition system comprising a low tension circuit, a source of current and an interrupter in said circuit, a high tension circuit inductively arranged with relation to said low tension circuit, a main spark gap and an auxiliary spark gap comprising two fixed electrodes, the end of one electrode having a smaller radius of curvature than the other, said electrodes arranged whereby when the primary circuit is closed the direction of the induced current in the secondary circuit is from one electrode to the electrode whose end has the smaller radius of curvature, the said auxiliary spark gap having a lower break down voltage than the break down voltage of the main spark gap.

7. The combination with an ignition system having a primary circuit, a source of voltage therefor, an interrupter in said circuit, and a secondary circuit inductively related to the primary circuit and having a spark gap therein, of an auxiliary spark gap in series with the secondary circuit said auxiliary spark gap having a break down potential substantially equal to the voltage of the current source multiplied by the ratio of the number of secondary to primary turns.

In witness whereof, I hereunto subscribe my name this 22d day of April, A. D., 1921.

CHARLES E. REDDIG.