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IGNITION MEANS

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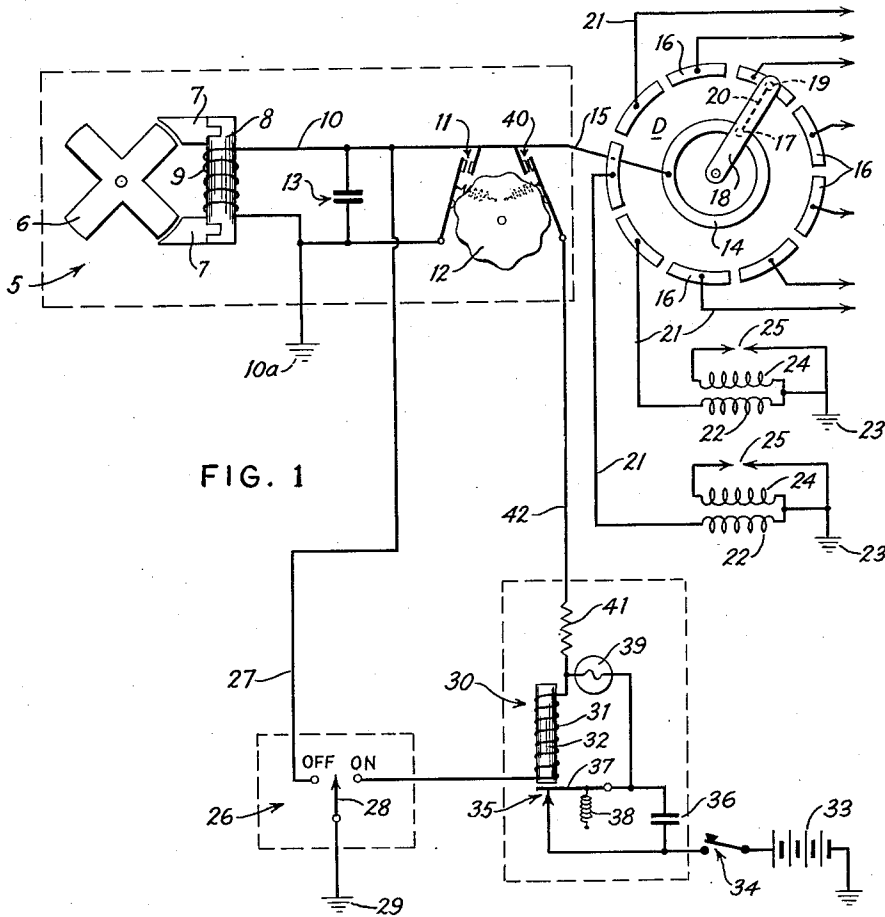


FIG. 1

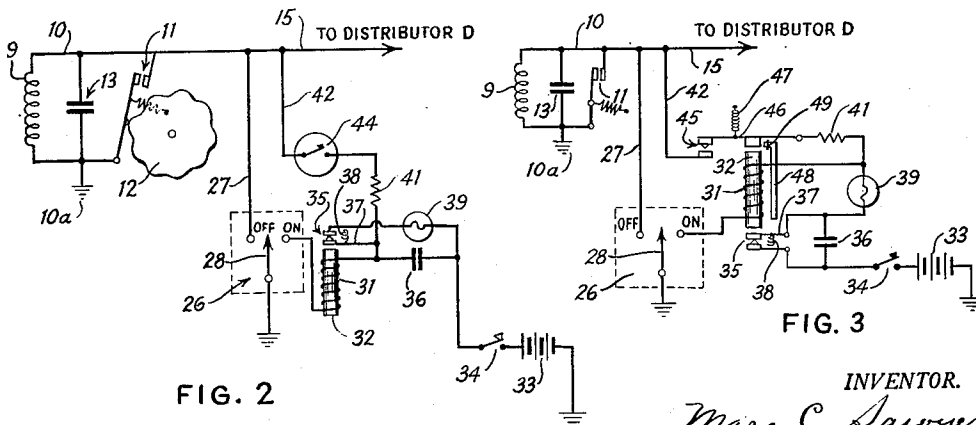


FIG. 2

FIG. 3

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IGNITION MEANS

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This invention relates to ignition means for internal combustion engines and more particularly to an ignition system adapted for use as a so-called booster for starting the engine.

One of the objects of the present invention is to provide a novel ignition system for an internal combustion engine wherein the electrical energy for firing the spark plugs is developed in a novel manner.

Another object of the invention is to provide a novel ignition system for an engine which is particularly adapted for low tension distribution of the electrical current to the spark plug circuits.

A further object is to provide a novel ignition circuit which is particularly adapted for use in starting internal combustion engines.

Still another object is to provide an ignition system wherein a booster or starting circuit is novelly combined with a conventional ignition system.

Another object is to provide a novel ignition system of the above character whereby a minimum amount of wiring is required.

A still further object is to provide a novel booster coil unit for use in conjunction with the ignition system of an internal combustion engine.

The above and further objects and novel features of the invention will more fully appear from the following detailed description when the same is read in connection with the accompanying drawing. It is to be expressly understood, however, that the drawing is for the purpose of illustration only and is not intended as a definition of the limits of the invention, reference for this latter purpose being primarily had to the appended claims.

In the drawing, wherein like reference numerals refer to like parts throughout the several views,

Fig. 1 is a diagrammatic view illustrating one type of ignition system embodying the features of the present invention;

Fig. 2 is a similar view showing a modification of the system of Fig. 1; and,

Fig. 3 is a similar view showing a second modification of the booster circuit.

In the limited number of embodiments illustrated in the drawing, the features of the invention are shown, by way of example, as being embodied in an ignition system for a 9-cylinder engine wherein the electrical current is distributed at low voltage, the voltage being stepped up at a transformer or spark coil near each spark plug for the purpose of creating the necessary ignition spark. In the form shown, the main ignition current for normal operation is generated by a

magneto 5 which embodies a magnetic rotor 6 adapted to cooperate with stator poles 7 which are in turn connected by a core 8 on which a coil 9 is wound. Upon rotation of rotor 6, such as by the engine, alternating current at relatively low voltage is generated in coil 9 in a manner well understood in the art.

One end of coil 9 is preferably grounded at 10a and the other end thereof is connected by a lead 10 to one contact of a circuit breaker 11, the other contact of which is also grounded at 10a or otherwise. The contacts of circuit breaker 11 are normally urged to engaged or closed position by suitable resilient means (not shown) and are periodically moved out of engagement with each other or to open position by a rotatable cam 12 which may also be driven by the engine. Cam 12 may be of any suitable design but, if the ignition system is used on a radial engine, the cam is preferably of the compensated type having a lobe for each cylinder of the engine, said lobes being spaced to properly time the sparks in each cylinder. A condenser 13 is preferably connected across the terminals of circuit breaker 11 to prevent arcing when the contacts are separated.

The insulated or ungrounded terminal of circuit breaker 11 is connected to a suitable distributor D which may take the form of any of many well-known designs. In the form shown, the distributor comprises a stationary insulated ring 14, to which circuit breaker 11 is connected by means of a lead 15, and a plurality of arcuate circularly arranged insulated contacts 16. Current delivered to ring 14 by the magneto or other suitable source is picked up by a carbon or similar brush 17 carried by a rotating distributor finger 18 and conducted to contacts 16 through a brush 19 which is also carried by said finger and electrically connected with brush 17 by a conductor 20. Distributor finger 18 may be rotated by the engine in timed relation with cam 12 and magneto rotor 6.

Each of the distributor contacts 16 is connected through a lead 21 to the primary winding 22 of a spark coil, which winding is in turn connected to ground at 23. By controlling the flow of electrical current at relatively low voltage to coil winding 22 in the manner to be hereinafter described, a high tension current is induced in secondary winding 24 of the spark coil and creates a spark across the points of a spark plug 25 in the cylinder of the engine.

When it is desired to stop the operation of the engine on which the above described ignition system is installed, the insulated end of magneto coil 9 may be connected to ground through an

ignition switch 26, the "off" terminal of which is connected by a lead 27 to said coil. The movable element 28 of the ignition switch may be grounded at 29 in any suitable manner.

In the operation of the ignition system thus far described, with ignition switch 26 in "on" position, the contacts of circuit breaker 11 are held in closed position during the build up of current in coil 9 of the magneto-generator. Each time the current in coil 9 approaches its maximum value, the points of circuit breaker 11 are opened by the lobes of cam 12, whereupon the current from the coil must flow through lead 15 and distributor D in the manner fully described above to a spark coil primary winding 22. This sudden surge of current through winding 22 is effective to induce the necessary energy in the secondary circuit, which includes winding 24, to create a spark at spark plug gap 25. As distributor finger 18 moves brush 19 over the contacts 16, the spark plugs of the engine are successively fired in a predetermined order, the timing of each spark being determined by the opening of circuit breaker 11.

In an ignition system of the above character, it is highly desirable to provide an electrical resistance in the primary circuit which is of sufficient magnitude to quickly dissipate the residual energy in said circuit after the occurrence of each spark at a spark plug. This dissipation of the residual energy is desirable in order to prevent arcing at the distributor contacts and to obviate the possibility of secondary sparks at the spark plugs when the distributor brush 19 moves from one contact of the distributor to another. The desired resistance is preferably incorporated in the primary windings 22 of the transformer coils, thereby making it possible to use smaller wire and reduce the size of these coils. In one satisfactory embodiment of the invention, a resistance of 16 ohms in each primary winding 22 has been found suitable. This resistance value may differ, however, with different installations—the most suitable value may be determined by resorting to oscillograph or like measuring means for determining the characteristics of the current in the primary circuit. The resistance may be incorporated in the primary circuit at any desired point and should only be sufficiently large to produce the desired dissipation of the residual energy.

Since rotor 6 is driven by the engine, sufficient energy cannot be generated by magneto 5 to start the engine when the crankshaft of the latter is turned slowly by the starting motor. Novel means which are independent of the speed of the engine are accordingly provided for generating the necessary starting energy. In the form shown, said novel means comprises a novel buzzer type booster coil unit 30 which includes a coil 31 having relatively high inductance wound on a core 32. Coil 31 is adapted to be connected in circuit with a battery 33 or other suitable source of current, a starter operated switch 34 and buzzer contacts 35, across which a condenser 36 may be connected to prevent arcing. One of the buzzer contacts is mounted on a pivoted arm 37 which is normally urged toward a contact closing position by a spring 38 or other suitable resilient means and which is adapted to be electromagnetically moved to contact open position when coil 31 is energized. A current limiting fuse 39 may be provided in the circuit between buzzer contacts 35 and coil 31 to obviate any danger of burning out the coil if said contacts should stick in closed position. The other end of coil 31

may be connected to ground at 29 through the "on" position terminal of ignition switch 26 and switch lever 28.

If the booster sparks can be permitted the same advance as the magneto sparks during normal operation of the engine, or if suitable automatic or manual means are provided for retarding the timing of the magneto to the engine for starting purposes, booster coil 31 may be directly connected to the input terminal 14 of the distributor so that the required timing might be effected by main circuit breaker 11. In this case, the timing would be effected by the opening of the main circuit breaker since the current from the booster will flow to ground through said breaker when the latter is closed and to the distributor when the breaker points are open. In most installations it is desirable to provide separate means for retarding the booster spark and this may be done by employing a second circuit breaker 40 connected between coil 31 and distributor ring 14. Breaker 40 may be operated by cam 12 or a second cam may be provided for this purpose.

A resistance 41 is preferably provided in the connection 42 between the booster coil or inductance coil 31 and the main ignition circuit to limit the current which may flow from the booster coil unit through magneto coil 9. The current which flows in this manner through the latter coil must be maintained sufficiently small to prevent any material demagnetization of magnet 8. Resistance 41 also prevents a dead short circuit when both of the circuit breakers 11 and 40 are closed during operation of the booster coil unit 30. In one suitable embodiment of the invention, resistance 41 has a value of approximately 3 ohms and the inductance of coil 31 is approximately 5 milli-henries but these values may vary with the characteristics of the magneto which said resistance protects, the resistance in the primary circuit and other characteristics of the system. The required value of resistance 41 to avoid undue demagnetization of rotor 6 may be readily determined by measuring the current flowing through coil 9 during operation of the booster circuit under all possible conditions of operation. The value of the inductance 41 must be large enough to properly energize coils 22, 24 under operating conditions and hence depends on the characteristics and requirements of the system.

When it is desired to start an engine equipped with the above described ignition system, arm 28 of switch 26 is placed in "on" position and starter switch 34 is closed. Since contacts 35 are normally held in closed position by spring 38, current will then flow from battery 33 through contacts 35, coil 31 and switch 26 to ground at 29. Upon excitation or energization of electromagnet 31, 32 in this manner, the buzzer contacts 35 are electromagnetically opened, thereby breaking the circuit to coil 31 so that said contacts will be closed again under the action of spring 38. This cycle of operation of the buzzer contacts is repeated again and again in rapid succession, as is well understood in the art.

During operation of the booster coil or buzzer as above described, circuit breaker 11 is periodically opened by cam 12. The relative positions of cam 12 and circuit breakers 11 and 40 are such that a few degrees of rotation of the cam after each opening of circuit breaker 11 permits booster circuit breaker 40 to move to closed position. This periodic closing of circuit breaker 40 is timed to occur at the moment it is desired to create a spark in one of the engine cylinders.

While the booster unit is operating with the parts in the last mentioned positions, i. e., with circuit breaker 11 open and circuit breaker 40 closed, a self-induced current flows in surges from coil 31 to the distributor D through lead 15 and, hence, to one of the spark coils 22, 24. A surge of current to the distributor and, hence, to a spark coil occurs each time buzzer contacts 35 are moved to open position. This current which is used in the creation of the sparks at spark plugs 25 for starting the engine is induced in booster coil 31 by the sudden collapse of the magnetic field which is built up around the coil when current from battery 33 is permitted to flow therethrough to ground. The inductance of coil 31 is made sufficiently high so that the transient voltage which is developed across said coil when contacts 35 are opened is sufficient to produce good booster sparks at spark plugs 25 in spite of the relatively high ohmic resistance of each primary winding 22 or other resistance provided in the primary circuit for the same reasons.

When the engine starts, i. e., when rotor 6 is turned sufficiently fast by the engine to produce the necessary current to operate the engine without the assistance of the booster coil unit, starter switch 24 may be opened automatically or otherwise by any of many suitable means well-known in the art. The operation of the booster coil unit will thus be stopped during normal operation of the engine.

In one embodiment of the invention which proved highly successful on a nine cylinder aircraft engine, a battery rated at 24 volts was employed and a 20 ampere current limiting fuse 39 was used. Condenser 36 had a value of .25 microfarad, the resistance of coil 31 was approximately one ohm and the inductance of said coil was approximately 5 milli-henries. In this same embodiment, the value of resistance 41 was approximately 3 ohms and the resistance of each of the primary windings 22 was 16 ohms, as heretofore pointed out.

In the modification of Fig. 2, the booster circuit breaker 40 is eliminated and the main circuit breaker 11 is employed for timing the booster impulses. In place of the booster circuit breaker, a suitable switch 44 is provided for cutting the booster circuit out of the system during normal operation of the engine to thereby prevent the booster from short-circuiting the magneto impulses. In all other respects the embodiments of Figs. 1 and 2 are the same. In operation, when ignition switch 26 is in "on" position and switches 34 and 44 are closed, the self-induced impulses from booster coil 31 upon opening of points 35 will flow to the distributor and, hence, to the spark coils 22, 24 only when circuit breaker 11 is in open position. When this circuit breaker is closed the current will flow across the points thereof and to ground at 10a. Accordingly, the timing of the initial booster spark in each engine cylinder is determined by the opening of circuit breaker 11. If desired, some suitable means known to the art may be employed for retarding the opening of circuit breaker 11 during the starting operation.

The embodiment illustrated in Fig. 3 is the same as that of Fig. 2 except that a solenoid operated relay switch is substituted for cut-out switch 44 in lead 42. Although the relay switch may be operated by any suitable solenoid, it is operated, in the form shown, by solenoid 31, 32 and comprises separable points 45, one of which is mounted on a pivoted arm 46. Points 45 are normally

held in open position by suitable resilient means, such as a coil spring 47 attached to arm 46. The latter is attracted by solenoid 31, 32 when the booster is in operation to thereby close the circuit at points 45 and permit the booster impulses to flow to the primary or distributor circuit. The operation is the same as described above in connection with Fig. 2 except for the automatic operation of cut-out switch 45.

Any well known method may be employed for insuring continued closure of switch 45 whenever buzzer contacts 35 are in operation. For example, armature 46 may be made heavier than arm 37 and/or spring 47 may be made lighter than spring 38. To provide ample insurance against any undesired opening of contacts 45 when spring 47 is made sufficiently strong to avoid any undesired closing of said contacts as a result of vibration or other cause during engine operation, a so-called flux catcher 48 may be provided. Element 48 concentrates the magnetic flux acting on armature 46 and hence prevents the opening of contacts 45 each time contacts 35 are opened even though spring 47 may be relatively strong. The effectiveness of means 48 may be increased by placing a shorted turn of copper wire 49 thereon to provide a shaded pole effect, as is well understood in the art.

There is thus provided a novel ignition circuit for an internal combustion engine wherein the electrical current delivered to the primary winding of a transformer or spark coil is produced in a novel and simplified manner. There is also provided an ignition circuit equipped with a booster for starting purposes wherein the wiring for the switch means is reduced to a minimum. Novel means are also incorporated in a low voltage distribution ignition system for supplying a starting current in properly timed surges to the primary windings of spark coils for inducing high tension current in the secondary windings of said coils. Additionally, the system provided by the present invention is also operable equally well at all altitudes.

Although only a limited number of embodiments of the invention have been diagrammatically illustrated in the drawing, it is to be expressly understood that changes in the details thereof may be made without departing from the spirit and scope of the invention. For example, many different types of distributors may be employed, the necessary resistances may be inserted at different points than illustrated and described, the resistances may be either concentrated in resistance units or distributed in leads where the same are required or desired, and the values of the various resistances, voltages, etc., may be varied to advantage in systems having different characteristics. Other changes which do not depart from the spirit and scope of the invention will also be apparent to persons skilled in the art. For a definition of the limits of the invention, reference is had primarily to the appended claims.

What is claimed is:

1. In ignition apparatus, electrical current-generating means including a coil and magnetic means for inducing alternating current therein, a first circuit breaker connected across said coil, means for normally holding said circuit breaker in closed position, means for periodically opening said circuit breaker in timed relation with the operation of said magnetic means, a transformer coil having primary and secondary windings, means for grounding said coils, means connecting the ungrounded side of said circuit breaker to the

ungrounded end of said primary winding, a condenser connected in parallel with said circuit breaker, a spark gap in series with said secondary winding, whereby a surge of electrical current flows through said primary winding to create a spark at said gap when said circuit breaker is opened, a source of uni-directional electrical current, a second circuit breaker having one side thereof connected to the ungrounded terminal of said source, means for normally holding said second circuit breaker in closed position, a self induction coil having the ungrounded end thereof connected to the other side of said second circuit breaker, said induction coil being adapted to electromagnetically open said second circuit breaker when energized by said source, a condenser connected in parallel with said second circuit breaker, a current limiting fuse connected in the circuit between said source and said induction coil, a resistance having one end thereof connected to the ungrounded end of said induction coil, a third circuit breaker having one side thereof connected to the other end of said resistance, means connecting the other side of said third circuit breaker to the ungrounded side of said first circuit breaker, and means for periodically closing said third circuit breaker when said first circuit breaker is in open position.

2. An ignition system comprising a main circuit including a source of electrical current, a circuit breaker through which current from said source normally flows, a condenser connected in parallel with said circuit breaker, means for periodically opening said circuit breaker, current distributing means having an input terminal to which current from said source flows when said circuit breaker is in open position and a plurality of ignition coils having the primary windings thereof connected to the output terminals of said distributor means for successive connection to said source, an auxiliary circuit comprising a second source of electrical current, a buzzer including a self induction coil connected with said second source and means connecting one end of said coil to ground, and means connecting the other end of said coil to the input terminal of said distributor.

3. An ignition system comprising a main circuit including a source of electrical current, a circuit breaker through which current from said source normally flows, a condenser connected in parallel with said circuit breaker, means for periodically opening said circuit breaker, current distributing means having an input terminal to which current from said source flows when said circuit breaker is in open position and a plurality of ignition coils having the primary windings thereof connected to the output terminals of said distributor means for successive connection to said source, an auxiliary circuit comprising a second source of electrical current, a buzzer including a self induction coil connected with said second source and means connecting one end of said coil to ground, means connecting the other end of said coil to the input terminal of said distributor, a circuit breaker in said last-named connecting means, and means for periodically closing said last-named circuit breaker while said first-named circuit breaker is in open position.

4. In an ignition system, a main circuit comprising a source of alternating electrical current including an induction coil, a circuit breaker through which said current normally flows, a condenser connected in parallel with said circuit breaker, a transformer having primary and secondary windings, means connecting said primary

winding to the ungrounded side of said circuit breaker and means for periodically opening said circuit breaker whereby a surge of current is caused to flow through said primary winding, an auxiliary circuit comprising a source of unidirectional electrical current, an inductance connected across said last-named source and a pair of buzzer contacts connected between said last-named source and the high potential end of said inductance, said buzzer contacts being operable to open position by the magnetic field of said inductance, and means for connecting the high potential end of said inductance to the ungrounded side of said circuit breaker.

5. In an ignition system, a main circuit comprising a source of alternating electrical current including an induction coil, a circuit breaker through which said current normally flows, a condenser connected in parallel with said circuit breaker, a transformer having primary and secondary windings, means connecting said primary winding to the ungrounded side of said circuit breaker and means for periodically opening said circuit breaker whereby a surge of current is caused to flow through said primary winding, an auxiliary circuit comprising a source of unidirectional electrical current, an inductance connected across said last-named source and a pair of buzzer contacts connected between said last-named source and the high potential end of said inductance, said buzzer contacts being operable to open position by the magnetic field of said inductance, means for connecting the high potential end of said inductance to the ungrounded side of said circuit breaker, a circuit breaker in said last-named connecting means, and means for periodically closing said last-named circuit breaker while said first-named circuit breaker is in open position.

6. An ignition system comprising a main circuit including a source of electrical current, a circuit breaker through which current from said source normally flows, a condenser connected in parallel with said circuit breaker, means for periodically opening said circuit breaker, current distributing means having an input terminal to which current from said source flows when said circuit breaker is in open position and a plurality of ignition coils having the primary windings thereof connected to the output terminals of said distributor means for successive connection to said source, an auxiliary circuit comprising a second source of electrical current, a buzzer including an induction coil connected with said second source and means connecting one end of said coil to ground, means connecting the other end of said coil to the input terminal of said distributor, and a cutout switch for disconnecting said auxiliary circuit from said main circuit.

7. In an ignition system, a main circuit comprising a source of alternating electrical current including an induction coil, a circuit breaker through which said current normally flows, a condenser connected in parallel with said circuit breaker, a transformer having primary and secondary windings, means connecting said primary winding to the ungrounded side of said circuit breaker and means for periodically opening said circuit breaker whereby a surge of current is caused to flow through said primary winding, an auxiliary circuit comprising a source of unidirectional electrical current, an inductance connected across said last-named source and a pair of buzzer contacts connected between said last-named source and the high potential end of said

inductance, said buzzer contacts being operable to open position by the magnetic field of said inductance, means for connecting the high potential end of said inductance to the ungrounded side of said circuit breaker, circuit breaker means for disconnecting said auxiliary circuit from said main circuit, yieldable means for normally holding said circuit breaker means in open position, and electromagnetic means for holding said circuit breaker means in closed position during operation of said buzzer contacts.

8. An ignition system comprising a main circuit including a source of electrical current, a circuit breaker through which current from said source normally flows, a condenser connected in parallel with said circuit breaker, means for periodically opening said circuit breaker, current distributing means having an input terminal to which current from said source flows when said circuit breaker is in open position and a plurality of ignition coils having the primary windings thereof connected to the output terminals of said distributor means for successive connection to said source, an auxiliary circuit comprising a second source of electrical current, a buzzer including an induction coil connected with said second source and means connecting one end of said coil to ground, means connecting the other end of said coil to the input terminal of said distributor, circuit breaker means in said last-named connecting means, means for normally holding said circuit breaker means in open position, and electromagnetic means including said induction coil for closing said circuit breaker means when said buzzer contacts are in operation.

9. The method of creating sparks across the gap of a spark plug in an engine cylinder which includes the steps of directing unidirectional current through a self-induction coil, interrupting the flow of said current, and discharging the resulting inductive surge of said coil through the primary winding of a transformer, the secondary winding of which is in series with said gap.

10. The method of creating sparks across the gap of a spark plug in an engine cylinder which includes the steps of directing unidirectional current from a source of electrical energy through a self-induction coil, utilizing the magnetic field around said coil to open the circuit between said source and coil, and directing current induced in said coil upon opening of said circuit through the primary winding of a transformer.

11. The method of producing sparks across a gap which includes the steps of directing unidirectional current from a source of electrical energy through a circuit including a self-induction coil, opening and closing said circuit in rapid succession to cause the current through said coil from said source to fluctuate, and directing the current surges thereby induced in said coil through the primary winding of a transformer, the secondary winding of which is in series with said gap.

12. In ignition apparatus, a source of unidirectional electrical current, a pair of separable contacts, means including an induction coil in circuit with said source and contacts for opening and closing the latter to thereby cause the current in said circuit to fluctuate, a transformer having the primary winding thereof connected to the high potential end of said coil, a second induction coil connected in parallel with said primary winding with respect to said source, mag-

netic means for inducing alternating current in said second induction coil, a circuit breaker connected across said second induction coil, and means for periodically opening said circuit breaker in timed relation with the operation of said magnetic means.

13. In ignition apparatus, a source of unidirectional current, a pair of buzzer contacts, means including a self-induction coil connected in circuit with said source for opening said contacts to thereby interrupt the flow of current through said coil from said source, a transformer having a primary winding, a second induction coil, said winding and second induction coil being connected in parallel to the high potential end of said first-named induction coil, magnetic means for inducing current in said second induction coil, circuit breaker means connected across said second induction coil, and means for periodically operating said circuit breaker means in timed relation with the operation of said magnetic means.

14. In ignition apparatus, a source of unidirectional current, a pair of buzzer contacts, means including a self-induction coil connected in circuit with said source for opening said contacts to thereby interrupt the flow of current through said coil from said source, a transformer having a primary winding, a second induction coil, said winding and second induction coil being connected in parallel to the high potential end of said first-named induction coil, magnetic means for inducing current in said second induction coil, circuit breaker means connected across said second induction coil, means for periodically operating said circuit breaker means in timed relation with the operation of said magnetic means, a circuit breaker in said connection to the high potential end of said first-named induction coil, and means for closing said circuit breaker when said circuit breaker means is in open position.

15. In ignition apparatus, a source of unidirectional current, a pair of buzzer contacts, means including a self-induction coil connected in circuit with said source for opening said contacts to thereby interrupt the flow of current through said coil from said source, a transformer having a primary winding, a second induction coil, said winding and second induction coil being connected in parallel to the high potential end of said first-named induction coil, magnetic means for inducing current in said second induction coil, circuit breaker means connected across said second induction coil, means for periodically operating said circuit breaker means in timed relation with the operation of said magnetic means, a normally open circuit breaker in said connection to the high potential end of said first-named induction coil, and means for magnetically holding said circuit breaker in closed position when said buzzer contacts are in operation.

16. In ignition apparatus, a source of unidirectional electrical current, a circuit including an inductance and a pair of buzzer contacts connected in series across said source, said buzzer contacts being operable in accordance with the flow of current through said inductance to cause said current to fluctuate, a transformer having a primary winding connected to the high potential end of said inductance, means including a circuit breaker for shunting current around said primary winding, and means for periodically opening said circuit breaker.

17. In ignition apparatus, a transformer having a primary winding and a secondary winding,

a source of unidirectional current, a self-induction coil connected in circuit with said source and through which current from said source normally flows, a circuit breaker in series with said coil and automatically operable to open position whenever the current through said inductance from said source reaches a predetermined value, resilient means for normally closing said circuit breaker, and means for connecting said primary winding to the high potential end of said coil, whereby current induced in said coil upon opening of said circuit breaker is directed through said primary winding.

18. In ignition apparatus, electrical current-generating means including a coil and magnetic means for inducing alternating current therein, a first circuit breaker connected across said coil, means for normally holding said circuit breaker in closed position, means for periodically opening said circuit breaker in timed relation with the operation of said magnetic means, a transformer coil having primary and secondary windings, means for grounding said coils, means connecting the ungrounded side of said circuit breaker to the ungrounded end of said primary winding, a condenser connected in parallel with said circuit breaker, a spark gap in series with said secondary winding, whereby a surge of electrical current flows through said primary winding to create a spark at said gap when said circuit breaker is opened, a source of uni-directional electrical current, a second circuit breaker having one side thereof connected to the ungrounded terminal of said source, means for normally holding said second circuit breaker in closed position, an induct-

ance coil having the ungrounded end thereof connected to the other side of said second circuit breaker, said inductance coil being adapted to electromagnetically open said second circuit breaker when energized by said source, a condenser connected in parallel with said second circuit breaker, a current limiting fuse connected in the circuit between said source and said inductance coil, a resistance having one end thereof connected to the ungrounded end of said inductance coil, a third circuit breaker having one side thereof connected to the other end of said resistance, means connecting the other side of said third circuit breaker to the ungrounded side of said first circuit breaker, means for periodically closing said third circuit breaker when said first circuit breaker is in open position, and periodically operable circuit breaker means shunting said primary winding for timing the flow of current through the latter.

19. In ignition apparatus, a transformer having a primary winding and a secondary winding, a source of electrical energy, a circuit including an inductance and a circuit breaker connected in series across said source, means for normally holding said circuit breaker in closed position, means for connecting the high potential end of said inductance to said primary winding, and means including said inductance for opening said circuit breaker whenever the current through said inductance from said source reaches a predetermined value, whereby current induced in said inductance flows in a surge through said primary winding when said circuit breaker is opened.

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