

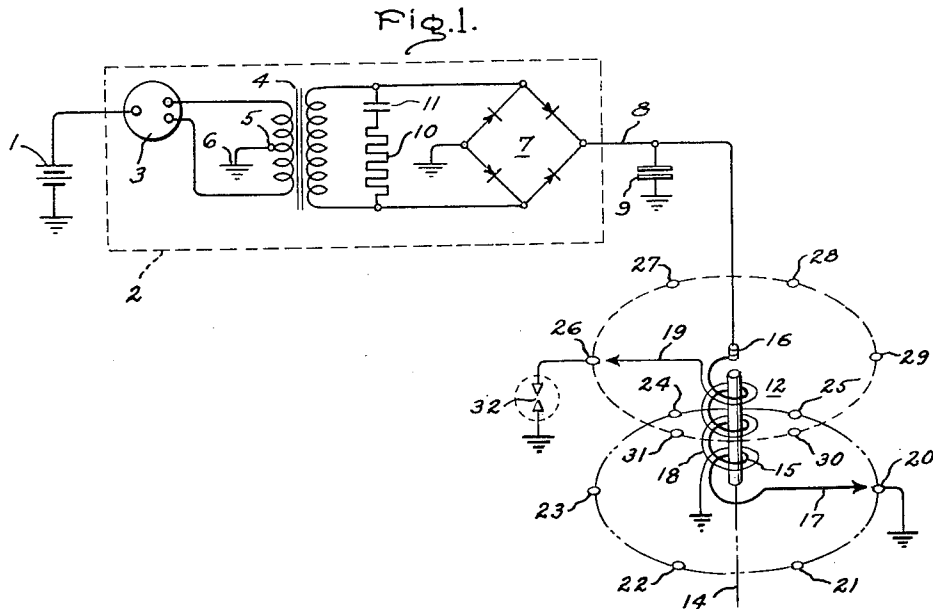
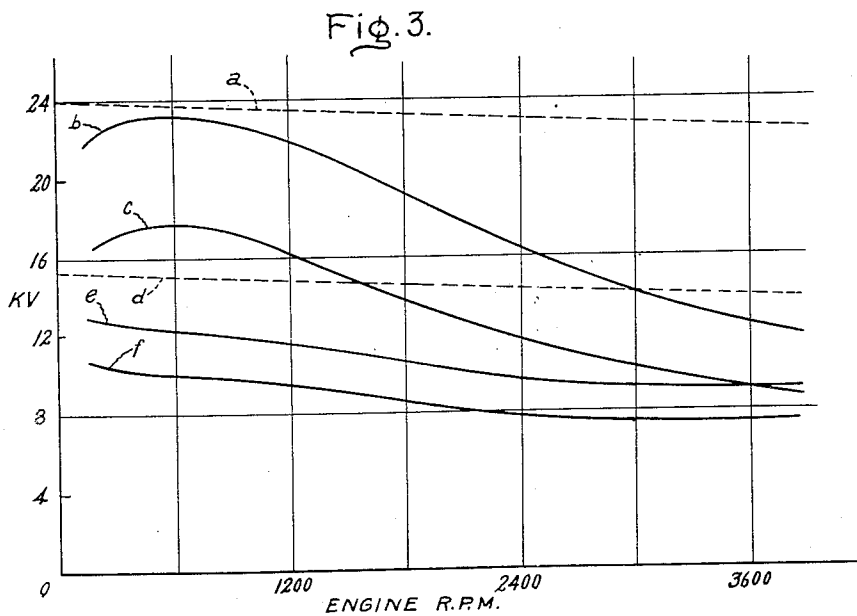
May 8, 1951

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HIGH-FREQUENCY IGNITION SYSTEM

2,552,212

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2 Sheets-Sheet 1



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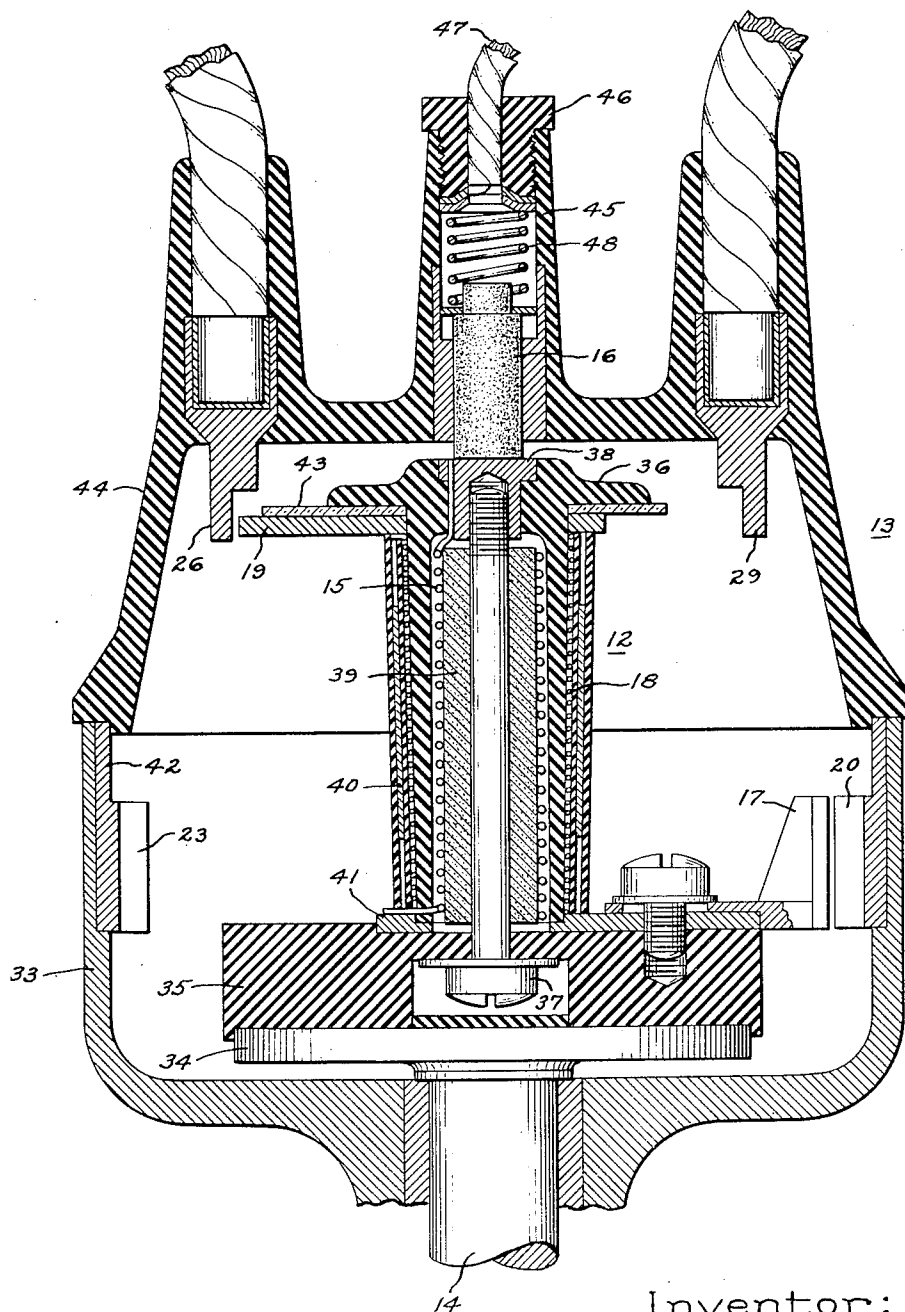
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Fig. 2.



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HIGH-FREQUENCY IGNITION SYSTEM

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This invention relates to ignition systems and more particularly to a breakerless type which provides a high frequency spark discharge.

Conventional ignition systems such as are found in the automotive and personal airplane field ordinarily employ a high voltage coil in conjunction with a breaker contact in the primary circuit of the coil. The breaker contact is actuated by an engine driven cam, and alternately makes and breaks the primary circuit. During the make period, current flow establishes a magnetic field in the coil. When the contact opens, this field collapses rapidly thus inducing a high voltage in the secondary winding of the coil which initiates a jump spark at the spark plug.

Disadvantages and limitations of conventional ignition systems are many. Their coil output voltage is sensitive to engine speed and this results in a considerable reduction in the available voltage reserve at high speeds. Due to the considerable inductance in the coil, the inductive component of spark discharge at high engine speed is of sufficient time duration to interfere with the production of successive sparks. This causes a reduction in output voltage, excessive breaker contact sparking and excessive spark plug gap erosion. The oscillatory frequency of the spark discharge is low and thus ineffective for adequately firing fouled spark plugs. Frequent inspection and maintenance of breaker contacts is required since normal wear detracts materially from peak ignition system efficiency. Finally, the inherent nature of the circuit break type of high voltage generation limits the output voltage available from a nominal 6-volt power supply because of the practical considerations of component size. This last limitation becomes particularly serious with increase in engine compression ratios.

An object of my invention is to provide an ignition system which produces at the spark plug, a voltage which is practically independent of engine speed.

Another object of my invention is to provide an ignition system in which the spark plug energy discharge occurs at a high rate thus producing a high frequency oscillation capable of firing fouled spark plugs far beyond the capabilities of conventional ignition systems.

A further object is to reduce the rate of distributor and spark plug electrode erosion.

Still another object of my invention is to eliminate troublesome breaker contacts.

A further object of my invention is to minimize radio noise by localizing high voltage regions and reducing average spark discharge energy.

A still further object of my invention is to provide an ignition system wherein the spark plug voltage, the spark timing and the ignition unit

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efficiency of operation remains practically unaffected by normal erosion or wear.

For easy visualization of my invention, my ignition system may be considered as having three major cooperative components; a voltage transducer, a discharge capacitor, and an engine driven unit comprising a housing containing a high frequency transformer, a primary distributor and a secondary distributor.

My transducer provides a high voltage such as will insure a continuously high level of charge on the capacitor. At the appropriate time in the engine cycle, the capacitor energy is discharged to ground via the primary of the high frequency transformer by means of a primary distributor thus producing a high frequency energy discharge through the transformer. A high level of voltage is subsequently produced in the secondary of the transformer which is then discharged through a secondary distributor to the appropriate spark plug.

The invention will be more fully understood by referring now to the accompanying drawings wherein:

Fig. 1 is an elementary, schematic representation of my ignition system;

Fig. 2 is a cross-sectional view of my engine driven unit and;

Fig. 3 is a graph of ignition voltage characteristics.

Referring now to Fig. 1 there is shown a conventional 6-volt battery 1 which supplies power to a transducer 2 of the so-called power-pack type such as is used for portable photo-flash photography. Its purpose is to convert electrical energy at storage battery voltage to a much higher voltage level, for example, over three thousand volts.

The transducer 2 comprises a vibrator 3 which converts the direct current energy from battery 1 to a transformable form. The output of the vibrator 3 is applied to the primary of a high voltage transformer 4 which has a mid-tap 5 connected to ground at 6. The output from the secondary of transformer 4 is connected to a selenium oxide type rectifier 7 to produce a D.-C. voltage between conductor 8 and ground for charging a capacitor 9. A transformer timing circuit comprising resistance 10 and capacitor 11 is serially connected across the output of transformer 4.

A detailed explanation of the transducer 2 is considered unnecessary since its general components are well known in the art and the attainment of good regulation is a matter of design. It will be necessary to provide a wattage rating sufficient to charge the capacitor 9 during the maximum discharge rate encountered in engine operation. It is necessary also to provide a capacitor charging circuit with a response time

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sufficiently short to fully charge the capacitor between each pulse from the vibrator 3. It should also be noted perhaps that the transformer must have a design which adapts it for operation with a mechanical vibrator fed from a low voltage direct current source.

The energy from capacitor 9 is delivered to a high frequency transformer 12 which is located within the engine-driven unit 13.

Although the engine-driven unit 13 will be described in detail in connection with Fig. 2, a brief preliminary explanation of the schematic representation of Fig. 1 will clarify the subsequent discussion.

The engine-driven unit 13 comprises the high frequency transformer member 12 which is supported for axial rotation by an engine-driven shaft schematically represented by the dotted line 14. The high frequency transformer 12 has a primary winding 15 having its upper end diagrammatically shown as being connected through a brush 16 to the output of capacitor 9. The lower end of primary winding 15 is connected to a primary distributor finger 17 which is fixed to rotate with the shaft 14.

The transformer 12 has a secondary winding 18, the lower end of which is connected to the finger 17. Alternately, the lower end of the secondary may be connected to ground directly. The upper end of secondary winding 18 is connected to a secondary distributor finger 19 which of course also rotates with the engine-driven shaft 14.

A plurality of primary electrodes 20-25 (six of which are illustrated but which number should be equal to the number of engine cylinders) are circumferentially spaced in cooperative relationship with the finger 17. These electrodes are positioned so as to discharge energy from capacitor 9 across a small air gap to ground at the proper time in the engine cycle.

Secondary electrodes 26-31 equal in number to the number of primary electrodes are each connected to their respective spark plugs only one of which is schematically shown at 32. The connection of electrodes 26-31 to other spark plugs is omitted for the purpose of clarity.

The terms referred to herein as primary distributor and secondary distributor are to be considered as distributors in a conventional sense wherein no mechanical contact is made between the rotor finger and the cooperating electrodes.

The operation of the ignition system illustrated in Fig. 1 will be better understood from the following explanation.

While the primary distributor finger 17 is rotating between adjoining electrodes, the discharge circuit of the capacitor 9 is open and during this period the capacitor 9 is being charged. When the primary distributor finger 17 comes within ionization distance of a primary electrode, such as 20, the energy stored in capacitor 9 is discharged through a circuit which may be traced through the primary winding 15 of the high frequency transformer 12, through finger 17, and across an air gap to the grounded electrode 20. At the instant of ionization, the secondary distributor finger 19 is positioned opposite its corresponding secondary electrode 26. The very rapid magnetic flux change, caused by capacitative current flow in the transformer primary 15, induces a high secondary voltage in the winding 18. This causes a current in the secondary winding 18 to flow across the secondary distributor air gap to the secondary elec-

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trode 26 then to the spark plug 32 and to ground. The secondary circuit is completed via the ionized primary distributor air gap, or alternately, the secondary circuit may be completed directly by connecting the lower end of winding 18 to ground.

The secondary finger 19 is relatively narrow compared to the primary finger 17 and therefore a considerable portion of the secondary finger 19 is already opposite a secondary electrode before the capacitor 9 can discharge across the primary air gap.

It will be realized that it is possible for more than one jump spark per spark plug per revolution to occur at low engine speed because of the peripheral width of a primary electrode. For example, the capacitor 9 may receive charging current at a frequency of say 230 pulses per second. For any distributor speed less than that required for the primary finger to pass an electrode in 1/230th of a second, more than one spark occurs. If the distributor shaft 14 comes to rest with the primary finger 17 opposite an electrode, the associated spark plug will deliver a shower of 230 sparks per second.

The maximum operating speed of this type of ignition system depends on the prime frequency of the vibrator 3. For a 115 cycle vibrator, which establishes 230 current pulses per second, a maximum distributor speed of 230/6 or 38.3 revolutions per second can be obtained for a six cylinder engine while the ignition system still delivers 1 spark per spark plug per revolution. For a four cycle engine this corresponds to 38.3 (60) (2) or 4596 crankshaft revolutions per minute.

Referring now to Fig. 2 it will be seen that the engine driven unit comprises the metallic lower portion of an enclosure having an engine driven shaft 14 centrally disposed and projecting upwardly through the bottom. On the shaft 14 is mounted a spider member 34 which supports an insulating base member 35 for fixed rotation with the spider 34 and shaft 14.

The body 36 of high frequency transformer 12 may be constructed of hard rubber and is secured in an upright position by means of a long holding screw 37, which projects upwardly from a recess in the insulating base member 35. The upper end of the holding screw 37 is threaded into a metallic contact button 38 having a shoulder which is drawn down against the transformer body 36 to hold it rigidly. Coaxially surrounding the holding screw 37 is a powdered iron core 39 which extends practically the full length of the holding screw 37 as shown.

The primary winding 15 may be wound spirally around the powdered iron core 39 and soldered at its upper end to the contact button 38. This winding may comprise, for example, 24 turns of No. 22 wire. The primary winding 15 fits within the hollowed center of the body 36 while the secondary is wound about the outside of body 36.

The secondary winding 18 may comprise for example, 400 turns of No. 41 wire wound around the periphery of the body 36. A better magnetic return path for the flux of the transformer may be provided by wrapping several insulated turns of thin inconel strip 40 around the secondary winding 18.

The bottom of the primary winding 15 is connected to a primary distributor which comprises a metallic conductor 41 extending across the top surface of the insulating base 35 to the metallic

finger 17 which is revolved in close cooperative relation to the primary electrodes 20-25.

The primary electrodes 20-25 are each supported on a metallic ring 42 which is tightly fitted into an annular groove inside the housing 33. The electrodes are positioned in accordance with the timing requirements of the engine. The gap between the finger 17 and the primary electrode is relatively small and may be for example in the order of .001 to .008 inch.

The upper end of the secondary winding 18 is connected to a secondary distributor comprising a metallic finger 19 which is supported on the body 36. Between the secondary finger 19 and a flange at the top of the body 36, there is disposed a washer-like insulated flash shield 43.

The enclosure of the engine driven unit 13 comprises a housing 33 covered by a conventional insulating cap 44 having the circumferentially spaced wells into which the secondary electrodes 26-31 are recessed for connection to the spark plug cables. The insulating cap 44 is provided with a central cylindrical well member 45 within which the carbon brush 16 is free to move axially. The upper end of the well member 45 is threaded to receive a cooperating connector 46 to which the cable 47 from the discharge capacitor 9 is electrically connected. A spring 48 placed between connector 46 and the brush 16 urges the brush 16 downward against the contact button 38. When the connector 46 is tightened into position, a continuous electrical connection exists between the cable 47 and the primary finger 17 via the primary winding 15.

Curves *a-d* of Fig. 3 offer a means for comparing the variation in sparking voltage with engine speed for a high frequency system and for a conventional system. Special attention is directed to the practically flat characteristic of curves *a* and *d* of the high frequency system, which is indicative of an ability to maintain high voltage output over the entire range of engine speed. The drooping characteristic of the conventional system as exemplified by curves *b* and *c* is typical of, and inherent in, all present-day automotive ignition systems.

Curves *a* to *d* further illustrate the effect of spark plug shunt resistance on sparking ability. A condition of spark plug fouling is simulated by paralleling carbon resistors of known value across the spark plug gap. Maximum voltage performance for a given shunt resistance may then be determined.

With normal sparking voltage, the conventional spark is extinguished by resistors of a value less than approximately 150,000 ohms. With a 5600 ohm resistor no spark occurs at any gap spacing. In contrast, the high frequency spark maintains itself at maximum voltage with shunt resistances of a value considerably less than 100,000 ohms, and in fact will maintain a spark of normal voltage even with a resistor 5600 ohms.

A further significant factor is that of ignition system voltage reserve. Curves *e* and *f* are typical spark plug "voltage required" curves and offer a basis for comparing voltage reserves necessary for present day and high compression engines respectively. Voltage reserve is defined as the excess of voltage available over the voltage required. This reserve is necessary because successive breakdown potentials of a given spark plug gap may vary considerably from the mean value for a given cylinder condition. Experience indicates that a reserve of at least 25% is neces-

sary for normal operation while a 50% reserve is desirable for lean mixture operation. Curve *c* shows that only a marginal reserve exists at high engine speeds for a conventional system with a high value of shunt resistance, while the voltage reserve is uniformly ample for a high frequency system having a relatively low value of shunt resistance as shown in curve *d*.

With the automotive industry considering high compression ratio engines for reasons of increased performance and fuel economy, ignition voltage reserve becomes an important consideration.

Curve *e* shows typical spark plug voltage requirements when considering compression ratios of 9 to 1. It will be noted from curve *e* that a conventional coil system would provide doubtful operation at high engine speeds, while a high frequency system would exhibit a safe margin of voltage reserve for all engine speeds, even under adverse conditions of plug fouling.

These curves will become particularly significant when one realizes that plug fouling problems become acute with high compression ratio engines. Such engines, as compared with present 7 to 1 ratio engines of today, will require plugs of greater heat range and a fuel with higher anti-detonant rating, both of which aggravate the plug fouling condition. My study of ignition system ability to fire foul spark plugs has pointed directly to the discharge frequency of a high frequency spark as being the characteristic responsible for superiority in this respect over conventional sparks. An operating engine test has shown that a high frequency spark has incendiary ignition characteristics similar to a conventional spark in igniting an air-fuel mixture. This consideration is important in view of the short time duration and small average energy of the spark discharge.

Conventional ignition systems are at a particular disadvantage during cold weather engine starting operations, as current for spark generation is required during the end of the compression stroke of the engine cranking cycle, when battery voltage is necessarily pulled down to a low value by demands of the engine starting motor. As a contrast, the capacitor energy storage feature of the present high frequency system makes it particularly suitable for cold weather starts. Although the minimum operating voltage of the system is approximately $4\frac{1}{2}$ volts, the discharge capacitor can be charged during the short intervals between compression strokes when the battery voltage rises to a nearly normal value. The rectifiers in the transducer will then maintain the capacitor charge during the period of low battery voltage until a spark is required.

If any fouling resistance is present across the spark plug gap, and if the secondary finger-to-electrode air gap is small, the capacitor 9 may tend to discharge slowly across the secondary air gap and through the fouling resistance before it has a chance to discharge directly across the primary air gap to ground. Thus to make the circuit operable with even high values of fouling resistance, the secondary air gap must be enlarged to a value that prevents breakdown at the potential appearing on the capacitor. This may detract however from the available voltage of the spark plug gap. For this reason, it is preferable that the low end of the secondary winding 18 be isolated from the primary winding 15 and connected directly to ground.

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It will be noted that my high frequency system is relatively simple in construction and that there is an absence of complexity in mechanical and electrical operation. I have employed the term "high-frequency" so as to distinguish the spark produced by my system from the spark furnished by a conventional ignition system.

It will be obvious of course that there are many modifications which may be made in the above-described embodiment by those skilled in the art without departing either in spirit or scope from the present invention. Hence, the appended claims aim to cover such modifications, and it is intended that all matter contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What I claim is:

1. Ignition apparatus comprising, primary and secondary distributors each having electrodes, means for driving said distributor in a predetermined relation so that they are simultaneously in position for discharge each to an electrode, a transformer mounted on said driving means and having primary and secondary windings, connections connecting said primary winding in series with said primary distributor, and connections connecting said secondary winding to said secondary distributor.

2. Ignition apparatus for producing high frequency voltage discharges comprising a primary distributor, a secondary distributor, a common driving means for said distributors, a transformer mounted to rotate with said means and having a primary and a secondary winding, said primary winding being connected serially to said primary distributor, said secondary winding being serially connected with said secondary distributor so as to provide voltage discharges in each of said windings at substantially the same time.

3. In ignition apparatus having a capacitor for providing a source of high frequency voltage for firing spark plugs the combination comprising, an engine driven unit adapted to be connected to said capacitor comprising, a high frequency transformer mounted on said engine driven unit and having a primary winding and a secondary winding, distributor means for periodically connecting said capacitor to said primary winding for discharging said capacitor and means for periodically connecting said secondary to a spark plug at a time just prior to said capacitor discharge.

4. Ignition apparatus for producing voltages at the spark plugs of an engine comprising, an engine driven unit comprising, a primary distributor and a secondary distributor, each of said distributors including primary and secondary electrodes corresponding in number to the spark plugs to be fired, said primary electrodes being connected to ground potential and said secondary electrodes being connected to an associated spark plug, a transformer connected to rotate with said driven unit and having a primary winding and a secondary winding, said primary winding being connected to said primary distributor, and said secondary winding being connected between said secondary distributor and ground potential.

5. In ignition apparatus for an engine, provided with a capacitor source of high voltage energy, the combination comprising a high frequency transformer adapted for rotation by said engine and having a primary and a secondary winding, rotor means integral with said trans-

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former for periodically discharging said capacitor through said primary winding, and means for discharging energy induced in said secondary winding at substantially the time of capacitor discharge through said primary winding.

6. Ignition apparatus for igniting spark plugs from, a source of high voltage comprising an engine driven distributor having primary and secondary rotors rotatable in unison, a transformer mounted integrally with said rotors and having a primary winding and a secondary winding, means for connecting said primary winding to said high voltage source and to said primary rotor, said distributor comprising one or more primary electrodes at ground potential disposed in cooperative relationship with said primary rotor whereby energy from said high voltage source is periodically discharged through said primary winding and one or more secondary electrodes disposed in cooperative relationship with said secondary rotor, and means for serially connecting said secondary winding with said secondary rotor and a spark plug at times corresponding substantially to the application of high voltage from said source to said primary winding whereby to ignite said last mentioned spark plug.

7. In ignition apparatus for firing spark plugs from a source of high voltage including a capacitor, the combination comprising an engine driven unit further comprising, a primary distributor, a secondary distributor and a high frequency transformer having a primary and a secondary winding, said primary winding being connected serially to said primary distributor so as to periodically produce a high frequency discharge through said primary winding from said capacitor, said secondary winding being serially connected with said secondary distributor and an associated spark plug so as to produce a high frequency voltage discharge at said associated spark plug at substantially the same time that said periodic discharge is initiated through said primary winding.

8. In ignition apparatus including a capacitor for firing spark plugs, the combination comprising, an engine driven unit further comprising, a high frequency transformer having a primary winding and a secondary winding, distributor means for discharging said capacitor through said primary winding periodically to produce a high frequency discharge therethrough, and means for periodically connecting said secondary winding to an associated spark plug at a time just prior to said capacitor discharge.

9. The combination comprising, an enclosure, a rotatable shaft projecting upwardly through said enclosure, a transformer having a primary winding adapted to receive a high voltage discharge therethrough and a secondary winding mounted on said shaft, a primary distributor comprising a primary rotor connected to said primary winding, one or more primary electrodes connected to said enclosure and circumferentially disposed in cooperative relation with said primary rotor, a secondary rotor connected to said secondary winding, and one or more secondary electrodes connected to said enclosure, said secondary rotor being rotatable in unison with said primary rotor, both of said rotors being disposed to move into close successive cooperative relationship with their respective electrodes.

10. The combination comprising, a housing having an engine driven shaft projecting upwardly therethrough, a spider mounted on said shaft, a powdered iron core projecting upwardly

from said spider, a transformer primary winding around said iron core, a body member secured to said spider and enclosing said winding, a distributor rotor connected to one end of said winding, a secondary winding wound around said body member, a secondary distributor rotor connected to one end of said secondary winding, the other end being connected to said shaft, one or more primary electrodes circumferentially disposed within said housing in cooperative relationship with said first mentioned distributor rotor, an insulated cap covering said housing having secondary electrodes circumferentially disposed therein in cooperative relation with said secondary distributor rotor, said cap having means for electrical connection to said primary winding.

11. The combination defined in claim 10 further comprising, an insulated strip forming a magnetic path disposed external to said secondary winding.

12. The combination defined in claim 10

wherein the distance between the first mentioned distributor rotor and a cooperative primary electrode is shorter than the distance between said secondary distributor rotor and a cooperative secondary electrode.

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