

Nov. 27, 1945.

S. RUBEN

2,389,637

HIGH FREQUENCY IGNITION SYSTEM

Filed April 2, 1942

2 Sheets-Sheet 2

Fig. 4

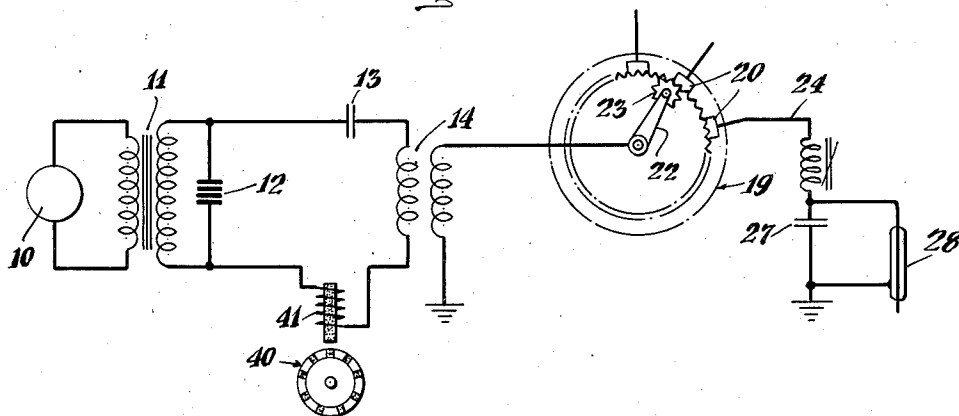


Fig. 5

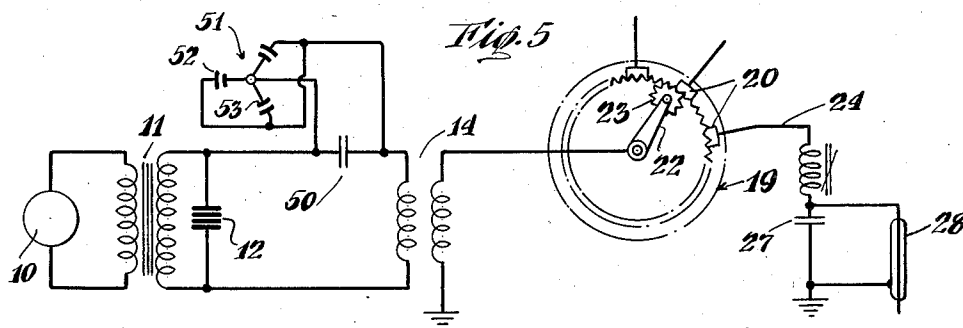


Fig. 6

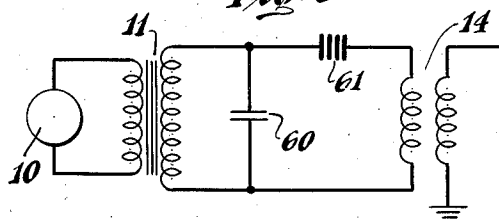


Fig. 7

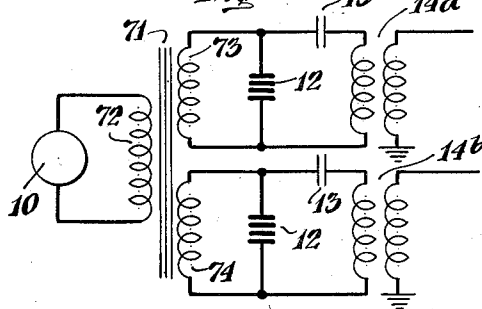
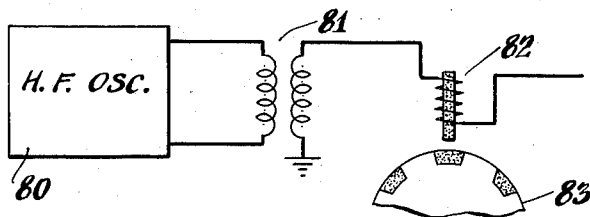


Fig. 8



INVENTOR.
Samuel Ruben
BY *Robbin + Carlson*

ATTORNEYS

UNITED STATES PATENT OFFICE

2,389,637

HIGH FREQUENCY IGNITION SYSTEM

Samuel Ruben, New Rochelle, N. Y.

Application April 2, 1942, Serial No. 437,322

11 Claims. (Cl. 123—148)

This invention relates to ignition systems for internal combustion engines.

An object of the invention is to improve high voltage ignition systems.

Another object is to improve the timing of ignition and produce a system whose timing remains constant over long periods of use.

A further object is to improve high altitude ignition systems, such as are used in aircraft, and to reduce or eliminate the ignition difficulties frequently encountered at high altitudes, such as corona discharge and electric breakdown of the system.

An additional object is to improve the operation of ignition systems under conditions of adverse spark plug fouling.

Other objects of the invention will be apparent from the following description and accompanying drawings taken in connection with the appended claims.

The invention comprises the features of construction, combination of elements, arrangement of parts, and methods of manufacture and operation referred to above or which will be brought out and exemplified in the disclosure hereinafter set forth, including the illustrations in the drawings.

In the drawings:

Figure 1 is a circuit diagram of an ignition system for a nine cylinder airplane engine, embodying features of my invention;

Figure 2 is a simple diagram of the equivalent circuit of the high frequency portion of the system; and

Figures 3, 4, 5, 6, 7 and 8 illustrate modifications of the system.

One of the principal limitations on high altitude flying has been the difficulty of providing ignition systems for airplane engines which are not subject to electric breakdown due to the rarefaction of the air at high altitudes. The low atmospheric pressure at these altitudes permits corona discharges to develop between points of high potential difference. In magneto systems the magneto may practically cease to function at times due to flash-over in the magneto itself. The high tension cables in the distributor manifold and leading from the magneto to the manifold also break down unless shielded in proper type of cables. The distributor also is subject to arc-over and disruption of proper timing at high elevations.

Another problem with ignition systems has been the gradual variation in the timing conditions of the circuit due to contact or cam wear.

A further difficulty has been the failure of the spark plugs to function properly when fouled by carbon due to cold plugs.

The system of the present invention utilizes a high frequency circuit and obtains accurate timing by use of an element for varying the resonance of the circuit to obtain accurate timing of the spark discharge. The system also has the resonant elements so arranged that the high voltage necessary for sparking is confined to a small section of the circuit adjacent to the spark plugs, the majority of the distribution circuit operating at a relatively low voltage at which disturbing effects at high altitudes are not encountered.

The system produces an ignition voltage of high frequency and steep wave front so as to effect sparking of the plugs even under conditions of adverse plug fouling.

The system also does away with the necessity for a distributor of the type using a spark gap between the rotating contact and the stationary terminals and enables the substitution of a direct contact type of distributor. The distributor is not required to make and break any substantial current, however, as the plug voltage is generated only when the distributor is in the middle of its contact position with any of the stationary terminals.

The system also allows the use of larger sizes of spark plugs for all operating conditions, thus improving the maximum power development of the engine during take-off and other periods of peak performance requirements.

In the past where high frequency systems have been used they have depended upon the use of a high frequency transformer to apply the voltage to the spark plug. This required a fairly high voltage transmission to the primary to avoid excessive or impractical transformer ratios and unless the transformer was close to the plug insulation and distributed capacity loss was effected.

In my system, due to the fact that the high potential is developed across a resonance circuit composed of an inductance and capacitance at high frequency, the inductance and capacitance can be of low values and small size. Due to the phase relation across such a series resonance circuit the total voltage across both due to resonance cancel each other. Thus a low applied voltage can be transmitted through the distributor and manifold and be resonated up to a high oscillating potential, such as 10,000 volts across a relatively small capacitance.

The timing is effected in the best practical man-

ner by varying the inductance in the radio frequency circuit. This is best accomplished by establishing resonance as the point when the variable inductance has minimum inductance. Another advantageous factor in doing this in this manner is that it allows only one spark train for a given angular position of the timing device.

Referring to the drawings, Figure 1 shows an ignition system utilizing features of my invention as applied to a nine cylinder radial airplane engine. The source of electric energy for the ignition system comprises a generator or alternator 10 which generates a low or intermediate frequency alternating current as indicated by curve A shown immediately below the generator in the circuit diagram. The frequency of the alternator is preferably sufficiently high to insure several oscillations at each sparking period. Thus an alternator capable of generating 3,000 cycles per second at an intermediate engine speed might be suitable. The alternator or generator should also preferably be of the type which will produce a substantially constant output voltage at all speeds.

The alternating current generated by alternator 10 is stepped up by low frequency transformer 11 to produce an alternating potential of higher voltage across the secondary of the transformer as indicated by curve B shown immediately under the transformer in Figure 1. Transformer 11 is designed to have a rising voltage characteristic with increase in frequency. A quenched spark gap 12 is connected across the terminals of the transformer secondary winding and a series circuit consisting of a condenser 13 and the primary winding of a high frequency transformer 14 is connected in shunt with the spark gap. The alternating voltage across the secondary of low frequency transformer 11 results in a periodic breakdown of spark gap 12, thereby generating damped oscillations in the oscillatory circuit including condenser 13 and the primary of high frequency transformer 14. These oscillations may be somewhat of the form illustrated in curve C in Figure 1 and have a characteristic frequency determined by the constants of the circuit such as capacitance 13 and inductance of the transformer 14.

The secondary winding of high frequency transformer 14 has one terminal grounded, the other terminal being connected through a variable inductance 16 to the rotating contact arm 22 of ignition distributor 19.

Variable inductance 16 is arranged for variation of its inductive impedance as follows: Inductance 16 is provided with a core of the powdered iron type and is mounted adjacent to a rotating disc 18 which comprises the rotor of inductive timer 15. Disc 18 is preferably formed of molded plastic insulating material and has nine evenly distributed inserts 17 of pressed iron powder or the like distributed around its periphery. The disc is driven by the engine at one-half the engine speed so that segments 17 move past a pole face of the core of inductance 16 at a speed corresponding to the sparking frequency of the engine.

Distributor 19 comprises a ring 21 of molded plastic or other insulating material having nine molded-in segments 20 distributed about its inner periphery. The inner periphery is cut with gear teeth and the end of rotating distributor arm 22 carries a small pinion gear contact 23 which rolls around the inner periphery of the ring, thus making contact with one segment after another in sequence. Rotating arm 22 of the distributor is

also driven at one-half engine speed and may be mounted on the same shaft with disc 18 of the inductive timer.

The segments 20 of the distributor are connected by individual conductors 24 through the cable manifold 25 to high frequency inductances 26 adjacent to individual spark plugs 28 of the engine. The other end of each inductance 26 is connected to the center electrode of its associated spark plug 28. A condenser 27 is associated with each coil 26 and is connected between the center electrode and the ground electrode of the spark plug. High frequency coil 26 is provided with a powdered iron core 26a which is adjustable to a certain extent to enable adjustment of the resonance frequency of the circuit.

By reference to Figure 2, it will be observed that a high frequency resonant circuit is formed by transformer secondary 14s, variable inductance 16, high frequency inductance 26 and capacitance 27. As this circuit is brought into resonance with the high frequency oscillations applied through transformer 14 from the quenched spark circuit by variation of inductance 16, the circuit will oscillate in such a manner as to develop a high oscillatory voltage at point P at which the spark plug is connected. This voltage is sufficient to produce a spark discharge across the electrodes of the spark plugs. With this circuit it will be observed that the high voltage is developed only in a comparatively small section of the circuit adjacent to the spark plug, the balance of the circuit operating at comparatively low voltages. Thus the entire circuit from transformer 14 to coil 26 is at low voltage including the cable manifold.

Variation in the inductance of winding 16 is produced by variation in the proximity of rotating segments 17 on rotor 18. While it is possible to adjust the circuit for resonance to the point of maximum or of minimum inductance in coil 16, it is preferred that the point of minimum inductance be used for resonance and the circuit be thrown out of resonance as the inductance of the coil is increased.

To summarize the operation of the system, the alternator 10 supplies an alternating current of low or intermediate frequency to the transformer 11 which steps up the voltage to a value necessary to initiate a discharge across quenched spark gap 12, thus setting up high frequency oscillations in the circuit comprising the spark gap, capacitance 13 and the primary of high frequency transformer 14. The turn ratio and the coupling of the oscillation transformer 14 is such that when resonated it will apply adequate sparking voltage at the spark plugs. Distributor 19 connects the secondary circuit periodically to each of the spark plug circuits. At the time rotating contact 23 of distributor 19 makes contact with any segment 20, the circuit is out of resonance and hence no substantial current flow occurs at the instant of first contact. When distributor contact 23 reaches substantially the middle of a stationary segment, the core of coil 16 reaches a point substantially midway between two of segments 17 on the timer rotor which is a point of minimum inductance and brings the circuit into resonance. As the circuit is brought into resonance, it will oscillate under the impulses received from the quenched spark circuit, thus developing a high oscillatory voltage across condenser 27 and the electrodes of the spark plug producing the discharge of condenser 27 through the spark plug.

The spark may be advanced or retarded in re-

lation to the engine cycle by rotating frame 15 of the timer slightly to change the position of the core of inductance 16 with respect to the rotating segments of the rotor.

A preferred frequency for the high frequency oscillations is 100,000 to 300,000 cycles per second, the oscillation circuit being designed to prevent excessive losses due to distributed capacitance, resistance and the like in the useful frequency range.

Figure 3 illustrates a circuit for the most part similar to that of Figure 1 but differing from it in the use of a variable condenser 31 for timing in place of the inductive timer of Figure 1. In this circuit a fixed capacitance 30 is connected in series between the secondary of high frequency transformer 14 and timer 19 and a relatively small variable condenser 31 is connected in shunt with condenser 30. Condenser 31 may comprise, as illustrated, three evenly spaced stator plates 32 and a three arm rotor 33 which is rotated at one and one-half times the engine speed, thus bringing the circuit into resonance at the proper rate for periodic sparking of the engine. The rotor 33 may preferably run in a liquid of high dielectric constant to increase the capacity of the condenser.

Figure 4 illustrates a modification wherein the rotary timer 40 is located in the quenched spark circuit of the ignition system where it varies the inductance of winding 41 in series with the primary of high frequency transformer 14. This arrangement produces very sharp tuning as the inductance located at this point suppresses frequencies other than those which are in resonance.

Figure 5 shows a modification wherein the condenser 13 of the quenched spark circuit is replaced by fixed condenser 50 shunted by variable condenser 51 having fixed plates 52 and a rotor 53 driven by the engine to vary the resonant frequency of the circuit.

Figure 6 illustrates a modification in the quenched spark circuit, the spark gap 61 in this instance being connected in series with the primary of high frequency transformer 14 and condenser 60 being connected across the secondary of low frequency transformer 11.

Figure 7 illustrates a circuit suitable for dual ignition wherein alternator 10 supplies low frequency alternations to the primary 72 of a low frequency transformer 71 having two secondaries 73 and 74 feeding separate oscillatory circuits of the kind already described which, in turn, supply high frequency ignition currents through transformers 14a and 14b to the two ignition circuits of the dual system.

Figure 8 illustrates a modification wherein a high frequency vacuum tube oscillator 80 is used to supply the high frequency oscillations which are fed through high frequency transformer 81 to the ignition circuit including variable inductance 82 varied by rotary inductive timer 83.

Instead of using an alternator 10 driven by the internal combustion engine, it is contemplated that in some instances a motor-generator set may be used to produce the low frequency alternations.

It is also contemplated that other sources of high frequency current may be used, such as a magneto or equivalent device supplying high voltage impulses to a make-and-break contact pair. It is likewise possible to use a contact operated spark coil supplied with direct current or a contact operated transformer.

The high voltage coil 26 and condenser 27 which are located adjacent the spark plug may be mounted directly on the plug or may be located at the terminal of the cable manifold to which the plug is connected.

The core of the periodically varying inductance is preferably formed of iron powder of low loss and small grain size. The core and its winding can be encased in a pressed iron powder shield and return path to afford a greater inductance variation and sharper minimum inductance points when the rotor segments pass the core face.

While the present invention, as to its objects and advantages, has been described herein as carried out in specific embodiments thereof, it is not desired to be limited thereby but it is intended to cover the invention broadly within the spirit and scope of the appended claims.

What is claimed is:

1. An ignition system comprising a source of oscillations, a plurality of series resonant lines each developing a high oscillating voltage in one section thereof, the remainder of each of said lines remaining at a lower voltage, a spark plug connected to the high voltage section of each line, and a variable impedance for bringing said lines individually into resonance with said oscillations in sequence.

2. In an ignition system, a source of oscillations, a series resonant line fed thereby, said line developing a high oscillating voltage in one section thereof in response to said oscillations while the remainder of said line remains at lower voltage, and a spark plug connected to said section of high voltage.

3. In an ignition system, a source of oscillations, a series resonant circuit fed thereby and comprising a capacitance and an inductance in series, and a spark plug electrode connected to the common terminal of said capacitance and inductance.

4. In an ignition system, a source of high frequency energy, a plurality of spark plugs and a plurality of series resonant lines, each having, when resonated, a point of high oscillatory voltage, each of said spark plugs being connected to the high voltage point of one of said lines, a distributor for periodically connecting said high frequency source to said lines in sequence and a periodically varying impedance in the common portion of said system preceding said distributor for bringing said lines into resonance with said source while they are connected thereto by said distributor.

5. In an ignition system, an energized oscillatory circuit, a second oscillatory circuit coupled thereto, said second circuit comprising a series resonant circuit, having, when resonated, a point of high oscillatory voltage, a spark plug connected to said point of high voltage, and a periodically varying impedance in one of said circuits for varying its natural frequency and periodically bringing said circuits to the same oscillatory frequency to produce resonance in said second circuit and resultant sparking of said plug.

6. An ignition system comprising a source of high frequency oscillations, a spark plug and a resonant line connecting said source to said plug, said line including a cable conductor extending from said source to the vicinity of said plug, a high frequency inductance connected between said conductor and the ungrounded electrode of said plug, and a capacitance connected in parallel with the electrodes of said plug, said resonant

line developing a high oscillatory voltage across said plug, while said cable remains at a relatively low voltage.

7. An electric ignition system comprising a source of high frequency oscillations, an impedance fed thereby, a distributor, and a plurality of high frequency lines having spark plugs associated therewith connected periodically by said distributor to said impedance and forming oscillatory circuits therewith, said impedance including a periodically varying reactance for bringing said lines into resonance with said source while they are connected thereto by said distributor.

8. An electric ignition system comprising an energized oscillatory circuit, an ignition distribution circuit, a coupling impedance coupling said distribution circuit to said oscillatory circuit, said distribution circuit comprising a distributor and a plurality of high frequency lines having spark plugs associated therewith connected periodically by said distributor to said coupling impedance to form resonant circuits therewith, said oscillatory circuit including a periodically varying reactance for bringing said oscillatory circuit to the frequency of said resonant circuits while each line is connected by said distributor to said coupling impedance.

9. An ignition system for an internal combustion engine comprising a relatively low frequency A. C. source, a discharge device periodically discharged thereby, a tuned oscillatory circuit oscillated by the discharges in said device, and an ignition distribution circuit coupled to said tuned circuit, said distribution circuit comprising a periodically varying inductance, a distributor fed thereby and a plurality of high frequency lines periodically sequentially connected by said dis-

tributor to said variable inductance to form resonant circuits therewith, spark plugs connected to said lines, and an inductance varying element driven by said engine for varying said inductance to bring said resonant circuits into resonance with said oscillatory circuit.

10. An ignition system for an internal combustion engine comprising a relatively low frequency A. C. source, a discharge device periodically discharged thereby, a tuned oscillatory circuit oscillated by the discharges in said device, said oscillatory circuit including a periodically varying inductance for varying the oscillatory frequency thereof, a coupling device, and an ignition distribution circuit coupled to said tuned circuit thereby, said distribution circuit comprising a distributor and a plurality of high frequency lines periodically sequentially connected by said distributor to said coupling device to form resonant circuits therewith, spark plugs connected to said lines, and an inductance varying element driven by said engine for varying said inductance to bring said oscillatory circuit to the resonance frequency of said resonant circuits.

11. An ignition system for an internal combustion engine comprising a high frequency vacuum tube oscillator, an ignition distribution circuit coupled thereto, said circuit comprising a distributor, a periodically varying inductance and a plurality of high frequency lines periodically sequentially connected by said distributor to said varying inductance to form resonant circuits therewith, said inductance bringing said circuits into resonance at the frequency of said oscillator while each line is connected by said distributor.

SAMUEL RUBEN.