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2,389,639

IGNITION SYSTEM

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*Fig. 1*

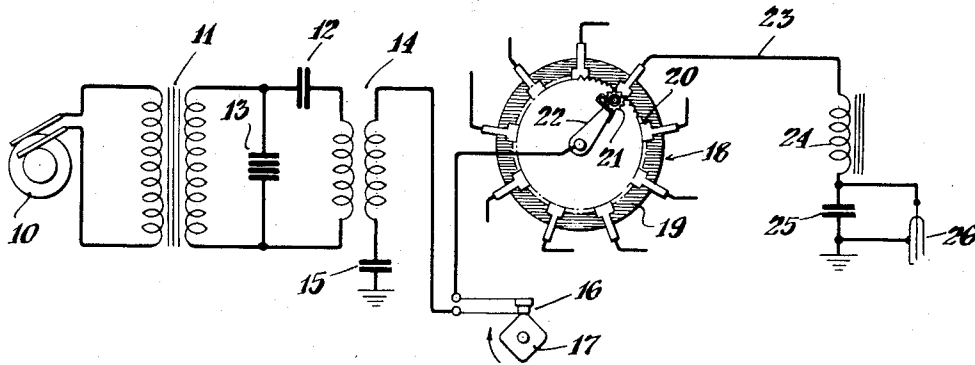


*Fig. 2*

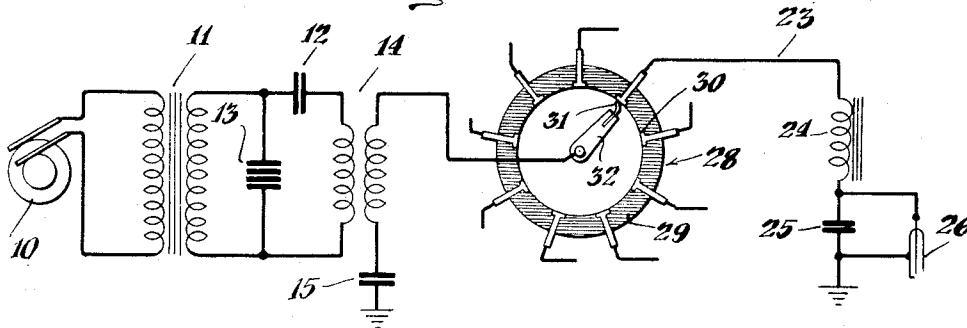
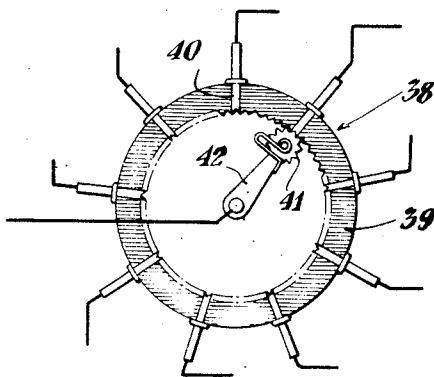


*Fig. 3*



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## UNITED STATES PATENT OFFICE

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## IGNITION SYSTEM

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9 Claims. (Cl. 315-212)

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 systems suitable for high altitude operation, as in aircraft.

A further object is to improve the distributor means of ignition systems.

Other objects of the invention will be apparent from the following description and accompanying drawing 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 drawing.

In the drawing:

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

Figure 2 illustrates a modification of the system; and

Figure 3 shows a distributor of modified construction.

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 rarification 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.

In an application for United States Letters Patent, Serial No. 437,322, filed April 2, 1942, Samuel Ruben has described a high frequency ignition system using a resonant circuit with the resonance 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.

The present invention comprises an improvement upon the systems described in the above application whereby the majority of the circuit

can be operated at a still lower voltage or at zero voltage. This may be accomplished by the introduction of a series capacitance in the resonant distributor circuit.

The invention also contemplates a means to effect timing and distribution of the spark impulses by direct making and breaking of a series resonant circuit.

The invention further relates to the use of a distributor of improved construction in a resonant ignition system.

In the Samuel Ruben application a system is described wherein a high potential is developed across a resonant 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 resonant circuit the voltage across the components cancel each other resulting in low total voltage. 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.

I have discovered that by the introduction of a further series capacitance between the secondary of the oscillation transformer which comprises part of the resonance circuit and ground, the potential on the distributor cable can be brought substantially to ground potential. The generation of high voltage through series resonance with low applied voltage gives a rapid decay of voltage with any interruption of the series circuit and allows the opening and closing of the resonant circuit without destructive arcing or sparking.

Referring to the drawing, 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 which generates a low or intermediate frequency alternating current. 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 comparatively high voltage across the sec-

ondary of the transformer. 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 12 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 12 and the primary of high frequency transformer 14.

The secondary of high frequency transformer 14 has one terminal connected through series capacitance 15 to ground. The other terminal of the secondary winding is connected through breaker contacts 16 to the rotating arm 22 of the ignition distributor 18. Breaker contacts 16 are periodically closed by a rotating cam 17 driven by the engine at one and one-eighth times engine speed, so that nine closed-contact periods are produced during one engine cycle.

Distributor 18 comprises a ring 19 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 spring mounting on which is a small pinion gear contact 21 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 driven at one-half engine speed.

The segments 20 of the distributor are connected by individual conductors 23 through the cable manifold to high frequency inductances 24 adjacent to individual spark plugs 26 of the engine. The other end of each inductance 24 is connected to the center electrode of its associated spark plug 26. A condenser 25 is associated with each coil 24 and is connected between the center electrode and the ground electrode of the spark plug. High frequency coil 24 is provided with a powdered iron core which is adjustable to a certain extent to enable adjustment of the resonance frequency of the circuit.

Whenever a circuit is completed from the secondary winding of high frequency transformer 14 through contacts 16 and distributor 17 to one of the individual spark plug circuits a high frequency resonance circuit is formed whose resonant frequency is determined by the values of capacitance 25, inductance 24, secondary inductance of transformer 14, and capacitance 15. The values of these are so chosen and adjusted that the circuit will resonate at the frequency of the high frequency oscillations applied through transformer 14 from the quenched spark circuit. Under these resonant conditions the circuit will oscillate in such a manner as to develop a high oscillatory voltage across the electrodes of the spark plug and capacitance 25, which is in shunt with the electrodes. This voltage is sufficient to produce a spark discharge across the electrodes of the spark plug.

Capacitance 15 is of such value in relation to the inductance of the transformer secondary as to balance the inductance voltage of the secondary at the resonant frequency used. This will result in a zero or ground potential on the distributor and cable conductors. The preferred relative values of capacitance and transformer secondary

inductance may be determined by the following equation:

$$C = \frac{10^9}{4\pi^2 f^2 L}$$

where C is the capacitance in microfarads, f is the frequency in cycles per second and L is the inductance of the secondary in microhenries. If the inductance of the secondary is 7500  $\mu$ h, and the frequency is 150 kilocycles per second then a capacitance 15 of .00015 microfarad would be preferred.

The timing of the ignition is determined by the closing and opening of breaker contacts 16 under control of cam 17. Distributor 18 does not make or break the current oscillations but rather connects the individual spark plug circuits to the breaker contacts 16 while the contacts are open. Contacts 16 then close the resonant circuit for an interval corresponding to the desired sparking time at the plug and again open the circuit before the distributor pinion passes off an individual segment.

Whenever the circuit is opened by the opening of contacts 16 it is thrown out of resonance and there results substantially no deleterious sparking or arcing at the contacts.

Figure 2 shows a modification of the circuit wherein a distributor 28 having a wiper contact 31 on arm 32 is used instead of the gear pinion distributor. In this form the stationary distributor segments 30 molded in insulating ring base 29 are made of such length as to provide a closed contact interval with wiper contact 31 corresponding to the sparking time required at the plug. Distributor 28 can then be used to make and break the resonant current circuit and separate breaker contacts can be eliminated.

Figure 3 shows a gear pinion distributor 38 of modified construction which can also be used in the circuit of Figure 2. In this distributor the stationary segments 40 each comprise one tooth or tooth-socket on the inner periphery of the distributor ring 39. The tooth pitch is related to the dimensions of the distributor so that pinion gear 41 on distributor arm 40 makes contact with each segment 40 for the length of time required for a spark.

To summarize the operation of the system, referring to Figure 1, 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 12 and the primary of high frequency transformer 14. The turn ratio and the coupling of the oscillation transformer 14 is such that an alternating potential of about 1000 volts is developed across the secondary winding. Distributor 18 connects the secondary circuit periodically to each of the spark plug circuits. At the time rotating contact 21 of distributor 18 makes contact with any segment 20, the circuit is open at contacts 16. When distributor contact 21 reaches substantially the middle of a stationary segment, contacts 16 close the resonant circuit permitting it to resonate. The circuit will oscillate under the impulses received from the quenched spark circuit, thus developing a high oscillatory voltage across condenser 25 and the electrodes of the spark plug producing the discharge of condenser 25 through the spark plug. Contacts 16 are opened before contact 21 of the distributor passes off the stationary dis-

tributor segment. Capacitance 15 balances the inductance voltage across the secondary of transformer 14 so that distributor 18 and the cable conductors 23 are substantially at zero potential in relation to ground. Only the minimum of insulation is therefore required and there is no danger of arcing or corona discharge from these parts under conditions of low atmospheric pressure, such as prevails at high altitudes.

The spark may be advanced or retarded in relation to the engine cycle by shifting the position of contacts 16 with respect to the cam in the system of Figure 1, or by rotating the frame of the distributor-timer in the system of Figure 2.

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.

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 the low frequency input circuit including condenser 12 may be resonated to any desired degree.

It is also contemplated that other sources of high frequency current may be used, such as a vacuum tube oscillator, or 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.

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 and a spark distribution circuit coupled thereto, said distribution circuit comprising a common section which is coupled to said source and a plurality of individual sections containing individual spark plugs, and a distributor for connecting said common section to said individual sections in sequence, said individual and common sections having reactive oscillatory circuit elements therein and, when connected together, comprising a resonant circuit tuned to the frequency of said source.

2. An ignition system comprising a source of oscillations and a spark distribution circuit coupled thereto, said distribution circuit comprising a common section which is coupled to said source and a plurality of individual sections containing individual spark plugs and a distributor for connecting said common section to said individual sections in sequence, said individual and common sections having oscillatory circuit elements therein and, when connected together, comprising a resonant circuit tuned to the frequency of said source, each of said sections comprising a series arrangement of inductance and capacitance.

3. An ignition system comprising a source of oscillations and a spark distribution circuit coupled thereto, said distribution circuit comprising a common section which is coupled to said source and a plurality of individual sections containing individual spark plugs, and a distributor for connecting said common section to said individual sections in sequence, said individual and common

sections having oscillatory circuit elements therein and, when connected together, comprising a resonant circuit tuned to the frequency of said source, each of said sections comprising a series arrangement of inductance and capacitance, the electrodes of said spark plugs being connected to the opposite electrodes of the capacitances in said individual circuits.

4. An ignition system comprising a source of oscillations and a spark distribution circuit coupled thereto, said distribution circuit comprising a common section which is coupled to said source and a plurality of individual sections containing individual spark plugs, and a distributor for connecting said common section to said individual sections in sequence, said individual and common sections having oscillatory circuit elements therein and, when connected together, comprising a resonant circuit tuned to the frequency of said source, each of said individual sections comprising a series arrangement of inductance and capacitance and said common section comprising an inductance coupled to an inductance carrying said oscillations and a capacitance between said inductance and ground.

5. An ignition system comprising a source of oscillations and a spark distribution circuit coupled thereto, said distribution circuit comprising a common section which is coupled to said source and a plurality of individual sections containing individual spark plugs, and a distributor for connecting said common section to said individual sections in sequence, said individual and common sections having oscillatory circuit elements therein and, when connected together, comprising a resonant circuit tuned to the frequency of said source, each of said individual sections comprising a series arrangement of inductance and capacitance and said common section comprising an inductance coupled to an inductance carrying said oscillations and a capacitance between said inductance and ground, said capacitance balancing said inductance at the frequency of said oscillations.

6. An ignition system comprising an energized oscillatory circuit, a transformer having its primary winding in said circuit, an ignition distribution circuit comprising a common section, a plurality of individual sections, and a distributor for connecting said common section to said individual sections in sequence, each of said individual sections comprising a series arrangement of inductance and capacitance and a spark plug having its electrodes connected in shunt with said capacitance, said common section including the secondary of said transformer and a capacitance connected between one end of said secondary and ground.

7. An ignition system comprising an energized oscillatory circuit, a transformer having its primary winding in said circuit, an ignition distribution circuit comprising a common section, a plurality of individual sections, and a distributor for connecting said common section to said individual sections in sequence, each of said individual sections comprising a series arrangement of inductance and capacitance and a spark plug having its electrodes connected in shunt with said capacitance, said common section including a pair of timer contacts, the secondary of said transformer and a capacitance connected between one end of said secondary and ground.

8. An ignition system comprising an energized oscillatory circuit, a transformer having its primary winding in said circuit, an ignition distribu-

tion circuit comprising a common section, a plurality of individual sections, and a distributor for connecting said common section to said individual sections in sequence, each of said individual sections comprising a series arrangement of inductance and capacitance and a spark plug having its electrodes connected in shunt with said capacitance, said common section including a pair of timer contacts, the secondary of said transformer and a capacitance connected between one end of said secondary and ground, said distributor comprising a pinion gear common contact mounted on the distributor arm and a stationary ring having conducting segments therein and provided with interior gear teeth meshing with said pinion.

9. An ignition system comprising a source of

oscillations and a spark distribution circuit coupled thereto, said distribution circuit comprising a common section which is coupled to said source and a plurality of individual sections containing individual spark plugs, and a distributor for connecting said common section to said individual sections in sequence, said individual and common sections having reactive oscillatory circuit elements therein and, when connected together, comprising a resonant circuit tuned to the frequency of said source, a contact pair in series with said common section and a cam driven in sequence with the moving contact of said distributor to close said contact pair when the moving contact of said distributor is on each stationary contact thereof.

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