July 30, 1968 L. W. BELL 3,394,689

RESONANT IGNITION SYSTEM

Filed Aug. 25, 1966 2 Sheets-Sheet 1

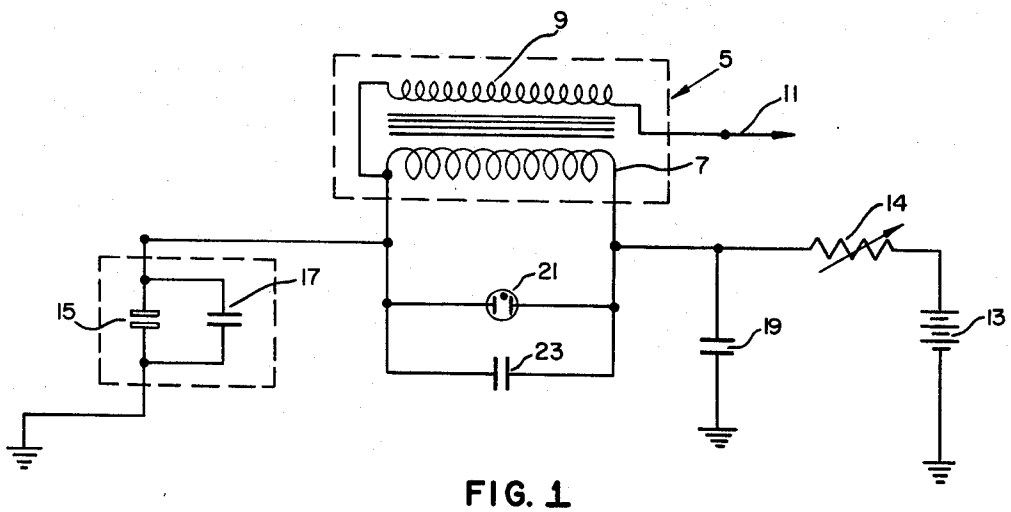


FIG. 1

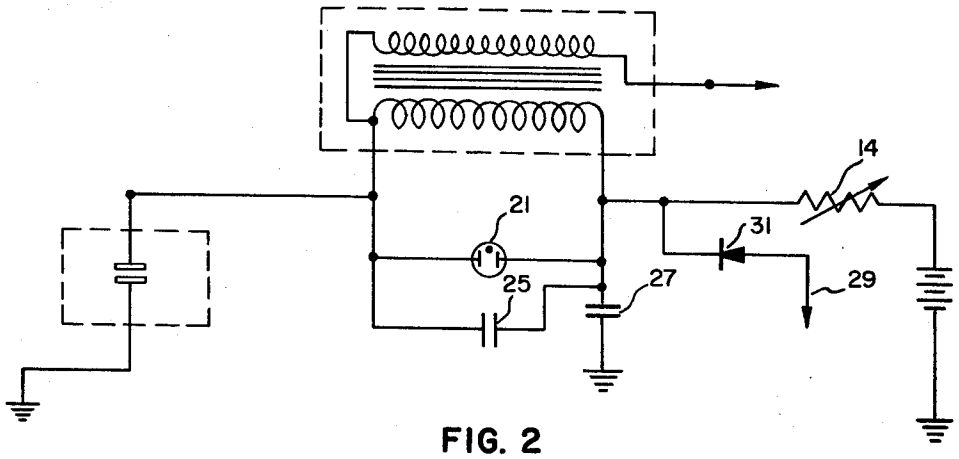


FIG. 2

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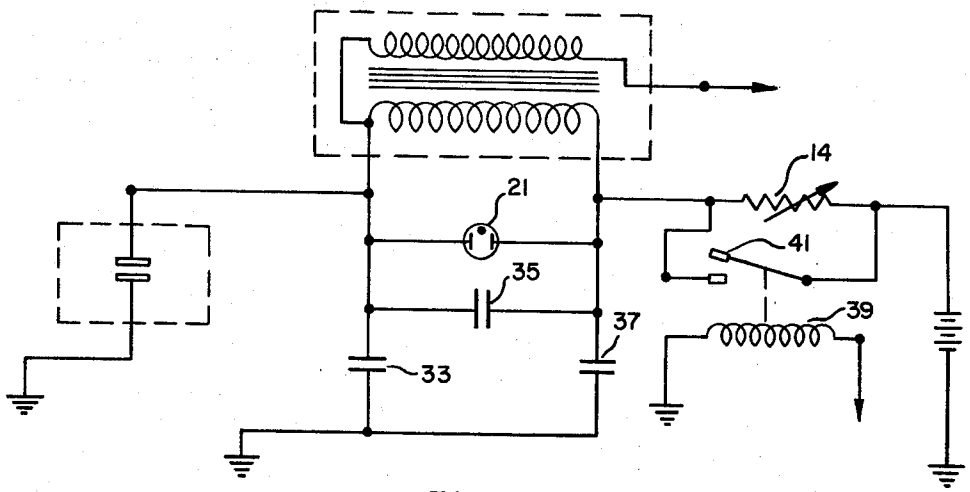


FIG. 3

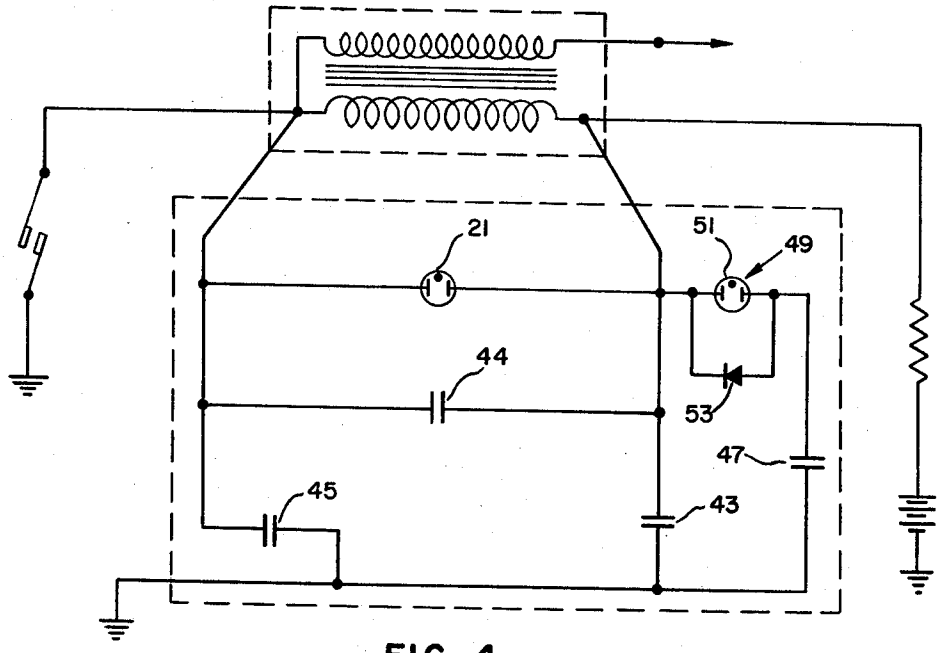


FIG. 4

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RESONANT IGNITION SYSTEM

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8 Claims. (Cl. 123—148)

ABSTRACT OF THE DISCLOSURE

A resonant ignition system wherein a gas discharge tube and a capacitor are placed across the primary winding of an induction coil. The capacitor is connected in parallel with the primary winding of the induction coil and forms a parallel resonant circuit therewith at one frequency. Another capacitor is connected in series with the primary winding of the induction coil to form a series resonant circuit therewith at another frequency. A feature of the present invention is the producing of multiple sparkling to cause a more efficient consumption of the fuel in an internal combustion chamber.

This invention relates to an improved form of electrical ignition for internal combustion engines and more particularly relates to the employment of a resonant circuit which gives a multiple spark, increasing the combustion efficiency of internal combustion engines.

Modern ignition systems ordinarily provide only a single spark for each cycle and when an engine is operating at a relatively high rate of speed, the time required for the flame front to move across the cylinder is such that there is insufficient time to burn all of the fuel in the cylinder. When a spark plug fires, it produces a cone of force directly in front of it and momentarily causes a difference in pressure between the burning flame front and the unburned combustion mixture in the rest of the combustion chamber. Due to the fact that the gas transfer velocity is much faster than the fuel burning rate, a swirling action is produced whereby unburned fuel mixture is forced around the spark plug. If it were possible at this point to cause another spark, another cone of force and a second flame front would result, greatly increasing the efficiency of the engine due to a more complete utilization of the fuel.

It is therefore an object of the present invention to provide a resonant spark system whereby a multiplicity of sparks is produced at each ignition point of the engine.

Another object of this invention is to provide a resonant spark system for an internal combustion engine which largely utilizes the conventional components of the ignition system and which utilizes a minimum of additional parts.

Still another object of this invention is to provide an ignition system of mechanical and electrical ruggedness and reliability having voltage and current limiting circuitry preventing overloading, overheating and the possible breakdown of insulation.

Still another object of this invention is to provide a resonant ignition system having a plurality of overlapping resonant frequencies whereby the circuitry will in effect be self adjusting over a wide range of engine speeds.

Another object of this invention is to provide a resonant ignition system of simple structure which can be installed and serviced by an ordinary mechanic without special training.

Still another object of this invention is to provide a resonant ignition system wherein conventional radio ignition noise suppressing means can be employed without adversely affecting the system.

Other objects will be apparent from the balance of the specification which follows:

In the drawings forming part of this application:

FIGURE 1 is a schematic diagram of an ignition system embodying the present invention;

FIGURE 2 is a schematic diagram similar to FIGURE 1 showing another embodiment of the invention;

FIGURE 3 is another schematic diagram showing a further embodiment of the invention;

FIGURE 4 is a schematic diagram of an embodiment of the invention particularly adaptable for rotary combustion (Wankel) engines.

Referring now to the drawings by reference characters, there is shown in FIGURE 1 a conventional ignition coil generally designated **5** having the usual primary **7** and secondary windings **9**, the latter having a wire **11**, leading to the usual distributor and spark plugs. The primary circuit includes the battery **13** and a current limiting resistor **14** which are in series with the points **15** of the usual distributor. A capacitor **17** is provided across points **15** to reduce arcing. In addition, the circuit may include the usual capacitor **19** for the purpose of suppressing radio interference. The circuitry so far described is the conventional ignition circuitry but in accordance with the present invention, a gas discharge tube **21** and a capacitor **23** are placed in parallel across the primary of the ignition coil. The selection of the capacity of the capacitor **23** will be discussed in detail hereinafter but it should be noted that the capacitor **23** is adapted to form a parallel resonant circuit at one frequency with the primary of the ignition coil. The gas discharge tube at **21** can be an ordinary neon tube such as NE–2 or NE–51 or it can be of any of the usual cold cathode voltage regulator tubes.

The function of the gas discharge tube **21** is threefold. In the first place, it serves as an indicator light to show that the circuit is operating properly. Secondly, it serves as a voltage regulator to limit the primary voltage on the coil to a safe maximum value so that secondary voltage does not exceed the safe maximum value of about 30 kilovolts. However, its most important function is to act as a multi-vibrator or relaxation oscillator in the circuit, producing multi-sparking at the spark plug while the breaker points are open, thereby causing multi-flame fronts in the fuel in the combustion chamber and thus effecting more efficient burning of the fuel.

The circuit of FIGURE 2 is similar to FIGURE 1 but here the capacitor which would ordinarily be across the distributor is disconnected from the circuit as well as any radio noise suppressor capacitor which would ordinarily be in the circuit. Here, in addition to the gas discharge tube **21**, a first capacitor **25** and a second capacitor **27** are inserted in the circuit, it being understood that the microfarad values of the two capacitors are such that the capacitor **25** will provide a parallel resonant circuit at a relatively high engine speed while the capacitor **27** will provide a series resonant circuit with the coil at a lower engine speed. Since the Q of the usual ignition coil is quite low, the resonant circuit produced by **25** and **27** covers a relatively wide range of frequencies and their frequency ranges overlap each other. Thus, there is an effective resonant circuit producing multiple sparks at every engine speed.

In FIGURE 2 another feature is shown in that a wire **29** leads to the hot side of the starter relay while a solid state rectifier **31** is provided to prevent back current flow. With this system, the full battery voltage is available for starting, the resistor **14** being effectively shorted out. Although an excessive current is drawn by this system,

the duration is so short that no harm is done to the components.

In FIGURE 3 another embodiment of the invention is shown. In accordance with this embodiment of the invention the radio noise suppressor capacitor and capacitor across the points have been removed and instead capacitors **33**, **35** and **37** are installed across the secondary together with a gas discharge tube **21** of the type previously described. In accordance with this embodiment of the invention, the capacitor **33** has a value selected to cause a series resonant circuit with the coil at about 4800 r.p.m. engine speed, capacitor **35** has a value selected to cause a parallel resonant circuit with the coil at an engine speed of about 3000 r.p.m. while **37** has a value to cause a series resonant circuit at an engine speed about 1200 r.p.m. Due to the low Q of the coil, and the apparent effective henries (hereinafter defined) of the coil primary caused by the reflected impedance from the coil secondary and its load, the three respective resonant circuits overlap in frequency response, thus covering effective engine speeds which range from idling speeds to the normal maximum speed of the engine in one continuous band. FIGURE 3 also illustrates another feature of the invention wherein a relay **39** is employed having contacts **41** which short out the resistor **14**. The hot side of the coil of relay **39** leads to the hot side of the engine starting relay so that whenever the starter motor is on, the contact **41** will be closed giving additional ignition voltage during starting.

In FIGURE 4 of the drawings, a preferred embodiment of the invention is shown which can be used with any engine and which is particularly useful with rotary combustion engines of the Wankel type. The Wankel engine poses particularly severe ignition problems because of the peculiar shape of the combustion zone, i.e., for a given volume the zone is spread over a large area. In this embodiment of the invention, capacitors **43**, **44**, and **45** serve substantially the same function as described in conjunction with FIGURE 3, but here a fourth capacitor **47** has been added together with a gating device generally designated **49** which consists of a combination of a gas discharge tube **51** and a solid state rectifier **53**. Here, the capacitor **47** can be effectively placed in parallel with the capacitor **43** through the gating device which operates as follows: The gas discharge tube **51** which can be an ordinary neon tube such as an NE–51 or an NE–2 is connected so that the current produced by the collapse of the magnetic field of the coil will be conducted in the forward direction through the diode **53** into capacitor **47** and returning through the gas discharge tube to the coil primary, thereby charging the capacitor **47** with a voltage of about 77.8 volts D.C., i.e., the breakdown voltage of the gas discharge tube. The gas discharge tube conduits any current which the diode cannot handle. At the instant the breaker points open, the capacitor **45** starts to charge and absorbs the first electrons produced by the back EMF of the coil, permitting the points to open with out arcing. The continued back EMF caused by the collapsing magnetic field forces current to flow through the coil primary in the opposite direction of the current which produced the field, charging capacitors **43** and **44** which have been selected so that they are rsonant at some predetermined frequency range, therefore the back EMF current sees only the resistance of the coil primary and is in phase with the voltage which caused it to flow, thus allowing the most rapid collapse of the magnetic field that is possible. This back EMF flows first in the capacitor **43** because it has the path of least resistance and the current flow is 90° ahead of the voltage which produced it, so **43** charges to full capacity before any current can enter the gate. After capacitor **43** is fully charged, current now flows through the gate **49** which has the effect of connecting capacitor **47** into the circuit. The long time constant and the small capacity of **43** provide a substantal excess of current which flows through the gate to charge capacitor **47** to full capacity at engine idling speed.

During the charging of capacitor **47** the voltage on the electrode connected to the coil primary is at a higher potential than on the electrode connected to the capacitor **47** because of the fully charged capacitor **43**. However, due to the small forward volt drop across the diode in the gating device **49**, there is little chance that the neon light will flash while the capacitor is charging. This is because a neon lamp such as an NE–51 or an NE–2 requires a voltage difference of 78 volts D.C. or 55 volts A.C. to fire and produce visible light even though the lamp is ionized and is conducting current during charging. The vast mapority of the current flows through the diode with only the forward voltage drop resistance between the back EMF current source and capacitor **47** with the result that there is only a very small increase in the time constant for charging. This provides capacitor **47** with a measurable direct current potential across it of not less than 75 volts and not more than 120 volts which is constantly varying between these limits.

The foregoing action has been taking place during the collapse of the magnetic field which produced the back EMF to cause the action, and the field has expended its energy, thus placing the coil primary in condition to accept the discharge from capacitors **43** and **47**.

Capacitor **43** discharges rapidly into the coil primary while **47** has to wait until there is enough difference in voltage between the two electrodes in the neon lamp to allow ionization of the gas and current flow. However, **43** has such a rapid discharge rate that the voltage difference between the electrodes is often great enough to cause the neon lamp to fire and thus produces an irregular flashing of the light.

If the recovery time of the diode is short enough in microseconds, all of the discharge current from capacitor **47** which flows back into the coil primary will have to pass through the neon lamp, but if a Zener diode is used, the capacitor **47** will discharge at resonant frequency back into the coil primary until the voltage across **47** has dropped from its peak charge voltage of approximately 115 D.C. volts to the Zener breakover voltage level. When this is attained, the avalanche effect ceases and the Zener diode blocks any further current flow through it from the capacitor **47** into the coil primary and the balance of the discharge current from **47** flows through the neon lamp. The longer time constant caused by the resistance of the lamp in the discharge circuit of capacitor **47** provides a higher voltage of longer duration for the operation of the multivibrator action of tube **21** across the coil primary thereby lengthening the multiple sparking action during the time when the breaker points are open.

Capacitor **44** is in a "tank" or anti-resonant circuit with the coil primary and has a phase angle difference of 180 degrees with respect to capacitors **45**, **43**, and **47**; therefore it operates only through the frequency ranges which it has been selected to cover.

The circuit of FIGURE 4 has a number of advantages. For one thing, the gate **49** acts as a phase operative disconnect switch betwen the capacitors **43** and **47** at the high frequencies at which the former capacitor is resonant. It also provides a path of low resistance into capacitor **47** so that **47** will charge at the resonant frequency rate, thus producing the most nearly vertical wave front and the least possible rise time with the highest regulated voltage in the coil secondary circuit which the coil design will permit. Further, due to the longer discharge time constant through the gas discharge tube, the duration of the multiple sparking action can be extended to cover the full time that the breaker points are open or by suitably selecting the lamp or diode, the time constant can be regulated to cover any portion of the point open period from about ¼ of the entire period to the full period. Since the gating circuit produces a

higher voltage across the primary of the coil, a special high brightness type of neon lamp having a higher firing voltage than normal may be employed advantageously.

It was previously mentioned that the capacitors were chosen to be resonant at various frequencies. In making such a determination, naturally one must take into consideration the number of cylinders and the number of cycles per second in arriving at the capacities to choose. For instance, at 300 r.p.m. a four cylinder engine will be operating at a rate of ten cycles per second while at 4800 r.p.m. an eight cylinder engine will operate at 320 cycles per second. In order to determine the proper capacities, it is first necessary to compute or measure the apparent effective henry values of the ignition coil. The average ignition coil has a primary reactance of between about .1 to 1.6 henries and a Q of between 8 and 12. The reflected impedance will depend on the amperage through the coil primary so that the effective henry value is in effect the addition of the measured reactance of the primary plus the reflected impedance of the secondary circuit. With these values available, one can then calculate the capacity necessary to resonate the circuit at any given frequency. In general, the capacity can range from about .06 microfarad to as much as 150 microfarads depending upon the inductance, number of cylinders and revolutions per minute. In the example of FIGURE 4, the capacitor **43** had a capacity of 0.11 mfd. capacitor **44** had a capacity of .4 mfd. capacitor **47** had a capacity of 0.1 mfd. and capacitor **45** had a capacity of 0.08 mfd. Diode **53** was 400 P.I.V. with 6A rating. The capacitors had 400 volt D.C. ratings. These naturally are only typical values and will depend in each instance upon the effective inductance of the ignition coil and also the more or less arbitrarily chosen ranges for the different capacities, it being only important that there is an overlap of frequency to yield a resonant circuit regardless of the engine speed.

I claim:

1. In an ignition system for an internal combustion engine, a coil with a primary winding and a secondary winding, a gas discharge tube connected across said primary winding, and means connected to said primary winding for forming a resonant circuit therewith to produce multiple sparking.

2. An ignition system as claimed in claim **1** wherein said means comprises a capacitor connected in parallel with said primary winding for forming a parallel resonant circuit therewith.

3. In an ignition system as claimed in claim **1** wherein said means comprises a capacitor connected in series with said primary winding for forming a series resonant circuit therewith.

4. In an ignition system as claimed in claim **2** wherein said means also includes another capacitor connected in series with said primary winding for forming a series resonant circuit therewith, whereby multiple sparking is provided over a range of frequencies.

5. In an ignition system as claimed in claim **2** wherein said means also includes another capacitor connected in series with one side of said primary winding for forming a series resonant circuit therewith and still another capacitor connected in series with the other side of said primary winding for forming a series resonant circuit therewith, whereby multiple sparking is provided over a range of frequencies.

6. In an ignition system as claimed in claim **4** and including a current limiting resistor connected in series with said primary winding, and a diode connected in series with said primary winding.

7. In an ignition system as claimed in claim **4** and including a current limiting resistor connected in series with said primary winding, a relay having contacts connected in parallel with said limiting resistor, and means for operating said relay to control the opening and closing of the contacts thereof.

8. In an ignition system as claimed in claim **5** and comprising a still further capacitor and a gating circuit connected in parallel with one of said capacitors forming a series resonant circuit with said primary winding, said gating circuit comprising a gas discharge tube with a diode connected across said last mentioned gas discharge tube.

References Cited

UNITED STATES PATENTS

3,173,410	3/1965	McLaughlin	123—179
3,327,165	6/1967	Hawthorne	315—223

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