

Feb. 7, 1967

K. STAIGER

3,303,385

IGNITION UNIT

Filed Feb. 11, 1964

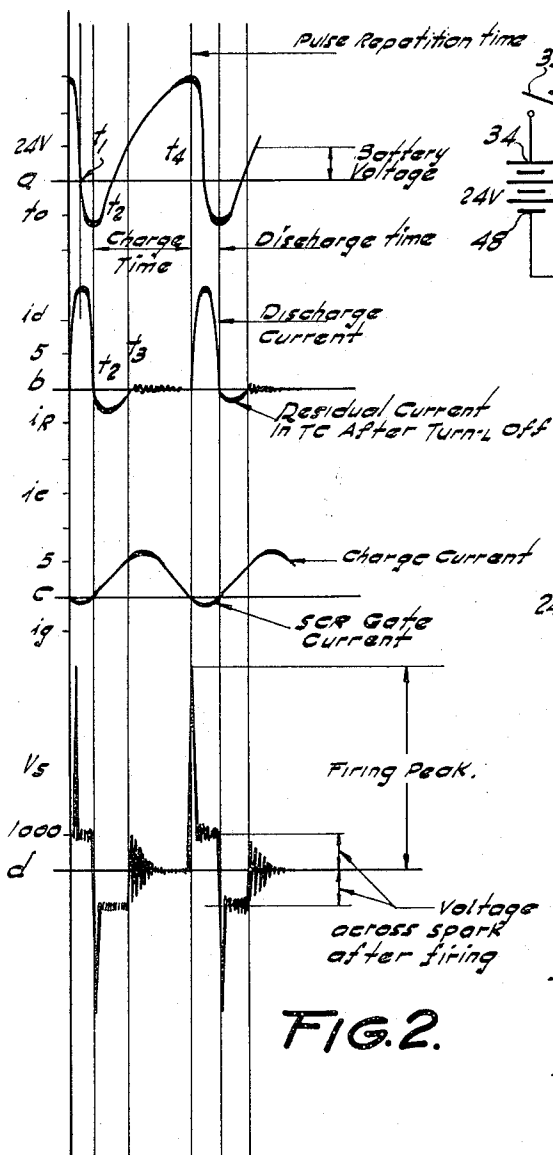


FIG. 2.

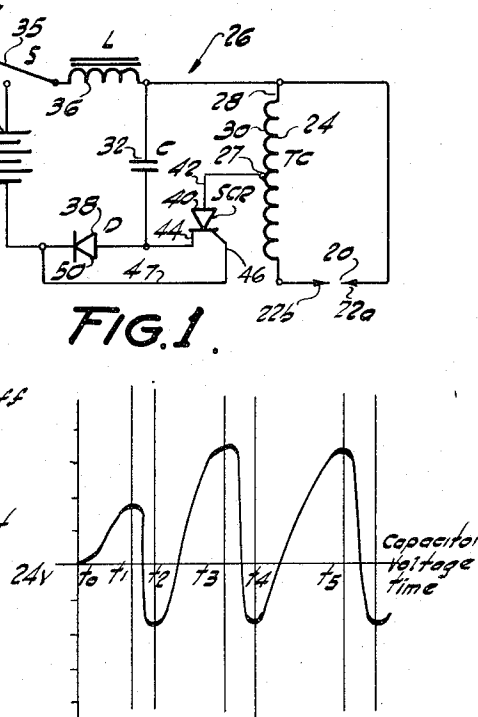


FIG. 1.

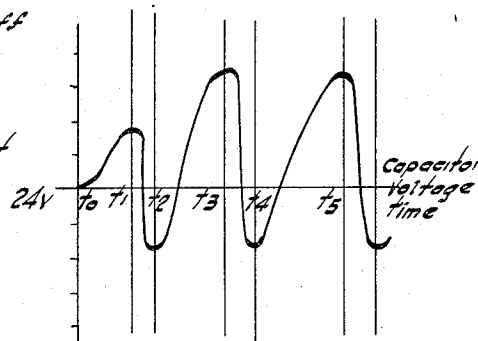


FIG. 3.

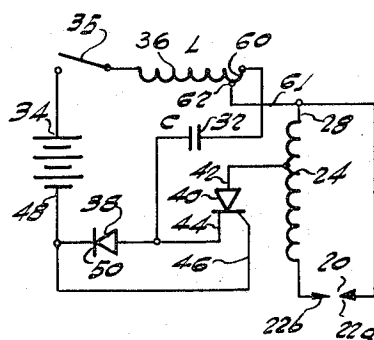


FIG. 4.

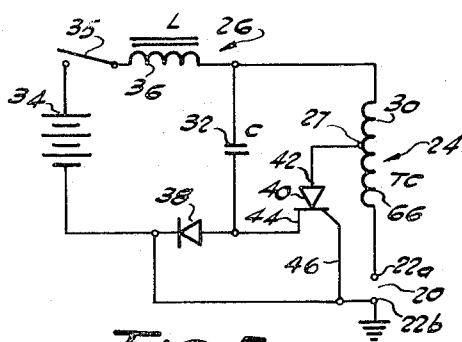


FIG. 5.

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3,303,385

IGNITION UNIT

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Filed Feb. 11, 1964, Ser. No. 344,003

9 Claims. (Cl. 315-206)

This invention relates to ignition systems for heaters. More particularly this invention relates to ignition systems for combustion heaters of the type used in automobiles or aircraft having low voltage D.C. power supplies.

Combustion heaters are preferably capable of being turned on and off rapidly for proper temperature control and hence use spark ignition systems. They usually include one or more spark plugs, an ignition coil and a vibrator or breaker points driven by the blower motor of the heater. An example of this type of heater system may be seen in U.S. Patent No. 2,880,718 issued to Frank A. Ryder, April 7, 1959.

It is readily apparent that the mechanical breaker points or vibrator are constant sources of potential trouble requiring costly preventive maintenance to keep them functioning properly.

Radio noise suppression is also a troublesome aspect of the previous combustion heater ignition systems. Extensive filtering means are required in order to eliminate the noise voltages generated by the mechanical interrupters.

As previously mentioned the sparking voltage for the old ignition coil systems is obtained by interrupting current in the ignition coil. Energy of the collapsing magnetic field is transferred into the distributed circuit capacity charging it to high voltage. The build up to high voltage in a coil of course takes an appreciable amount of time during which leakage current flowing in a fouled plug can sap the energy away to a point where firing voltage is no longer reached. This has the effect of materially shortening the effective life of the spark plug.

It is an object of this invention to provide a unique ignition system for combustion heaters or the like.

It is also an object of this invention to provide an ignition system which eliminates the need for mechanical breaker points or vibrator for establishing high voltages.

A further object of this invention is to provide an ignition system in which radio noise signal generation is held to a minimum.

Also it is an object of this invention to provide an ignition system employing inexpensive trouble-free components in a manner to obtain their maximum utilization.

The present invention comprises a unique capacitor discharge type of system in which the energy for each spark is stored in a capacitor and discharge through transformer means to provide a secondary voltage of proper magnitude to fire the plug. An inductance is included in the charging circuit and electronic switching means are utilized to alternately connected the capacitor to its charging and discharging circuits in such a manner that the inductance of the transformer means and the inductance in the charging circuit cause the capacitor to be charged to a voltage substantially in excess of the variable D.C. power source.

The capacitor discharge ignition system of this invention runs freely, thus eliminating the need for breaker points or a vibrator to provide continuous spark pulses. In addition there is a marked decrease in the generated radio noise which may be adequately filtered by means of relatively inexpensive filter means.

In the capacitor discharge system the spark plug receives full voltage almost instantaneously after the capacitor is switched to its discharge circuit. Hence there

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is very little time for leakage current to flow through a fouled plug during the build up of the voltage thereacross. The firing voltage may therefore be reached despite the dirty plug and hence its useful life is appreciably extended.

This invention will be better understood upon a further reading of this specification especially when taken in view of the accompanying drawings in which:

FIG. 1 is a circuit diagram of one embodiment of an ignition system including the teachings of this invention;

FIG. 2 is a graphical representation of the waveforms present at different points in the circuit of FIG. 1 under normal operation;

FIG. 3 is a graphical representation of the voltage versus time function of the circuit charging capacitor.

FIG. 4 is a circuit diagram of a modified system embodying this invention; and

FIG. 5 is a circuit diagram of another modification to the basic circuit embodying this invention.

Reference is now made to FIG. 1 which shows a spark gap 20 formed by a pair of electrodes 22a and 22b connected across the high voltage output of an autotransformer 24. A pulse generating circuit 26 feeds a pulse signal to the autotransformer between the tap 27 and the end 28 of transformer winding 24. The input portion 30 of the autotransformer between the tap 27 and the end 28 forms a vital part of the pulse generation circuit 26 as hereinafter described.

The voltage pulses fed to the autotransformer 24 are generated across capacitor 32 which is charged through a circuit comprising D.C. voltage source 34, switch 35, inductance 36, and forward connected diode 38 which is preferably, but not necessarily, of the silicon type.

A silicon controlled rectifier 40 has its anode 42 and its cathode 44 connected to the transformer tap 27 and the capacitor 32, respectively. Thus the capacitor has a discharge circuit through the input portion 30 of the autotransformer which includes the anode and cathode of silicon controlled rectifier 40.

The circuit is switched from its charging mode to its discharging mode by action of the gate electrode 46 of the silicon controlled rectifier which is connected by conductor 47 to a point between the negative terminal 48 of the D.C. power source 34 and the cathode 50 of diode 38.

To understand the action of the circuit it is best to consider first its operation in a steady pulse generating condition by following the voltages and currents as a function of time in the coordinated timing diagram of FIG. 2. FIG. 2a of the diagram shows the voltage across the capacitor 32, FIG. 2b shows the capacitor discharge current through the portion 30 of the autotransformer winding, FIG. 2c shows the capacitor charging current through the inductance 36 and FIG. 3D shows the voltage across the spark gap 20.

It is assumed for the purposes of this discussion that the circuit has been running for at least several cycles so that at time T_0 the voltage across the capacitor 32 has reached its peak of value which is substantially greater than the voltage of the D.C. power supply 34 or about three times that value. The inductance of choke coil 36 and the inductance of the autotransformer 24 make it possible for the capacitor 32 to charge up to this high voltage in a manner as hereinafter described.

Thus at T_0 , when the capacitor 32 is at its peak voltage well above the power source voltage, the capacitor begins to discharge through the choke coil 36, switch 35 and power supply 34. Because the diode 38 is blocking in this discharge current direction the current flows through conductor 47 to the gate 46 of the silicon controlled rectifier. The silicon controlled rectifier is thus triggered to its on or conducting state so that the capacitor voltage appears across the input portion 30 of the autotransformer 24.

The sudden appearance of the capacitor voltage causes a high voltage spike to be induced across the spark gap 20 thus establishing a spark.

When the spark is established the voltage across the gap 20 drops to a much lower value permitting a high discharge current to flow. Because of the inductance in the transformer 24 the current lags the capacitor discharge voltage. Thus, the capacitor discharge voltage goes to zero at approximately the same time the discharge current has reached its peak value as may be seen at T_1 in FIGS. 2a and 2b. From T_1 to T_2 a reverse voltage is built up on the capacitor 32 by action of the inductance in the transformer winding. At time T_2 when the current in the silicon controlled rectifier goes to zero the voltage applied thereto from the capacitor 32 is in the reverse direction thereby turning it off and effectively disconnecting the autotransformer from the capacitor. The silicon controlled rectifier will remain in its non-conducting state until triggered again by another positive current pulse on its gate 46.

At time t_2 when the SCR current is cut off energy is still present in the magnetic field of the autotransformer coil which produces a residual current in the spark gap circuit. This residual current is shown in FIG. 2b as a small negative peak between t_2 and t_3 . The residual current maintains the spark at the gap 20 as shown in FIG. 2d until energy in the coil has dropped to a point where it can no longer sustain the spark. Remaining energy then left in the system shows up as a damped oscillation thereafter.

Meanwhile the capacitor 32 is charged again through the choke coil 36 starting from the reverse voltage built up thereon. This reverse voltage adds to the D.C. power source voltage and permits the recharge of the capacitor to more than twice the battery voltage. At time t_4 the capacitor reaches again the voltage it had at time T_0 and the cycle starts to repeat itself.

Thus, it is the energy feedback action of the discharge cycle that causes the capacitor to charge to a voltage of three to five times that of the D.C. power source. This permits output levels of several watts in the spark using capacitors of reasonable size. If there were no feedback action and the capacitor were charged merely to the D.C. power supply voltage the capacitor would have to be extremely large in order to store sufficient energy to supply the spark.

As may be seen from the charge current plot in FIG. 2c the charge current is essentially a rectified sign wave with a very small amount of reverse current added at the bottom during the discharge cycle which represents the silicon controlled rectifier gate current. Pulse repetition time is determined as the sum of the discharge time of capacitor 32 plus one half of the natural cycle time of the choke coil, capacitor charge circuit. As may be seen in FIG. 2d two voltage spikes, one positive and one negative, occur during each cycle of the pulse generator 26 which are both of sufficient magnitude to create sparks across the gap.

To understand more fully the build up of the capacitor peak voltage to the high values mentioned reference is now made to the diagram of FIG. 3. It is assumed that at time T_0 the switch 35 (FIG. 1) is closed and capacitor 32 begins charging through the inductance of choke coil 36. Basic resonance theory indicates that capacitor 32 will charge to twice the power supply voltage in a loss-free circuit and to slightly less in a practical circuit having losses from winding resistance, the diode, the power supply and other sources. This of course is due to the effective energy storage built up in magnetic field of the choke coil 36 during current flow and the transfer of this energy to the capacitor as current in the circuit goes toward zero.

At time T_1 the discharge current begins flowing through the gate 46 of the silicon controlled rectifier 40 to thus fire the unit and connect the transformer input winding

portion 30 to the capacitor 32. The secondary voltage obtained at the transformer coil however is not yet high enough to fire the spark plug, and, except for internal circuit losses in the coil and the silicon controlled rectifier, the capacitor energy is returned to the capacitor in the subsequent oscillation.

The action of the transformer winding is such that the capacitor is charged to an opposite polarity voltage which is close to twice the battery voltage as shown at time T_2 . The opposite polarity causes the silicon controlled rectifier 40 to cut off and the capacitor 32 to begin recharging through choke coil 36.

Applying again basic resonant circuit theory it is found that this charged cycle should continue to a voltage which is nearly four times the battery power source voltage at time T_3 . The silicon controlled rectifier again fires and there is more than adequate secondary voltage at the transformer 24 to fire the spark plug. The spark at the gap draws considerable energy, thus limiting the reverse voltage built up on the capacitor to a value substantially lower than the peak of the first half of the cycle. The reverse voltage is still approximately twice the power source voltage which is comparable to the reverse voltage peak occurring at time T_2 on the capacitor.

To maintain operation the transformer 24 must be designed to limit the energy extraction of the spark to a level which permits the circuit to operate in an oscillatory mode. That is, if too much energy is extracted, damping occurs and no reverse voltage appears across the capacitor to turn off the silicon controlled rectifier. Thus, it is necessary to maintain a certain range of leakage inductance in the transformer coil. Many existing ignition coils will meet this requirement and permit operation for resistance values in the spark circuit ranging from zero or short circuit to infinite or open circuit.

If such an ignition coil is not obtainable it is possible to achieve the same action by utilizing the circuit shown in FIG. 4. This circuit is identical with the circuit of FIG. 1 except that the return path for the energy stored in the transformer coil 24 to the capacitor 32 includes a portion 60 of the winding of the choke coil 36 in view of the conductor 61 between the end 28 of the transformer coil 24 and tap 62 on the choke coil 36. The added inductance in the capacitor discharge circuit prevents the oscillation from being more than critically damp so that a reverse polarity voltage will appear across the silicon controlled rectifier to turn it off. Since all other components of the circuit are identical with the circuit of FIG. 1 and their functions are the same they have been given the same reference numbers and no further explanation is believed necessary.

The circuit shown in FIG. 5 is another modification of the basic circuit shown in FIG. 1 and is useful in applications where it is desirable to ground one electrode of the spark gap. The capacitor charging and discharging circuits have their components arranged in substantially the same manner as in FIG. 1, the only material difference in the circuit being the path for the current through the spark gap 20. This path may be traced from electrode 22a through the high voltage portion 66 of the transformer winding 24, anode 42 of the silicon controlled rectifier 40, diode 38 to ground and returning to the electrode 22b.

It is recognized that many modifications and additions may be made to the embodiments hereinbefore described. It is therefore intended that this invention be limited only by the scope of the appended claims.

What is claimed is:

1. An ignition system for a combustion heater or the like comprising a pair of electrodes forming a spark gap, an autotransformer having a high voltage winding in connection with said gap to provide high voltage pulses thereacross, a silicon controlled rectifier having an anode, a cathode and a gate, a tap on said winding connected to said anode, a D.C. power source having a nega-

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tive terminal in connection with said gate, an inductance in connection at one end with the positive terminal of said D.C. power source and at its other end with said winding, a capacitor in connection between the other end of said inductance and said cathode, and a diode in forward connection between said cathode and the negative terminal of said power source.

2. An ignition system for a combustion heater or the like comprising a pair of electrodes forming a spark gap, a transformer having a high voltage winding in connection with said electrodes, a silicon controlled rectifier having an anode, a cathode and a gate, a low voltage winding in mutual inductance relationship with said high voltage winding having one end connected to said anode, a D.C. power source having a negative terminal in connection with said gate, an inductance in connection at one end with the positive terminal of said D.C. power source and at its other end with the other end of said low voltage winding, a capacitor in connection between the other end of said inductance and said cathode, and a diode in forward connection between said cathode and the negative terminal of said power source.

3. An ignition system for a combustion heater or the like comprising a pair of electrodes forming a spark gap, an autotransformer having a high voltage winding in connection with said gap to provide high voltage pulses thereacross, a silicon controlled rectifier having an anode, a cathode and a gate, a tap on said winding connected to said anode, a D.C. power source having a negative terminal in connection with said gate, an inductance in connection at one end with the positive terminal of said D.C. power source and at its other end with said winding, a capacitor in connection between the other end of said inductance and said cathode, a diode in forward connection between said cathode and the negative terminal of said power source and means for selectively interrupting at least one of said connections to said D.C. power source.

4. An ignition system for a combustion heater or the like comprising a pair of electrodes forming a spark gap, an autotransformer having a high voltage winding connected at one end to one of said electrodes, a silicon controlled rectifier having an anode, a cathode and a gate, a tap on said winding connected to said anode, a D.C. power source having a negative terminal in connection with said gate and the other one of said pair of electrodes, an inductance in connection at one end with the positive terminal of said D.C. power source and at its other end with the other end of said winding, a capacitor in connection between the other end of said inductance and said cathode, and a diode having an anode in connection with said silicon controlled rectifier cathode and a cathode in connection with negative terminal of said D.C. power source.

5. The system of claim 4 comprising in addition means for selectively interrupting at least one connection to said D.C. power source.

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6. An ignition system for a combustion heater or the like comprising a pair of electrodes forming a spark gap, an autotransformer having a high voltage output winding connected across said gap, a silicon controlled rectifier having an anode, a cathode and a gate, a tap on said winding connected to said anode, a D.C. power source having a negative terminal in connection with said gate, an inductance in connection at one end with the positive terminal of said D.C. power source and at its other end with one of said electrodes, a capacitor in connection between the other end of said inductance and said cathode, and a diode having an anode in connection with said silicon controlled rectifier cathode and a cathode in connection with the negative terminal of said power source.

7. The system of claim 6 comprising in addition means for selectively interrupting at least one of said connections to said D.C. power source.

8. An ignition system for a combustion heater or the like comprising a pair of electrodes forming a spark gap, an autotransformer having a high voltage winding in connection with said gap to provide high voltage pulses thereacross, a silicon controlled rectifier having an anode, a cathode and a gate, a tap on said winding connected to said anode, a D.C. power source having a negative terminal in connection with said gate, an inductance in connection at one end with the positive terminal of said D.C. power source, a capacitor in connection between the other end of said inductance and said cathode, a tap on said inductance in connection with said winding, and a diode in forward connection between said cathode and the negative terminal of said power source.

9. An ignition system for a combustion heater or the like comprising a pair of electrodes forming a spark gap, a transformer having a high voltage winding in connection with said electrode to provide high voltage pulses across said gap, a silicon controlled rectifier having an anode, a cathode and a gate, a low voltage winding in mutual inductive relationship with said high voltage winding having one end connected to said anode, a D.C. power source having a negative terminal in connection with said gate, an inductance in connection at one end with the positive terminal of said D.C. power source, a capacitor in connection with the other end of said inductance and said cathode, a tap on said inductance in connection with the other end of said low voltage winding, and a diode in forward connection between said cathode and the negative terminal of said power source.

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