

[54] **IGNITION SYSTEM**

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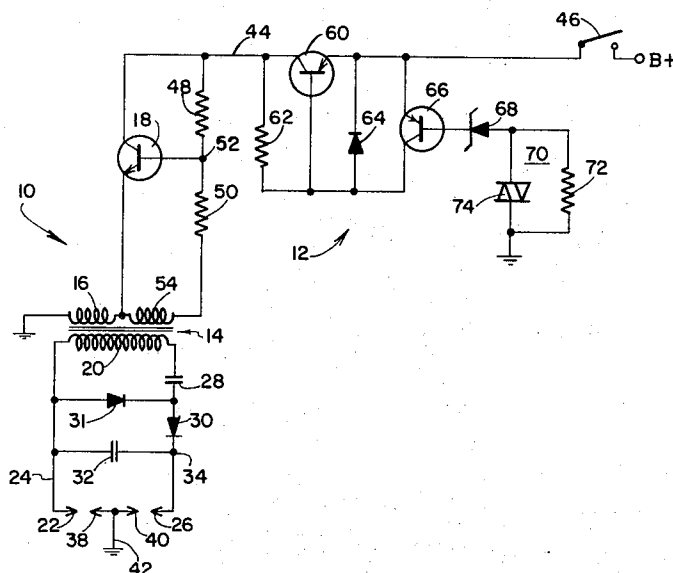
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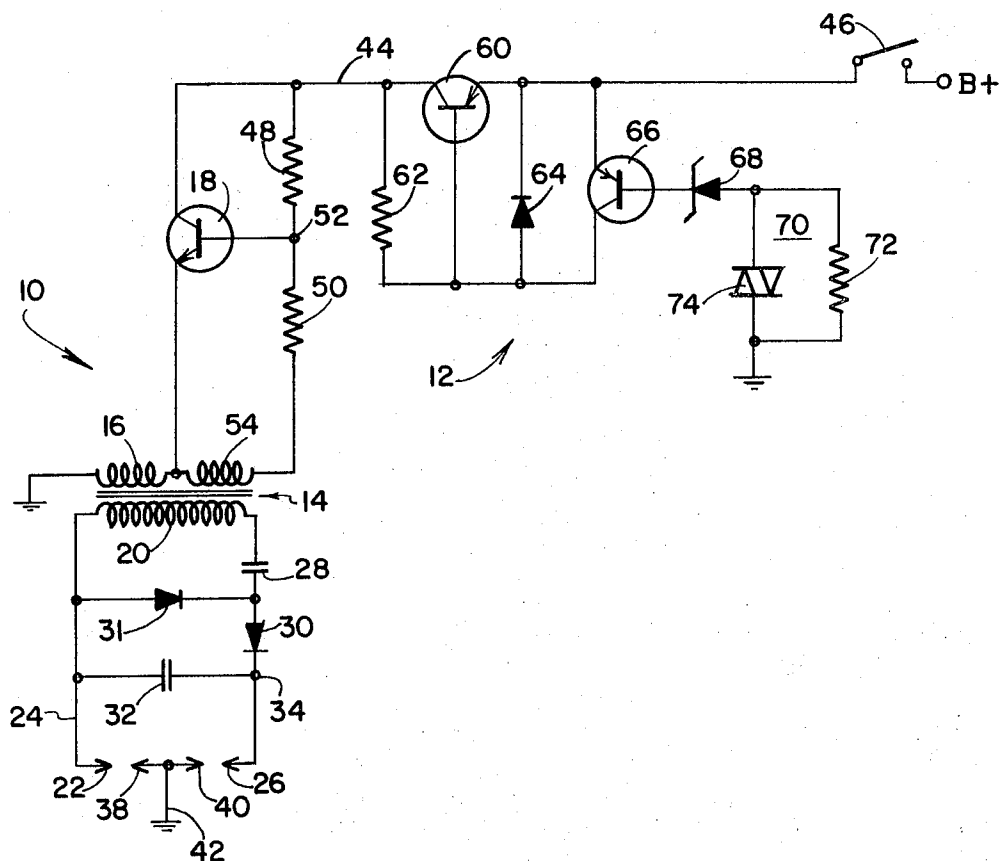
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[57] **ABSTRACT**

An ignition system includes a step-up transformer wherein the primary winding is connected to an oscillator circuit to receive pulses of direct current voltage at a relatively high frequency to cause corresponding high voltage pulses to be developed in the secondary winding thereof. One end of the secondary winding is coupled to a first electrode forming a first spark gap and the other end of the secondary winding is coupled to a second electrode forming a second spark gap, and each of the spark gaps includes a common potential electrode. The output of the secondary is accumulated in a high voltage capacitor until a sufficiently high voltage is obtained to cause simultaneous spark discharges at both spark gaps. A voltage regulator circuit is connected in series with the pulsing circuit to regulate the voltage supplied thereto, which, in turn, controls the rate of spark discharge between the spark gaps.

4 Claims, 1 Drawing Figure





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IGNITION SYSTEM

BACKGROUND OF THE INVENTION

This invention relates generally to ignition systems, and more particularly to ignition systems which can be used as turbine igniters.

Heretofore, ignition circuits have been provided to ignite fuel injected into turbine engines to initiate operation thereof. However, such prior art devices generally include a step-up transformer of one kind or another having the secondary winding thereof arranged for connection to a spark coil through a suitable switching device. This requires the use of two transformers, i.e., the transformer of the ignition circuit and that of the ignition coil.

Furthermore, ignition circuits of the prior art provide only a single spark gap at which the spark discharge is created to initiate combustion within the fuel chamber of a turbine engine. Where additional spark discharges are desired at various locations within the combustion chamber, or within several combustion chambers, it is generally provided that a single ignition circuit will provide all the sparks to the various spark gaps but on a time shared basis, applying a spark first to one spark gap at one instance and then applying a subsequent spark to another spark gap during a second instance, and so on until a spark is again applied to the first spark gap. This method of distributing an ignition spark to the combustion chamber can be accomplished by any suitable distributor device. Also, a plurality of different spark gaps may receive ignition sparks from separate ignition systems associated with each spark gap. In either case, the cost and reliability of such ignition systems are greatly affected because of the inherent increase in the number of components in such systems.

SUMMARY OF THE INVENTION

Therefore, it is an object of this invention to provide an ignition system for use as a turbine engine igniter wherein a pair of spark gaps are provided for operation from a single secondary winding of a step-up transformer to cause simultaneous spark discharges to occur at the respective spark gaps.

Another object of this invention is to provide an ignition system wherein a voltage regulator is provided in series therewith to maintain the frequency of the spark discharge within the predetermined prescribed limits.

A still further object of this invention is to provide an ignition system for use with turbine engines which is inexpensive to manufacture, efficient and reliable in operation and has a minimum number of components.

Briefly, the ignition system includes a step-up transformer having at least one primary winding for receiving pulses of direct current voltages and a secondary winding for applying high voltage pulses to a pair of spark gaps. One end of the secondary winding is direct current coupled to a first electrode of a first spark gap while the other end of the secondary winding is coupled through a capacitor and a diode, which form a voltage doubler network, to a second electrode of a second spark gap. Connected in parallel with the secondary winding is a high voltage storage capacitor which receives pulses of charge from the secondary winding at a relatively high frequency until the voltage thereacross reaches the breakover voltage, or spark voltage, of the respective spark gaps to initiate a spark discharge therebetween. A free-running, pulse forming oscillator forms the pulsing circuit and includes a single transistor having its emitter-collector current path connected in series with the primary winding of the step-up transformer. An additional winding is formed on the transformer and coupled to the primary winding to provide a current feedback from the emitter of the transistor to the base thereof for self-sustained pulsing operation. This oscillator preferably operates at a frequency of about 5,000 Hz, but it will be understood that any suitable frequency may be used.

To ensure that the frequency of the high voltage spark discharge from the storage capacitor is maintained within a predetermined limit a voltage regulator is connected in series

with the oscillator circuit. The regulator includes a transistor having its collector-emitter current path connected in series between the oscillator circuit and a source of operating potential applied thereto while the base electrode of the transistor receives control potential through a reference voltage circuit. In the illustrated embodiment, the reference voltage circuit includes a second transistor connected across the base-emitter junction of the voltage regulating transistor, and wherein the base electrode circuit of the second transistor there is connected a reference voltage device, such as a zener diode, to a ground potential. In this instance, the zener diode is of a low power type requiring only a small amount of current therethrough to provide for proper voltage regulation of the voltage regulating transistor.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawing there is seen a schematic wiring diagram of an ignition system and voltage regulator circuit constructed in accordance with the principles of this invention. Here, the spark producing ignition circuit is designated generally by reference numeral 10 and the voltage regulator circuit is designated generally by reference numeral 12. For turbine igniters it is desired to produce spark discharges at selected electrodes at a rate sufficiently high to ensure proper ignition of the fuel within one or more combustion chambers but also to limit the rate of spark discharges so as to preserve and extend the life of the electrodes forming the spark gap or gaps. To this end the voltage regulator circuit 12 limits the voltage value applied to the ignition circuit 10 to, for example, 10 volts, more or less, so that the frequency of operation of the ignition circuit 10 will be within the desired limits.

The ignition circuit 10 includes a step-up transformer 14 having a primary winding 16 connected in series with a transistor 18. The transistor 18 forms a free-running oscillator circuit which applies direct current pulses to the primary winding 16 during operation of the ignition system 10. The frequency of such pulses is, for example, a range of 500 to 10,000 Hz, and a frequency of 5,000 Hz may be most desirable. The step-up transformer 14 includes a secondary winding 20 which has one end thereof direct current coupled to a first electrode 22 via a line 24. However, the other end of secondary winding 20 is coupled to a second electrode 26 through a capacitor 28 and a diode 30. A diode 31 is connected across the secondary winding 20 and together with capacitor 28 forms a voltage doubler circuit so that the voltage value of pulses applied to a storage capacitor 32 is twice that developed at the secondary winding 20. However, the number of pulses required to fully charge capacitor 32 to a spark discharge potential will be determined by, among other things, the distance between the spark gaps formed by electrodes 22, 38 and 26, 40. The frequency of discharge of capacitor 32 is preferably many orders of magnitude less than the frequency of the oscillator formed by transistor 18. This frequency of discharge is preferably in the range of 0.5 to 2 Hz. Preferably, the capacitance value of capacitor 28 is less than the capacitance value of capacitor 32. Thus, the capacitance value of capacitor 32 also determines the number of pulses required to fully charge the capacitor to a spark discharge potential. By using a voltage doubler circuit as disclosed in the illustrated embodiment herein, the voltage rating of the capacitor 28 and diode 31 may be substantially reduced, i.e., about one half the discharge voltage value on capacitor 32. Also, the number of turns on the secondary winding 20 can be decreased and the transformer 14 is thereby made smaller and less expensive.

Associated with the electrodes 22 and 26 are electrode forming means 38 and 40, respectively, which are tied together at a common circuit and connected to ground potential by a line 42. It will be noted that in the circuit arrangement of the ignition circuit 10 the secondary winding 20 of the transformer 14 is free-floating with neither end thereof connected to a reference potential such as ground.

Therefore, in operation when a sufficient number of pulses have been applied to the storage capacitor 32 the high voltage developed thereacross will be discharged simultaneously at the spark gaps defined by electrodes 22, 38 and 26, 40. The spark gaps may be located at different places within the combustion chamber of a turbine engine to increase the chances of proper ignition of the fuel injected into the combustion chambers. Also, it will be understood that the electrodes 38 and 40 may be common electrodes formed of a single electrode member positioned between electrodes 22 and 26 and spaced from different surfaces thereof.

Operating potential is applied to the transistor 18 via a line 44 in response to the closing of a switch 46 which is connected to any suitable DC voltage source. Where the voltage applied to switch 46 is within a range of 10-30 volts the voltage applied to line 44 is regulated to a predetermined voltage value, say for example, never to exceed 10 volts or so, by means of the voltage regulator circuit 12. Forward bias condition is applied to the transistor 18 by means of a pair of series connected resistors 48 and 50 having the center circuit point 52 thereof connected to the base electrode of the transistor 18. In the illustrated embodiment, transformer 14 includes a feedback winding 54 connected between the emitter electrode of transistor 18 and the base electrode thereof through the resistor 50. Induced magnetic fields within the transformer 14 as a result of current flow through the primary winding 16 will cause feedback current to be applied to the base electrode of transistor 18 to effect self-sustained pulse oscillations of the circuit.

The voltage regulator circuit 12 includes a transistor 60 having its collector electrode connected to the line 44 and its emitter electrode connected to the switch 46. A resistor 62 is connected between the base electrode of transistor 60 and the line 44 to provide a forward bias current path for the transistor 60 thereby rendering the transistor 60 highly conductive for voltage values of the applied power source equal to or below the desired regulated voltage value. A diode 64 has its cathode connected to the emitter electrode of transistor 60 and its anode connected to the base electrode thereof and serves as a protection device for the transistor 60 by preventing the base of transistor 60 from becoming more positive than the forward voltage drop of the diode 64.

Also connected between the emitter and base electrodes of transistor 60 is a second transistor 66 the conduction of which controls the conduction of a transistor 60. That is, a high voltage applied through switch 46 will forward bias transistor 66 as a result of the current path through the emitter and base electrodes thereof through a reference voltage device 68 and a resistor network 70 to ground potential. The reference voltage device 68 preferably is a low power zener diode which will operate in the breakover range thereof with only a small amount of current flow therethrough.

The resistance network 70 includes a fixed resistor 72 and a voltage dependent resistor device 74. The voltage dependent resistor device 74 is of a value to provide automatic regulation of the base current of transistor 66 with variations in applied voltage through the switch 46 only when current flow passes through the reference voltage device 68. That is, upon breakover current passing through the zener diode 68 to set the voltage value to be regulated, increase in voltage beyond this value will be controlled or regulated by the voltage dependent resistor device 74. However, for all voltage conditions below the breakover voltage of the zener diode 68 the transistor 60 will be at maximum or substantially maximum conduction.

Accordingly, the ignition system of the illustrated embodiment provides means for initiating spark discharges between first and second spark gaps without the use of switching devices for controlling the current to such spark gaps. Also, the illustrated embodiment provides a voltage regulator circuit for regulating the frequency of the pulsing circuit to insure that the frequency of the high voltage spark discharges are within a predetermined desired range.

I claim:

1. A spark igniter circuit comprising a step-up transformer having a primary winding and a secondary winding, each end of secondary winding being connected to first and second electrode means respectively which form first and second spark gaps having one end thereof coupled to a first electrode means which forms a first spark gap with respect to a reference potential, and the other end of said secondary winding being coupled to a second electrode means which forms a second spark gap with respect to the reference potential, a capacitor connected across said secondary winding to receive charge therefrom, an oscillator circuit connected to said primary winding and applying pulses thereto of a given frequency to cause a plurality of high voltage pulses to be developed in said secondary winding thereby charging said capacitor, with the same being discharged, to create simultaneous spark discharges at said first and second spark gaps at a frequency less than said given frequency, a voltage regulator circuit connected to said oscillator circuit for limiting the frequency of oscillations of said oscillator to limit the rate of spark discharge between said first and second spark gaps, said voltage regulator circuit including a first transistor having its load electrodes connected in series with said oscillator circuit and a control electrode, a second transistor connected in circuit with the control electrode of said first transistor, and a zener diode connected to the control electrode of said second transistor to cause conduction thereof upon a voltage applied thereto exceeding a predetermined voltage whereby an increase of voltage applied to said regulator circuit causes a decrease in the frequency of operation of said oscillator and a decrease of voltage applied thereto causes an increase in the frequency of operation of said oscillator.

2. The spark igniter circuit of claim 1 further including a variable voltage resistance element connected in series with said zener diode to cause regulation of voltage values above said predetermined voltage value.

3. A spark igniter circuit comprising a supply potential, first and second transistors each having emitter, base and collector electrodes, with said emitter electrode of said first transistor being connected to said supply potential and said collector electrode being connected to said base electrode of said second transistor with said first transistor progressively clamping said emitter to said base of said second transistor by variable conduction of said first transistor, a zener diode, a voltage dependent resistance, said zener diode and voltage dependent resistance being connected in series between said base of said first transistor and a reference potential, said zener diode providing precise definition of the conduction voltage point and said voltage dependent resistance providing automatic regulation of said base current in said first transistor for voltages above said zener diode breakover voltage, said emitter electrode of said second transistor being connected to said supply potential to regulate voltage, a third transistor having emitter, base and collector electrodes, said collector electrode of said second transistor being connected to said collector electrode of said third transistor, a transformer having primary, secondary, and feedback windings, first and second resistors, said emitter of said third transistor being connected to said primary winding and feedback winding and coupled to said base electrode by said feedback winding and said first resistance in series, said base electrode of said third transistor being connected by said second resistance to said collector electrode of said second transistor, first and second capacitors, first and second diodes, with said secondary of said transformer being connected to said first capacitor, said first diode and said first capacitor connected across said secondary winding for rectifying the signal thereof, two spark gaps, said second diode being connected between the junction of said first capacitor and said first diode and one of said spark gaps, said second capacitor being connected across said first and second diodes with said diodes being poled so said secondary winding and said first capacitor charge said second capacitor with signals of one polarity only, thereby forming voltage doubling means, said spark gaps being connected between a

reference potential and said voltage doubling means with said spark gaps firing simultaneously and the frequency of said spark gap firing being less than the oscillator frequency.

4. The spark igniter circuit of claim 1 wherein said oscillator frequency comprises a range on the order of 1,000 to 10,000 5 Hz, and the range of frequencies of said spark discharges comprises the range of on the order of 0.5 to 2 Hz.

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