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Matthews

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[54] **DIRECT SPARK IGNITION SYSTEM WITH SAMPLING FLAME SENSOR**

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[58] **Field of Search** 431/66, 67, 70, 71, 78, 431/80; 317/96

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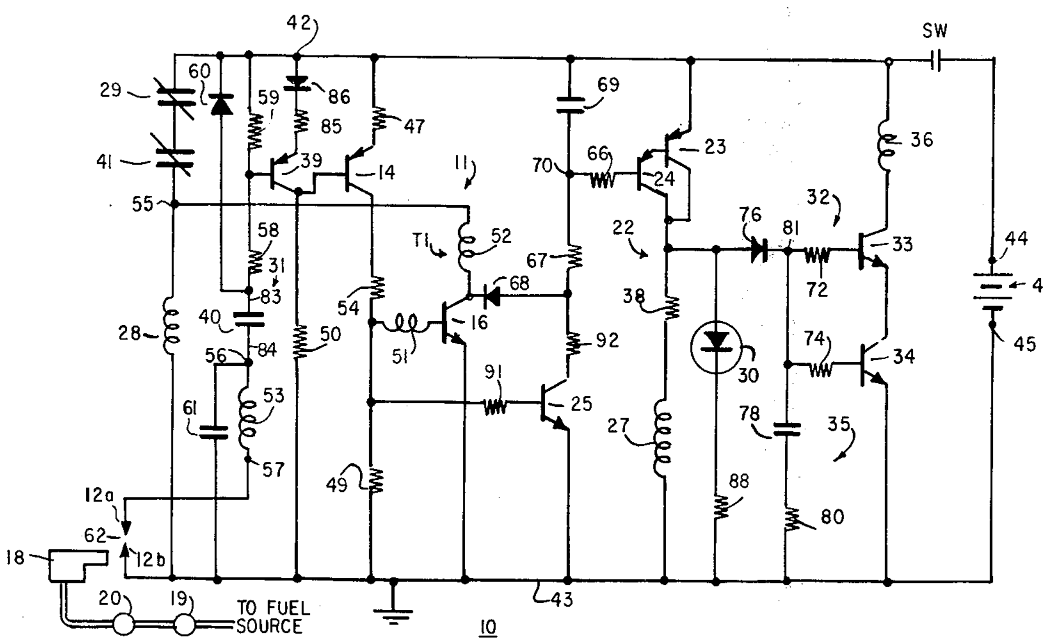
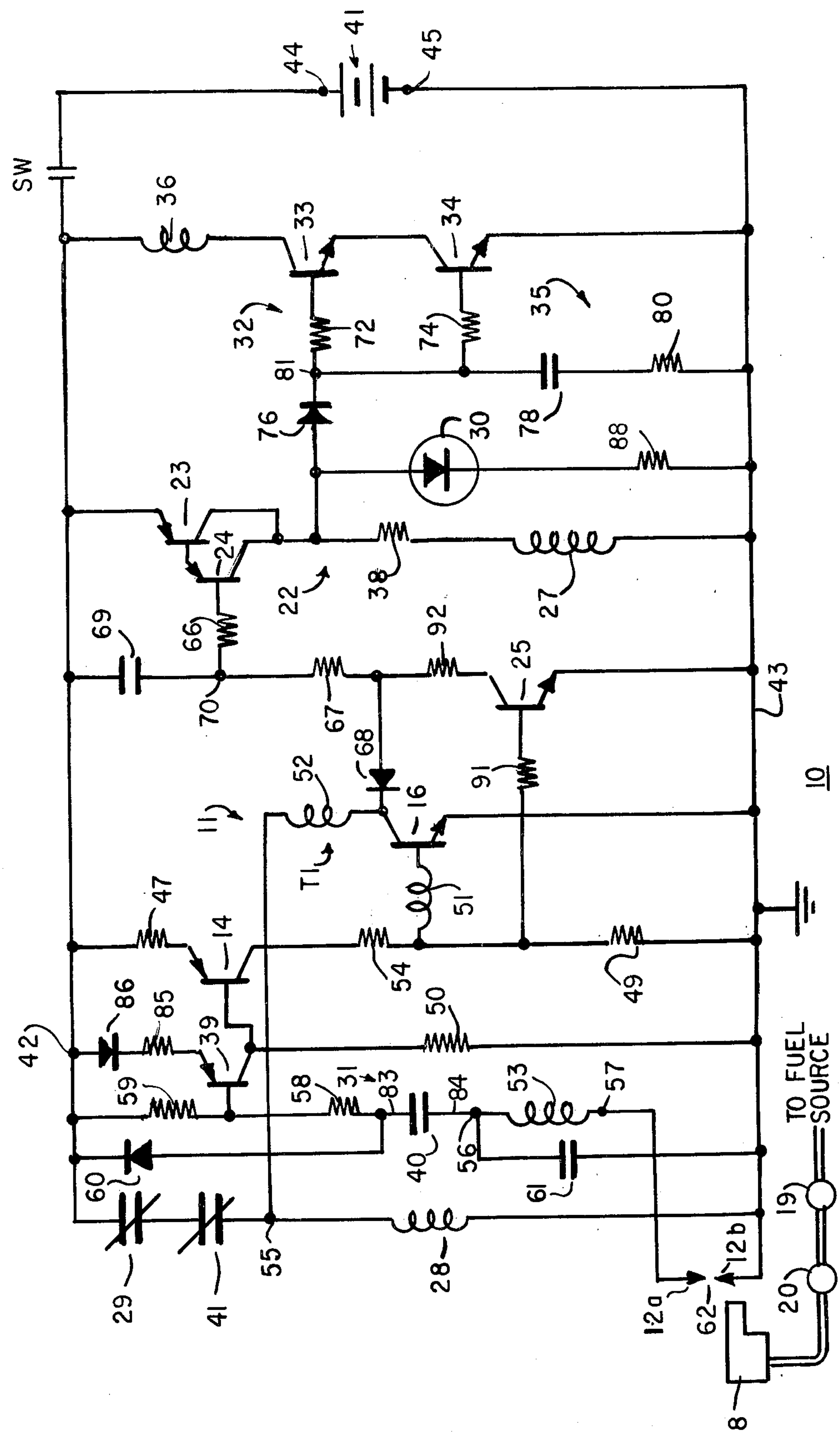
[57] **ABSTRACT**

An automatic fuel ignition system includes an ignition circuit for generating ignition sparks for igniting fuel discharged by a fuel outlet, an energizing circuit controlled by the ignition circuit to operate redundantly connected fuel valves to supply fuel to the fuel outlet, and a flame sensing circuit operable when a flame is established to normally disable the ignition circuit and to periodically enable the ignition circuit to test the operability of the ignition circuit. A light emitting diode, controlled by the energizing circuit, provides remote indication of the operability of the ignition circuit.

17 Claims, 1 Drawing Figure




SW
TO FUEL SOURCE

DIRECT SPARK IGNITION SYSTEM WITH SAMPLING FLAME SENSOR

BACKGROUND OF THE INVENTION

1. Field of the Invention.

This invention relates to automatic fuel ignition systems, and more particularly to a self-checking fuel ignition system providing automatic shut off of fuel in the event of loss of flame or ignition sparks.

2. Description of the Prior Art.

Automatic fuel ignition systems generally include an igniter circuit having a pulse generator operable when enabled to generate high voltage pulses which are applied to a pair of ignition electrodes positioned adjacent a fuel outlet. The ignition electrodes are spaced apart to provide a gap there between such that the high voltage pulses applied to the electrodes produce ignition sparks for igniting fuel emanating from the outlet to establish a flame. When the flame is established, a flame sensing circuit, which includes a second pair of electrodes, disables the pulse generator. In the event of a flame out, the flame sensing circuit reenables the pulse generator to attempt reignition of the fuel.

In certain igniter circuits, a pulsating control device is employed for disabling the pulse generator whenever a flame is established. In ignition systems energized from an AC voltage source, the cyclical AC voltage can be used to drive such control device. However, in ignition systems energized from a DC source, such as may be employed in a heating system for a mobile recreational vehicle, an inverter circuit is necessary to provide the required pulsating drive resulting in additional cost and complexity to the ignition circuit.

A further consideration is that in the event of a flame-out condition, reignition of the fuel depends upon the operability of the spark generator of the igniter circuit. Thus, in the event of a malfunction of the spark generator, unburned gas will be wasted as the igniter circuit cycles to attempt reignition. Moreover, since the igniter circuit usually is located in an enclosure and is generally not readily accessible to view, failure of the spark generator may go unnoticed for a long period of time.

Accordingly, it would be desirable to have an automatic fuel ignition system in which the operability of the igniter circuit is continuously monitored. It would also be desirable to have an automatic fuel ignition system which indicates whether or not the igniter circuit is operating properly. Moreover, it would be desirable to be able to provide such indication at a location remote from the location of the igniter circuit.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide an automatic fuel ignition system which provides automatic shut off of the fuel supply in the event of loss of flame or loss of ignition sparks.

Another object of the invention is to provide a self-checking fuel ignition system which automatically tests the operability of an ignition spark generator of the system.

A further object of the invention is to provide a fuel ignition system which permits remote indication of loss of spark and flame.

Another object of the invention is to provide an automatic fuel ignition system which employs a single pair of electrodes for both igniting the fuel to establish a flame and for sensing the presence of the flame.

A further object of the invention is to provide an automatic fuel ignition system having an inverter circuit which operates directly from a DC source.

These and otherobjects are achieved by the present invention which has provided an automatic fuel ignition system including ignition means operable when enabled to produce ignition sparks in the proximity of a fuel outlet, energizing means controlled by the ignition means to control the operation of valve means to supply fuel to the fuel outlet for ignition by the ignition sparks to establish a flame, and flame sensing means operable when a flame is established to normally disable the ignition means to inhibit the generation of ignition sparks and to periodically enable the ignition means when the flame is established to test the operability of the ignition means and the presence of flame.

In accordance with a disclosed embodiment, the ignition means includes oscillator means and enabling means for enabling the oscillator means to generate high voltage pulses for application to electrode means to produce ignition sparks. The oscillator means is energized from a DC source and employs feedback means to effect the generation of the voltage pulses. Accordingly, an inverter circuit is not required to convert DC input power to AC power in order to produce an alternating voltage for spark generation purposes.

The voltage pulses produced by the oscillator means also control the energizing means which includes a control means responsive to such pulses to effect operation of the valve means to supply fuel to the fuel outlet, and sampling means enabled by the control means to maintain the valve means operated when a flame is established.

When a flame is established, the flame sensing means, which includes the electrode means, normally disables the oscillator means of the ignition means to inhibit spark generation, but periodically permits enabling of the oscillator means to test the operability of the oscillator means and to detect the presence of the flame to maintain the valve means operated.

When the oscillator means is disabled, the generation of voltage pulses is interrupted and thus, the control means is also disabled. However, the sampling means maintains the valve means operated whenever the control means is disabled as long as the control means continues to be periodically enabled by the ignition means under the control of the flame sensing means.

Should the flame fail to be established within a predetermined time, or for a flame-out condition, the control means effectsdeactivation of the valve means to interrupt the supply of fuel to the fuel outlet.

Only a single pair of electrodes is required to provide both ignition of the fuel and sensing of the resultant flame. The flame sensing means detects the presence of the flame.

In accordance with the present invention, an indicator means is controlled by the control means for pulsed operation each time an ignition spark is generated. In the event the oscillator means fails to operate when enabled by the flame sensing means, the indicator means is continuously energized to indicate failure of the oscillator means. Moreover, upon loss of ignition spark, the control means deactivates the valve means to interrupt the supply of fuel to the fuel outlet.

DESCRIPTION OF PREFERRED EMBODIMENTS

General Description

Referring to the drawing, there is shown a schematic circuit diagram of the self-checking automatic fuel ignition system **10** provided by the present invention which, for example, may be used in a heating system for recreational vehicles. The fuel ignition system **10** includes a pulse generating circuit **11** which effects the generation of ignition sparks between a pair of electrodes **12***a* and **12***b* located in the proximity of a main burner **18**, for igniting gaseous fuel supplied to the burner **18.** The pulse generating circuit **11** includes a control transistor **14** which supplies base drive current to a transistor **16** which together with windings **51** and **52** of an ignition transformer T1 comprise an oscillator circuit operable to produce high voltage pulses for application to the electrodes **12***a* and **12***b* to produce the ignition sparks.

Fuel is supplied to the main burner **18** whenever a main valve **19** and a redundant valve **20** are operated. The redundant valve **20** has an operate winding **28** connected in series with normally closed contacts **29** of a warp switch and normally closed contacts **41** of a limit switch (not shown)between conductors **42** and **43** over which the system **10** is energized such that the redundant valve **20** is normally maintained operated when the thermostat is calling for heat.

The main valve **19** has a pickup winding **27** which is energized by a control circuit **22** to operate the valve **19** to supply fuel to the burner **18** for ignition by ignition sparks to establish a flame. The control circuit **22** is in turn controlled by the pulse generating circuit **11.** The control circuit **22** includes a pair of transistors **23** and **24,** connected in Darlington configuration, which are pulsed into conduction by pulses provided by oscillator transistor **16** whenever the pulse generating circuit **11** is enabled. Energizing current is supplied to the pickup winding **27** of the main valve **19** whenever transistors **23** and **24** are conducting. The control transistors **23** and **24** also energize a warp switch heater **38** which controls the operation of a warp switch contacts **29.** In the event of a flame-out condition or loss of ignition sparks through failure of the pulse generating circuit **11,** the warp switch heater **38** operates associated contacts **29** to deenergize winding **28** of the redundant valve **20** to deactivate the valve **20** thereby interrupting the supply of fuel to the burner **18.**

A sampling circuit **32,** enabled by the control circuit **22** energizes a hold winding **36** of the main valve **19** to maintain the valve **19** operated when a flame is established. The sampling circuit **32** includes redundant transistors **33** and **34** and an integrating network **35** controlled by pulses supplied by the control transistors **23** and **24** to maintain the hold winding **36** of the valve **19** energized when the flame is established. The use of redundant transistors **33** and **34** assures that the hold winding **36** of the main valve **19** can be deenergized. Thus, should one of the transistors **33** or **34** become short-circuited from emitter to collector, the hold winding **36** will be deenergized when the other transistor is cutoff during normal operation of the sampling circuit **32.**

In an alternative embodiment, the windings **27** and **36** may be windings of a two winding relay (not shown) and a control winding of the valve **19** may be connected in series with normally open contacts of the relay between point **55** and conductor **43,** the control winding being energized to operate the valve **19** whenever winding **27** or **36** is energized causing the relay to operate.

For the purpose of controlling the operation of the pulse generating circuit **11** when the flame is established such that the operability of the pulse generating circuit **11** can be tested periodically, the electrodes **12***a* and **12** *b* are connected in a flame sensing circuit **31** which senses the presence of the flame. Thus, the electrodes **12***a* and **12***b* are used to both ignite the fuel and to sense the presence of the flame. The flame sensing circuit **31** enables the fuel ignition system **10** to operate in a sampling mode in which the pulse generating circuit **11** and the control circuit **22** are normally disabled but are periodically enabled during sampling periods defined by the charging time of capacitor **40** of the flame sensing circuit **31.** Capacitor **40,** which is alternately charged and discharged whenever the flame is established, provides a control potential for enabling a transistor **39** of the flame sensing circuit **31** to conduct to disable the control transistor **14** after a first period during which the capacitor **40** charges.

During a second period, while capacitor **40** discharges, the pulse generating circuit **11** and the control circuit **22** are disabled. At the end of the second duration, capacitor **40** again charges while transistor **39** is cutoff such that the pulse generating circuit **11** is reenabled to produce further ignition sparks. At such time, pulse provided by the pulse generating circuit **11** enable the control circuit **22** to supply pulses to the sampling circuit **32** to maintain the main valve **19** operated as will be described hereinafter.

The periodic disabling of the control circuit **22** limits current flow through the warp switch heater **38** and the pick-up winding **27** of the main valve **19.** With the presence of a flame at the electrodes **12**a and **12**b, the current flowing through winding **27** and warp switch heater **38** is only a fraction of that without the flame. Accordingly, heating of the warp switch heater **38** is negligible when a flame is established so that warp switch contacts **29** remain closed to energize the redundant valve winding **28.**

Moreover, the average current through the pick-up winding **27** of the main valve **19** is maintained at a low value, the main valve **18** being held open by the hold winding **36** which is energized by the sampling circuit **32.**

The periodic disabling of the control circuit **22** enables control pulses to be provided for the sampling circuit **32** permitting transistors **33** and **34** to be maintained conductive to maintain the main valve **18** operated.

The control circuit **22** further includes a visual indicating device **30,** embodied as a light emitting diode, which permits a loss of spark condition to be indicated at a remote location remoted from the ignition circuit. Thus, while the electrodes must be positioned adjacent the main burner **18** which is generally enclosed and not readily accessible, the light emitting diode **30** may be located on the outside of the heating unit which employs the fuel ignition system **10** of the present invention.

When the fuel ignition system **10** is operating in the sampling mode, the light emitting diode **30** is pulsed on by the control circuit **22** each time an ignition spark is generated as transistors **23** and **24** of the control circuit

22 are periodically rendered conductive and non-conductive through operation of the flame sensing circuit **31**.

In the event of loss of spark caused by a malfunction of the pulse generating circuit **11**, or a short circuit between the electrodes **12***a* and **12***b*, transistor **25** of the pulse generating circuit **11** enables the control transistors **23** and **24** to conduct continuously to energize the warp switch heater **38** causing deactivation of the redundant valve **20** and to maintain the light emitting diode **30** continuously on to indicate the loss of spark condition.

Detailed Description

Power is supplied to the fuel ignition system **10** from a DC voltage source **41** which is connectable to a pair of conductors **42** and **43** over switch contacts SW which may be thermostatically controlled. In an exemplary embodiment, the voltage source is a 12 volt battery. When the contacts SW are closed, conductor **42** is connected to the positive terminal **44** of the voltage source **41**. Conductor **43** is connected to the negative terminal **45** of the voltage source **41** which is connected to ground.

Transistor **14** of the pulse generating circuit **11** is connected in an enabling circuit between conductors **42** and **43**. The emitter of transistor **14** is connected through a resistor **47** to conductor 42 and the collector of transistor **14** is connected through series connected resistors **48** and **49** to conductor **43**. The base of transistor **14** is connected through resistor **50** to conductor **43**. Transistor **14** is normally conducting when switch contacts SW are closed, supplying base current to transistor **16** of the oscillator circuit over resistor **48** and a feedback winding **51** of the ignition transformer **T1**, which is connected between the base of transistor **16** and the junction of resistors **48** and **49** at point **54**. The collector of transistor **16** is connected through the primary winding **52** of the ignition transformer **T1** to point **55** and over normally closed limit switch contacts **41** and warp switch contacts **29** to conductor **42**. The emitter of transistor **16** is connected to conductor **43**.

The base drive supplied to transistor **16** by transistor **14** enables transistor **16** to begin to conduct permitting current flow through the primary winding **52** of the ignition transformer **T1**, providing regenerative feedback to the base of transistor **16** until saturation is attained. At such time, the primary flux begins to decrease generating a reverse voltage in the feedback winding **51** which tends to cutoff transistor **16** reducing the feedback, permitting transistor **16** to again be driven to saturation and the cycle repeats. The oscillating current in the primary winding **52** generates alternating high voltage pulses in the secondary winding **53** for application to the electrodes **12***a* and **12***b*.

The high voltage secondary winding **53** of the ignition transformer **T1** is connected in a series circuit path with the ignition electrodes **12***a* and **12***b* between the conductors **42** and **43**. More specifically, one end **56** of secondary winding **53** is connected through capacitor **40** and resistors **58** and **59** to conductor **42**. The other end **57** of secondary winding **53** is connected to electrode **12***a*. The other ignition electrode **12***b* is connected to conductor **43**. A capacitor **61** is connected between the junction of capacitor **40** and end **56** of secondary winding **53** and conductor **43**. The electrodes **12***a* and **12***b* are spaced apart to provide a gap **62** therebetween to permit the generation of ignition sparks in the gap **62** whenever high voltage pulses are applied to the electrodes **12***a* and **12***b* over the secondary winding **53**.

The pulses provided at the collector of transistor **16** of the pulse generating circuit **11** also enable transistors **23** and **24** of the control circuit **22** to effect operation of the main valve **19** by energizing the pick-up winding **27**, which is a low resistance winding enabling fast operation of the valve **19**. Transistors **23** and **24** are connected in Darlington configuration with the base of transistor **23** being connected to the emitter of transistor **24** and the collector of transistor **23** being connected to the collector of transistor **24**. The emitter of transistor **23** is connected to conductor **42**. The base of transistor **24** is connected over resistors **66** and **67** and diode **68** to the collector of transistor **16**. A capacitor **69** is connected between the junction of resistors **66** and **67** at point **70** and conductor **43**.

Whenever transistor **16** is conducting, transistors **23** and **24** also conduct to supply energizing current to the pickup winding **27** and the warp switch heater **38**. Thus, when switch SW is operated to enable the pulse generating circuit **11** to generate ignition sparks, the control circuit **22** effects operation of the main valve **19**. As shown in the drawing, the main valve **19** and the redundant valve **20** are connected in series between a fuel source (not shown) and the main burner **18**. Since the operate winding **28** of valve **20** is connected in series with normally closed warp switch contacts **29** and the normally closed limit switch contacts **41**, the redundant valve **20** is normally operated whenever power is applied to conductors **42** and **43**. Thus, gaseous fuel is supplied to the main burner **18** when the main valve is operated. In the event the gas discharged by the main burner **18** is not ignited within a predetermined time, the warp switch heater **38** operates contacts **29** to effect deactivation of the redundant valve **20** to interrupt the supply of fuel to the main burner **18**.

The sampling circuit **32** includes redundant transistors **33** and **34**, the base electrodes of transistors **33** and **34** being connected through resistors **72** and **74**, respectively, and suitably poled diode **76** to the collector of transistor **24** to receive the enabling signals. The hold winding **36** of the main valve **19** is connected in an energizing circuit between the collector of transistor **33** and conductor **42**, the emitter of transistor **33** being connected to the collector of transistor **34** and the emitter of transistor **34** being connected to conductor **43**. Thus, the hold winding **36** is energized whenever transistor **33** and **34** are conducting. Once rendered conductive, transistors **33** and **34** are maintained conductive by an integrating network **35** which includes resistor **80** and capacitor **78** which are connected in series between the junction of resistors **72** and **74** and diode **76** at point **81**. The integrating network **35**, including capacitor **78** and resistor **80**, responds to the enabling signals provided by the control circuit **22** to maintain a potential at point **81** sufficient to maintain transistors **33** and **34** conducting for a duration defined by the values of capacitor **78** and resistor **80**.

When ignition of the gas discharged by the main burner **18** is accomplished, the sensing circuit **31** including electrodes **12***a* and **12***b* senses the presence of the flame which bridges the gap **62** between the electrodes **12***a* and **12***b* and the system begins to operate in the sampling mode.

As indicated above, capacitor **40** of the flame sensing circuit **31** charges and discharges through the flame, providing a control potential for rendering transistor **39** alternately conductive and non-conductive. Transistor **39** in turn controls the conductivity of transistor **14** of the pulse generating circuit **11** to normally inhibit spark generation by cutting off oscillator transistor **16** when the flame is established, but to periodically enable spark generation by supplying base drive to transistor **16** to test the operability of the pulse generating circuit **11.**

Diode **60,** secondary winding **53** and the electrodes **12***a* and **12***b* form a portion of a charging path for capacitor **40.** Diode **60** is connected between one side **83** of capacitor **40** and conductor **42.** The other side of capacitor **40** is connected through secondary winding **53** to electrode **12***a*. Whenever a flame bridges the gap **62** between the electrodes **12***a* and **12***b*, capacitor **40** charges over a path which extends from one side **83** of the capacitor **40,** through diode **60** to conductor **42,** through the battery **41** to conductor **43** and over electrodes **12***a* and **12***b* and the flame and through secondary winding **53** to the other side **84** of capacitor **40.**

Capacitor **40** then discharges over a path including transistor **39** to cause transistor **39** to conduct. The emitter of transistor **39** is connected through a resistor **85** and suitably poled diode **86** to conductor **42.** The base of transistor **39** is connected to the junction of resistors **58** and **59,** and the collector of transistor **39** is connected to the base of transistor **14** and over resistor **50** to conductor **43.**

As capacitor **40** discharges, current flows from side **84** of capacitor **40** through secondary winding **53,** electrodes **12***a* and **12***b* and the flame to conductor **43,** through the battery **41,** to conductor **42,** through diode **86,** resistor **85** the emitter-base circuit of transistor **39** and through resistor **58** to the other side **83** of capacitor **40.** The discharge current flowing through transistor **39** causes transistor **39** to conduct, raising the base potential at the base of transistor **14** causing transistor **14** to be cut off, interrupting the flow of base current to oscillator transistor **16** to temporarily inhibit the generation of high voltage pulses. This condition exists for a time until the charge has leaked off capacitor **40,** which for example, may take approximately **15** to **20** seconds. Then transistor **39** becomes cutoff allowing transistor **14** to conduct to turn on transistor **16** permitting spark generation for approximately one second at which time the cycle repeats.

The light emitting diode **30** which provides a visual indication of the operability of the pulse generating circuit **11,** is connected in series with a current limiting resistor **88** between the collector of transistor **24** of the control circuit **22** and conductor **43.** Under normal operating conditions, the light emitting diode **30** flashes every time a spark is generated, approximately every **15** to **20** seconds, when control transistors **23** and **24** are rendered conductive in response to operation of the pulse generating circuit **11.**

In the event electrodes **12***a* and **12***b* become shorted or should a malfunction occur in the pulse generating circuit **11,** transistor **25** of the control circuit **22** effects continuous energization of the light emitting diode **30** to indicate a failure.

Transistor **25** has a base electrode connected through resistor **91** to the junction of resistors **48** and **49** in the collector circuit of transistor **14.** The collector of transistor **25** is connected through resistors **92** and **67** and **66** to the base of transistor **24.** The emitter of transistor **25** is connected to conductor **43.**

For a loss of spark condition, transistor **14** is rendered conductive, causing transistor **25** to turn on. Transistor **25** in turn enables transistors **23** and **24** to turn on energizing the light emitting diode **30.** The warp switch heater **38** is also energized to permit contacts **29** to operate deactivating the redundant valve **20** to interrupt the supply of fuel to the main burner **18.**

Operation

Assuming initially that the main valve **19** is unoperated and that warp switch contacts **29** and limit switch contacts **41** are closed so that the redundant valve **20** operates, when the switch contacts SW are closed and the **12** volt potential provided by the battery **41** is applied to conductors **42** and **43.** Accordingly, current flows from conductor **42** over resistor **47** and the emitter-base circuit of transistor **14** and thence over resistor **50** to conductor **43** causing transistor **14** to conduct. When transistor **14** conducts, collector current flows through resistor **48** and the feedback winding **51** of the ignition transformer T1 to the base and out the emitter of transistor **16** to conductor **43,** causing transistor **16** to begin to conduct. Accordingly, current flows over warp switch contacts **29,** limit switch contacts **41** and through the primary winding **52** of the ignition transformer T1 and the collector-emitter circuit of transistor **16** to conductor **43.** The flux generated as the result of such current flow induces a voltage in the feedback winding **51** resulting in an increase in the conduction of transistor **16** with an attendant increase in collector current and thus the feedback voltage until transistor **16** is driven to saturation.

When transistor **16** is saturated, a feedback voltage is no longer induced in the feedback winding **51** and the primary flux in winding **52** begins to decrease causing a reverse voltage to be generated in feedback winding **51** which tends to cutoff transistor **16.** This in turn reduces the feedback and thus base current for transistor **16** starts to flow again to repeat the cycle. The net effect is an oscillating current in the primary winding **52** which generates alternating high voltage pulses on the order of 10KV to 12KV in the secondary winding **53.** Each voltage pulse thus produced causes a spark to jump from electrode **12***a* to electrode **12***b* to ground.

When transistor **16** is conducting, current flows from conductor **42** over the emitter-base circuit of Darlington connected transistors **23** and **24** and through resistors **66** and **67,** diode **68,** and the collector-emitter circuit of transistor **16** to conductor **43,** causing transistors **23** and **24** to conduct to supply collector current to the warp switch heater **38** and the pick-up winding **27** of the main valve **19.** When the pickup winding **27** is energized, the main valve **19** is operated supplying gaseous fuel to the main burner **18.** It is pointed out under normal conditions, ignition occurs before heating of the warp switch heater **38** is sufficient to cause operation of the warp switch contacts **29** as would deactivate the redundant valve **20.**

In addition, when transistors **23** and **24** conduct, charging current for capacitor **78** of the sampling circuit **32** flows through diode **76,** capacitor **78** and resistor **80,** establishing a potential at point **81** sufficient to cause transistors **33** and **34** to turn on, energizing the hold winding **36** of the main valve **19.**

As soon as the gas discharged by the main burner **18** is ignited, the presence of the flame is sensed by the flame sensing circuit **31** which enables the fuel ignition system **10** to operate in the sampling mode during which the pulse generating circuit **11** is enabled for one second intervals to produce ignition pulses for generating ignition sparks and is disabled for 15 to 20 second intervals after each pulse generation period.

When end **56** of secondary winding **53** becomes positive, current flows through capacitor **40**, diode **60**, conductor **42** through the battery **41** and over conductor **43** to the electrodes **12***a* and **12***b* through the flame to electrode **12***a* and through secondary winding **53**, placing a charge on capacitor **40.** Capacitor **40** then starts to discharge with discharge current flowing from one side of capacitor **40** at point **84** through secondary winding **53**, the flame, conductor **43**, the battery **41**, conductor **42**, diode **86**, resistor **85** the emitter-base circuit of transistor **39** and resistor **58** to the other side of capacitor **40** at point **83.** The discharge current causes transistor **39** to conduct permitting current flow through resistor **50** thereby increasing the potential at the base of transistor **14**, such that transistor **14** cuts off, in turn cutting off transistor **16** to inhibit further spark generation. The discharge time of capacitor **40** is approximately 15–20 seconds after which time transistor **39** is cut off, allowing transistor **14** to conduct to reenable transistor **16** for approximately one second while capacitor **40** charges and the cycle repeats.

During the one second intervals in which transistor **16** oscillates, the control transistors **23** and **24** are pulsed on and off supply current pulses to the warp switch heater **38** and the pick-up winding **27**. Also, the light emitting diode **30** flashes every time a spark is generated. However, as long as pulses are provided at 15 to 20 second intervals, such pulses do not cause heating of the warp switch heater **38** to a point where deactivation of the redundant valve **20** is effected.

The pulses supplied to the warp switch heater **38** and pick-up winding **27** are also supplied to the integrating network **35** of the sampling circuit **32** so that capacitor **78** remains charged to a potential sufficient to maintain transistors **33** and **34** conducting to hold the main valve **19** open.

If the gas discharged by the main burner **18** fails to ignite or fails to be reignited in the event of a flame out condition, the pulse generating circuit **11** continues to operate and the current supplied to the warp switch heater **38** eventually heats to a point at which warp switch contacts **29** operate to deactivate the redundant valve **20** to shut off the supply of fuel to the main burner **18.**

As indicated above, the light emitting diode **30** flashes every time a spark is generated, approximately every 15 to 20 seconds. In the event of a failure of the pulse generating circuit **11**, the light emitting diode **30** is maintained continuously on to indicate such failure. For a loss of spark condition, transistor **14** will conduct. Assuming oscillator transistor **16** is open circuited, when transistor **14** conducts, transistor **25** is turned on due to the voltage drop across resistor **49.** Conduction of transistor **25** causes transistor **23** and **24** to conduct energizing the warp switch heater **38** to effect shut off of the redundant valve **20** and to energize the light emitting diode **30.**

Thus, the fuel ignition system **10** responds to two failures. Loss of flame for any reason or any failure that simulates loss of flame results in operation of the warp switch contacts **29** to deactivate the redundant valve **20.** Loss of spark for any reason, including shorted electrodes, results in operation of the warp switch contacts **29** to shut off the redundant valve **20** and the continuous energization of the light emitting diode **30** to indicate the failure.

I claim:

1. In a fuel ignition system including valve means operable when energized to supply fuel to a fuel outlet, an ignition circuit for controlling the operation of said valve means and for igniting fuel discharged by said fuel outlet, said ignition circuit comprising ignition means operable when enabled to generate ignition sparks in the proximity of said fuel outlet, energizing means controlled by said ignition means to energize said valve means to supply fuel to said fuel outlet for ignition by said ignition sparks to establish a flame, sensing means enabled whenever a flame is established to disable said ignition means during a first period to inhibit the generation of ignition sparks and for enabling said ignition means to generate ignition sparks during a second period, and indicator means controlled by said energizing means to provide a first indication each time an ignition spark is generated, and to provide a second indication whenever said ignition means fails to produce ignition sparks during said second period.

2. A fuel ignition system as set forth in claim **1** wherein said energizing means includes first switching means enabled by said ignition means to effect operation of said indicator means, said ignition means being operable when enabled to provide control pulses for said first switching means effecting pulsed operation of said first switching means to permit said indicator means to operate each time an ignition spark is generated.

3. A fuel ignition system as set forth in claim **2** wherein said ignition means includes means for continuously enabling said first switching means whenever said ignition means fails to produce ignition sparks during said second period to provide continuous operation of said indicator means.

4. A fuel ignition system as set forth in claim **2** wherein said indicator means comprises a light emitting diode which is normally energized to emit light intermittantly in correspondance with the generation of ignition sparks and which is continuously energized whenever said ignition means fails to produce ignition sparks during said second period.

5. in a fuel ignition system including valve means for supplying gaseous fuel to a fuel outlet, an ignition circuit for controlling the operation of said valve means and for igniting fuel discharged by said fuel outlet, said ignition circuit comprising ignition means including electrode means, oscillator means, and enabling means for enabling said oscillator means to generate high voltage pulses for application to said electrode means to produce ignition sparks in the proximity of said fuel outlet, energizing means controlled by said ignition means for controlling said valve means to permit fuel to be supplied to said fuel outlet for ignition by said ignition sparks to establish a flame, flame sensing means including said electrode means operable when a flame is estblished to disable said enabling means for a first period whereby said oscillator means is disabled for said first period, said flame sensing means enabling said enabling means for a second period to thereby enable said oscillator means to generate further voltage pulses, and means enabled by said enabling means whenever said oscillator means fails to produce voltage pulses during said second period to enable said energizing means to control said valve means to interrupt the supply of fuel to said fuel outlet.

6. A fuel ignition system as set forth in claim **5** which includes means for supplying a DC energizing potential to said ignition circuit to permit said enabling means to normally extend a DC enabling signal to said oscillator means, said oscillator means being responsive to said DC enabling signal to produce AC voltage pulses in an output circuit thereof, first means for coupling said voltage pulses to said electrode means to effect the generation of ignition sparks and second means for coupling said voltage pulses to said energizing means to permit energization of said valve means.

7. A fuel ignition system as set forth in claim **6** wherein said oscillator means comprises semiconductor means, said first means comprising a transformer means having a first winding connected to extend siad DC enabling signal to a control input of said semiconductor means, a second winding connected to said electrode means, and third winding connected in an output circuit of said semiconductor means to permit said voltage pulses to be coupled to said second winding.

8. A fuel ignition system as set forth in claim **5** wherein said flame sensing means includes switching means operable when enabled to inhibit said enabling means and timing means operable whenever a flame is established to enable said switching means for said first duration and to disable said switching means for said second duration.

9. A fuel ignition system as set forth in claim **8** wherein said timing means includes capacitor means, first circuit means including said electrode means for permitting said capacitor means to charge over a first circuit path whenever a flame is established, and second circuit means including said switching means and said electrode means for permitting said capacitor means to discharge over a second circuit path to thereby operate said switching means, the discharge time of said capacitor means being greater than the charge time of said capacitor means whereby the first duration for which the oscillator means is inhibited is gerater than the second duration for which said oscillator means is enabled.

10. A fuel ignition system as set forth in claim **6** wherein said energizing means includes control means having first switching means responsive to said voltage pulses to provide further pulses for energizing a control winding of said valve means for operating said valve means to supply fuel to said fuel outlet for ignition by said ignition sparks, and sampling means having second switching means and timing means responsive to said further pulses to energize a further control winding of said valve means to maintain said valve means operated when a flame is established.

11. In a fuel ignition system including normally unoperated first valve means and normally operated second valve means connected in series between a fuel source and a fuel outlet, an ignition circuit for controlling the operation of said first and second valve means to supply fuel to said fuel outlet and for igniting fuel discharged by said fuel outlet, said ignition circuit comprising ignition means including first means operable when enabled to generate ignition sparks in the proximity of said fuel outlet for igniting fuel discharged by said fuel outlet to establish a flame, and second means for enabling said first means, energizing means controlled by said first means for effecting the operation of said first valve means, and sensing means operable whenever a flame is established to control said second means to disable said first means for a first period to thereby inhibit the generation of ignition sparks and to enable said first means for a second period to permit the generation of further ignition sparks, said ignition means including third means enabled by said second means whenever said first means fails to be enabled during said second period to effect deactivation of said second valve means to interrupt the supply of fuel to said fuel outlet.

12. A fuel ignition system as set forth in claim **11** which includes indicator means controlled by said energizing means to provide an indication each time a spark is generated.

13. A fuel ignition system as set forth in claim **11** wherein said energizing means includes control means having first switching means enabled by said first means to energize a pickup winding of said first valve means to operate said first valve means to supply fuel to said fuel outlet for ignition by said ignition sparks, and sampling means including second switching means enabled by said first switching means to energize a hold winding of said first valve means to maintain said first valve means operated when a flame is established.

14. A fuel ignition system as set forth in claim **11** wherein said energizing means includes control means having first switching means, said first means including means for generating control pulses to enable said first switching means to provide current pulses for effecting operation of said first valve means, said first switching means being disabled during said first period when the flame is established, and sampling means including second switching means and timing means responsive to said current pulses to provide a potential for enabling said second switching means to maintain said valve means operated during said first period.

15. A fuel ignition system as set forth in claim **14** which includes third switching means energized by said first switching means to deactivate said second valve means whenever a flame fails to be established after a predetermined number of control pulses have been supplied to said first switching means by said first means.

16. A fuel ignition system as set forth in claim **15** which includes indicator means energized by each current pulse provided by said first switching means.

17. A fuel ignition system as set forth in claim **16** wherein said third means is enabled by said second means to continuously energize said second switching means whenever said first means fails to produce said control pulses during said second period to thereby effect continuous energization of said indicator means.

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