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COMBUSTION CONTROL APPARATUS

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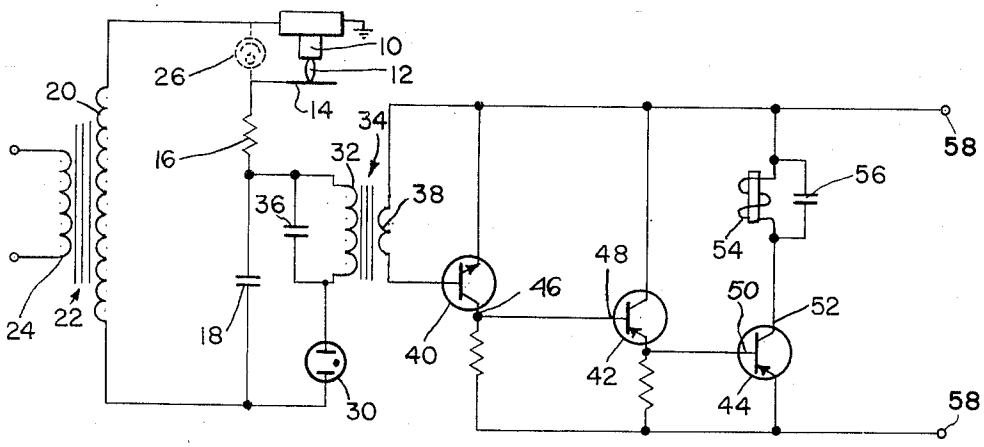


FIG. 1

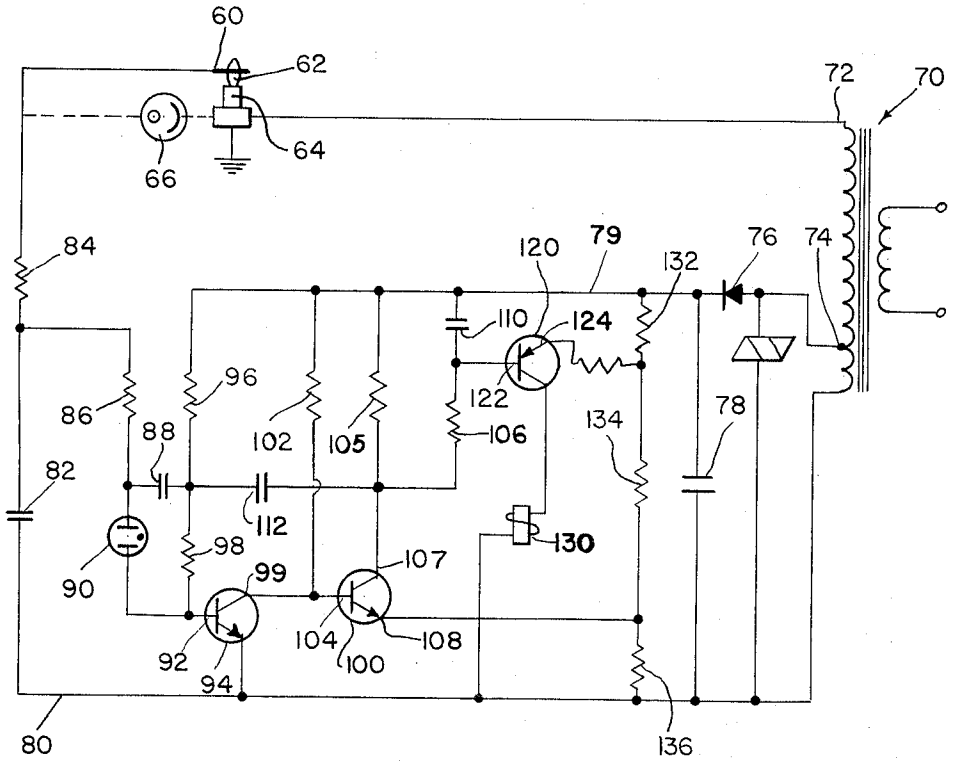


FIG. 2

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COMBUSTION CONTROL APPARATUS

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This invention relates to combustion supervision circuitry and more particularly to circuitry employing flame sensors having rectifying properties.

Certain types of flame detection devices use the rectifying property of the flame to detect its presence. The so-called flame rod is a device which makes use of this property. A related type of detector is the photocell which also has rectifying properties. In either case in the presence of a flame a small rectified current is produced which conventionally is used to charge a capacitor, which charge is sensed and indicates the presence of flame. Due to the small magnitude of the charge that can be generated by flame sensors of this type for storage by capacitors, it has been necessary to use a detection device of high input impedance so that the detection device will draw no more charge from the capacitor than can be supplied by the rectification type of flame sensor and coupled circuitry. The control electrode of a vacuum tube previously has been the only practical device employed to detect this charge on the capacitor. However, since vacuum tubes have a relatively short operating life, compared to solid state components, it is highly desirable to develop apparatus for detecting the small currents provided by the flame rectification type of flame sensors suitable for use in combination with such components.

Accordingly, it is an object of this invention to provide novel and improved circuitry which enables a flame sensor of the rectifying type to be employed with solid state component detection circuitry.

Another object of the invention is to provide novel and improved flame sensing circuitry embodying a flame sensor of the rectifying type and read out circuitry employing solid state components.

Another object of the invention is to provide novel and improved circuitry for coupling a high impedance flame sensing circuit into low input impedance detection and indicating circuitry.

In accordance with the invention a combustion supervising system including a flame sensor having rectifying properties is employed. This sensor may be a flame electrode which is disposed in the flame itself and as the flame conducts electrical current better in the direction toward ground than in the opposite direction, a rectified current is produced. Another suitable type of flame sensor is the photocell which has similar asymmetrically conductive characteristics in response to the sensing of radiation from a flame. A high voltage is applied to either of these type sensors and in response to the sensing of flame a rectified current is produced which is applied to a capacitor to build up a charge thereon indicative of the presence of flame. Connected across this capacitor is a discharge circuit including a voltage responsive device which operates to discharge the capacitor when a predetermined level of voltage is built up as a result of the charge storage operation. This discharge device in the preferred embodiment is a gas filled glow tube (one that contains neon gas, for example). The surge of current which results from the discharge of the capacitor is applied as a current pulse of substantial magnitude to a circuit of low input impedance, such as the control electrode of a transistor, which pulse is sufficient to actuate the transistor circuitry. As soon as the charge level on the capacitor drops below a predetermined level as a result of the discharge action, the high impedance condition of the voltage sensitive device is restored and the capacitor again commences to accumulate charge indicative of the presence of flame. Thus in the presence of flame the circuitry provides a series of relatively high current pulses of sufficient magnitude to actuate transitorized circuitry. Each pulse output signal is applied through electronic valve circuitry in an amplification operation to operate a flame relay, which operation indicates the presence of flame. The circuitry is designed so that in the presence of flame the flame relay will be held in continuously.

Thus the invention provides electronic circuitry employing low input impedance electronic valve components such as transistors for use with a flame sensor having rectifying properties which permits reliable indication of the presence of a flame.

Other objects, features and advantages of the invention will be seen as the following description of embodiments thereof progresses, in conjunction with the drawing, in which:

FIG. 1 is a schematic diagram of a first embodiment of combustion supervision circuitry; and

FIG. 2 is a schematic diagram of a second embodiment of combustion supervision circuitry.

The circuitry shown in FIG. 1 is arranged to supervise the gas flame **12** from a burner **10** disposed in a combustion chamber. An electrode **14** disposed in the flame **12** is connected in circuit with a resistance **16** and a capacitance **18** across the secondary winding **20** of a step up transformer **22** having a primary winding **24** to which a 115 volt A.C. signal is applied. One terminal of the transformer secondary is grounded as is the gas burner **10**, and the other terminal is at a voltage of about 300 volts so that a high voltage is applied to the flame electrode circuitry. (An alternative sensor in the form of a photocell **26** may be connected as indicated in circuit with resistance **16** and capacitance **18** across the transformer secondary **20** to sense the flame **12**.)

Due to the rectifying characteristics of these types of flame sensors a small D.C. current will flow in the sensor circuit when the sensor is exposed to flame and this current gradually charges the capacitor **18**. Connected across the capacitor is a discharge circuit which includes glow discharge tube **30** which operates when the charge level on capacitor **18** reaches a potential level corresponding to the breakdown voltage of the glow tube **30** to draw off a portion of the charge on capacitor **18** through the lowered impedance of the glow discharge device when that device is in ionized condition. The capacitor charge is reduced until its potential falls to the de-ionization potential of the glow tube at which point the glow tube returns to its high impedance state and the flow of current in the discharge circuit ceases.

Connected in the discharge circuit across capacitor **18** and in series with the glow discharge tube **30** is the primary winding **32** of a transformer **34**. Capacitor **36** is connected across the primary winding. This capacitor modifies the width of the current pulse as applied to primary winding **32** and also forms a damped oscillatory circuit with the inductance of the primary winding so that a series of pulses are derived from the original pulse. The several pulses produced as a result of the breakdown of the glow tube **30** are electromagnetically induced into the secondary winding **38** of transformer **34** and the resulting series of voltage pulses are applied to the transistor amplifier circuitry which is shown as having three stages. Transformer **34** has a step down turns ratio and thus provides a lower output impedance to better match the impedance of the first stage of the transistor amplifier circuitry. That first stage employs an NPN transistor which is connected in common emitter configuration and the amplified pulse is applied from the collector **46** of transistor **40** to the base **48** of the PNP transistor **42** of

the second stage. Transistor 42 is connected in emitter follower configuration and applies a pulse signal to the base 50 of the third stage PNP transistor 44 which in turn produces an inverted pulse at its collector 52. Connected in series with the collector circuit of transistor 44 is coil 54 of a relay which has contacts to control a circuit providing an indication of the flame condition in the supervised combustion area. Capacitor 56 serves to produce a slow release relay operation. The amplifier circuitry is supplied by a suitable D.C. source (in the order of 20 volts) connected across terminals 58.

A second embodiment of the invention is shown in FIG. 2. In that circuitry there is provided a similar arrangement of a flame electrode 60 disposed in the flame 62, fuel for which is supplied from fuel nozzle 64. Again as indicated by the dotted lines a photocell 66 may be employed in the circuit as an alternative flame sensing device. The flame electrode 60 is energized from the voltage step up transformer 70 which has a secondary winding 72, one terminal of which is grounded by connection to the nozzle 64; a high voltage terminal (300 volts) connected to line 80; and a center tap terminal 74 which provides a 21 volt signal that is rectified by diode 76 and smoothed by capacitor 78 to supply a D.C. supply voltage on line 79. Connected between the high voltage line 80 and the flame electrode 60 is a capacitor 82 and a resistance 84. A second resistance 86 has one terminal connected to the junction between capacitor 82 and resistor 84 and the other terminal is connected to a charge storage circuit including capacitor 88 and neon glow tube 90. The capacitor 88 and glow tube 90 are connected to a series network of resistors 96 and 98 connected between line 79 and the base 92 of transistor 94.

In operation, transistor 94 is normally in a conductive state as its base electrode 92 receives sufficient current through the resistors 96 and 98 to saturate its emitter-collector circuit. When the flame electrode 60 senses flame a small D.C. current component flows through resistor 84 and resistor 86 to charge capacitor 88. This current is of very small magnitude but is sufficient to gradually charge capacitor 88 to a negative voltage sufficient to cause the tube 90 to break down into an ionized state. When this occurs the resulting low impedance of tube 90 drops the voltage on base electrode 92 and permits capacitor 88 to discharge rapidly through the tube 90 and apply a current pulse to the base electrode 92 of transistor 94. This current pulse causes the transistor's emitter-collector circuit to be rendered nonconducting and produces a voltage transition at the collector electrode 99. As soon as capacitor 88 has discharged below a voltage equal to the ionization sustaining voltage required for conduction of neon tube 90, that tube will return to its high impedance condition so that capacitor 88 will start to be recharged by the rectified current supplied by the flame sensor.

In a preferred embodiment of this circuitry resistor 86 has a value of 5.6 megohms and is employed to control the charging rate of capacitor 88 so that a substantial number of half cycles of the rectified current from flame electrode 60 will be required to charge capacitor 88 to the tube breakdown voltage and the amount of charge received by capacitor 88 in the absence of flame, due to random pulses that might be caused by intermittent contact between the flame rod and ground for example, is minimized. However, the desirable series resistance value is so high that the distributed capacitance effect between the flame rod leads and ground would prevent any appreciable voltage from being applied to the flame rod 60. In order to overcome this condition capacitor 82 (of 0.5 microfarads) is employed in conjunction with resistor 84 (of 1.5 megohms) which serves to allow sufficiently rapid charging of the distributed capacitance. Thus resistors 84 and 86 together with capacitor 82 function in conjunction with capacitor 88 as a filter to allow a D.C. charge to accumulate on capacitor 88 while an A.C. signal is applied between the flame rod 60 and ground.

The circuitry including transistors 94 and 100 functions as a monostable multivibrator. As indicated above, in the stable state transistor 94 is in conducting condition, but when the gas tube 90 breaks down it is rapidly switched to nonconducting condition and as the collector 99 of transistor 94 is connected to the positive supply line 79 through resistor 102 the potential at the collector 99 and at the base 104 of transistor 100 rapidly rises.

As the potential of the base 104 of NPN transistor 100 rises that transistor turns on and is driven to saturation so that the potential of its collector 107 falls substantially to the potential of its emitter 108 and the resulting current flow charges capacitor 110. At the same time the potential transition from the collector 107 of transistor 100 is applied to capacitor 112 and imposes a bias through resistor 98 on the base 92 of transistor 94 which maintains that transistor in nonconducting condition. This nonconducting condition remains until capacitor 112 has discharged (principally through resistor 105) at which time the voltage on the base 92 has risen to the point that transistor 92 is again conducting. (The period of the multivibrator is selected to be a time interval less than that required to charge capacitor 88 to insure that gas tube 90 will not be ionized during the period of the output pulse of the multivibrator.)

Initially, with no voltage on capacitor 110 the base electrode 122 of transistor 120 is at a potential positive with respect to the emitter 124 due to the effect of the voltage divider network comprising resistor 132, resistor 134 and resistor 136. Immediately after the multivibrator is triggered, the voltage impressed on the base 122 through resistor 106 becomes negative with respect to the potential of emitter 124, causing that transistor to conduct. Capacitor 110 is also charged during the triggered period of the multivibrator and its charge is slowly dissipated, principally through resistors 105 and 106 during the interval that the multivibrator is in its stable state, thus extending the period that base 122 remains negative with respect to emitter 124. During the period that base 122 of transistor 120 is negative with respect to the emitter 124 that transistor conducts and energizes the flame relay 130 to provide an indication of the presence of flame as sensed by flame electrode 60. Capacitor 110 (which has a discharge path through resistors 105 and 106) is chosen to be large enough so that the flame must be absent for a predetermined period of several seconds before the relay is allowed to drop out.

In this arrangement there is provided a flame sensing combustion supervision circuit using a flame rectification type of sensor which produces an output pulse periodically, which output pulse in turn produces an intermediate signal of fixed amplitude and duration independent of the characteristics of the initial pulse. In this manner the energy requirements of the input pulse are minimal as all that is required is sufficient energy to trigger the multivibrator. The energy required for holding the flame relay in is supplied by the multivibrator circuitry. In addition, there is provided a storage circuit which enables the multivibrator to be reset in anticipation of the next input pulse without necessitating de-energization of the flame relay.

Thus it will be seen that the invention provides novel flame supervising circuitry employing a flame sensor having rectifying characteristics coupled to low input impedance control circuitry employing solid state components for providing an indication of the flame condition in the supervised area. While two embodiments of the invention have been shown and described, other modifications thereof will be obvious to those skilled in the art. For example, the transistor control circuit may be connected with reference to the emitter electrode rather than the collector electrode of the first transistor. The charge

storage capacitor is charged up towards the breakdown voltage of the voltage sensitive device and then upon breakdown is discharged through the device to turn on the transistor. Control devices such as silicon controlled rectifiers or switches may also be utilized to respond to the flame indicating signal. Therefore, it is not intended that the invention be limited to the disclosed embodiments or to details thereof and departures may be made therefrom within the spirit and scope of the invention as defined in the claims.

I claim:

1. In combination, a flame sensor having rectifiying properties,
- means for applying an energizing signal to said flame sensor,
- electric charge storage means connected in circuit with said flame sensor so that current flow produced by said sensor in response to the sensing of flame accumulates a charge on said storage means,
- an isolating circuit connected between said flame sensor and said charge storage means including a series resistance capacitance circuit to enable distributed capacitance in the sensor circuit to be charged relatively rapidly,
- a second resistance having a higher value than the resistance in said series circuit, said second resistance being connected in circuit between said charge storage means and said series circuit to provide an isolating effect of A.C. signals applied from said flame sensor on said charge storage means,
- a discharge circuit connected to said charge storage means including voltage sensitive means having first and second impedance states as a function of the voltage applied thereto,
- said voltage sensitive means being connected to said charge storage means to sense the accumulation of electric charge by said storage means,
- a low input impedance electronic valve,
- means to apply a signal to said electronic valve in response to the changing of said voltage sensitive means from said first impedance state to the second impedance state in response to the accumulation of charge on said storage means to actuate said electronic valve,
- and flame relay means connected in circuit with said electronic valve to provide an indication of the flame condition in the supervised area when said valve is actuated.

2. The combination as claimed in claim 1 wherein said electronic valve is a transistor having a control electrode and said voltage sensitive means is connected in series between said control electrode and one terminal of said charge storage means.

3. The combination as claimed in claim 1 and further including a resistance in series with said charge storage means for limiting the current flow to said charge storage means and providing a control on the charging rate thereof.

4. The combination as claimed in claim 1 wherein said voltage sensitive means is a gas filled glow tube having two spaced electrodes.

5. Apparatus for sensing flame in a supervised area comprising a flame sensor having rectifying properties,
- means to apply a high voltage to said flame sensor to energize said flame sensor circuit,
- a capacitor connected in circuit with said flame sensor responsive to a direct current flow produced by said flame sensor in response to the sensing of flame,
- a discharge circuit connected across said capacitor including a voltage responsive device having a high impedance condition when subjected to voltages below a predetermined value and a low impedance condition when subjected to voltages above said predetermined value,
- said voltage responsive device acting to produce a pulse of current when the charge on said capacitor is accumulated sufficiently to produce a potential above said predetermined level,
- a transformer having a step down voltage turns ratio with a primary winding connected in series with said voltage responsive means and said charge storage means, a capacitor connected across the primary winding of said transformer to provide a damped oscillatory circuit,
- an electronic valve having a low input impedance,
- means to couple said pulse of current to the input electrode of said electronic valve,
- and flame relay means coupled to said electronic valve for providing an indication of a flame condition in the supervised area in response to a series of current pulses produced upon repetitive operation of said voltage responsive device.

6. The apparatus as claimed in claim 5 wherein said voltage responsive means is a gas filled glow tube having two spaced electrodes.

7. The apparatus as claimed in claim 5 wherein said electronic valve is a transistor having a control electrode and said voltage responsive means is connected in series between said control electrode and one terminal of said charge storage means.

8. Apparatus for supervising flame comprising a flame sensor having rectifying properties,
- means to apply a high voltage to said flame sensor to energize said flame sensor,
- a capacitor connected in circuit with said flame sensor so that the current flow produced by said sensor on sensing of flame builds up a charge on said capacitor,
- a capacitor discharge circuit connected across said capacitor including a voltage sensitive gaseous discharge tube having an ionization level at which the discharge tube will break down into a relatively low impedance and a de-ionization level at a substantially lower potential at which the initial high impedance of the device will be restored,
- a transformer having a step down voltage turns ratio with a primary winding connected in series with said discharge tube and said capacitor, a second capacitor connected across the primary winding of said transformer to provide a damped oscillatory circuit,
- an electronic valve having a control electrode,
- means to couple the current pulse produced on the breakdown of said discharge device to the control electrode of said valve,
- and flame relay means connected to said valve for providing an indication of a flame condition in the supervised area in response to the pulse signals produced on breakdown of said gaseous discharge tube.

9. The apparatus as claimed in claim 8 and further including a resistance in series with said capacitor for limiting the current flow to said capacitor providing a control on the charging rate thereof.

10. In combination, a flame sensor having rectifying properties,
- means for applying an energizing signal to said flame sensor,
- electric charge storage means connected in circuit with said flame sensor so that current flow produced by said sensor in response to the sensing of flame accumulates a charge on said storage means,
- a discharge circuit connected to said charge storage means including voltage sensitive means having first and second impedance states as a function of the voltage applied thereto,
- said voltage sensitive means being connected to said charge storage means to sense the accumulation of electric charge by said storage means,
- a transformer having a step down voltage turns ratio with a primary winding connected in series with said voltage sensitive means and said charge storage means, a capacitor connected across the primary

winding of said transformer to provide a damped oscillatory circuit,

a low input impedance electronic valve,

means to apply a signal to said electronic valve in response to the changing of said voltage sensitive means from said first impedance state to the second impedance state in response to the accumulation of charge on said storage means to actuate said electronic valve,

and flame relay means connected in circuit with said electronic valve to provide an indication of the flame condition in the supervised area when said valve is actuated.

11. Apparatus for sensing flame in a supervised area comprising a flame sensor having rectifying properties,

means to apply a high voltage to said flame sensor to energize said flame sensor circuit,

a capacitor connected in circuit with said flame sensor responsive to a direct current flow produced by said flame sensor in response to the sensing of flame,

an isolating circuit connected between said flame sensor and said charge storage means including a series resistance capacitance circuit to enable distributed capacitance in the sensor circuit to be charged relatively rapidly,

a second resistance having a higher value than the resistance in said series circuit,

said second resistance being connected in circuit between said charge storage means and said series circuit to provide an isolating effect of A.C. signals applied from said flame sensor on said charge storage means,

a discharge circuit connected across said capacitor including a voltage responsive device having a high impedance condition when subjected to voltages below a predetermined value and a low impedance condition when subjected to voltages above said predetermined value,

said voltage responsive device acting to produce a pulse of current when the charge on said capacitor is accumulated sufficiently to produce a potential above said predetermined level,

an electronic valve having a low input impedance,

means to couple said pulse of current to the input electrode of said electronic valve,

and flame relay means coupled to said electronic valve for providing an indication of a flame condition in the supervised area in response to a series of current pulses produced upon repetitive operation of said voltage responsive device.

12. Apparatus for supervising flame comprising a flame sensor having rectifying properties,

means to apply a high voltage to said flame sensor to energize said flame sensor,

a capacitor connected in circuit with said flame sensor so that the current flow produced by said sensor on sensing of flame builds up a charge on said capacitor,

an isolating circuit connected between said flame sensor and said capacitor including a series resistance capacitance circuit to enable distributed capacitance in the sensor circuit to be charged relatively rapidly,

and a second resistance having a higher value than the resistance in said series circuit,

said second resistance being connected in circuit between said capacitor and said series circuit to provide an isolating effect of A.C. signals applied from said flame sensor on said capacitor,

a capacitor discharge circuit connected across said capacitor including a voltage sensitive gaseous discharge tube having an ionization level at which the discharge tube will break down into a relatively low impedance and a de-ionization level at a substantially lower potential at which the initial high impedance of the device will be restored,

an electronic valve having a control electrode,

means to couple the current pulse produced on the breakdown of said discharge device to the control electrode of said valve,

and flame relay means connected to said valve for providing an indication of a flame condition in the supervised area in response to the pulse signals produced on breakdown of said gaseous discharge tube.

13. The apparatus as claimed in claim **12** wherein said electronic valve is a transistor having a control electrode and said discharge tube is connected in series between said control electrode and one terminal of said capacitor.

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