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FLAME DETECTION APPARATUS

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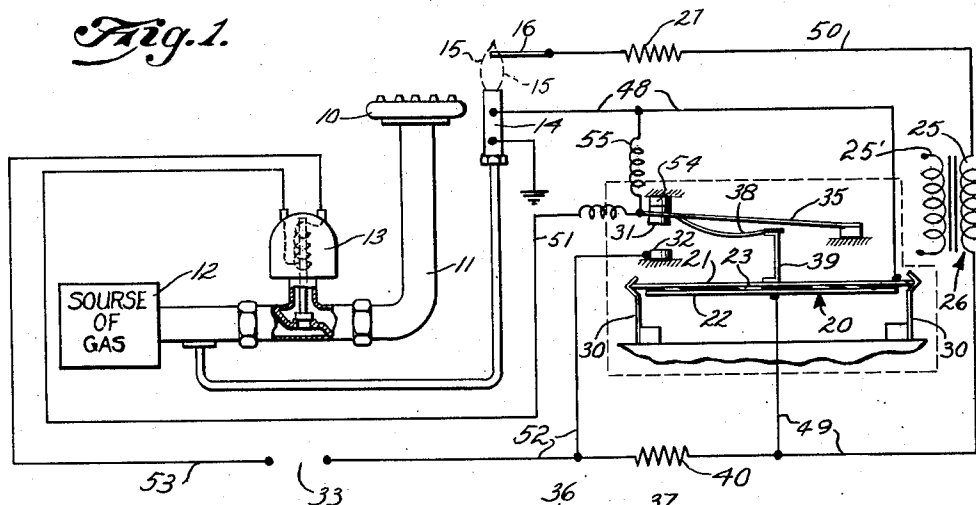
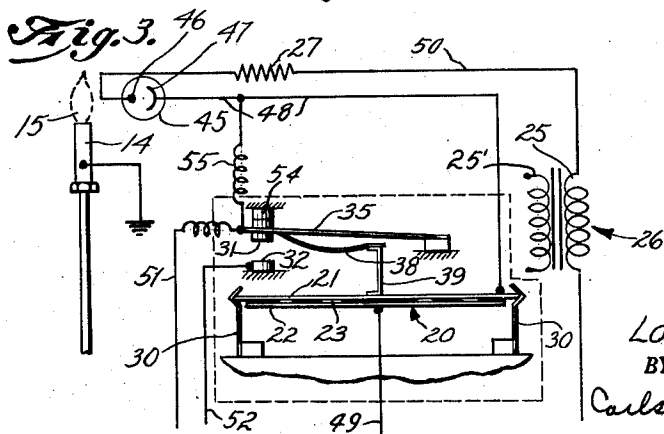
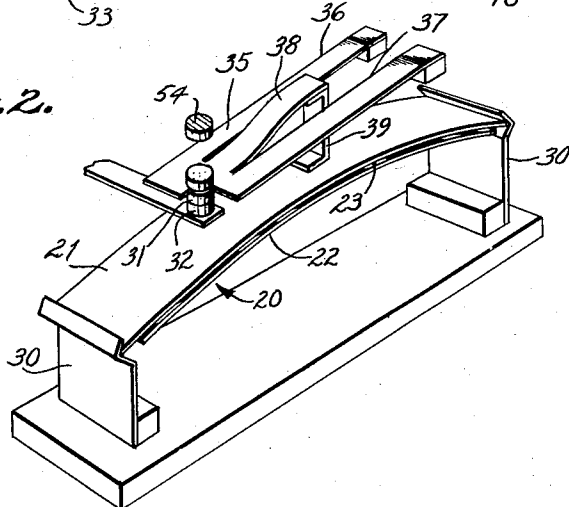


Fig. 2.



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FLAME DETECTION APPARATUS

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This invention relates generally to apparatus for detecting the presence of a flame and giving a signal such as actuation of a switch in response thereto. More particularly, the invention relates to flame detection apparatus of the rectifier type which responds to rectifying impedance between two electrodes contacting a flame or of a rectifying photoconductive cell exposed to the light of a flame and which distinguishes such impedance from a bilaterally conductive impedance. Heretofore, such apparatus has required complicated electronic circuits including electron tubes.

One object of the invention is to provide apparatus of the above character which completely avoids the use of electron tubes while still providing the safeguards obtainable with prior apparatus, which is of low cost, and which requires little maintenance.

Another object is to provide a novel relation of circuit elements which enables the apparatus to respond to small currents through the rectifying impedance while still operating quickly to signal the absence of the flame after the latter is extinguished.

Other objects and advantages of the invention will become apparent from the following detailed description taken in connection with the accompanying drawing in which

Figure 1 is a schematic wiring diagram of flame detection apparatus embodying the novel features of the present invention, shown during the "flame out" condition.

Fig. 2 is a schematic diagram similar to a part of Fig. 1 but showing the "flame on" condition.

Fig. 3 is a fragmentary schematic diagram of modified apparatus.

Turning now to the drawing, the invention will be described in connection with a gas burner 10, such as used in a gas furnace, gas hot water heater or the like. Such burner is supplied from a gas line 11 from a source 12, the flow being under the control of a solenoid valve 13 which preferably is arranged to permit the flow of gas when the solenoid is energized. Connected ahead of the solenoid is a pilot burner 14 having a normally lighted flame occupying a position 15 adjacent the burner 10. Positioned within the flame space is an electrode 16.

In accordance with the present invention, a novel flame detector circuit is provided, including a capacitor which is charged by the rectifying action of the flame 15 acting in conjunction with the flame electrode 16 and the pilot burner 14, the capacitor being so constructed and arranged as to deform in response to the charge and thereby turn off the flow of gas to the main burner when the pilot flame is extinguished. The capacitor indicated in the drawing at 20 has a main plate 21 and an auxiliary plate 22, the plates being separated by a layer of dielectric 23 having piezoelectric properties. For the dielectric 23, I prefer to use barium titanate which, in addition to being piezoelectric, has an extremely high dielectric constant so that the capacitor plates 21, 22 have

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a high capacity in relation to their size, a capacity which may be on the order of .015 of a microfarad.

In the present embodiment, a series detector circuit is employed, the capacitor plates 21, 22 being connected by conductors 48 and 49 respectively to the pilot burner 14 and to one terminal of a secondary winding 25 of a transformer 26 providing a source of alternating current when its primary winding 25' is connected to suitable alternating current supply lines (not shown). To complete the detector circuit, the flame electrode 16 is connected through a series resistor 27 and a conductor 50 to the other terminal of the secondary 25. The circuit thus extends in series from the flame electrode 16 to the flame 15 through the series resistor 27, the conductor 50, the secondary winding 25, the conductor 49, the capacitor 20, the conductor 48 and the pilot burner 14. The transformer secondary should be capable of producing approximately 500 volts r.m.s. The series resistor 27 may have a resistance on the order of one megohm to protect the transformer 26 and to limit the current through the capacitor 20 when the flame electrode 16 and the burner 14 are short-circuited.

In carrying out the invention, the main plate 21 of the capacitor 20 is formed of a relatively stiff plate of metal engaged at its ends in resilient brackets 30, exerting endwise pressure on the plate. The second or auxiliary plate 22 is preferably somewhat shorter, as shown, and more flexible so as to offer much less resistance to flexing or bowing. The preferred dielectric material, barium titanate, is a polycrystalline ceramic material which is per se known in the art and the use of which is discussed, for example, in an article entitled "Titanate Ceramics for Electromechanical Purposes" appearing in the February, 1950 issue of Industrial and Engineering Chemistry published by the American Chemical Society. When subjected to an electric field of proper polarity, polycrystalline barium titanate tends to expand physically in a direction parallel to the field and to contract strongly in all directions at right angles to the field. In the present device, the field between the plates 21, 22 resulting from the unidirectional charge built up thereon causes the capacitor to bodily bow or flex in the direction of the stronger plate 21 and it is such flexure which is utilized to control the flow of gas in the present device. The flexure of the capacitor 20, greatly exaggerated, is shown in Fig. 2.

In order to control the operation of the solenoid, the center portion of the capacitor 20 is coupled to a movable contact 31 which, together with a stationarily supported contact 32, forms a pair of normally open contacts that are arranged in series with the valve and with a source of valve operating voltage 33. For this series arrangement, the movable contact is connected by a flexible conductor 51 to one terminal of the valve, the fixed contact 32 is connected by a conductor 52 to one terminal of the source and the other terminals of the valve and the source are connected by a conductor 53. Interposed between the contacts and the plate 21 of the capacitor is a snap action mechanism including the snap action leaf spring 35 having a pair of supporting legs 36, 37 and a central or compression leg 38 which is engaged by a bracket 39 suitably secured to the plate 21. Thus, when the capacitor bows upwardly, as shown in Fig. 2, the central or compression leg 38 is raised above the level of the two supporting legs causing the movable contact 31 to snap downwardly against the contact 32. This completes the energizing circuit for the valve 13 and the valve stays open as long as the capacitor plates are bowed. When the plates straighten as shown in Figs. 1 and 3, the movable contact 31 is shifted over-center and against another stationary contact 54 spaced from the first contact 32.

To insure that the contacts 31 and 32 open promptly upon failure of the pilot flame 15, the capacitor plates 21, 22 are shunted by a shunt or leakage resistor 40 whenever the contacts are closed. The value of the resistor 40 is correlated with the capacitance between the plates 21, 22 to dissipate the charge on the latter quickly to the shutdown value when the charging circuit is interrupted while still delaying such dissipation for a definite time interval long enough to maintain the contacts 31 and 32 closed and to avoid a nuisance shutdown when the flame merely flickers but is not extinguished.

In carrying out the invention the leakage resistor 40 is not in the circuit when the contacts 31, 32 are open, i.e., under "flame off" conditions. This is accomplished by connecting the resistor 40 effectively in a series circuit including the capacitor 20 and the contacts 31, 32, although it will be apparent that contacts auxiliary to the contacts 31, 32 and operated as an incident to movement of the leaf spring 35 may be employed for this purpose. To provide this circuit, the resistor is connected at opposite ends to one capacitor plate 22 through the conductor 49 and to the first fixed contact 32 through the conductor 52. Also, the movable contact 31 is connected by another flexible conductor 55 and the conductor 48 to the other capacitor plate 21. When the contacts 31 and 32 are closed, the resistor is connected across the capacitor by the conductors 49, 52, 55 and 48. When the contacts are open, this circuit is interrupted.

Since the resistor 40 is effectively out of the circuit when the contacts 31 and 32 are open, all of the unidirectional current flowing from the electrode 16 is available to charge the capacitor 20. Accordingly, the sensitivity of the device is extremely high and sufficient bowing of the capacitor plate 21 takes place so as to positively throw the switch-operating mechanism over center when the pilot flame is turned "on." "Sensitivity" as used herein is the ratio of deflection of the capacitor 20 and the unidirectional current flow. Once the contacts 31, 32 have closed the resistor 40 is connected in parallel with the capacitor by the conductors 49, 52, 55 and 48 so that a portion of the current in the detector circuit through the flame 15 flows through the resistor and thus is no longer effective for charging purposes. Furthermore, during the "idle" half cycles of the current wave, the charge is partially leaked from the capacitor plates in the circuit through the parallel resistor. The net effect of this is to reduce the amount of bowing of the capacitor 20, causing the snap switch mechanism to be slightly retracted toward the point of changeover. Stated in other words, the effect of the leakage resistor 40, connected as shown, is to "condition" the switch to turn "off." Thus, while the sensitivity of the device is initially high so as to cause positive switching action when the flame is initially turned on, the sensitivity is substantially reduced after closure of the contacts 31, 32 to insure that the switch turns off quickly upon failure of the pilot flame. Using the present shunt resistor arrangement, it is possible to employ snap switch mechanisms of the type having a large mechanical differential and hence an extremely positive switching action while keeping the electrical differential within reasonable bounds. In a practical case, it was found that with a leakage resistor on the order of 40 megohms resistance, the closure of the contacts occurred at a capacitor voltage of 125 volts and opening of the contacts occurred at approximately 75 volts. Changing the value of the resistance provides a convenient way of adjusting the voltage to which the capacitor charges after closure of the contacts 31, 32, decreasing the value of the resistance serving to decrease that voltage and thus reduce the operating voltage differential.

In the operation of the apparatus, let it be assumed that no flame is present at the pilot burner 14 and that the capacitor 20 is discharged. Under these conditions,

the plates 21 and 22 are substantially straight in their relaxed shapes and the switch contacts 31 and 32 are open to interrupt both the energizing circuit for the fuel valve 13 and the leakage path through the resistor 40. Should a short circuit develop between the flame electrode 16 and the burner 14, the series resistor 27 limits the current flow to the plates to instantaneous values insufficient to produce bowing of the plates for closure of the contacts 31 and 32. The plates also fail to become charged to a value high enough to close the contacts 31 and 32 when any other bilaterally conductive impedance bridges the conductors connecting the flame electrode and the burner into the circuit, for example, distributed capacitance between the conductors.

As soon as a flame 15 appears at the burner 14 to provide a rectifying impedance, a larger current flows from the flame rod 16 to the burner 14 in the series detector circuit during alternate half cycles of the source 25 than flows in the opposite direction during the intervening half cycles. Such current impulses of greater magnitude are integrated by the capacitor 20 which thus becomes charged to apply a field to the dielectric body 23 causing the latter to deform and the main plate 21 to bow outwardly. The compression leg 38, moving with the main plate, shifts the movable contact 31 over-center and into engagement with the normally open fixed contact 32 when the charge on the plates reaches the higher valve energizing value. Closure of the contacts completes the energizing circuit for the fuel valve 13 through the conductors 51, 53 and 52 and the leakage path through the resistor 40 through the conductors 49, 52, 55 and 48.

Upon completion of the leakage path through the resistor 40, the charge on the plates 21 and 22 drops. However, by a proper selection of the value of this resistor, the charge remains higher than the shutdown value as long as the impedance between the flame electrode and burner conductors is rectifying. When the flame is extinguished and the capacitor charging circuit is opened, the charge on the plates is dissipated through the leakage resistor until the shutdown value is reached. As an incident to such dissipation, the dielectric body 23 tends to return to its original shape and the main plate 21 tends to straighten, the movable contact 31 shifting over-center at the shutdown value to open the contacts 31 and 32 and interrupt the leakage path and the energizing circuit for the fuel valve, thereby shutting off the fuel. Since the shutdown time interval is determined by the resistance-capacitance relation between the leakage resistor and the capacitor, this interval remains substantially constant. Upon interruption of the leakage path, the remainder of the charge on the plates is dissipated through the internal leakage resistance of the capacitor.

To summarize the operation, the capacitor 20 is charged when the flame 15 is present to complete the charging or detector circuit which extends from the flame electrode 16 through the resistor 27, the conductor 50, the transformer secondary 25, and the conductor 49 to the auxiliary plate 22 of the capacitor, from the main plate 21 of the capacitor to the burner 14 through the conductor 48, and from the burner through the flame 15 to the electrode 16. Such charging results in deformation of the dielectric body 23 and bowing of the capacitor plates for closure of the contacts 31, 32 to complete the energizing circuit for the valve 13 and, also, the shunt circuit through the leakage resistor 40. Upon completion of the energizing circuit which extends in series through the contacts 31, 32, the conductor 52, the source 33, the conductor 53, the valve 13 and the conductor 51, the valve opens to permit fuel to flow to the main burner 10. The shunt circuit extending from the fixed contact 32 through the conductor 52, the leakage resistor 40, and the conductor 49 to the auxiliary capacitor plate 22 and from the main plate 21 through

the conductors 48 and 55 to the movable contact 31 provides a leakage path through which the capacitor is discharged when the flame is extinguished and the charging circuit is interrupted. As an incident to such discharge, the dielectric body 23 and the capacitor plates resume their original shape in which the contacts 31 and 32 are open to interrupt both the leakage path through the resistor 40 and the valve energizing circuit thereby permitting the valve to close and shut off the fuel supply to the main burner 10.

It will be apparent that the novel apparatus described above responds only when a rectifying impedance bridges the flame electrode and burner conductors and fails to give a false indication of a flame 15 either when the conductors are bridged by a bilaterally conductive impedance or when an open circuit condition develops at any point in the circuit. The plates 21 and 22, in addition to applying a field to the dielectric body 23 for deforming the latter, also cooperate therewith to provide a capacitance for integrating the impulses of unidirectional current resulting from rectifying impedance. Since the leakage path through the resistor 40 is open during initial charging of the capacitor, the latter will become charged sufficiently to close the contacts 31 and 32 in response to small impulses of current resulting from a small rectifying ratio of the impedance to current flow from the burner 14 to the flame rod 16 to the impedance to current flow in the opposite direction. Since the dielectric constant of the preferred piezoelectric material, barium titanate, is extremely high as compared to conventional piezoelectric materials, the capacitance is high, for example, 0.015 mfd., and thus even a small D.-C. component is capable of building up a large charge on the plates and resulting in substantial deformation thereof. The apparatus may be constructed easily of few parts excluding vacuum tubes and therefore is inexpensive not only to manufacture, but also, to maintain in service use.

While the invention has been described in connection with a rectifying electrode 16 located within the flame, it will be apparent to one skilled in the art that the invention is not so limited but would include the use of other sensitive means for providing a unidirectional component of current under "flame on" conditions. Such means may include a photoconductive cell with rectifying properties, for example, a photoelectric vacuum tube 45 having an anode 46 and a cathode 47 with the anode 46 taking the place of the electrode 16. When a light impinges upon the cathode 47 electrons are given off from the cathode surface, thereby producing a limited current flow during alternate half cycles of the exciting alternating current wave and the capacitor 20 is thereby charged, in the presence of flame, just as outlined above.

While the invention has been described in connection with controlling flow of gas to a gas burner, it will be understood that it is not by any means limited thereto and may be used to control the flow of fuel to oil burners and other types of burners regardless of the fuel employed.

I claim as my invention:

1. In apparatus for detecting the presence of a flame at a burner in a combustion control system, the combination of, a body of dielectric material having the property of changing dimension when subjected to an electric field, a pair of plates of conducting material straddling said body to create an electric field therein and cooperating with the body to form a capacitor, means constructed to include the flame for producing a rectifying impedance when a flame is present at said burner, a source of alternating voltage connected in a circuit with said impedance means and said plates for building up a charge on the latter and deforming said body when a flame is present at said burner, a switch having a part connected to said body and actuated in

one sense by deformation of the body when said charge is higher than a first predetermined value and in the opposite sense by restoration of the body resulting from dissipation of the charge below a second predetermined value, and a normally open circuit shunting said capacitor and closed in response to actuation of said switch in said one sense, said shunting circuit including a resistor cooperating with said capacitor to reduce the discharge time of the latter after extinguishment of the flame and having a resistance high enough for the maintenance of said charge above said second value when the shunting circuit is closed and said impedance is rectifying.

2. In apparatus for detecting the presence of a flame at a burner in a combustion control system, the combination of, a body of dielectric material having the property of changing dimension when subjected to an electric field, a pair of plates of conducting material straddling said body to create an electric field therein and cooperating with the body to form a capacitor, means constructed to include the flame for producing a rectifying impedance when a flame is present at said burner, a source of alternating voltage connected in a circuit with said impedance means and said plates for building up a charge on the latter and deforming said body when a flame is present at said burner, a switch having a part connected to said body and actuated in one sense by deformation of the body when said charge is higher than a first predetermined value and in the opposite sense by restoration of the body resulting from dissipation of the charge below a second predetermined value, a resistance element connected in series with said source and limiting current flow to said capacitor to an instantaneous value insufficient to actuate said switch when said impedance means is short circuited, and a second resistance element connected in a shunt around said capacitor and cooperating therewith to determine the time interval required for dissipation of said charge to said second value after extinguishment of the flame and cessation of the rectifying action of said impedance.

3. In apparatus for detecting the presence of a flame at a burner in a combustion control system, the combination of, a body of dielectric material having the property of changing dimension when the material is subjected to an electric field, two plates of conducting material straddling said body to create an electric field through the body when a voltage is applied to the plates, said plates and said body cooperating to form a capacitor, means constructed to include the flame for producing an impedance which is rectifying when a flame is present at said burner, a source of alternating voltage connected in a circuit with said impedance means and said plates to provide a rectified current for building up a charge on said plates when a flame is present at said burner, a switch having a part connected to and movable with said body for actuation of the switch in response to the change in dimension of the body when the charge on said plates reaches a predetermined value, and a resistance element connected in said circuit in series with said source and limiting current flow to said capacitor to a safe value insufficient to produce actuation of said switch when said impedance means is short circuited.

4. In apparatus for detecting the presence of a flame at a burner in a combustion control system, the combination of, a body of dielectric material having the property of changing dimension when subjected to an electric field, two plates of conducting material straddling said body to create an electric field therein and cooperating with the body to form a capacitor, means constructed to include the flame for producing an impedance which is rectifying when a flame is present at said burner, a source of alternating voltage connected in a circuit with said impedance means and said plates for building up a charge on the latter to deform said body when a flame is present at said burner and said im-

pedance is rectifying, a switch having a part connected to said body for actuation of the switch in one sense by the deformation of the body when the charge on said plates is higher than a first predetermined value and for actuation of the switch in an opposite sense when said charge is below a second predetermined value, and a resistance element connected in a shunt around said plates and cooperating with said capacitor to control the time interval required for dissipation of said charge to said second predetermined value following extinguishment of said flame and cessation of the rectifying action of said impedance.

5. In a combustion control system including a burner, the combination of, a source of fuel for said burner, a body of dielectric material having the property of changing dimension when the material is subjected to an electric field, two spaced plates of conducting material sandwiching said body to create an electric field through the body when a voltage is applied to the plates, said plates and said body cooperating to form a capacitor, means including the flame for producing an impedance which acts as a rectifier when a flame is present at said burner,

a source of alternating voltage connected in a circuit with said rectifier and said plates to build up a direct charge on the latter for changing the dimension of said body when a flame is present and said impedance is rectifying, means including a leakage circuit and operable in response to a change of the dimension of said body to complete the circuit for reducing the sensitivity of the capacitor, and means for shutting off the flow of fuel when said body is substantially restored to its original dimension.

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