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2,737,643

FLAME DETECTION APPARATUS

Filed Oct. 2, 1952

2 Sheets-Sheet 1

Fig. 1.

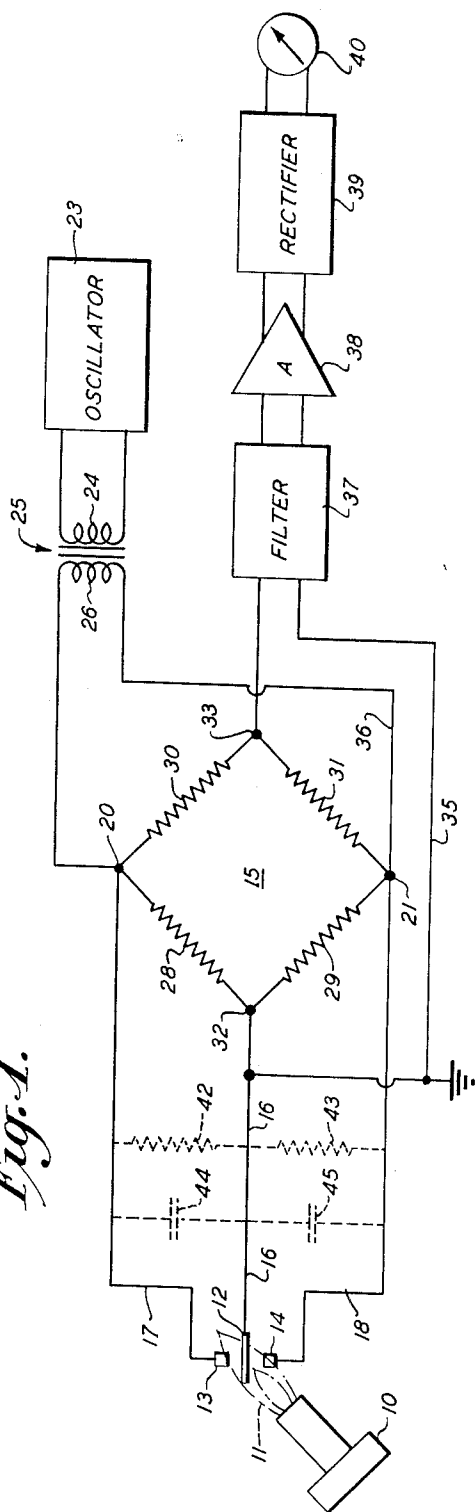
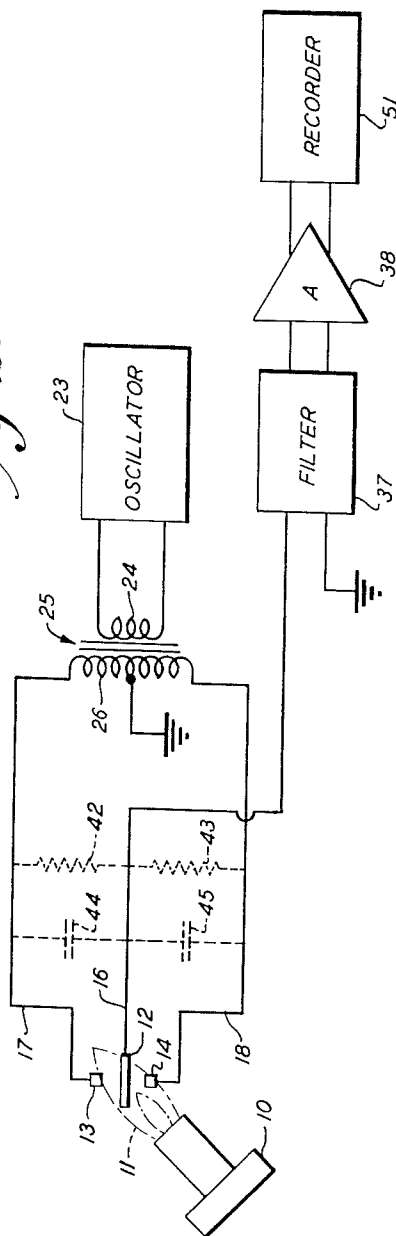


Fig. 2.



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2 Sheets-Sheet 2

Fig. 3.

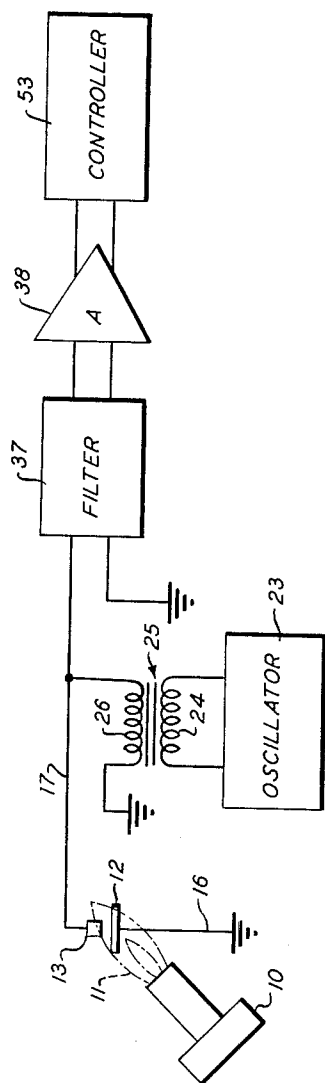
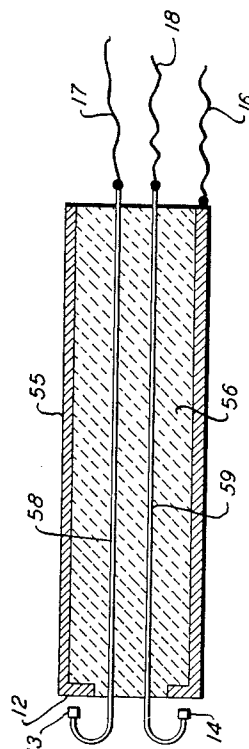


Fig. 4.



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FLAME DETECTION APPARATUS

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14 Claims. (Cl. 340—228)

This invention relates to flame detection. In another aspect it relates to apparatus for indicating the presence of flame. In still another aspect it relates to a probe element adapted to be disposed in the region of a flame to indicate the presence thereof.

In the operation of various types of furnaces and burners, it is essential that means be provided to detect the presence or absence of flame. For example, should a gas flame be extinguished for any reason, this condition must be detected immediately so that appropriate steps can be taken to reignite the burner or to shut off the fuel supply in order to prevent an accumulation of unburned gases which may become ignited at a later time to cause an explosion. Various forms of flame detection apparatus are of course known in the art which respond in one manner when flame is present and in another manner when flame is absent or in the event that the flame detecting apparatus is not functioning properly. For the most part the operation of such flame detection apparatus is based upon the known fact that a flame and the ionized atmosphere immediately surrounding a flame are to a certain extent electrically conductive.

In accordance with the present invention, an improved flame detector is provided which is based upon the known property of a flame to conduct electricity and also upon the rectifying action of a flame disposed in the region between a pair of opposing electrodes of unequal size. It has been discovered that if an alternating potential is applied across a pair of spaced electrodes of unequal size which are disposed in the region of a flame, the action of the flame path between the electrodes is such as to provide a rectified signal which contains frequencies of the second harmonic of the applied voltage. By disposing a pair of such flame paths in a bridge circuit, a device equivalent to a full wave rectifier is established to provide an output signal which consists predominantly of second harmonic voltages. Through the use of an appropriate electrical filter this output signal is restricted to frequencies of the second harmonic of the applied voltage so as to minimize the extraneous signals which may be introduced by stray capacitance and leakage resistance.

Accordingly, it is an object of this invention to provide an improved flame detector which is based upon the electrical conducting and rectifying properties of a flame.

Another object is to provide a probe adapted to be disposed in the region of a flame whereby the rectifying properties of the flame are employed to generate electrical signals representative of the presence of flame in the region of the probe.

A further object is to provide flame detecting apparatus which is reliable in operation, economical to manufacture and which employs a minimum number of electrical components.

Various other objects, advantages and features of this invention should become apparent from the following detailed description taken in conjunction with the accompanying drawing in which:

2

Figure 1 is a schematic circuit drawing of a first embodiment of this invention;

Figure 2 is a schematic circuit drawing of a second embodiment of this invention;

Figure 3 is a schematic circuit drawing of a third embodiment of this invention; and

Figure 4 is a cross-sectional view of a probe element adapted to be disposed in the region of the flame being detected.

Referring now to Figure 1, the numeral 10 designates a burner having a flame 11 emitting therefrom. Disposed within the region of flame 11 is an electrode structure comprising a center electrode 12 and having a pair of smaller electrodes 13 and 14 disposed symmetrically on opposite sides thereof. Electrodes 12, 13, and 14 are connected to a bridge network 15 by respective electrical leads 16, 17, and 18, the latter two of which are connected to respective opposite terminals 20 and 21 of bridge 15. The bridge network is energized from a suitable source of alternating potential such as an oscillator 23 having its two output terminals connected to the primary winding 24 of a transformer 25. The end terminals of the secondary winding 26 of transformer 25 are connected to respective terminals 20 and 21 of bridge 15. A first pair of impedance elements 28 and 29 are connected in series between terminals 20 and 21 and a second pair of impedance elements 30 and 31 are likewise connected in series between terminals 20 and 21 in parallel with elements 28 and 29. The junction between elements 28 and 29 is designated by numeral 32 and the junction between impedances 30 and 31 is designated by numeral 33. Electrical lead 16 is connected directly to terminal 32 and to a point of reference potential such as ground. Terminals 32 and 33 of bridge 15 are connected by respective leads 35 and 36 to the input terminals of a filter network 37 which is tuned to pass only signals of frequency twice the frequency of the signals generated by oscillator 23. The output terminals of filter 37 are connected directly to the input terminals of an amplifier 38; the output terminals of amplifier 38 are connected to the input terminals of a rectifier 39; and the output terminals of rectifier 39 are connected to a direct current meter 40. Electrical leakage paths between leads 17, 18 and between leads 18, 16 are represented by the respective resistors 42 and 43. Electrical capacitance between leads 17 and 16 is represented by a capacitor 44 and electrical capacitance between leads 18 and 16 is represented by a capacitor 45.

In Figure 2 there is illustrated a circuit somewhat similar to the one shown in Figure 1 wherein corresponding parts are designated by like reference numerals. In the circuit of Figure 2 the secondary winding 26 of transformer 25 is provided with a center tap which is maintained at ground potential. The end terminals of winding 26 are connected directly to electrodes 13 and 14 by respective leads 17 and 18. Thus an electrical bridge circuit is defined by the impedances represented by the air gap between electrodes 12, 13, the air gap between electrodes 12, 14, and the two half portions of secondary winding 26 of transformer 25. Lead 16 connects electrode 12 to one input terminal of filter 37, the second input terminal of input 37 being maintained at ground potential. In the particular embodiment illustrated in Figure 2, the output signal from amplifier 38 is applied to a suitable recording instrument 51.

A third embodiment of this invention is illustrated in Figure 3. The electrode structure positioned within flame 11 comprises only a single pair of electrodes 12 and 13. Electrode 12 is maintained at ground potential and electrode 13 is connected to one end terminal of the secondary winding 26 of transformer 25 and to one input

terminal of filter 37. The second end terminal of winding 26 and the second input terminal of filter 37 are maintained at ground potential. The output signal from amplifier 38 is connected to a controller 53 which can comprise a circuit actuated by a relay, the winding of which is energized by the output of amplifier 38. A second form of controller 53 can be a commercial pneumatic-operated instrument wherein the electrical signal regulates an output air pressure.

In Figure 4 there is illustrated a probe element which includes electrodes 12, 13 and 14. This probe comprises a hollow tubular metallic casing 55 having the interior thereof filled with an insulating material 56. A pair of spaced electrical conductors 58 and 59 are disposed longitudinally within insulating material 56. One end of casing 55 preferably is bent inward to form a cylindrical ring which corresponds to electrode 12 illustrated in Figures 1, 2 and 3. The ends of conductors 58 and 59 are bent such that the tips thereof are disposed adjacent ring electrode 12 to form respective electrodes 13 and 14. Electrical lead 16 is connected to casing 55 and leads 17 and 18 are connected to respective conductors 58 and 59. Casing 55 preferably is formed of a material that is non-corrosive in order that it may be disposed for prolonged periods of time to the region of a flame. Suitable materials for such construction include stainless steel, nickel and Inconel. Insulating body 56 preferably is formed of a ceramic refractory material such as aluminum oxide, magnesium oxide or mullite. It should be apparent, however, that these materials are only illustrative of the types of materials which preferably are employed for the construction of the electrode assembly.

The operation of this invention is based upon the fact that a current rectifying action is obtained between the spaced electrodes disposed in the region of flame 11. It should be evident that whenever flame 11 bridges the gap between electrodes 12 and 13 and the gap between electrodes 12 and 14, electrical circuits are completed between these various electrodes, and it further should be evident that the conductivity of these two paths is greater in one direction than in the other. The rectifying action of a flame is partly dependent upon the fact that the chemical action of combustion results in the ionization of some of the molecules of gas in the flame. It is the pressure of these electrically charged particles that enables the flame to conduct a current between a pair of electrodes which may be in contact therewith. It is of course understood that when a gas is ionized both negative ions and positive ions are formed. The negative ions comprise free electrons while the positive ions are molecules positively charged by the loss of electrons. Whenever a potential difference is applied across a pair of electrodes having an ionized gas therebetween, there is a migration of these charge particles in opposite directions which results in a current flow between the two electrodes.

The second fact which contributes to the rectification produced between a pair of electrodes having unequal size is that current flows more readily in one direction than in the other. It should be remembered that the positive ions are much heavier than the free electrons and as such require considerably larger potential differences to provide equal migration. Thus, when an alternating potential is applied across two electrodes, the free electrons therebetween migrate considerably farther during each half cycle of the applied voltage than do the corresponding positive ions. If the surface areas of the two facing electrodes are unequal, it should be apparent that considerably more free electrons are attracted to the larger electrode during the half cycles of applied potential when the larger electrode is positive than are positive ions attracted to the same electrode during the following half cycle when a negative potential is applied thereto. The same thing happens at the opposing smaller electrode. Therefore, the flow of current in one direction

in the external circuit is substantially greater than in the other direction. This results in a rectifying action by the flame.

Referring again to Figure 1 it can be seen that bridge 15 forms a Wheatstone bridge circuit which normally is in electrical balance in the absence of a flame being applied in the region of electrodes 12, 13 and 14. This balance is accomplished by having impedances 28 and 30 equal to one another and by having impedances 29 and 31 equal to one another. Satisfactory results can be obtained with impedances 28, 29, 30 and 31 being resistors of from approximately 100,000 ohms to 10 megohms, by way of illustration. Under this condition there obviously is no current applied to filter 37. However, the application of a flame 11 in the region of electrodes 12, 13, and 14 creates a pair of rectifiers between respective pairs of electrodes 12, 13 and 12, 14. This produces an electrical unbalance in the bridge circuit during alternate half cycles of applied voltage, which unbalance signal is applied by leads 35 and 36 to the input of filter 37. Because of the rectifying action this unbalance signal contains a large proportion of second harmonic frequencies which are passed by filter 37. Because of the symmetrical bridge arrangement, leakage resistance and capacitance between the various leads 16, 17 and 18 are effectively minimized. In addition, any signal resulting from such resistance and capacitance is blocked by filter 37. Thus the only signal indicated by meter 40 is one created by the presence of flame in the region of the electrode structure.

The operation of the bridge circuit illustrated in Figure 2 is essentially the same as that of the circuit shown in Figure 1. The presence of flame between the spaced electrodes results in unequal current flows through the two air gaps, which in turn results in a second harmonic signal being applied through filter 37. The circuit shown in Figure 3 is one in which an alternating voltage is applied directly across a single pair of electrodes of unequal facing surface area. This also results in a certain amount of second harmonic frequencies being produced and transmitted through filter 37.

From the foregoing description it can be seen that there is provided in accordance with this invention a simplified form of flame detection apparatus which is based upon the rectifying properties of a flame. By measuring the second harmonic signal which is generated by the action of a flame a reliable indication of the flame is provided. Leakage resistance and stray capacitance are balanced out and eliminated from the indicating circuit. Current indicating meter 40, recorder 51 and controller 53 are illustrated in schematic form because it should readily be apparent to those skilled in the art that various forms of known indicating, recording and control apparatus can be associated with the output signal from the flame detector.

While this invention has been described in conjunction with present preferred embodiments thereof, it is to be understood that various modifications can be made without departing from the scope of the invention.

What is claimed is:

1. Flame detecting apparatus comprising, in combination, an electrical circuit adapted to function as a rectifier when bridged by a flame, a source of alternating electrical energy of first frequency applied across said circuit, and current indicating means connected across said circuit, said current indicating means including a filter tuned to pass signals of frequency twice the frequency of said source of alternating electrical energy and to block signals of the frequency of said source of alternating electrical energy.
2. The combination in accordance with claim 1 wherein said electrical circuit includes a pair of spaced electrodes adapted to be disposed in the region of a flame.
3. The combination in accordance with claim 2 where-

in said spaced electrodes are of unequal facing cross-sectional area.

4. Flame detecting apparatus comprising, in combination, a first electrode, a pair of second electrodes each spaced from said first electrode in symmetrical relationship, said first and second electrodes being adapted for insertion in a flame whereby the gaps between said first electrode and said pair of second electrodes are bridged by said flame, a source of alternating electrical energy of first frequency applied across said pair of second electrodes, and current indicating means connected between said first electrode and a point of reference potential, said current indicating means including a filter tuned to pass signals of frequency twice the frequency of said source of alternating electrical energy and to block signals of the frequency of said source of alternating electrical energy.

5. The combination in accordance with claim 4 wherein said first electrode is of larger cross-sectional area than said pair of second electrodes.

6. Flame detecting apparatus comprising, in combination, a balanced electrical bridge circuit, a source of alternating electrical energy of first frequency applied across opposite terminals of said bridge circuit, a first electrode, a pair of second electrodes each spaced from said first electrode in symmetrical relationship, said first and second electrodes being adapted for insertion in a flame whereby the gaps between said first electrode and said pair of second electrodes are bridged by said flame, said second electrodes being connected across said bridge circuit whereby an alternating potential is applied therebetween, said first electrode being connected to a point of first potential on a first arm of said bridge circuit, and current indicating means connected between said point of first potential and a point of corresponding potential on a second arm of said bridge circuit, said current indicating means including a filter tuned to pass signals of frequency twice the frequency of said source of alternating electrical energy and to block signals of the frequency of said source of alternating electrical energy.

7. Flame detecting apparatus comprising, in combination, an electrically balanced Wheatstone bridge network, a source of alternating electrical energy of first frequency applied across first and second opposite terminals of said bridge, a first electrode, a pair of second electrodes each spaced from said first electrode in symmetrical relationship, said first and second electrodes being adapted for insertion in a flame whereby the gaps between said first electrode and said pair of second electrodes are bridged by said flame, said second electrodes being connected to respective said first and second terminals, said first electrode being connected to a third terminal of said bridge, and current indicating means connected between said third terminal and the fourth terminal of said bridge opposite said third terminal, said current indicating means including a filter tuned to pass signals of frequency twice the frequency of said source of alternating electrical energy and to block signals of the frequency of said source of alternating electrical energy.

8. The combination in accordance with claim 7 wherein said first electrode is of larger cross-sectional area than said pair of second electrodes.

9. A flame detecting element comprising a casing of electrically conductive material, a quantity of electrical insulating material disposed within said casing, and a pair of electrical conductors disposed within said casing in spaced relationship with one another and with said casing, said conductors protruding from said casing to form a pair of air gaps between said casing and said respective conductors whereby said air gaps are bridged by flame present in the region of said element.

10. A flame detecting element comprising a first electrode, and a pair of second electrodes each spaced from said first electrode in symmetrical relationship so as to be electrically insulated from one another and from said

first electrode, said first electrode being of different cross-sectional area than said pair of facing second electrodes, said first and second electrodes being constructed of electrical conductive flame resistant material, said first and second electrodes being adapted for insertion in a flame whereby the gaps between said first electrode and said pair of second electrodes are bridged by said flame.

11. Flame detecting apparatus comprising, in combination, a casing of electrically conductive material, a quantity of electrical insulating material disposed within said casing, a pair of electrical conductors disposed within said casing in spaced relationship with one another and with said casing, said conductors protruding from said casing to form a pair of air gaps between said casing and said respective conductors whereby said air gaps are bridged by flame present in the region of said element, a source of alternating potential of first frequency applied across said pair of conductors, and current indicating means connected between said casing and a point of reference potential, said current indicating means including a filter tuned to pass signals of frequency twice the frequency of said source of alternating potential and to block signals of the frequency of said source of alternating potential.

12. Flame detecting apparatus comprising, in combination, a tubular casing of electrically conductive material, a quantity of electrical insulating material disposed within said casing, a pair of electrical conductors disposed within said casing in spaced relationship with one another and with said casing, said conductors protruding from said casing to form a pair of air gaps between said casing and said respective conductors whereby said air gaps are bridged by flame present in the region of said element, an electrically balanced Wheatstone bridge network, a source of alternating potential of first frequency applied across first and second opposite terminals of said bridge, said conductors being connected to respective said first and second terminals, said casing being connected to a third terminal of said bridge, and current indicating means connected between said third terminal and the fourth terminal of said bridge opposite said third terminal, said current indicating means including a filter tuned to pass signals of frequency twice the frequency of said source of alternating potential and to block signals of the frequency of said source of alternating potential.

13. Flame detecting apparatus comprising, in combination, an electrical circuit adapted to conduct current in a non-linear manner when bridged by a flame, a source of alternating electrical energy of first frequency applied across said circuit, and current indicating means connected across said circuit, said current indicating means including filter means to pass signals of a frequency which is a harmonic of the frequency of said source of alternating electrical energy and to block signals to the frequency of said source of alternating electrical energy.

14. A flame detecting element comprising a tubular casing of electrically conductive material closed at one end except for an opening of cross-sectional area less than the inner cross-sectional area of said casing, a mass of electrically insulating material positioned within said casing, and a pair of electrical conductors extending through said mass of insulating material in spaced relationship with one another and said casing so as to be electrically insulated from one another and from said casing, the first ends of said conductors extending through said opening to positions in spaced relationship with said casing adjacent said one end.

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