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Horn

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[54] **INFRARED DYNAMIC FLAME DETECTOR**

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Related U.S. Application Data

[62] Division of Ser. No. 425,039, Dec. 14, 1973, abandoned.

[52] **U.S. Cl.** **431/79**; 250/338

[51] **Int. Cl.** **F23n 5/08**

[58] **Field of Search** 431/79; 250/338

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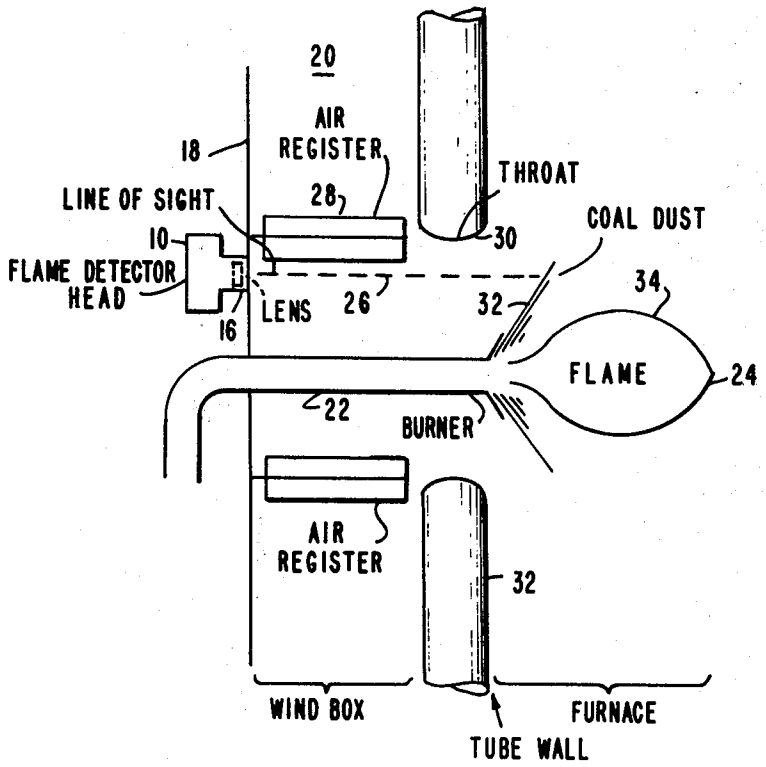
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[57] **ABSTRACT**

A compact signal transmitter head infrared flame detector unit is mounted in a small opening in the wall of a fossil fuel fired furnace. The unit includes a preamplifier solid state circuit including an infrared sensor which is focused on the combustion zone of the furnace for sensing and transforming flame fluctuations into corresponding preamplified signal current fluctuations, which are conducted by a shielded cable to a transistorized main amplifier filter and rectifier circuit in a remote signal receiver terminal unit. The unit has the capability of distinguishing from the fluctuations inherent in the flame from the background radiation. An integrated control circuit is associated with the main amplifier circuit for digitally processing the signal fluctuations and automatically operating flame indicators and/or alarms as required by the condition of the flame combustion zone.

12 Claims, 6 Drawing Figures



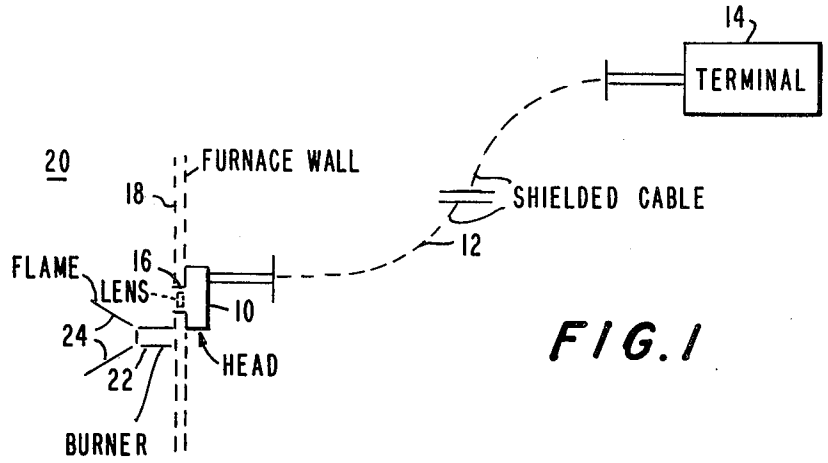


FIG. 1

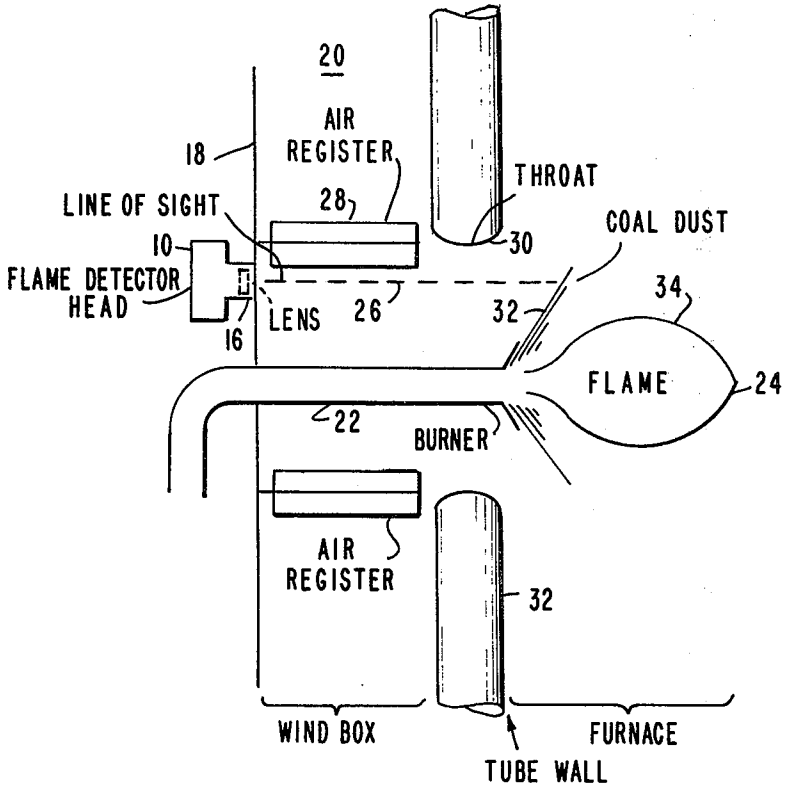


FIG. 2

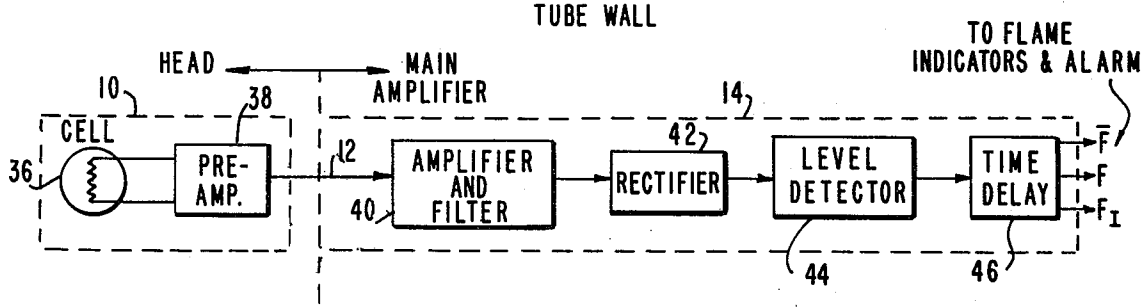


FIG. 3

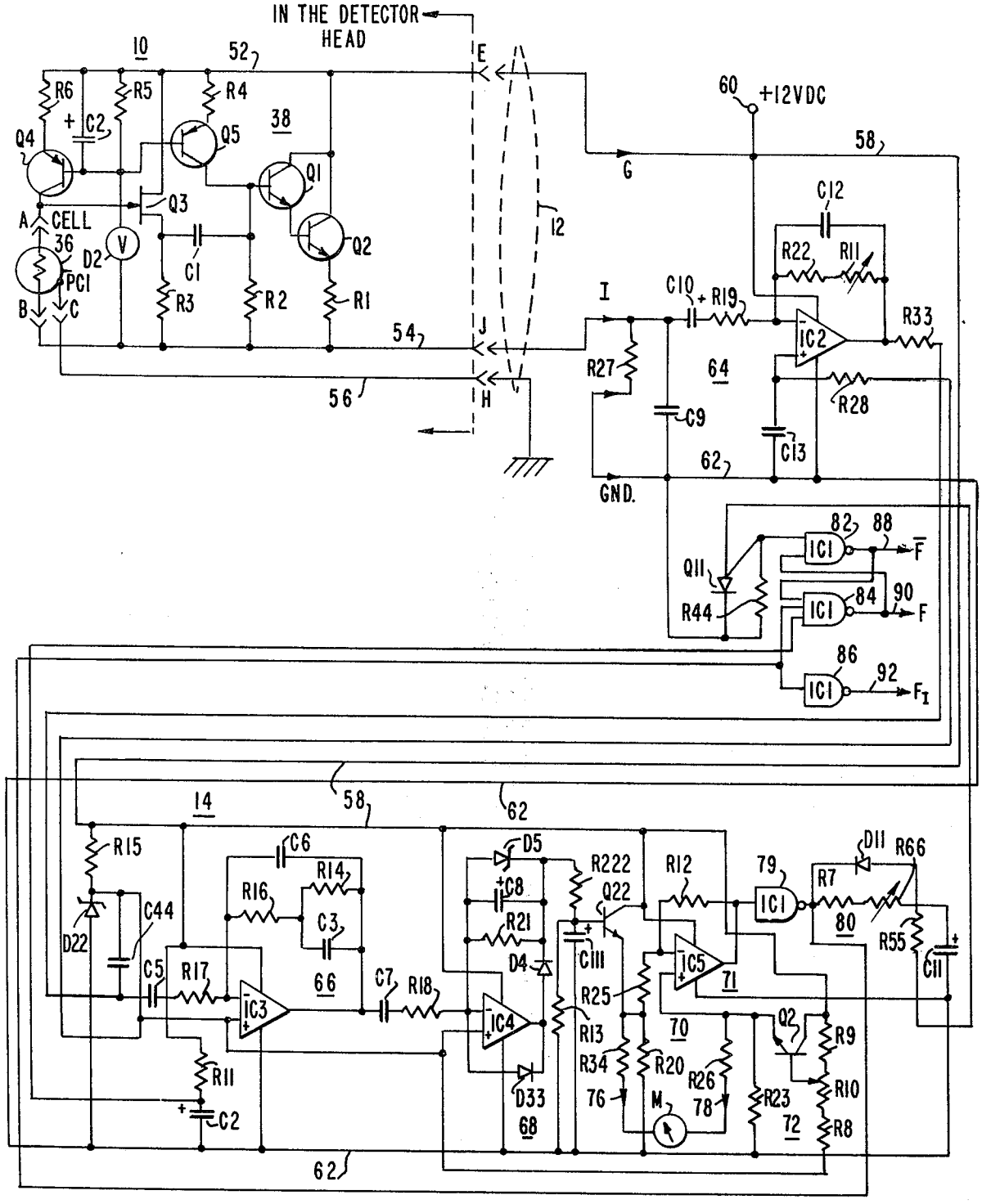

IN THE DETECTOR HEAD
10
52
E
60
+12VDC
58
R6
R5
R4
C2
38
Q4
Q5
Q1
Q3
Q2
A
CELL
36
D2
V
PCI
B
C
C1
R3
R2
R1
12
G
C12
R22
R11
I
C10
R19
IC2
R33
54
J
R27
64
R28
C9
C13
56
H
62
GND.
82
88
IC1
F
Q11
R44
84
90
86
92
F_I
14
58
62
R15
C6
R14
R16
C3
D22
C44
C5
R17
IC3
66
C7
R18
IC4
D5
C8
R21
D4
D33
68
R222
Q22
C111
R25
R13
R34
76
R20
M
R26
78
IC5
71
70
R12
79
IC1
D11
R66
R7
80
R55
C11
Q2
R9
R10
R8
R23
72

FIG. 4

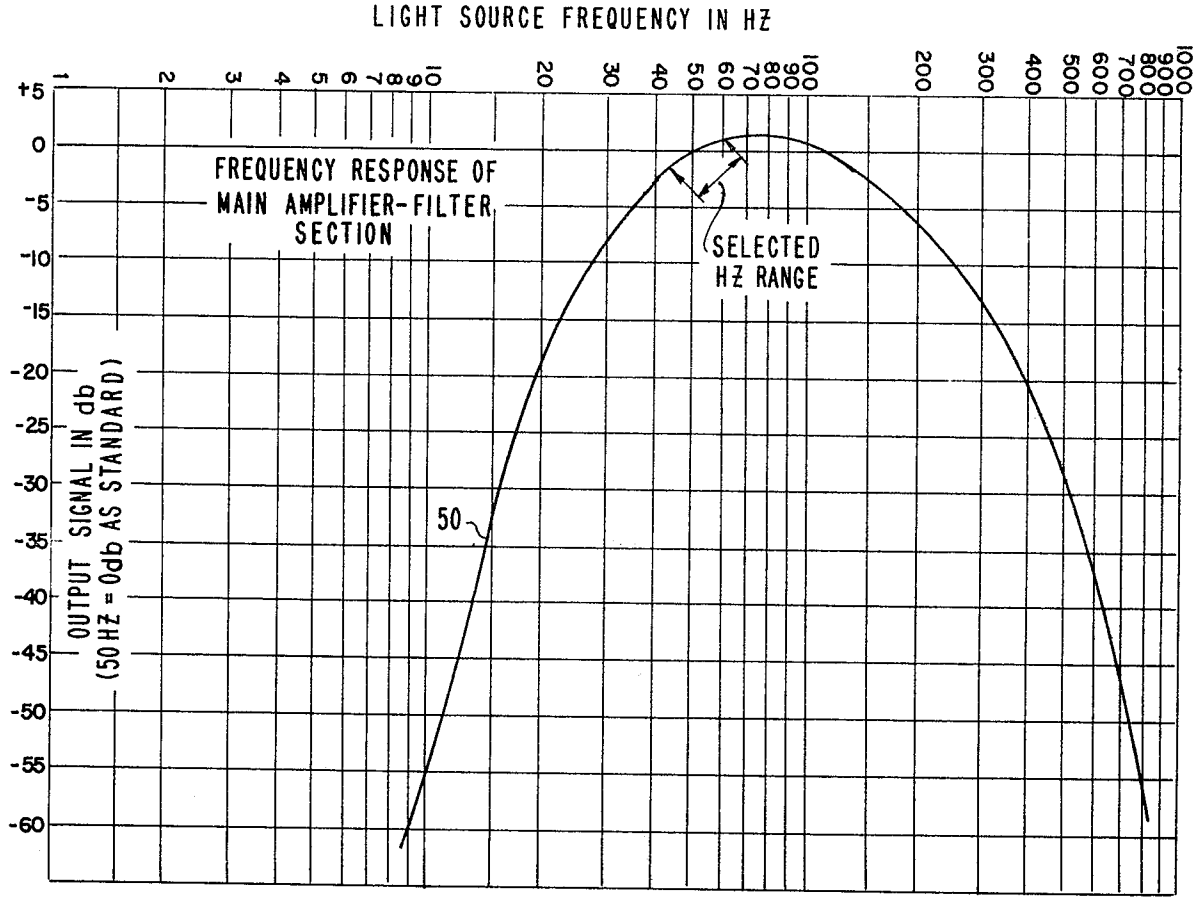

LIGHT SOURCE FREQUENCY IN HZ
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1000
+5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
OUTPUT SIGNAL IN db
(50 HZ = 0db AS STANDARD)
FREQUENCY RESPONSE OF
MAIN AMPLIFIER-FILTER
SECTION
SELECTED
HZ RANGE
50

FIG. 5

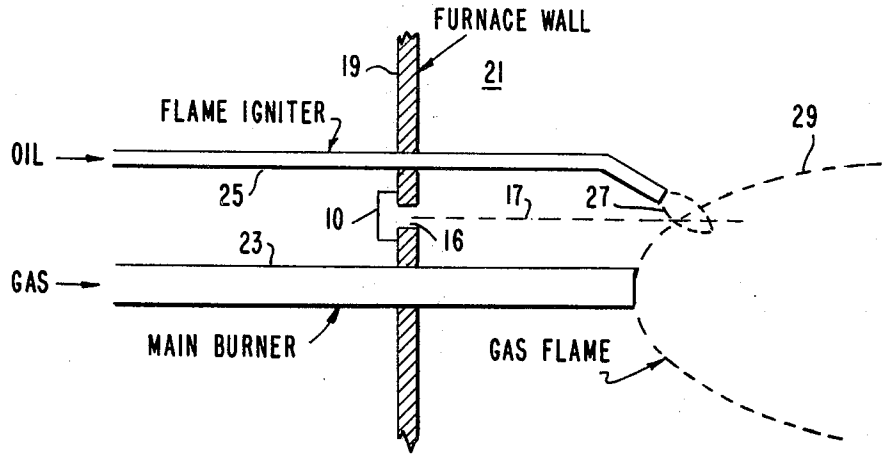

FURNACE WALL
19
21
FLAME IGNITER
OIL
29
25
17
27
10
16
23
GAS
MAIN BURNER
GAS FLAME

FIG. 6

INFRARED DYNAMIC FLAME DETECTOR

CROSS REFERENCE TO RELATED APPLICATION

This is a division of application Ser. No. 425,039 filed Dec. 14, 1973, now abandoned.

BACKGROUND OF THE INVENTION

The present invention relates to an infrared flame detector system for monitoring fossil fuel fired furnace and controlling indicators as well as the flow of fuel to selected burners in accordance with flame operation. For example, in case of flame failure, it is desirable that such failure be indicated and an alarm be operated and fuel flow be stopped as soon as possible to avoid flooding and possible explosion in the furnace.

While the present invention is applicable to both coal and oil fired furnaces, it is particularly advantageous where used with pulverized coal fired burners. The instant invention also finds advantageous use in connection with gas fired furnaces provided with oil fired igniters, since the infrared detector can discriminate between the oil fired ignition and the gas fired combustion. In the case of coal fired burners, the infrared detector is able to see through the coal dust and smoke enveloping the combustion zone, which is not possible with ultraviolet flame detectors which require the flame sighting to take place relatively close to the flame.

The invention provides an infrared dynamic detector system for fuel fired furnaces, in which amplification of the sensed signal is accomplished by a small transistorized preamplifier circuit, and a remote solid state main amplifier circuit. The main amplifier circuit is housed in a signal receiver terminal unit that is remote with respect to the preamplifier circuit which is housed in a signal transmitter unit or head. The circuits in such units are connected by a twoconductor shielded cable extending a considerable distance from one unit to the other. The signal transmitter unit is relatively compact, and is provided with a small optical nipple that fits in an opening provided therefor in the furnace wall, substantially in line with the flame being monitored.

The small solid state infrared signal preamplifier circuit includes an infrared sensor (photosensitive) cell which is aimed at the combustion zone of the monitored flame, with such nipple being located on the head unit so as not to extend into the furnace. Thus, the cell is able to pick up infrared radiation emitted in the combustion zone of the furnace without damage through heat and sparks adjacent thereto, by seeing through any murky atmosphere around such zone. The infrared sensor transforms the flame fluctuations which are present in the combustion zone under surveillance by the cell into a fluctuation equivalent electrical signal that is preamplified by the transistor circuit in the transmitter unit for conduction through the long shielded cable to the main amplifier circuit in the remote signal receiver terminal unit.

The main amplifier circuit receives the signal fluctuations from the infrared sensor circuit, and further amplifies such fluctuations. The main amplifier circuit comprises a filter section responsive to an optimum frequency range of from 40 to 60 Hz in the light source frequency, since the primary combustion zone is very rich in such frequencies, and background frequencies fall outside of such range. The output signal db/light source frequence characteristic curve between 9 and 75 Hz rises gradually to a maximum of +2 db at 75 Hz (50Hz equals zero db), and then falls somewhat more slowly at higher Hz values of light source frequencies. Undesirable noise is thus eliminated. The main amplifier circuit in combination with an integrated control circuit further amplifies and digitally processes the amplified signal fluctuations for controlling flow of fuel to the flame burner being monitored in a flame safety and alarm system which, for example, operates an alarm indicator and shuts off flow of fuel to the burner automatically when such flame fails after a suitable delay.

In brief, the system of the present operation operates as follows: As the variable infrared radiation from the combustion or ignition zone strikes the photosensitive cell, the resistance of the cell changes with the intensity of the infrared source. Such variable resistance in conjunction with a constant current, generates a variable voltage which is amplified. The amplified variable voltage in turn, is converted to a variable current which is driven through the shielded cable to the main amplifier. In the main amplifier the variable current flows through a resistor, generating a variable voltage which is coupled through a capacitor to a first stage integrated amplifier. After such first stage of amplification, the AC signal of flame fluctuations is passed to an integrated filter circuit. After the signal is filtered, it is applied to a half-wave rectifier and integrator. The resultant signal (DC) is compared with a manually pre-set integrator signal (DC) of the background, and processed accordingly through time delay and digital circuits as required for controling the burner.

The terminal unit is provided for receiving the preamplified signals corresponding to the infrared fluctuations sensed by the photosensitive cell viewing the combustion zone in the furnace, from the detector head, which are transmitted through the elongated shielded cable for a considerable distance. Such terminal unit comprises four major sections consisting of the following: (1) an amplifier and filter section; (2) a rectifier section; (3) a signal level detector section; and (4) a time delay section. The first section comprises a circuit for further amplifying and filtering that part of the signal which is between 45 and 60 cps, and rejects all other frequencies to some extent. The second section comprises a circuit for converting the AC output of the first section to a proportional DC level. The third section comprises a circuit which then compares the output of the second section with a pre-set limit to determine if a flame is present or not. The fourth section comprises an adjustable time delay circuit on flame out before the output signals F (FLAME) and $\overline{F}$ (NOT FLAME) from the circuit responds to the flame out. There is no delay when the flame is first detected.

The present invention provides a frequency response characteristic curve in the light source frequency range of 45–60 Hz which produces a minimum of undesirable noise, i.e., between −1 and +1 db (50Hz equals zero db as standard) in the amplified signal fluctuations. Since the signal transmitter unit or head is mounted in a small opening in the wall of the furnace, it does not suffer from the problems which affect prior sensors in which a lengthy sight tube containing an ultra-violet photosensitive cell, extends into the furnace for monitoring the flame. Such tubes often fail due to the intense heat, and also the severe thermal stress decreases the accuracy of the device. Thus, the present invention is particularly advantageous when used in coal fired furnaces.

In gas fired furnaces with oil fired ignitors, the present infrared detector can distinguish between the two, indicating when the igniter is in operation. This is not possible in the case of conventional ultra-violet detectors. Also, the invention can be quickly and easily serviced should that become necessary in the field by simply replacing one or more of the units or parts thereof.

SUMMARY OF THE INVENTION

In accordance with an illustrative embodiment demontrating features and advantages of the present invention, there is provided an infrared dynamic flame detector for use with fossil fuel fired burners in a furnace formed from walls having port openings for receiving the burners. A signal transmitter unit is mounted in the openings including a preamplifier circuit having an infrared sensor provided with an optical nipple aimed at the combustion zone for transforming flame fluctuations thereof into corresponding preamplified signal fluctuations. A remote signal receiver unit is provided with a main signal amplifier circuit and a shielded cable connects the units for conducting signal fluctuations from the preamplifier circuit to the main amplifier circuit. An integrated control circuit is associated with the main amplifier circuit for digitally processing the amplified signal fluctuations.

BRIEF DESCRIPTION OF THE DRAWINGS

The above brief description, as well as further objects, features, and advantages of the present invention will be more fully appreciated by reference to the following detailed description of a presently preferred but nonetheless illustrative embodiments in accordance with the present invention, when taken in connection with the accompanying drawings wherein:

FIG. **1** is a schematic view of an infrared dynamic detector system embodying the invention;

FIG. **2** is a view mainly in side elevation of a coal fired boiler provided with a flame detector head of the invention located in an opening in the furnace wall;

FIG. **3** is a block diagram of the system of the invention;

FIG. **4** is a circuit diagram of the entire system;

FIG. **5** is a characteristic frequency response curve of the output signal/light source frequency, provided by the main amplifier; and

FIG. **6** is a fragmentary view mainly in side elevation of a gas fired burner having an oil fired ignitor provided with a flame detector head comprising the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

As shown in FIG. **1**, the infrared dynamic flame detector system is composed of a compact head unit **10**, an elongated shielded cable **12**, and a remote terminal unit **14** which may be located a considerable distance from the head unit **10**. The head unit **10** has a short tubular projection constituting an optical nipple **16** that fits a small corresponding opening in the furnace wall **18** of a boiler **20**, for example, in which a burner **22** produces a flame **24**. Preamplified signals, corresponding to the flame fluctuations, are generated and transmitted from the head **10** through cable **12** to the terminal unit **14** where such preamplified signals are further amplified and digitally processed for control and/or indication of the ON/OFF state of flame **24**, as may be required.

As shown in FIG. **2**, the line of sight **26** of the optical system in the short tube **10** or nipple **16** is parallel to burner **22**, but within air register **28**, and through the throat **30** of the boiler **20**. The flame **24** is surrounded by a conical train **32** of smoke and coal dust, in a combustion zone **34**, which is seen through the line of sight **26** when the burner **22** is in operation. Thus, the head **10** is protected from thermal damage while in use.

As shown in FIG. **3**, the head **10** comprises a box which contains an infrared photosensitive cell **36** and a small solid state preamplifier circuit **38**. The cell **36** is arranged with the optical system for exposure to radiation emitted from the flame under surveillance. The cell **36** and preamplifier circuit **38** transforms the flame fluctuations, which are present in the combustion zone, into an equivalent electrical signal which is preamplified for transmission through the cable **12** to the terminal unit **14**. The cable **12** is shielded and contains two insulated conductors. A main amplifier circuit **40** is provided in the terminal unit **14** as shown in FIG. **3**, and may be located some distance from the detector head **10**.

The terminal **14** utilizes integrated circuits and includes the following four major sections, (1) a main amplifier and filter section **40**; (2) a rectifier section **42**; (3) a signal level detector section **44**; and (4) a time delay section **46** having output signal circuits with F designating FLAME, $\overline{F}$ designating NOT FLAME and F_I desinating instantaneous FLAME. The circuit of section **40** amplifies that part of the signal which is between 45 and 60 cps (Hz), and rejects all other frequencies to a certain extent. The circuit of section **42** converts the AC output of the amplifier filter section **40** to a proportional DC level; and the circuit of section **44** then compares the output of the rectifier section **44** with a pre-set limit to determine if a flame is present or not. The output of the level detector section **44** goes to the time delay section **46**, the circuit of which provides an adjustable delay on flame out before the F (FLAME) and $\overline{F}$ (NOT FLAME) signals respond. There is no delay on the flame F_I signal.

The response curve **50**, FIG. **5**, of the main amplifier filter section **40** rises to a maximum of +2 db output signal at about 75 Hz of light source frequency, and then falls gradually thereafter, as shown. The output signal is plotted in db (50 Hz equals zero db as standard). The primary combustion zone is very rich in such frequencies, whereas the tail end or background flame frequencies fall outside of the response curve **50**. The optimum frequency range is selected from 45 to 60 Hz, and frequencies substantially above and below such range are cut off. This places the useful response on the front portion of the curve **50**, which effectively eliminates undesirable noise.

As shown in FIG. **4**, the photosensitive cell **36** is provided with pin type terminals A, B and C for quick assembly with and removal from corresponding sockets which are connected to the preamplifier circuit **38**. Such circuit comprises a positive supply voltage lead **52**, a negative lead **54**, and a ground lead **56**. Such leads are connected to corresponding leads in the shielded cable **12** by quick disconnect pin and socket connectors E, J and H, respectively. Thus, the entire head **10** can be removed quickly for repair and/or replacement in the field. The cell **36** converts variable radiation to a variable resistance.

Resistor R5, capacitor C2 and diode D2 are connected to provide a constant voltage source to two con-

stant current sources. Capacitor C2 provides filtering for the constant voltage source. Resistor R6 and transistor Q4, along with such constant voltage source generate a constant current source for the cell **36.** Likewise, resistor R4, transistor Q5 and resistor R2 are connected in series across leads **52** and **54** to provide a constant current source for biasing a Darlington connected configuration of transistors Q1 and Q2, also connected across leads **52** and **54.** Transistor Q3 and resistor R3 are connected in the circuit **38** to provide an impedance match between the cell circuit (high impedance) and the output transistors (low impedance). A capacitor C1 couples only the AC component of the flame signal to the output transistors Q1, Q2.

In operation, as variable infrared strikes the cell **36,** the resistance thereof changes with the intensity of the infrared source. The constant current and variable cell resistance generate a voltage at the terminal A of the cell **36.** Such variable voltage is then coupled to output transistors Q1, Q2 by the operation of the circuit comprising transistor Q3, resistor R3 and capacitor C1. Transistors Q1 and Q2 convert this variable voltage to a variable current signal which is driven through the shielded cable **12** to the main amplifier resistor R27.

The terminal unit **14** receives the output signal from the cable **12** through quick disconnect pin/socket connectors or terminals G and I, for repair and/or replacement of the unit **14** as may be necessary in the field. The main amplifier circuit is provided with a positive voltage lead **58** that is connected to the (+) terminal **60** of a single end 12 volt DC supply. Resistor R15 and diode D22 are connected in series across (+) lead **58** and the ground lead **62,** which also contains resistor R27, to provide a reference voltage for the operational amplifier, since the amplifier operates across the single end supply (+12VDC).

A capacitor C10 is connected in the circuit to provide an AC coupling for the first stage **64** of amplification of the received signal. Undesirable high frequencies are shunted to ground by a capacitor C9 which is connected across resistor R27. The first stage **64** of the signal amplification circuit comprises a resistor R19, an integrated circuit IC2, a resistor R28, a capacitor C13, a resistor R22, adjustable resistor R11, and a capacitor C12. The voltage gain of the first stage **64** of amplification is controlled by adjustment of resistor R11. The main frequency filter circuit **66** comprises a capacitor C5, a resistor R17, a resistor R16, a resistor R14, a capacitor C3, a capacitor C6, an integrated circuit IC3, a capacitor C7, a resistor R18, a resistor R33, and a capacitor C44. The frequency filter circuit **66** attenuates the high and low frequencies of the flame signal, preferably above and below a selected range of 45 to 60 Hz.

A half-wave rectifier-integrator and filter circuit **68** is provided in the unit **14,** comprising an integrated circuit IC4, a diode D33, a diode D4, a resistor R21, a capacitor C8, a diode D5, a resistor R222, a capacitor C111, and a resistor R13. The circuit **68** rectifies the filtered flame signal and provides a DC voltage at the base of transistor Q22.

Transistor Q22 and resistor R20 are connected to provide an emitter follower circuit **70** for isolation between the rectifier integrator circuit **68** and an integrated comparator circuit **71** and connections to a meter M.

A voltage divider circuit **72** for background voltage generation is provided comprising a resistor R8, an adjustable resistor R10, and a resistor R9. The desired background setting is obtained by adjusting resistor R10.

The comparator circuit **71** comprises an integrated circuit IC5, a resistor R25 and a resistor R12. The comparator circuit **71** acts to compare the DC flame signal to the background signal, and generates an appropriate output to circuit **79.** The pins **76, 78** provide quick disconnect means for the meter M from the unit **14** for repair calibration, and/or replacement.

An (IC1) integrated circuit **79** provides a driver for the signal through the following circuit stages including a time delay circuit **80.** The circuit **80** comprises, in addition to the integrated circuit **79,** a diode D11, a resistor R7, an adjustable resistor R66, a resistor R55, a capacitor C11, a transistor Q11, a resistor R44. The IC1 integrated circuits **82, 84** and **86,** have three (3) flame signal output circuits **88, 90** and **92** for flame F, or no flame $\overline{F}$, on a delayed flame loss; and flame F_f without a delay.

The variable current flowing through resistor R27 from the preamplifier circuit **38,** generates a variable voltage across the resistor R27, which is coupled through capacitor C10 to the first stage of amplification **64.** The AC signal is amplified, and passed to the filter section **66.** After being filtered the signal is passed on to the half-wave rectifier and integrator section **68.** The resultant DC signal is compared with the background setting by the comparator stage **71** and automatically processed accordingly through digital circuit **79,** the time delay, circuit **80** and digital circuits **82, 84** and **86.**

As shown in FIG. **5,** the main filter section **66** of FIG. **4,** is used to attenuate the high and low frequencies above 60 Hz and below 45 Hz of the frequency response characteristic **50** of the infrared cell **36,** the preamplifier **38** and main amplifier **64** are utilized for optimum results. Since the best frequency range is from 45 to 60 Hz, the front portion of the frequency response curve **50** is used, and frequencies substantially above **60** Hz are cut off thus eliminating noise.

As shown in FIG. **6,** the head **10** of the present invention is used in a gas fired furnace **21** provided with a main burner **23** that is fueled with gas, and an oil fired flame igniter **25** is provided which extends through openings in furnace wall **19,** as does the optical nipple **16** of the head **10.** The line of sight **17** of the sensor in this case looks at both the zone of the gas flame **29** and that of the oil (igniter) flame **27.** The present infrared detector can discriminate between the oil fired ignition and the gas fired ignition, and thus determine whether the oil fired igniter is in operation. This is not possible with conventional ultra-violet flame detectors.

The present invention is also applicable to coal and oil fired boilers. However, it is particularly advantageous when used in a coal fired boiler because the use of infrared radiation is one of the only successful ways of flame detection in a coal fired boiler. Due to the smoke and dust created in a coal fired furnace, it is difficult if not impossible to detect the presence or absence of flame using other methods of detection. Heretofore, the principal method of flame detection required an ultra-violet sensor which in turn required a rather lengthy tube extending into the furnace, and with such long tube being close to the flame, it was subject to severe thermal stresses which quickly render the optical system innaccurate. Also, the ultra-violet light,

necessary for proper operation of the ultra-violet detector, was masked by the smoke and coal dust which are present in the furnace. The present invention does not suffer from such problems, since the head is substantially flush with furnace wall.

A latitude of modification, change and substitution is intended in the foregoing disclosure and in some instances some features of the invention will be employed without a corresponding use of other features. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the spirit and scope of the invention herein.

What is claimed is:

1. An infra-red dynamic flame detector for use with fossil fuel fired burners in a furnace formed with walls having port openings for receiving said burners comprising: Infra-red sensor means responsive to energy of a selected bandwidth and providing an AC output signal in response thereto, means responsive to said AC signal for amplifying same when the frequency thereof falls between about 45 and 60 CPS and substantially rejecting all other signals, rectifier means for converting said amplified AC signal to a proportional DC level of the amplifier means output, circuit means for comparing the DC output of the rectifier means with a selected limit value and delivering an appropriate output indicative thereof, time delay means responsive to said comparitor for providing an output indicative of a flameout condition for a period longer than a selected delay of said time delay means, when the proportional DC signal falls below the selected limit whereby a flame momentarily affected by fluctuations in intensity may be detected.

2. The infra-red dynamic flame detector of claim **1** wherein said infra-red sensor includes an infra-red responsive cell and an optical nipple for coupling the infra-red energy of the flame thereto.

3. The infra-red dynamic flame detector of claim **2** further including a preamplifier for preamplifying the infrared signals detected by the cell through said nipple and delivering an output signal therefrom.

4. The infra-red dynamic flame detector of claim **3** further including a remote receiver terminal unit for housing said amplifier means, rectifier means, signal detector means, and time delay means and a conducting cable for coupling the output signals of said preamplifier to the amplifier of said remote receiver terminal unit.

5. The infra-red dynamic flame detector according to claim **3** wherein said preamplifier includes regulated DC voltage supply means and amplifier means responsive to the output of the cell for converting the variable infrared radiation energy into a signal corresponding to a variable resistance, and output circuit means for delivering only the AC component of the signal corresponding to the variable resistance.

6. The Infra-red dynamic detector according to claim **5** wherein said regulated DC voltage supply includes leads of opposite polarity, a resistor and a diode connected in series across said leads, a capacitor connected in a parallel circuit with said resistor for filtering said constant voltage, a resistor and transistor connected in series across said positive and negative leads, means connecting the base of said transistor to the negative side of said capacitor, so that a constant current source is provided for the cell which converts variable infra-red radiation to the corresponding variable resistance, a resistor and a transistor connected in series across said leads for generating a constant current source, two output transistors connected in a Darlington configuration across said leads, and to said last named transistor for biasing the latter configuraation with such constant current output, a transistor and a resistor connected in series across the cell circuit and output transistors to provide an impedance match, and a capacitor coupling only the AC component of the flame signal to the output transistors.

7. An infrared dynamic flame detector according to claim **6** in which said cell is provided with a ground, positive and negative, leads each provided with quick disconnect terminal pin elements for mating with corresponding external socket elements, so that said cell can be easily removed and replaced.

8. An Infra-red dynamic flame detector according to claim **4** including a housing for said optical nipple preamplifier and cell and wherein said conducting cable is equipped with quick disconnect pin elements mating with corresponding circuit socket elements in said housing and remote terminal unit.

9. An infrared dynamic flame detector according to claim **5** in which said cell resistance changes in accordance with fluctuations in the infrared source intensity, which variable cell resistance together with the constant current generates a variable voltage at the positive terminal of said cell, such variable voltage then being coupled to the output transistors, thereby causing the latter to convert such voltage to variable current which constitutes the preamplified signal output which is thereafter transmitted.

10. An infrared dynamic flame detector according to claim **1** adapted for use in a coal fired furnace in which formations of smoke and coal dust are formed in the combustion zone of said furnace, in which an optical nipple of the infrared sensor is sized for mounting outside of said combustion zone such that the unit is effectively protected from damage by the intense flame of the burner.

11. An infrared dynamic flame detector according to claim **1** in which the furnace is fired with gas having an oil fired ignitor associated with the gas burner; and said infrared sensor includes a photosensitive cell for converting infrared radiation from said oil fired ignition to fluctuations, whereby the means responsive to the AC signal distinguishes between the oil fired ignition and the gas fired combustion, indicating whether said oil fired ignition is in actual operation.

12. An infrared dynamic flame detector according to claim **1** in which the amplifier means amplifies the AC signal corresponding in frequency to the flame fluctuations, and wherein the means responsive to the AC signal comprises a filter circuit having the aforementioned frequency response of about 45 to 60 CPS that is rich in primary combustion zone frequencies, with the background frequencies falling outside of such response range, being attenuated by the filter circuit.

* * * * *