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(54) METHOD OF AND APPARATUS FOR DETERMINING THE PRESENCE OR ABSENCE OF A FLAME

(71) We, GERBERUS AG., a corporation organised under the laws of the confederation of Switzerland, of Mannedorf, Switzerland, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a method of an apparatus for determining the presence or absence of a flame in which visible and/or invisible radiation from the flame is applied to at least two photoelectric sensors having different spectral sensitivities, and the output signals from the sensors are then evaluated. The flame may be detected in order to provide a fire alarm signal or, for example, to supervise operation of burners, furnaces and the like.

Flame detectors in which radiation from the flames is sensed have been proposed, utilizing radiation derived from the flames in the visible light range, in the infra-red (IR) range, or in the ultra-violet (UV) range. Known flame detectors, to provide outputs representative of presence of a flame, and operating purely within the above referred to light ranges, frequently are not reliable, since signals are derived not only from radiation due to flames which are required to be detected, but also caused by extraneous radiation, such as daylight, artificial light sources, radiant heaters providing IR radiation, and the like, although no real flame of the kind to be sensed is present. It is therefore necessary to take account of characteristic differences which distinguish flame radiation from extraneous disturbance radiation when evaluating the signals in order to prevent erroneous signals and mal-function.

In one flame detector, which has been proposed, differences in the spectral composition of radiation from flames is used in order to distinguish between radiation from flames and disturbing or interfering radiation. Two photoelectric sensors with different spectral sensitivities are exposed to radiation from

the flame; for example, one photoelectric sensor is sensitive to blue light, and one is sensitive to red light. The photo cells may be connected in series. At the junction point between the two photocells there will appear a d.c. signal which depends on the spectral composition, that is, the colour of the light radiation to which the sensors are exposed. Such a flame detector, while functioning properly under most conditions may, however, react to interfering radiation which by chance has the same, or similar, spectral composition as radiation from a flame.

It has also been proposed to distinguish between signals from flames and disturbing signals by utilizing the fluctuation of radiation from a flame. Flames do not radiate constantly, that is, with uniform intensity, but rather fire, or flames are subject to flicker, particularly within a certain frequency range. The signal from a photo-sensor is applied to a band pass filter which passes signals only in a limited frequency range which is characteristic of flame flicker. Such apparatus unfortunately also can be triggered by disturbing radiation of varying intensity, for example light reflected from water surfaces, sunlight interrupted by leaves and branches moving in the wind, or by fluorescent lights which are about to burn out and flicker off and on.

The two above referred to characteristics of flames can be combined, and in a further previously proposed flame detector, the two characteristics are both evaluated. First, a difference signal from two photoelectric devices of different spectral sensitivity is formed, and later the a.c. component within a specific flicker frequency is derived. The sensitivity, or amplification, of the two photoelectric devices is so set that the difference signal is zero for certain expected disturbing radiations of known spectral composition. Such an apparatus may eliminate, however, only a single interfering radiation, and can be set only to eliminate such a single interference, for example sunlight or daylight; other inter-



fering radiation of different spectral composition, for example artificial light sources, fluorescent lamps and the like, may still trigger an erroneous "flame present" signal.

5 According to the present invention there is provided a method of detecting the presence or absence of a flame which comprises providing two photo-electric sensors sensitive to different spectral ranges of incident light, and providing respective sensor signals representative of received radiation in said ranges, combining each of said sensor signals with a portion of the other to obtain a respective difference signal and providing a control signal if their a.c. components of said difference signals, in a predetermined low-frequency band, fall between predetermined limits of amplitude and are mutually in phase.

10 The invention also provides flame detector apparatus comprising two photo-electric sensors responsive to different spectral ranges of incident light by providing respective sensor signals, means for combining each of said sensor signals with a portion of the other to develop a respective difference signal and means responsive to said signals and arranged to provide a control signal if the a.c. components of said difference signals lying within a predetermined low-frequency band fall within predetermined limits of amplitude and are mutually in phase.

15 In carrying out the invention, the relationship of the a.c. components of output signals from sensors of different spectral sensitivity is evaluated to determine if the relationship of the a.c. components falls within a predetermined frequency range between two limiting values; a "flame present" signal is generated only if the relationship is between these two values. Preferably, one of the sensors is sensitive to blue radiation and the other to red radiation, the sensitivity of the sensors being so adjusted that at one specific colour temperature the output of the sensors is equal. A suitable colour temperature is, for example, in the order of about 1,400°K. The sensor signals are evaluated by forming a difference signal between the red signal and a portion of the blue, and the blue signal and a portion of the red, and then analyzing the relative phases of the output signals within a limited low-frequency range, for example about 2 to 50 Hz, preferably about 5 to 25 Hz.

20 In accordance with a feature of the invention, the means for evaluating the signals from the sensors includes at least one difference amplifier to which the signals are applied, and a phase comparator which has the two weighted difference signals applied thereto and which compares the phase differences between the signals and provides a "flame present" signal when the first and second difference signals, derived as above, have the same phase position.

25 Embodiments of the invention will be described by way of example with reference to the accompanying drawings, wherein:

Figure 1 is a general schematic block circuit diagram of an apparatus in accordance with the present invention;

Figure 2 is a detailed circuit diagram of the apparatus of Figure 1;

Figure 3 is a fragmentary detailed diagram of a different embodiment of the sensing and difference forming circuit; and

Figure 4 is a graph relating output current from the respective sensors (ordinate) to colour temperatures in °K (abscissa).

Two photoelectric sensors 1, 2 (Figure 1) are exposed to light radiating from the flame. The sensor 1 is primarily sensitive to red radiation, and the sensor 2 is primarily sensitive to blue radiation, and the output signals are denoted red (R) and blue (B), respectively. The spectral sensitivity, therefore, of the two sensors is different. Various types of photo-electric sensors may be used; the sensor is shown only schematically and may include, if necessary, further circuit elements, for example amplifiers and the like, to convert the incident radiation into an electrical signal. The different spectral sensitivities can be obtained either by using different types of photoelectric sensors, or by placing suitable filters before the sensors. The spectral sensitivities of the two photoelectric sensors may be selected to be in any desired range of electromagnetic radiation; a preferred range, however, is visible light and infra-red radiation, sensitivity to red and blue being only an example. In the example of Figure 1, the sensor 2 is sensitive to blue light, the sensor 1 is sensitive to red light. The sensors may, however, also be sensitive for example to different wavelengths, or ranges of wavelengths within the infra-red band.

The two output signals, R and B, from the photoelectric cells are applied to two inputs of a difference amplifier 3. The difference amplifier 3 is so arranged that at the outputs thereof signals appear which are proportional to $(R - k_1 B)$ and $(B - k_2 R)$, in which k_1 and k_2 are constants. The amplifier is so designed that it passes only the a.c. component within a predetermined low-frequency range of the signals; this low-frequency range is so selected that it is characteristic for the flicker of flames and is, for example, in the range of from 2 to 50 Hz. If better selectivity is desired, then the range may be narrowed to be between 5 and 25 Hz. The difference amplifier 3 preferably includes a difference amplifier unit 4 which has two outputs, connected to filters 5, 6, passing the desired frequency band only; alternatively, instead of filters, frequency selective amplifiers may be used.

The two output signals from the difference amplifier 3 are applied to the two inputs of a phase comparator 7. The phase comparator

7 first includes threshold detectors 8, 9, one each connected to an input of the phase comparator. The threshold detectors 8, 9 pass a signal only if the input signal exceeds a predetermined threshold level. The threshold level can be selected to be low, that is, just slightly greater than zero, so that even low radiation from small flames can still be detected. The two signals are then applied to the inputs of a gate 10 which provides an output signal only if the two input signals applied have the same phase, that is, are either instantaneously both positive, or both negative; no signal is derived from gate 10 when the two signals are oppositely phased. The output signal from gate 10 is applied by way of a rectifier 11 arranged to form an average value signal to an output which, if the system is to be a fire detector, provides an alarm signal.

The output itself preferably includes a timing circuit 12 between it and the alarm circuit itself; when present, the timing circuit provides an output signal to the actual alarm system, schematically shown as a switch 13 only if the input signal persists for a predetermined period of time, in order to prevent false alarms due to short interferences or disturbances, for example when room illumination is first switched on or off.

The output signal can trigger an external alarm if the flame detector is utilized in a fire alarm system. The output signal may, however, also be utilized to signal the presence of a desired flame, that is, to supervise presence of a flame from a burner, for example.

A feedback circuit F is provided to test the correct operation of the system by applying a test signal from a central line to one input of the gate F.

One embodiment of a detailed circuit is seen in Figure 2: The two photoelectric devices 1, 2 are connected in parallel. Each includes a photo resistor 14, 15 and a series connected trimmer resistor 16, 17 and, further, each has an optical filter r_1, r_2 , filtering radiation from flames; the filters have different spectral pass band ranges, for example preferentially passing red and blue light, respectively.

The output signals which arise at the junction point between the photo resistor and the fixed trimmer resistor of the two photoelectric sensors 1, 2, are applied over capacitors 18, 19 to the difference circuit 4. The difference circuit 4 includes, for each of the signals, an amplifier having transistors 20 and 21 and associated collector and base resistors 22, 23 and 24, 25.

The transistors are so connected that each one has a separate emitter resistor r_1 and r_2 , respectively, which are commonly connected to a common resistor r_0 . By arranging the circuit such that the transistors have both

separate and common emitter resistors, signals V_1 and V_2 will be obtained at the outputs of the difference circuit 4 which are defined by equations (1) and (2).

$$V_1 = g_1(R - k_1 B) \quad (1) \quad 70$$

$$V_2 = g_2(B - k_2 R) \quad (2)$$

In these equations, the factors k_1 and k_2 are derived from the resistors r_0 , r_1 and r_2 as set forth in equations (3) and (4).

$$k_1 = \frac{r_0}{r_0 + r_2} < 1 \quad (3) \quad 75$$

$$k_2 = \frac{r_0}{r_0 + r_1} < 1 \quad (4)$$

The proportionality factors g_1 and g_2 are derived from the amplification data and from the operating characteristics of the transistors 20, 21, respectively, as well as from the value of the resistors 22, 23 for transistor 20 and 24, 25 for transistor 21, as well as of the relative values of the resistances r_1 , r_2 and r_0 .

The output signals V_1 and V_2 of the difference circuit 4 are applied over coupling capacitors 26, 27 to band pass filters or band pass amplifiers 5, 6 which, in turn, provide their output signals to the input capacitors 28, 29 of the phase comparator 7.

The phase comparator 7 includes a transistor 30, having its base coupled by capacitor 29 to the output signal from band pass filter or band pass amplifier 6. The transistor 30 further has a base resistance 31, and its collector is connected to the junction between capacitor 28 and a diode 32. The anode of the diode 32 is connected to one terminal of a capacitor 33 with a parallel connected resistor 34.

If the signals V_1 and V_2 are in phase, then the circuit operates like the well known voltage doubler circuit, in which, however, the transistor 30 replaces a further diode, similar to the diode 32. When the alternating voltage across capacitor 29 is in phase with the alternating voltage across capacitor 28, transistor 30 is alternately conductive and blocked, in phase, that is, in rhythm or in synchronism, with the signal across capacitor 28, so that capacitor 33 will have twice the input voltage of capacitor 28 built up thereacross. If, however, the two inputs signals are oppositely phased, transistor 30 is opened in the wrong rhythm, and will block at the wrong time to permit capacitor 33 to charge; no output voltage can build up across capacitor 33 or, respectively, the capacitor discharges immediately over resistor 34. Simultaneously, the circuit provides for rectification, so that the

(17)

output terminal A of the phase comparator 7 will have a voltage built up thereacross which is a direct voltage, but only if the two input signals are in synchronous phase; no voltage will build up when the phase position is different.

The embodiment of Figure 3 utilizes a first photoelectric device 1 which, again, includes a photo-sensitive resistor 14 and a trimmer resistor 16 in series therewith. The second photoelectric device 2, however, includes a photodiode 35 with a parallel connected load resistor 36. Both photoelectric sensors are so selected that they have, due to their characteristics, different spectral sensitivities. Additional filters may thereby be avoided. In one practical example, the sensor 14 is a lead sulphide resistor with a germanium filter; the photodiode 35 is a silicon diode of the solar cell type. Both the sensor 14 as well as the silicon diode are located behind a common infra-red filter glass. The maximum sensitivity of the sensor unit 14 is at about 2.2 microns and that of the silicon diode is at about 0.9 microns.

The difference circuit 4' has two input capacitors 43, 45 and two transistors 37, 38 having respective collector and base resistors 39, 40; 41, 42. The emitter resistor 44 of transistor 38 is directly connected to one terminal of the supply line; the emitter resistor 46 of the transistor 37 is connected, however, to the output of the other photoelectric device 2, that is, to the silicon diode solar cell 35, with parallel connected resistor 36. This circuit provides, again, the signals V_1 and V_2 of the relationships (1) and (2) above, in dependence on the input signals R and B. The factors k_1 and k_2 will, however, be as given by equations (5) and (6).

$$k_1 = 1 \quad (5)$$

$$k_2 = -\frac{r_3}{r_4} \quad (6)$$

A negative temperature coefficient (NTC) resistor 51 and a transistor 50 can be connected in series with the lead sulphide cell 14. The base of the transistor 50 is connected to the tap or junction point of the voltage divider formed by resistors 52, 53. Change in the dark current and the photo-sensitivity of the PbS resistor 14 due to temperature changes is thereby compensated. A capacitor 54 is connected in parallel to the photo resistor 14 and the balance or trimmer resistor 16 to provide for smoothing of the voltage on the photo resistor 14.

The present invention is not restricted to the examples shown, nor to the circuits described; other circuits may be used, which provide output signals of similar characteristics. Various different types of circuit elements,

components and sub-circuit assemblies may be used which provide similar outputs with similar input signals.

The operation of the system will now be described with reference to Figure 4: Curve R—full line—illustrates the relative output signals of a detector which operates in a range of relatively high wavelength, for example in the high infra-red range, in dependence on absolute temperature T of a radiation source. The broken-line curve B shows relative output current for a temperature sensor sensitive to relatively shorter wavelength. It will be seen that the colour temperature/output signal characteristic represented by curve R shows that the output signal of the R sensor changes at a lesser rate with changing colour temperature than does that of the B sensor. The trimmer resistors 16, 17 and 36, respectively, of the photoelectric sensors 1 and 2 are so adjusted that the output signals R and B are equal at a given temperature. The given colour temperature selected is the average temperature T_s which is ordinarily expected in a flame; a typical temperature is in the order of about 1,400°K. This is a suitable colour temperature when the system is to be used for fire detection.

The resistance values associated with the difference amplifier are then so selected that the factors k_1 and k_2 are between 0 and 1; a suitable value, for example, is about 1/3. If the red/blue signal relationship, after the sensors are adjusted to an average temperature, becomes less than 1, that is, if the source of radiation has a higher colour temperature, then the output signals from the two amplifiers will be oppositely phased if the red/blue ratio becomes smaller than the factor k_1 . A source of radiation of lower colour temperature, that is, having a red/blue relationship greater than 1, provides oppositely phased signals when the red/blue relationship becomes greater than $1/k_2$. At assumed values of $k_1 = 1/3$ and $k_2 = 1/3$, and an adjustment for an average temperature of 1,400°K, a temperature range of the radiation source of about 1,150°K to 1,700°K will still provide output signals in which the two signals are in phase, that is, a range in which an alarm signal will be obtained. Above a colour temperature of about 1,700°K, that is, in the range in which natural light sources are prevalent (sunlight, average daylight) and practically all artificial light sources (incandescent lamps, discharge lamps, fluorescent lamps), alarm signals are blocked since the two output signals from the amplifier will be in phase opposition. Radiation sources which have colour temperatures below about 1,150°K, that is, artificial heat sources such as heat radiation lamps, heat generating apparatus, exhaust pipes from internal combustion engines, and the like, also will not lead to an output signal which might trigger a fire alarm.

Monochromatic radiation sources and most radiation sources which do not provide a continuous spectrum of radiation usually do not lead to an output signal from the detection system, since the portion of radiation from such sources in the spectral ranges which are being evaluated by the system of the present invention is usually very different. In the example of Figure 3, the factor k_2 is negative, and in this special situation, the lower limit will be close to zero.

Apparatus according to the present invention has the advantage with respect to previously proposed flame detection and flame supervision systems and method, that it reacts only to radiation within a narrow temperature range, which is characteristic for flames, and is essentially immune to radiation from artificial light sources. Additionally, it is sensitive only to radiation which has the typical changes in intensity, or flicker frequencies, of a flame. The additional possibility presents itself to prevent an output signal if this flicker is strictly cyclical and not random, as in a flame. Detection of a flame can, therefore, be made less subject to extraneous disturbances, and will be practically free from false alarms, or erroneous indication of presence of a flame.

It will be apparent to those skilled in the art that various changes and modifications may be made in the described embodiments without departing from the scope of the invention as defined by the claims and that features described in connection with one of the embodiments may, similarly, be used with the other.

WHAT WE CLAIM IS:—

1. A method of detecting the presence or absence of a flame which comprises providing two photo-electric sensors sensitive to different spectral ranges of incident light, and obtaining respective sensor signals representative of received radiation in said ranges, combining each of said sensor signals with a portion of the other to develop a respective difference signal and providing a control signal if the a.c. components of said difference signals, in a predetermined frequency range, fall between predetermined limits of amplitude and are mutually in phase.

2. A method in accordance with claim 1, and further comprising and providing an output signal only if said control signal persists for a predetermined period of time.

3. A method in accordance with claim 1 or claim 2, wherein said frequency range is between 2 and 50 Hertz.

4. A method in accordance with any one of claims 1—3, wherein said frequency range is between 5 and 25 Hz.

5. A method in accordance with any one of claims 1—4 and comprising the further step of adjusting the sensitivity of said sensors to

supply similar output signals when irradiated by luminescent radiation of a colour temperature in the order of about 1,400°K.

6. A method in accordance with any one of claims 1—5, which comprises forming a first difference signal representing the difference between a first sensed signal from one of the sensors and a second sensed signal from the other sensor weighted by a predetermined first factor k_1 , forming a second difference signal representing the difference between the second sensed signal and the first sensed signal weighted by a predetermined second factor k_2 , and utilizing that portion of said difference signals which falls within said low-frequency band.

7. A method in accordance with claim 6, wherein the factors k_1 and k_2 are each 1/3.

8. A method in accordance with claim 6 or 7 wherein two sensors are provided, one sensor having a peak sensitivity in one spectral range (R) and the other sensor having a peak sensitivity in another spectral range (B), and wherein the step of forming said first difference signal comprises forming a signal V_1 defined by the relationship $V_1 = g_1 (R - k_1 B)$ and the step of forming the second difference signal comprises forming a signal V_2 defined by the relationship:

$$V_2 = g_2 (B - k_2 R),$$

wherein g_1 and g_2 are predetermined proportionality factors; and R and B are the signals from the respective sensors.

9. A method in accordance with claim 8 and further comprising the step of adjusting the sensitivity of the sensors of the different spectral response to supply equal output signals when irradiated by luminescent radiation of a predetermined colour temperature and wherein one of the sensors is adjusted to have a colour temperature/output signal characteristic which changes at a lesser rate than the change of output signal with respect to colour temperature of the other sensor in the ranges on either side of said predetermined colour temperature.

10. Flame detector apparatus comprising two photoelectric sensors responsive to different spectral ranges of incident light by providing respective sensor signals, means for combining each of said sensor signals with a portion of the other to develop a respective difference signal, means responsive to said difference signals and arranged to provide a control signal if the a.c. components of said difference signals lying within a predetermined frequency band fall within predetermined limits of amplitude and are mutually in phase.

11. Apparatus in accordance with claim 10, and including filter circuits passing a.c. signal components of said sensor signals within said predetermined low-frequency range, together

Monochromatic radiation sources and most radiation sources which do not provide a continuous spectrum of radiation usually do not lead to an output signal from the detection system, since the portion of radiation from such sources in the spectral ranges which are being evaluated by the system of the present invention is usually very different. In the example of Figure 3, the factor k_2 is negative, and in this special situation, the lower limit will be close to zero.

Apparatus according to the present invention has the advantage with respect to previously proposed flame detection and flame supervision systems and method, that it reacts only to radiation within a narrow temperature range, which is characteristic for flames, and is essentially immune to radiation from artificial light sources. Additionally, it is sensitive only to radiation which has the typical changes in intensity, or flicker frequencies, of a flame. The additional possibility presents itself to prevent an output signal if this flicker is strictly cyclical and not random, as in a flame. Detection of a flame can, therefore, be made less subject to extraneous disturbances, and will be practically free from false alarms, or erroneous indication of presence of a flame.

It will be apparent to those skilled in the art that various changes and modifications may be made in the described embodiments without departing from the scope of the invention as defined by the claims and that features described in connection with one of the embodiments may, similarly, be used with the other.

WHAT WE CLAIM IS:—

1. A method of detecting the presence or absence of a flame which comprises providing two photo-electric sensors sensitive to different spectral ranges of incident light, and obtaining respective sensor signals representative of received radiation in said ranges, combining each of said sensor signals with a portion of the other to develop a respective difference signal and providing a control signal if the a.c. components of said difference signals, in a predetermined frequency range, fall between predetermined limits of amplitude and are mutually in phase.

2. A method in accordance with claim 1, and further comprising and providing an output signal only if said control signal persists for a predetermined period of time.

3. A method in accordance with claim 1 or claim 2, wherein said frequency range is between 2 and 50 Hertz.

4. A method in accordance with any one of claims 1—3, wherein said frequency range is between 5 and 25 Hz.

5. A method in accordance with any one of claims 1—4 and comprising the further step of adjusting the sensitivity of said sensors to

supply similar output signals when irradiated by luminescent radiation of a colour temperature in the order of about 1,400°K.

6. A method in accordance with any one of claims 1—5, which comprises forming a first difference signal representing the difference between a first sensed signal from one of the sensors and a second sensed signal from the other sensor weighted by a predetermined first factor k_1 , forming a second difference signal representing the difference between the second sensed signal and the first sensed signal weighted by a predetermined second factor k_2 and utilizing that portion of said difference signals which falls within said low-frequency band.

7. A method in accordance with claim 6, wherein the factors k_1 and k_2 are each 1/3.

8. A method in accordance with claim 6 or 7 wherein two sensors are provided, one sensor having a peak sensitivity in one spectral range (R) and the other sensor having a peak sensitivity in another spectral range (B), and wherein the step of forming said first difference signal comprises forming a signal V_1 defined by the relationship $V_1 = g_1 (R - k_1 B)$ and the step of forming the second difference signal comprises forming a signal V_2 defined by the relationship:

$$V_2 = g_2 (B - k_2 R),$$

wherein g_1 and g_2 are predetermined proportionality factors; and R and B are the signals from the respective sensors.

9. A method in accordance with claim 8 and further comprising the step of adjusting the sensitivity of the sensors of the different spectral response to supply equal output signals when irradiated by luminescent radiation of a predetermined colour temperature and wherein one of the sensors is adjusted to have a colour temperature/output signal characteristic which changes at a lesser rate than the change of output signal with respect to colour temperature of the other sensor in the ranges on either side of said predetermined colour temperature.

10. Flame detector apparatus comprising two photoelectric sensors responsive to different spectral ranges of incident light by providing respective sensor signals, means for combining each of said sensor signals with a portion of the other to develop a respective difference signal, means responsive to said difference signals and arranged to provide a control signal if the a.c. components of said difference signals lying within a predetermined frequency band fall within predetermined limits of amplitude and are mutually in phase.

11. Apparatus in accordance with claim 10, and including filter circuits passing a.c. signal components of said sensor signals within said predetermined low-frequency range, together



19

with a difference amplifier having the signals applied thereto and forming a first difference signal V_1 defined by $V_1 = g_1(R - k_1 B)$, and a second difference signal V_2 defined by $V_2 = g_2(B - k_2 R)$ wherein g_1 and g_2 are proportionality factors determined by the circuit components of the difference amplifier means, R and B are the output signals from the respective sensors and k_1 and k_2 are other proportionality factors determined by the relative circuit components of the difference amplifier means and a phase comparator having the first and second difference signals applied thereto and comparing the phase relationship between said signals and providing a "flame present" signal when said first and second difference signals have the same relative phase position.

12. Apparatus in accordance with claim 11 wherein the difference amplifier means comprises two transistors having their bases controlled by the photoelectric sensors, and having, each, an individual separate resistor connected in the emitter-collector path and a common resistor in the emitter-collector paths of the transistors.

13. Apparatus in accordance with claim 11 or 12, wherein the phase comparator comprises a voltage doubler circuit including a capacitor and a diode connected to one output of the difference amplifier means, and a transistor, controlled from the other output of the difference amplifier means, one output providing one of said difference signals and the other output providing the other of said difference signals.

14. Apparatus in accordance with any one of claims 11-13, and further including a timing circuit connected to the output of the phase comparator and developing said output signal only if the output signal from the phase comparator persists for a predetermined period of time.

15. Apparatus in accordance with any of claims 10-14 and further comprising a temperature-sensitive, temperature-compensating component in circuit with at least one of the photoelectric sensors.

16. Apparatus in accordance with claim 15

wherein the temperature sensitive component comprises a negative temperature coefficient resistor connected in series with the photoelectric sensor.

17. Apparatus in accordance with claim 12 or in accordance with any one of claims 13-16 as dependent on claim 12, wherein said separate base resistors have resistances r_1 and r_2 , respectively, and are connected to a common junction, and said common resistor has a resistance of r_0 and connects the common junction to a source of power supply, the relative values of the resistances being such that

$$r_0/(r_0 + r_2) < 1$$

and

$$r_0/(r_0 + r_1) < 1.$$

18. Apparatus in accordance with claim 17 wherein each of said transistors has its collector connected in an amplifier circuit and the gain of amplification of each amplifier circuit is matched to the spectral response of each of the sensors such that a predetermined colour temperature of radiation, the difference signals will be equal, and change of different signals upon change of said colour temperature of irradiation of the sensors has opposite effect on the difference signals from said transistors.

19. Apparatus in accordance with claim 18, 20, wherein said predetermined colour temperature is about 1,400°K.

20. Flame detector apparatus constructed and operating substantially as described with reference to the drawings.

21. A method of detecting the presence or absence of a flame substantially as described with reference to the drawings.

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