A METHOD OF REMOTE OPTICAL DETECTION OF GAS

The invention relates to a method of optically detecting gas, in particular polluting gas, and it is applicable in particular to monitoring industrial sites such as factories, refineries, gas storage installations, etc.

Proposals have already been made in European patent No. 0 544 962, for a method of detecting gas based on selective absorption of infrared radiation from the surroundings by a gas present in the field of observation.

That known method uses an infrared imager associated with a measurement filter which is sensitive to the presence of the looked-for gas (the transmission band of the filter includes at least one specific absorption line of the gas), and a reference filter which is insensitive to the presence of the gas (the transmission band of the filter is comparable to that of the measurement filter but it does not include the absorption line(s) specific to the gas). Contrasts in the image of the zone observed through the measurement filter and contrasts in the image of said zone observed through the reference filter are determined, which contrasts are provided by the flux differences coming from points at different temperatures in the observed zone and passing through the looked-for gas. The ratio of the contrast in the measurement image (seen through the measurement filter), and in the reference image (seen through the reference filter) makes it possible by calculation to determine the quantity of gas present on the light path between the background of the observed zone and the observer.

This ratio of the contrasts in the measurement and reference images makes it possible, under certain conditions and to a first approximation, to eliminate emission specific to the looked-for gas and to be unaffected by the temperature values of points in the

observed zone and the differences between said temperatures.

Nevertheless, it has been found that when the range of background temperatures in the scene is relatively large, the measurements performed do not enable exact values of the concentration of the detected gas to be obtained, and that the measurement error is, in addition, a function of the position in the spectrum of the absorption line of the looked-for gas.

A particular object of the present invention is to eliminate those drawbacks.

Another object of the present invention is to significantly reduce the minimum value of the concentration from which it is possible to detect gas.

A further object is to improve the above-mentioned method, in particular to systematize and optimize detection of a plurality of gases present in an observed three-dimensional zone.

To this end, the invention provides a method of optically detecting gas by remotely observing a three-dimensional zone by means of a measurement filter whose transmission band includes a specific absorption line of a looked-for gas and a reference filter whose transmission band corresponds to that of the measurement filter but does not include a specific absorption line of said gas, the method consisting in detecting the presence of the gas by determining flux differences passing through the gas and coming from points at different temperatures of a calculation window, and by determining the ratio of the flux differences seen through the measurement filter and of the flux differences seen through the reference filter, the method being characterized in that it consists in using said ratio to determine a measurement magnitude that is independent of the temperatures in the calculation window and in determining or calculating the concentration of the gas from said magnitude, this being determined by weighting

the above-specified ratio by the mean flux in the calculation window or by weighting said ratio as a function of the difference between a predetermined temperature and the temperatures of the scene background detected in the calculation window.

In a first implementation of the invention, said measurement magnitude is equal to $(\eta.\Phi^p)/K$, where η is the above-mentioned ratio, Φ is the mean flux in the calculation window, p is a parameter depending on the measurement and reference filters, and K is a normalization parameter equal to Φ^p for a predetermined temperature of the calculation window, e.g. equal to 20°C.

In a variant implementation of the invention, the method consists in previously determining, for different temperatures of the scene background, values of the temperature derivative of the spectral luminance of a black body at a given mean temperature, in deducing the temperature derivative of the above-mentioned ratio for the same given mean temperature and in the absence of gas, in recording the values of said derivative in memory, and in correcting the values of the measured ratio as a function of the differences between the temperatures of the scene background and a predetermined mean temperature.

It is thus possible to correct the effects of background temperatures of the scene on the gas concentration measurements.

According to another characteristic of the invention, the method also consists, in order to detect a plurality of gases, in using a set of filters of transmission bands that are determined relative to one another as a function of absorption lines of the gases to be detected in such a manner that a filter usable as a reference filter for detecting one gas is usable as a measurement filter for detecting another gas, or vice versa, in associating the filters in pairs, each pair of

filters being for detecting one or more gases, in making the above-mentioned flux difference measurements for each filter, in calculating the values of the above-mentioned ratio for each pair of filters, and in deducing therefrom the presence and the concentration of the above-mentioned gases in the observed three-dimensional zone.

This method makes it possible to systematize and optimize the method described in the above-specified European patent, by implementing an overall measurement of flux through each of the filters used and then by determining by calculation which gases are present in the observed zone. It is then possible to apply the method for detecting a plurality of gases whose specific absorption lines are distinct from one another, or on the contrary, overlap in part, which is quite common in practice.

In a preferred implementation of the invention, the method consists in forming an identification matrix in which the rows correspond to the filter pairs and the columns correspond to the gases to be detected, an element i,j of said matrix being formed by the calibration value obtained for a pair i of filters in the presence of a known quantity of a gas j for detection, in forming a measurement vector whose rows correspond to the filter pairs and in which the element i represents the measurement made on filter pair i (this element being constituted, for example, by a mean of the above-mentioned ratio values obtained at different points of the image of the observed zone), in calculating the correlation coefficients of the columns of the identification matrix with the measurement vector, and in comparing said coefficients with determined thresholds in order to deduce therefrom the presence and the concentration of the above-mentioned gases in the observed zone.

According to another aspect of the invention, the method consists in using, for the purpose of forming one

or more pairs of measurement and reference filters, a series of filters having transmission bands which are spaced over an observation wavelength band and which optionally overlap, in obtaining an image of the observed zone in each transmission band, and in summing said images in order to reconstruct images seen through broad band measurement filters and images seen through broad band reference filters.

This reconstitution of images over a broad band of wavelengths from images obtained over narrow bands of wavelengths is advantageous when it is desired to adapt the method of the invention to instruments possessing a plurality of observation channels, or when it is desired to detect the presence of a large number of gases in the same zone.

According to yet another characteristic of the invention, the reference filters are synthesized filters made by stacking thin layers and having one or more narrow transmission stop bands, corresponding to the absorption lines of the gas(es) for detection.

Such synthesized filters can have transmission stop bands that are determined in extremely precise manner, thus improving the sensitivity and the precision of measurement.

In a variant, it is possible to use a continuously-tunable filter whose transmission band can be moved across the entire spectrum of wavelengths under study.

According to yet another characteristic of the invention, the method consists in comparing the images obtained through the various filters with one another in order to detect relative movement between the observer and the observed zone and/or movement within the observed zone, the method then comprising repositioning the images relative to one another prior to processing them, so as to eliminate the influence of the above-mentioned relative movement and/or so as to eliminate from said

images those portions which correspond to movement within the observed zone.

By way of example, this makes it possible to perform measurements over extended zones by aerial observation (instrument on board an aircraft or a satellite) or performed on board a vehicle, or by scanning a scene with a camera from a fixed point.

This can be done by using an algorithm for detecting moving objects in the observed zone, the algorithm consisting in:

· calculating the pixel-to-pixel difference between two measurement images respectively obtained at an instant t-1 and at an instant t;

· calculating a standard deviation of the difference image, thereby obtaining the overall spatial noise of the image;

· thresholding at (threshold1.standard_deviation) to obtain a binary image of suspect points:

· labeling points in regions of related points;

· thresholding on the number of points in said regions and retaining as moving regions those that contain more than (threshold2) points; and

· reiterating the steps on the reference images obtained at t-1 and t.

Applying a binary AND to the two maps of moving regions in the measurement images and the reference images gives a matrix of valid "moved" points that is applied to the map of the above-mentioned ratio of flux differences at instant t.

In a variant, the difference between an image at instant t and a "accumulated scene background" at instant t is used. The scene background is calculated by means of a recursive filter of the auto regressive moving average (ARMA) type. The scene background is updated at instant t by injecting therein the measurement (or reference) image at instant t-1, together with the matrix of moved points at instant t-1, so as to update the

background only at locations where there has not been any movement, thus obtaining a genuine background of the scene without any moving object.

The "time" memory used for calculating the scene background can also be used for calculating noise, the pixel-to-pixel difference of the measurement (or reference) image at instant t and the scene background at instant t being injected into another recursive filter of the same type as that mentioned above, thereby obtaining accumulated noise. The accumulated noise at instant t makes it possible to perform thresholding using time noise criteria of the difference image(t) - background(t) in addition to thresholding using spatial noise criteria, thereby reinforcing the robustness of the algorithm.

The invention will be better understood and other characteristics, details, and advantages thereof will appear more clearly on reading the following description made by way of example and with reference to the accompanying drawing, in which:

· Figure 1 is a diagram of means for implementing the invention;

· Figure 2 is a graph showing variations as a function of wavelength in the temperature derivative of the spectral luminance of a black body for a plurality of predetermined mean temperatures;

· Figure 3 is a graph showing specific absorption lines of three gases for detection, and the transmission bands of three filters used for detecting them; and

· Figure 4 is a graph showing the wavelength positions of a series of filters usable as measurement filters and as reference filters.

Reference is made initially to Figure 1 which is a diagram showing means for implementing the invention, comprising a thermal imager or camera 10 associated with a data processing system 12 via an analog-to-digital converter 14 and serving to observe a three-dimensional zone 16 comprising, for example, a background 18,

buildings 20, and possibly also a cloud 22 of one or more gases whose presence is to be detected and whose concentration is to be determined.

The camera 10 used for observing the zone 16 comprises an optical system 24, at least one filter 26, and a photosensitive element or set of elements 28 on which the optical system 24 forms an image of the observed zone 16 through the filter 26.

The camera 10 may be a charge coupled device (CCD) type television camera or the like for measurements in the visible spectrum or a thermography camera capable of supplying temperature measurements of observed zones directly. The term "thermal imager" is used as a general term to designate an appliance capable of providing an image of the temperatures of the observed zone, i.e. an image in which colors or gray-scale densities are a function of the temperatures of the observed points.

As already described in the above-mentioned European patent No. 0 544 962, in order to detect a given gas, it is necessary to use two filters 26 having wavelength transmission bands that are similar overall, but one of which (the band of the measurement filter) includes at least one absorption line specific to the gas that is to be detected while the other one of which (the band of the reference filter) does not include said specific absorption line(s). The method described in the above-specified patent consists in determining contrasts in the reference image and in the measurement image, i.e. differences between heat fluxes coming from points at different temperatures in the observed zone and passing through the cloud 22 of gas to be detected, the measurement image being the image seen through the measurement filter and the reference image being the image seen through the reference filter, the method then consisting in taking the ratio of said contrasts or flux differences in the two images in order to obtain a magnitude which is independent of the flux emitted by the

gas cloud 22, of the overall gain of the camera or thermal imager 10, of the temperatures of the points under consideration in the observed zone, of the temperature differences between said points, and of the temperature of the gas to be detected.

That approximation is legitimate providing the temperature range of the background of the scene is not very wide (a few degrees) and when the absorption line of the looked-for gas is at the wavelength of the emission maximum of the scene background. Otherwise, particularly in an industrial environment, account needs to be taken of the temperatures of the scene background in order to determine precisely the concentration of the gas in the cloud 22.

To do this, in a first implementation of the invention, it is possible to use a measurement magnitude that is invariant as a function of temperature, said measurement magnitude being of the form:

$$\Psi = (\eta \times \Phi^p)/K$$

where:

- Φ is the mean object flux in the calculation window;
- η is the above-mentioned ratio of contrasts or flux differences in said window;
- p is a parameter depending on the measurement filter and the reference filter, and which can be calculated or measured; and
- K is the normalization parameter which is equal to Φ^p for a predetermined temperature (e.g. 20°C).

The integrated concentration of gas in the line of sight is determined by the following relationship:

$$\int_\ell C.d\ell \; b(a - \Psi)$$

where:

- ℓ is the line of sight; and
- a and b are parameters that can be measured by calibration (b expresses sensitivity to a given gas and a

depends on the selected filters and on the temperature of the observed scene).

It has been verified, for example, that variation in the measurement magnitude Ψ as a function of the mean temperature of the calculation window in a temperature range extending from about 25°C to about 35°C is approximately one-seventh that of η.

In a variant of the invention, it is also possible to proceed as described below.

The ratio of contrasts or flux differences in the measurement image and in the reference image can be written as follows:

$$\eta = 1 + \frac{\int_{\Delta\lambda g} \tau c.\tau n \left[\frac{dL\lambda}{dT}\right]_{\overline{T}} \Delta T.d\lambda}{\int_{\Delta\lambda ref} \tau c \left[\frac{dL\lambda}{dT}\right]_{\overline{T}} \Delta T.d\lambda}$$

where:

$\left[\frac{dL\lambda}{dT}\right]_{\overline{T}}$ is the temperature derivative of the spectral luminance of a black body at temperature $\overline{T}$;

τc is the relative spectral response of the camera 10;

τn is the transmission coefficient of the gas cloud;

$\overline{T}$ is the mean temperature of the observed scene;

ΔT is the temperature contrasts of the observed scene;

$\Delta\lambda g$ is the wavelength difference between the measurement filter transmission band and the reference filter transmission band; and

$\Delta\lambda ref$ corresponds to the wavelength transmission band of the reference filter.

Contrary to that which can be accepted as a first approximation for certain transmission bands and when the temperature range in the observed scene is not very wide, the temperature derivative of the spectral luminance of a

black body at a given mean temperature is not constant but varies as a function of wavelength and also as a function of mean temperature, as can be seen from the curves in Figure 2 which show variations in said function over a wavelength range extending from about 2 μm to about 15 μm for three mean temperatures, 320 K, 300 K, and 280 K, respectively.

It can be seen from the curves that the shape of this function changes with mean temperature and that its maximum moves towards shorter wavelengths as the mean temperature increases.

The invention takes account of these variations by proceeding as follows:

- ideal values η_0 of the ratio η in the absence of gas are evaluated or calculated for different mean temperatures of the scene background and for different temperature ranges of the scene background and these ideal values are recorded;
- the camera 10 is used to measure the temperatures of points in the scene background in a calculation window of the image of the observed zone;
- the mean temperature and the range of temperatures of the scene background in said window are determined;
- the ratio of the above-mentioned flux differences is measured for the scene background; and
- the values of the above-mentioned ratio are corrected with the help of the ideal values recorded in memory.

The corrections of the values of the above-mentioned ratio are "local": each measurement is performed over a set of 16 to 25 pixels, for example, and correction is performed taking account of the temperatures of the surrounding pixels.

It is thus possible to correct measurement errors that result from the presence in the scene background of an element that is very hot, for example a chimney in operation.

As mentioned above, it is possible to evaluate the improvements that result from the corrections of the invention on the minimum concentration values from which it is possible to detect gas:

- when the range of temperatures of the scene background is ±1 K relative to the mean temperature, the evaluated improvement lies in the range 1.1 to 1.4;
- when said temperature range is ±5 K, the evaluated improvement lies in the range 1.3 to 3.1;
- when said temperature range is ±20 K, the evaluated improvement lies in the range 2.2 to 10; and
- when said temperature range is ±40 K, the evaluated improvement lies in the range 3.4 to 18,

the minimum value of the improvement being that obtained for a gas whose absorption line is at the emission maximum of the background, while the maximum value is that obtained for a gas whose absorption line is at the sensitivity limit of the camera or thermal imager (8 μm in IR band III), with the correction making it possible to reduce the detection threshold by a factor of about 10.

This assumes that the scene background temperatures are determined exactly.

Such determination is associated with knowledge about the emissivity of the scene background. When the observed zone is stationary, it is possible to discover or evaluate the emissivities of the various portions of the scene background, thus making it possible to obtain precision of a few tenths of a degree concerning the temperatures of the scene background.

Otherwise, lack of knowledge about emissivity leads to imprecision in determined temperature. In infrared band III (8 μm - 12 μm), most materials (excepting paint) have emissivities lying in the range 0.8 to 1, i.e. having a value of 0.9 ± 0.1 and the precision with which temperatures can be determined in the scene background can then be ±5°.

The improvements that result from taking account of scene background temperatures in terms of minimum concentration values for detection are then as follows:

· temperature range ±20 K = improvement lying in the range 1.7 to 3.2; and

· temperature range ±40 K = improvement lying in the range 2.6 to 5.8.

Reference is now made to Figure 3 which is a diagram showing variations over a certain range of wavelengths in the transmission of three gases G1, G2, and G3 for detection, each gas being characterized by a specific absorption line, the absorption lines of gases G2 and G3 being very close to each other and overlapping in part. Figure 3 also shows the transmission bands of three highpass type filters F1, F2, and F3, which when used in combination in pairs enable the presence or the absence of the three gases G1, G2, and G3 in the observed three-dimensional zone to be detected.

As can be seen in Figure 3, the transmission band filter F1 includes the absorption lines of all three gases G1, G2, and G3, the band of filter F2 includes the absorption line of gas G3, and a portion of the absorption line of gas G2, and the transmission band of filter F3 does not include any of the absorption lines of the gases G1, G2, and G3.

The filter F1 can thus be used as a measurement filter and the filter F2 can be used as a reference filter for detecting the gases G1 and G2.

The filter F2 can be used as a measurement filter and the filter F3 can be used as a reference filter for detecting the gases G2 and G3.

Under such circumstances, if gas is detected using filter pair F1, F2 and no gas is detected using filter pair F2, F3, then the gas present in the observed zone is G1.

If gas is detected using filter pairs F1, F2, and F2, F3, then the gas present in the observed zone is G2.

If no gas is detected using filter pair F1, F2 and if gas is detected using filter pair F2, F3, then the gas present in the observed zone is G3.

It will be understood that the group of filters F1, F2, and F3 having transmission bands determined as a function of the specific absorption lines of the looked-for gases, enables the presence of one or more of these gases to be detected even if their specific absorption lines are very close together or overlap in part.

This method can be generalized as follows:

For a group of gases to be detected, a group of filters is determined having transmission bands that are defined relative to the specific absorption lines of the gases in such a manner that a filter which is used as a reference filter for detecting one or more of the gases can be used as a measurement filter for detecting another one or more gases, or vice versa, and the filters are associated in pairs such that each filter pair serves to detect one or more gases, the contrasts or flux differences coming from the observed zone through each of the above-mentioned filters are measured, the values of the above-mentioned ratio of contrasts are determined for each pair of filters, and the presence and the concentration of the various gases in the observed three-dimensional zone are deduced from said values.

The method may be implemented as follows:

A gas identification matrix is constructed in which each column is associated with one of the gases to be detected and in which each row is associated with one of the above-mentioned filter pairs, an element i,j of said matrix corresponding to the value of the ratio of the contrasts in the measurement image and the contrasts in the reference image for a known quantity of gas j, the pair of filters used being referred to as Ci.

The elements i,j of said identification matrix can be determined experimentally by calibration or theoretically by calculation.

A series of measurements consists in reading the responses of the various filters, and if one or more gases are detected, in constructing a measurement spectra in which element i is the value of the above-specified ratio of contrasts for filter pair Ci.

Thereafter, correlation coefficients are calculated between the various columns of the identification matrix and the measurement vector. Each correlation coefficient is determined using a known method (e.g. by calculating the ratio whose numerator comprises the covariance of the column of the identification matrix and of the measurement vector, and whose denominator is the product of the variant of the column of identification matrix multiplied by the variance of the measurement vector) and this coefficient qualifies the correlation that exists between column j of the identification matrix (said column corresponding to one of the looked-for gases) and the measurement vector that was built up from the measurements made on the various pairs of filters.

For example, each element of the vector may correspond to a mean of the values for the above-mentioned ratio at various points in the image of the observed zone.

When one of the correlation coefficients exceeds a threshold of predetermined value, the gas corresponding to said correlation coefficient is declared as being identified.

Naturally, it is possible to define a plurality of threshold levels which correspond to a plurality of levels of reliability in the identification of the looked-for gases.

The concentrations of the gases in the observed zone can be determined by solving the system of equations constituted by the n measurements obtained from the n pairs of filters and by the concentrations of the p gases (the identification matrix comprising n rows and p columns).

The system can be solved once the number n of measurements is greater than or equal to the number p of gases to be detected.

The measurement and reference filters used for detecting gases in the method of the invention are typically filters having a transmission band that is broad relative to the absorption lines of the gases to be detected. These filters may be replaced by filters having narrower transmission bands spaced relative to one another in wavelength as shown diagrammatically in Figure 4, or by a continuously-tunable filter having a transmission band centered on a wavelength which can be caused to vary continuously over the spectrum under investigation, e.g. from 8 μm to 12 μm. The tunable filter may be a Fabry-Perot etalon fitted with piezoelectric wedges.

In Figure 4, each reference 1, 2, 3, 4, 5, ..., designates the transmission band of a different filter, e.g. mounted on a different channel of an observation appliance. It can be seen that these transmission bands are close to one another, that they can overlap in part (as between bands 1 and 2, 2 and 3, and 4 and 5), or they can be separate from one another (as applies to bands 3 and 4), it also being possible for these bands to be uniformly spaced apart over a range of wavelengths.

The various filters provided in the various channels of the observation appliance make it possible to reconstruct measurement images and reference images over a broad band, by summing a plurality of channels of the observation appliance.

For example, if the gas to be detected presents a specific absorption line in transmission band No. 2, a measurement image may be obtained by summing channels corresponding to transmission bands 1, 2, 3, 4, and 5, and a reference image can be obtained by summing channels corresponding to transmission bands 1, 3, 4, and 5.

When the transmission bands of the filters are contiguous, combining them enables a broad transmission band to be reconstituted. If they are discontinuous, summing them makes it possible to overcome the presence of interfering gases by eliminating the wavelengths at which such gases absorb.

The method of filtering represented by Figure 4 is advantageous when using a multichannel observation appliance, and also when a large number of gases are to be detected. This provides an imaging spectrometer having small spectral resolution while nevertheless conserving large three-dimensional resolution.

Filters presenting one or more transmission stop bands, such as the bands between transmission bands 3 and 4 in Figure 4, can be made with great precision using a technique of stacking thin layers, thus enabling filters adapted to the gases for detection to be synthesized, thereby greatly improving the sensitivity of detection.

It is also possible in this manner to make synthetic filters presenting a plurality of transmission stop bands for detecting a gas having a plurality of absorption lines. Such filters are particularly suitable for detecting gases having a spectrum with a plurality of absorption lines included in the sensitivity band of the camera or the thermal imager, since using a synthesized filter makes it possible to reproduce accurately the spectrum of the gas in the reference channel and thus makes it possible to work over the entire sensitivity band of the camera, thereby reducing the minimum concentration of gas that can be detected by a factor of about 3 compared with that which is possible when using a conventional reference filter whose wavelength transmission band is necessarily very narrow.

CLAIMS

1/ A method of optically detecting gas by remotely observing a three-dimensional zone by means of a measurement filter whose transmission band includes a specific absorption line of a looked-for gas and a reference filter whose transmission band corresponds to that of the measurement filter but does not include a specific absorption line of said gas, the method consisting in detecting the presence of the gas by determining flux differences passing through the gas (22) and coming from points at different temperatures of a calculation window, and by determining the ratio of the flux differences seen through the measurement filter and of the flux differences seen through the reference filter, the method being characterized in that it consists in using said ratio to determine a measurement magnitude that is independent of the temperatures in the calculation window and in determining or calculating the concentration of the gas from said magnitude, this being determined by weighting the above-specified ratio by the mean flux in the calculation window or by weighting said ratio as a function of the difference between a predetermined temperature and the temperatures of the scene background detected in the calculation window.

2/ A method according to claim 1, characterized in that said measurement magnitude is equal to $(\eta.\Phi^p)/K$, where η is the above-mentioned ratio, Φ is the mean flux in the calculation window, p is a parameter depending on the measurement and reference filters, and K is a normalization parameter equal to Φ^p for a predetermined temperature of the calculation window, e.g. equal to 20°C.

3/ A method according to claim 1, characterized in that it consists in determining, for different temperatures of the scene background, values of the temperature

derivative of the spectral luminance of a black body at a given mean temperature, in deducing the temperature derivative of the above-mentioned ratio for the same mean temperature in the absence of gas, in recording the values of said derivative in memory, and in weighting the measured values of the above-mentioned ratio as a function of the differences between the temperatures of the scene background and a predetermined mean temperature.

4/ A method according to any one of claims 1 to 3, characterized in that in order to detect a plurality of gases, it consists in using a set of filters (F1, F2, F3) of transmission bands that are determined relative to one another as a function of absorption lines of the gases (G1, G2, G3) to be detected in such a manner that a filter (F2) usable as a reference filter for detecting one gas (G1) is usable as a measurement filter for detecting another gas (G2, G3), or vice versa, in associating the filters in pairs, each pair of filters being for detecting one or more gases, in making the above-mentioned flux difference measurements for each filter, in calculating the values of the above-mentioned ratio for each pair of filters, and in deducing therefrom the presence and the concentration of the above-mentioned gases in the observed three-dimensional zone.

5/ A method according to claim 4, characterized in that it consists in previously determining calibration values for the above-mentioned ratio for each pair of filters in the presence of a known quantity of each above-mentioned gas, in calculating correlation coefficients between said calibration values and the values calculated from the above-mentioned measurements, and in deducing that a gas is present in the observed zone when a correlation coefficient is greater than a predetermined threshold.

6/ A method according to claim 5, characterized in that it consists in forming an identification matrix in which the rows correspond to the filter pairs and the columns correspond to the gases to be detected, an element i,j of said matrix being formed by the calibration value obtained for a pair i of filters in the presence of a known quantity of a gas j for detection, in forming a measurement vector whose rows correspond to the filter pairs and in which the element i represents the measurement made on filter pair i (e.g. a mean of values for the above-mentioned ratio for different points in the image of the observed zone), in calculating the correlation coefficients of the columns of the identification matrix with the measurement vector, and in comparing said coefficients with determined thresholds in order to deduce therefrom the presence and the concentration of the above-mentioned gases in the observed zone.

7/ A method according to any preceding claim, characterized in that it consists in using, for the purpose of forming one or more pairs of measurement and reference filters, a series of filters having transmission bands (1, 2, 3, 4, 5) which are spaced over an observation wavelength band and which optionally overlap, in obtaining an image of the observed zone in each transmission band, and in summing said images in order to reconstruct images seen through broad band measurement filters and images seen through broad band reference filters.

8/ A method according to claim 7, characterized in that the images in said narrow bands (1, 2, 3, 4, 5) are obtained simultaneously on parallel channels of an observation appliance.

9/ A method according to any preceding claim, characterized in that it consists in comparing the images obtained through the various filters with one another in order to detect relative movement between the observation means (10) and the observed zone (16) and/or movement within the observed zone (16), then in repositioning the images relative to one another prior to processing them, so as to eliminate the influence of the above-mentioned relative movement and/or so as to eliminate from said images those portions which correspond to movement within the observed zone (16).

10/ A method according to claim 9, characterized in that movement is detected by taking the difference between images at instants t and (t-1), by calculating a standard deviation, by comparing the standard deviation with a multiple threshold, by comparing the number of points retained at a given threshold in order to obtain a movement map, and by applying a binary AND function to the movement maps for instant t in the measurement images and the reference images.

11/ A method according to claim 10, characterized in that a difference at instant t is calculated between an image and an accumulated scene background updated by means of an ARMA type recursive filter from the image at instant t-1 and a map of points that have moved at instant t-1.

12/ A method according to any preceding claim, characterized in that the reference filters are synthesized filters made by stacking thin layers and having one or more narrow transmission stop bands, corresponding to the absorption lines of the gas(es) for detection.