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G2J JFN JF101

(56) Documents Cited
GB 2165941 A **EP 0703444 A1** **EP 0243139 A2**
US 5479019 A **US 5036198 A**

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UK CL (Edition O) **G1A ACDD ACDG , G2J JFN**
INT CL[6] **G01N 21/31 21/35 21/37**
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(54) Filter wheel for use in a gas filter correlation system

(57) Gas filter correlation apparatus for detecting the presence of a target gas within a sample chamber (8) comprises a rotatable filter wheel (4) through which infrared radiation from a source (2) passes into the sample chamber (8) and thence to a detector (16). The filter wheel (4) contains samples of the target gas and of a reference gas (e.g. an isotope of the target gas) which are successively interposed in the radiation path as the filter wheel (4) rotates. An alternating signal is therefore produced, since when the target gas is interposed by the filter wheel (4), the detector output will be unaffected by any target gas present in the sample chamber (8). The filter wheel (4) contains a plurality of small cells arranged around the periphery of the wheel (4), the cells alternately containing the target gas and the reference gas. One embodiment of the filter wheel contains alternate cells linked by common reservoirs of the target and reference gases which are located within the wheel construction.

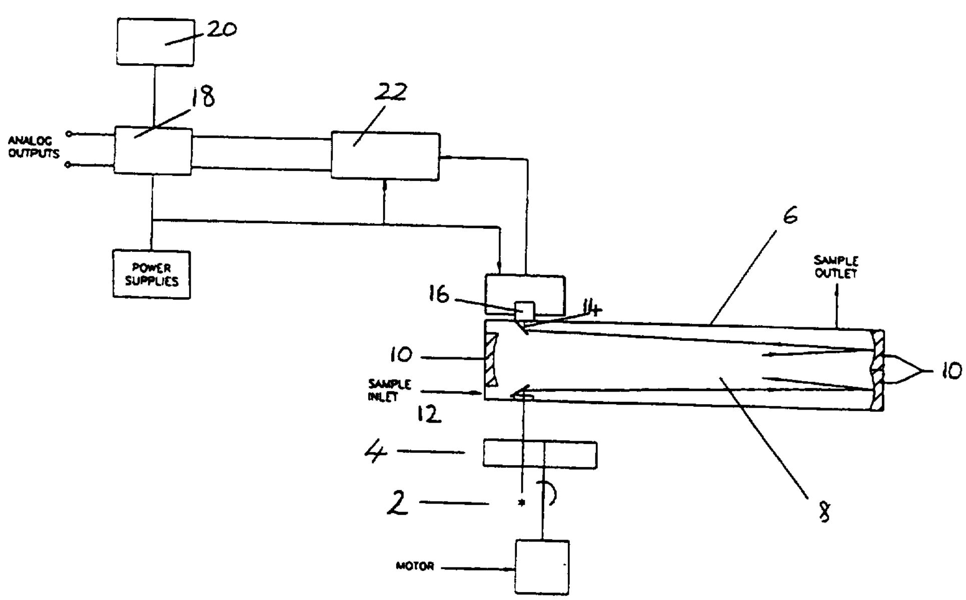


Figure 1

GB 2 314 411 A

The print reflects an assignment of the application under the provisions of Section 30 of the Patents Act 1977.

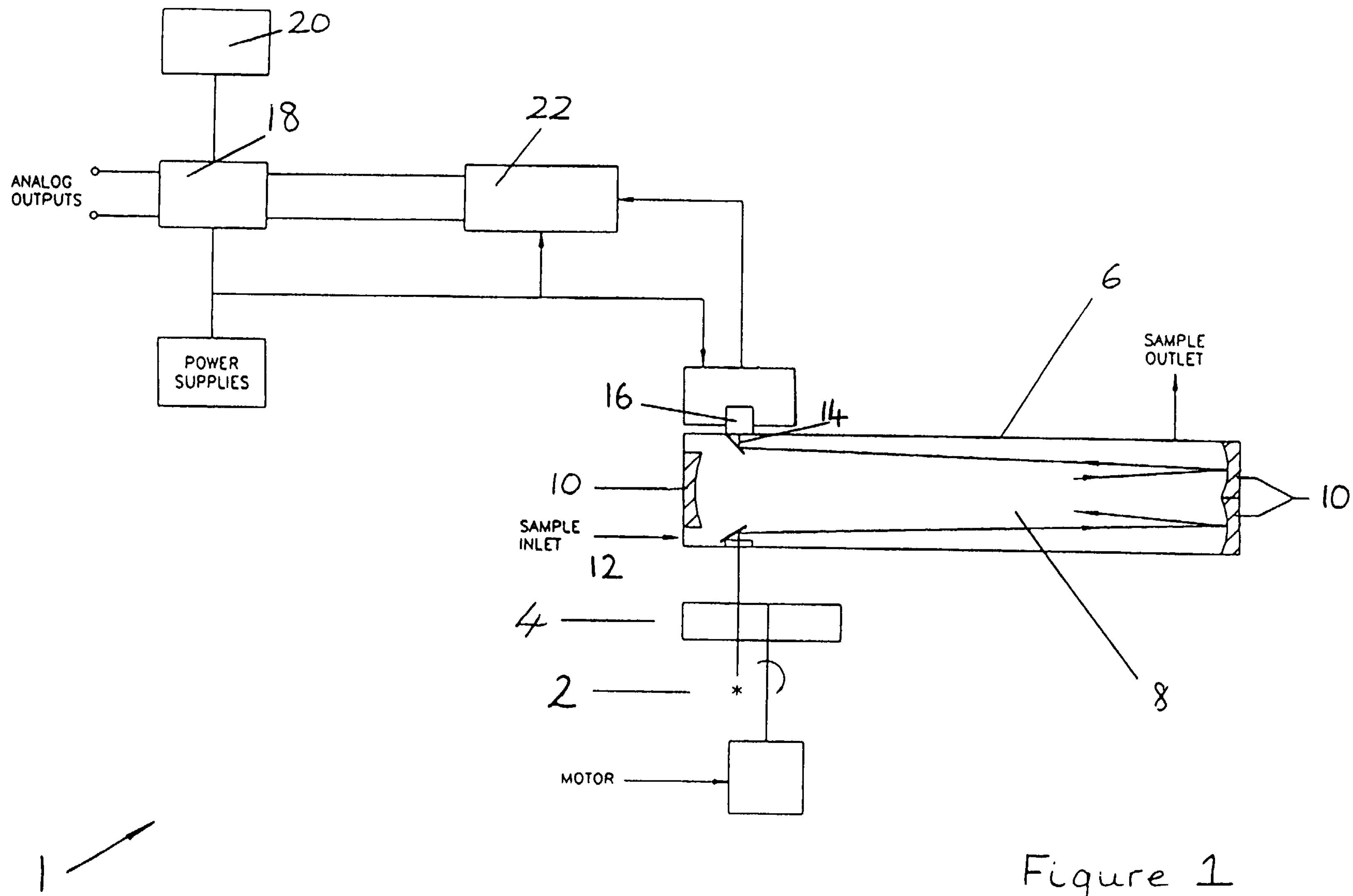

20
18
22
ANALOG OUTPUTS
POWER SUPPLIES
6
SAMPLE OUTLET
16
14
10
10
SAMPLE INLET
12
8
4
2
MOTOR
1

Figure 1

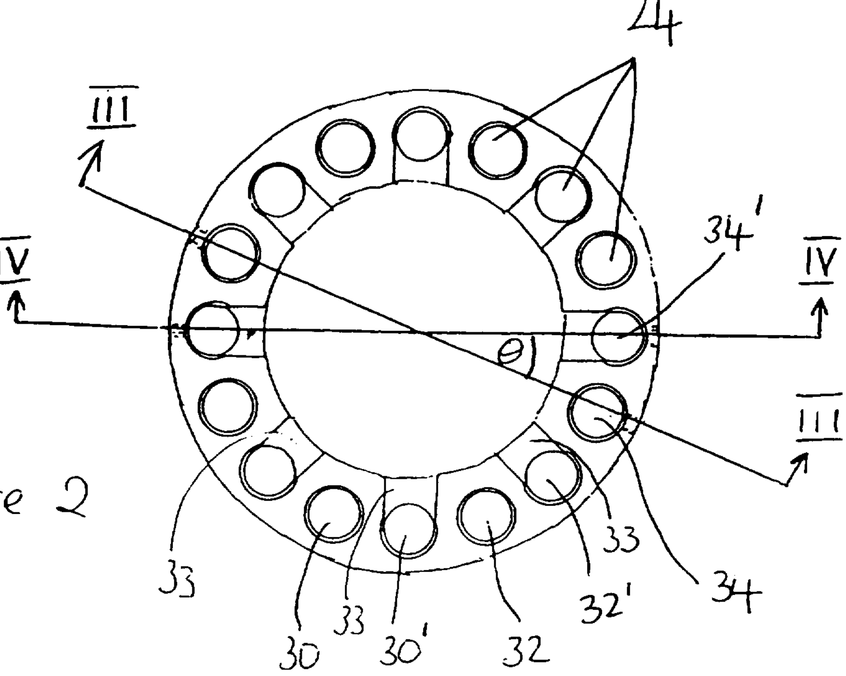


Figure 2

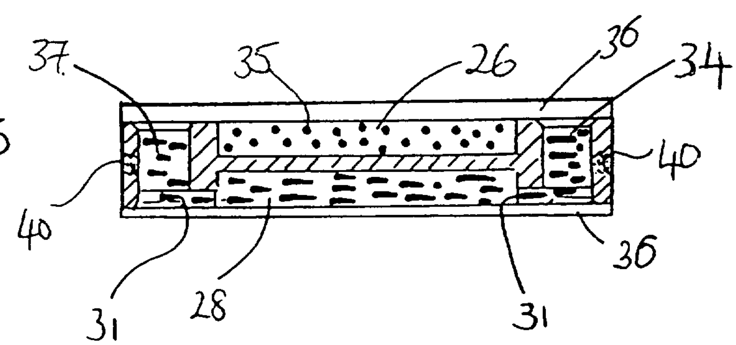


Figure 3

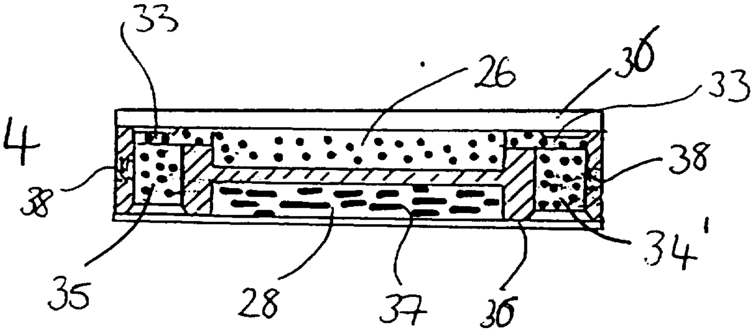
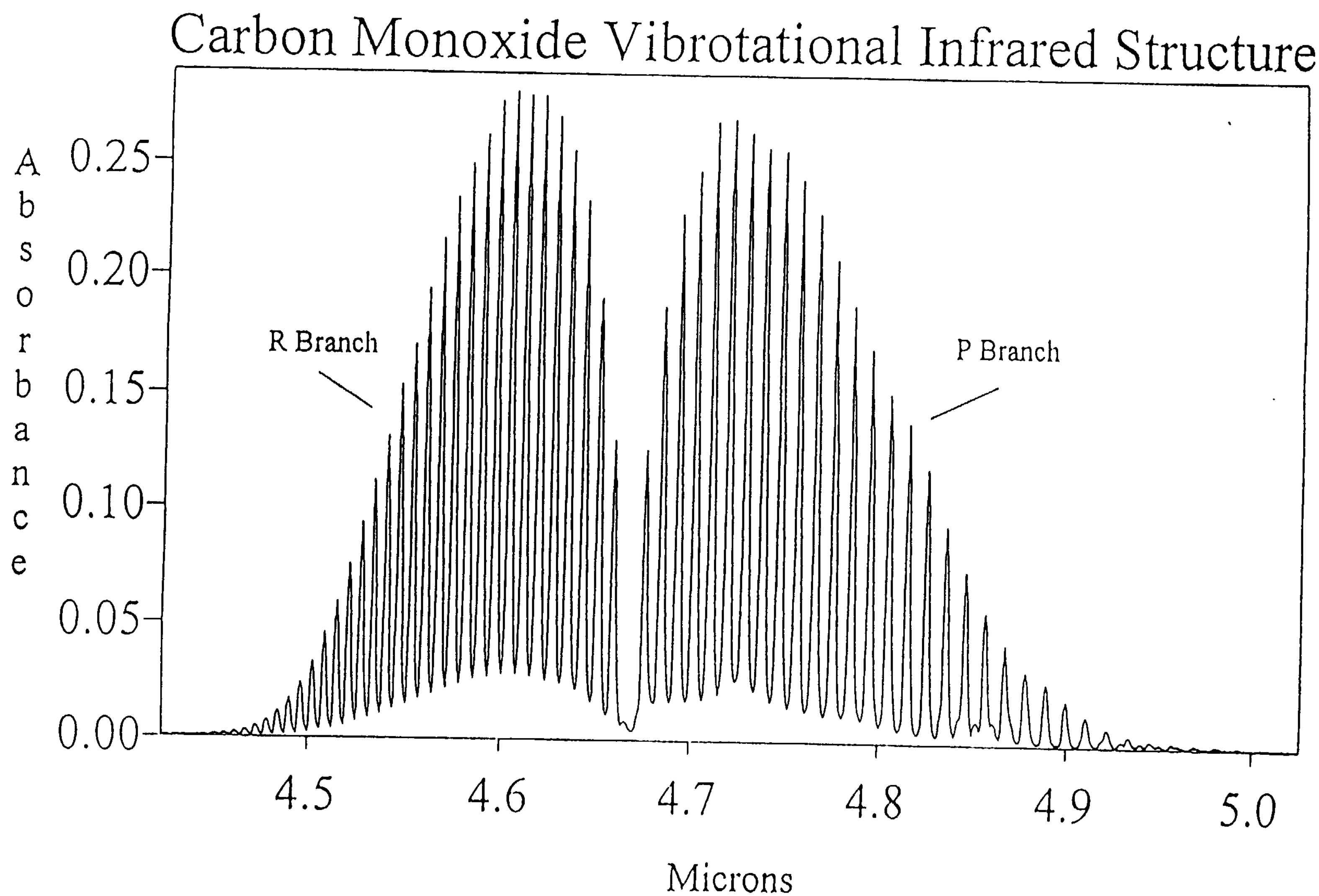


Figure 4

Figure 5



Carbon Monoxide Vibrotational Infrared Structure
R Branch
P Branch
Absorbance
0.25
0.20
0.15
0.10
0.05
0.00
4.5
4.6
4.7
4.8
4.9
5.0
Microns

INFRARED SPECTROSCOPY METHODS AND ARRANGEMENTS

The invention relates generally to infrared (IR) spectroscopy methods and arrangements. Infrared spectroscopy methods embodying the invention, and to be described in more detail below by way of example only, relate to gas filter correlation (GFC) infrared spectroscopy methods for the detection of carbon monoxide.

The technique of gas filter correlation spectroscopy offers improved sensitivity over conventional infrared techniques for the detection of toxic or explosive gases. Gas filter correlation spectroscopy detects these gases by measuring the infrared absorption characteristics of a sample of the atmosphere to be tested and comparing the resulting spectrum with the infrared absorption spectrum of a sample of the gas to be detected.

According to the invention, there is provided an axially rotatable filter wheel for a gas filter correlation spectrometer, comprising means defining a plurality of radiation-transmitting cells positioned side by side along a line concentric with the axis of the wheel whereby rotation of the wheel interposes the volume of each of the cells in turn, and any gas therein, in a predetermined radiation path, the volume within each cell being isolated from the volume in each of the next adjacent cells on each side.

According to the invention, there is further provided an axially rotatable filter wheel for a gas filter correlation spectrometer, the wheel having a rim formed with a plurality of axially directed bores arranged side by side around the rim, alternate ones of the bores being connected by respective radial connections to a first reservoir carried by the wheel and encompassed by the rim, intervening ones of the bores being connected by respective radial connections to a second reservoir carried by the wheel and encompassed by the rim and spaced axially from the first reservoir, and radiation transmitting means closing off the ends of all the bores to form respective cells, whereby rotation of the wheel positions each of the cells in turn, and any gas therein, in a predetermined radiation path.

According to the invention, there is also provided a method of detecting the presence of a gas ("target gas") in an atmosphere using a gas filter correlation technique in which a measurement radiation signal and a reference radiation signal are successively directed along a radiation path through the atmosphere to a detector which produces a successively varying signal in the presence of the target gas, the method comprising the steps of producing the reference signal by transmitting radiation through a sample of the target gas and producing the measurement signal by transmitting the radiation through a sample of an isotopic form of the target gas.

According to the invention, there is still further provided apparatus for detecting the presence of a gas ("target gas") in an atmosphere using a gas filter correlation technique in which a measurement radiation signal and a reference radiation signal are successively directed along a radiation path through the atmosphere to a detector which produces a successively varying signal in the presence of the target gas, the apparatus comprising means for producing the reference signal by transmitting the infrared radiation through a sample of the target gas, and means for producing the measurement signal by transmitting the infrared radiation through a sample of an isotopic form of the target gas.

Apparatus and methods according to the invention, for detecting gases using gas filter correlation techniques, will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram of one form of the apparatus;

Figure 2 is a front view of a filter wheel used in the apparatus of Figure 1;

Figure 3 is a cross-sectional view on line III-III of Figure 2;

Figure 4 is a cross-sectional view on line IV-IV of Figure 2; and

Figure 5 is the infrared absorption spectrum for carbon monoxide.

The basic components of a gas filter correlation spectrometer for the detection of carbon monoxide are shown in Figure 1. The spectrometer 1 comprises an infrared light source 2 incident on a rotatable gas filter wheel 4 adjacent a multipass optical bench 6 and sample chamber 8. The optical bench 6 and sample chamber 8 contain a series of relay and field mirrors 10. The optical bench 6 is further provided with a radiation inlet 12, adjacent the gas filter wheel 4, and a radiation outlet 14. An infrared detector 16 is situated at the radiation outlet 14 such that any radiation transmitted through the outlet 14 is incident on the detector.

The output of the infrared detector 16 is connected to a microcomputer 18 and digital display 20 via a signal processor and demodulator 22.

The filter wheel 4 is shown in detail in Figures 2 and 3 in which corresponding parts are similarly referenced.

The filter wheel 4 is provided with a series of countersunk cylindrical holes 24 positioned at regular intervals around the circumference of the wheel 4. The filter wheel 4 is further provided with two reservoirs 26,28, the first reservoir 26 being positioned centrally on a first side of the wheel 4 and the second reservoir 28 being positioned centrally on a second side of the wheel 4. The reservoirs 26,28 are isolated from each other.

Holes 30,32,34 and all subsequent alternate holes form a first set of holes each hole being individually connected to the reservoir 28 by an axially directed channel 31, two of which are shown in Figure 3. The remaining holes 30',32',34', and the remaining alternate holes, form a second set of holes each hole being individually connected to the reservoir 26 by axially directed channels 33 as shown in Figure 2.

Each side of the filter wheel 4 is sealingly covered with an infrared transparent material 36. The infrared transparent material 36, when in place over the first and second sides of the filter wheel 4, isolates the first set of holes 30,32,34 the channels 31 and the reservoir 28 from the second set of holes 30',32',34' the channels 33 and the reservoir 26. In this way, the holes 30,32,34 form a series of cells connected to reservoir 28 and the holes 30',32',34' form a series of cells connected to reservoir 26. Reservoir 26, and hence the second set of cells, 30',32' and 34' are filled with carbon monoxide gas 35. Reservoir 28, and hence the first set of cells 30,32,34, are filled with a form of carbon monoxide ($^{12}C^{18}O$) in which one of the constituent atoms has been replaced by a different isotope.

For example in $^{12}C^{18}O$ the oxygen atom (^{16}O) has been replaced with a heavy oxygen isotope (^{18}O). It will be appreciated that it need not be the oxygen that is replaced, the carbon may also be replaced, and the oxygen need not be replaced with a heavy oxygen isotope, any suitable oxygen isotope may be used. For ease, the term isotope will be used to denote a molecule where one or more of the atoms has been substituted.

The reservoirs 26,28 are filled via gas inlets 38,40 respectively.

In use, infrared radiation from the infrared light source 4, is incident on the rotating filter wheel 4. As the filter wheel 4 rotates, the cells are successively placed in the infrared beam. The resulting radiation transmitted through either the carbon monoxide 35 or the carbon monoxide isotope 37 contained in the cells 30,32 or 30',32' respectively then passes into the optical bench 6 and sample chamber 8, where absorption by the sample gas occurs. The radiation is reflected via the mirrors 10 and exits the sample chamber 8 via the radiation outlet 14 and falls on the infrared detector 16. The infrared detector 16 produces a signal which is processed by the signal processor and demodulator 22 and recorded by the microcomputer 18.

The rotating filter wheel 4 acts to produce a reference radiation beam and a sample radiation beam. The operation is explained with reference to Figure 5 which shows the absorption spectrum of carbon monoxide. When the radiation is incident on cell 30', for example, which is filled with carbon monoxide gas 35, the radiation transmitted through the cell cannot be further attenuated by any carbon monoxide in the gas contained in the sample chamber 8. The resulting radiation detected by the infrared detector 16 is thus a reference signal characteristic of the gas in the sample chamber excluding any carbon monoxide therein. The cells 30',32',34' are termed the reference cells.

The filter wheel 4 then rotates through an angle θ and the infrared radiation produced by the infrared light source 2 will be incident on cell 30. Cell 30 is filled with a heavy oxygen isotope of carbon monoxide $^{12}C^{18}O$ and the resulting infrared radiation transmitted through the chamber 30 enters the sample chamber 8. In a similar manner to that described above, the radiation is reflected via the mirrors 10 through the gas contained in the sample chamber 8. The isotope is selected so that it absorbs radiation within the radiation band (see Figure 5). However, the individual components of the absorption do not overlap. Thus, the isotopic and the non-isotopic carbon monoxide absorb in the same spectral region but one gas cannot absorb radiation that would be absorbed by the other. Therefore, any non-isotopic carbon monoxide present in the sample chamber 8 will absorb some of the radiation which has passed through cell 30 and this will be detected by the infrared radiation detector whose output is therefore characteristic of any carbon monoxide in the sample chamber 8. Cells 30,32,34 are termed the measurement cells.

The filter wheel 4 then rotates through an angle θ and the infrared radiation produced by the infrared light source 2 will be incident on chamber 32 and the process will repeat.

In this way, the signal produced by the detector 16 is modulated by the alternation between the two gas filters, carbon monoxide 35 and the heavy oxygen isotope 37 of carbon monoxide $^{12}C^{18}O$, and the amplitude of the signal is therefore related to the concentration of carbon monoxide gas in the sample chamber 8. Other gases present in the sample chamber 8 do not cause modulation of the detector signal as they absorb the reference and measurement beams equally. Thus, the system responds specifically to carbon monoxide.

The use of a heavy oxygen isotope of carbon monoxide $^{12}C^{18}O$ in the measurement cells causes the radiation to be absorbed at wavelengths displaced due to an isotopic shift. The concentration of isotopically selected carbon monoxide can be adjusted to produce exactly the same absorption as the cells full of carbon monoxide. The system will therefore produce a zero signal in the absence of carbon monoxide in the sample chamber 8. In order to produce such a zero signal in the presence of interferant gases, it is necessary to ensure that neither the absorption of the carbon monoxide in the reference cells nor the absorption of the isotopic carbon monoxide in the measurement cells overlaps the absorption due to the interferant gases, but for common interferants such as water or ammonia, this is usually the case.

It will be appreciated that other isotopes of carbon monoxide such as $^{13}C^{16}O$ could be used to fill the measurement cells.

It will also be appreciated that if the system is to be used to detect other target gases, instead of the carbon monoxide, it will be necessary to substitute both the carbon monoxide and the isotopic carbon monoxide with the gas to be detected and a suitable isotope of that gas.

Instead of filling the measurement cells with the isotope 37 of carbon monoxide, however, a different sample of a gas transparent to infrared radiation such as nitrogen can be used. Although this produces a sample signal dependent only on the carbon monoxide present in the sample chamber 8, a non-zero signal will result if there is no carbon monoxide in the sample chamber 8. This signal can be offset to zero by placing a neutral density filter in line with the measurement cells. This causes the system to read zero when there is no carbon monoxide in the sample chamber. However, this renders the system sensitive to the presence of any interferant gases such as water or ammonia. Therefore, it is not possible simultaneously to minimise the zero offset and the effect of any interferants.

Most infrared detectors are affected by noise inversely related to the frequency. It is therefore desirable that the calculation data is encoded at the highest possible frequency. The filter wheel 4 described above is therefore advantageous because the multiple number of reference and measurement cells encodes the calculation data at a relatively high frequency. In the example described, the gas concentration information will be encoded at a frequency equal to half the chopping frequency. It will be appreciated that it is possible to vary the number of cells provided on the filter wheel to further increase the rate of encoding the data for the same rotational speed.

The filter wheel 4 is thus advantageous over types of filter wheel having only two cells each occupying half the area of the wheel. Such cells are generally D-shaped and are joined together along their straight edges by a partition wall the length of the diameter of the wheel. In effect, the wheel is divided into two cells. One cell is the measurement cell and the other the reference cell. A multi-bladed chopper mask is attached to one face of the wheel. As the wheel spins, the transmitted radiation is modulated on-off with a 50% duty cycle. Information about the optical integrity of the system is encoded at the chopping frequency whilst the data needed to calculate the concentration of carbon monoxide is encoded at the rotational frequency, i.e. 16 x lower than the chopping frequency. However, although such two-cell types of filter wheel do not encode the calculation data at the desired high frequency, under certain circumstances they may be used in the apparatus described with the reference cell filled with the carbon monoxide (or other gas to be detected in the sample chamber) and with the measurement cell filled with the isotope of the carbon monoxide or other gas.

CLAIMS

1. An axially rotatable filter wheel for a gas filter correlation spectrometer, comprising means defining a plurality of radiation-transmitting cells positioned side by side along a line concentric with the axis of the wheel whereby rotation of the wheel interposes the volume of each of the cells in turn, and any gas therein, in a predetermined radiation path, the volume within each cell being isolated from the volume in each of the next adjacent cells on each side.

2. A wheel according to claim 1, in which the volumes of alternate ones of the cells are connected together to form a first common volume and the volumes of the intervening cells are connected together to form a second common volume which is isolated from the first common volume.

3. A wheel according to claim 2, including a first reservoir connected to the first volume and a second reservoir connected to the second volume.

4. A wheel according to claim 3, in which the first and second reservoirs are mounted within the area of the wheel encompassed by the concentric line.

5. A wheel according to claim 4, in which the first and second reservoirs are axially separated on the wheel.

6. An axially rotatable filter wheel for a gas filter correlation spectrometer, the wheel having a rim formed with a plurality of axially directed bores arranged side by side around the rim, alternate ones of the bores being connected by respective radial connections to a first reservoir carried by the wheel and encompassed by the rim, intervening ones of the bores being connected by respective radial connections to a second reservoir carried by the wheel and encompassed by the rim and spaced axially from the first reservoir, and radiation transmitting means closing off the ends of all the bores to form respective cells, whereby rotation of the wheel positions each of the cells in turn, and any gas therein, in a predetermined radiation path.

7. A wheel according to any one of claims 1 to 5, in which the alternate cells contain the gas ("target gas") to be detected by the gas filter correlation spectrometer, and the intervening cells contain a gas having absorption characteristics for the radiation which are different from those of the gas to be detected.

8. A wheel according to any one of claims 3 to 6, in which the

first reservoir and the cells connected thereto contain the gas to be detected by the gas metre correlation spectrometer, and the second reservoir and the cells connected thereto contain a gas ("other gas") having absorption characteristics for the radiation which are different from those of the gas to be detected.

9. A wheel according to claim 7 or 8, in which the other gas is an isotope of the target gas, the isotope being selected so that it absorbs the said radiation to an extent matching the absorbance thereof by the target gas but at wavelengths displaced relative to the absorbance wavelengths of the target gas.

10. A wheel according to claim 9, in which the target gas is carbon monoxide and the other gas is the heavy oxygen isotope of carbon monoxide.

11. A method of detecting the presence of a gas ("target gas") in an atmosphere using a gas filter correlation technique in which a measurement radiation signal and a reference radiation signal are successively directed along a radiation path through the atmosphere to a detector which produces a successively varying signal in the presence of the target gas, the method comprising the steps of producing the reference signal by transmitting radiation through a sample of the target gas and producing the measurement signal by transmitting the radiation

through a sample of an isotopic form of the target gas.

12. Apparatus for detecting the presence of a gas ("target gas") in an atmosphere using a gas filter correlation technique in which a measurement radiation signal and a reference radiation signal are successively directed along a radiation path through the atmosphere to a detector which produces a successively varying signal in the presence of the target gas, the apparatus comprising means for producing the reference signal by transmitting the infrared radiation through a sample of the target gas, and means for producing the measurement signal by transmitting the infrared radiation through a sample of an isotopic form of the target gas.

13. A method or apparatus according to claim 11 or 12, in which the isotope is selected so that it absorbs the said radiation at wavelengths different from those absorbed by the target gas.

14. A method or apparatus according to claim 13, in which the wavelengths of the radiation absorbed by the target gas and the wavelengths of the radiation absorbed by the isotope do not overlap the wavelengths absorbed by predetermined interferant gases.

15. A method or apparatus according to any one of claims 11 to 14, in which the target gas is carbon monoxide and the isotope is the heavy oxygen isotope of carbon monoxide.

16. A method or apparatus according to any one of claims 11 to 15, in which the radiation is infrared radiation.

17. A rotatable filter wheel for a gas filter correlation spectrometer, substantially as described with reference to Figures 2,3 and 4 of the accompanying drawings.

18. A method of detecting a target gas using a gas filter correlation technique, substantially as described with reference to the accompanying drawings.

19. Apparatus for detecting a target gas using gas filter correlation techniques, substantially as described with reference to the accompanying drawings.

Application No:	GB 9613007.5	**Examiner:**	James Porter
Claims searched:	1-10, 17	**Date of search:**	31 October 1996

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): G1A (ACDD, ACDG). G2J (JFN)

Int Cl (Ed.6): G01N 21/31, 21/35, 21/37

Other: Online database: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB2165941 A	(LAND COMBUSTION) See p2 lines 52-68	1, 7
X	EP0703444 A1	(MARQUETTE) See p3 line43 to p5 line 18	1, 7
X	EP0243139 A2	(PROCAL) See col. 3 line 54 to col. 4 line 7	1, 7
X	US5036198 A	(BODENSEEWERK) See col. 3 lines 44-62	1, 7

X Document indicating lack of novelty or inventive step
Y Document indicating lack of inventive step if combined with one or more other documents of same category.
& Member of the same patent family
A Document indicating technological background and/or state of the art.
P Document published on or after the declared priority date but before the filing date of this invention.
E Patent document published on or after, but with priority date earlier than, the filing date of this application.

Application No:	GB 9613007.5	**Examiner:**	James Porter
Claims searched:	11-16	**Date of search:**	26 February 1997

Patents Act 1977
Further Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): G1A (ACDD, ACDG)

Int Cl (Ed.6): G01N 21/31, 21/35, 21/37

Other: Online database: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	US5479019 A (MIC)	-

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.