TÜV RHEINLAND IMMISSIONSSCHUTZ
UND ENERGIESYSTEME GMBH

Akkreditiertes Prüfinstitut

Deutscher Akkreditierungs Rat DAR

DAP-PL-3856.99

Translation of the report on the suitability test of the multi-component air measuring system airpointer of the company recordum Messtechnik GmbH for the components NO, NO_2, NO_x, SO_2, O_3 and CO

TÜV Report: 936/21209700/A
Cologne, 01/15/2009

www.umwelt-tuv.de

luft@de.tuv.com

TÜV Rheinland Immissionsschutz und Energiesysteme GmbH holds an accreditation under the terms of DIN EN ISO/IEC 17025 in the following fields of work:

- Determination of emissions and immissions of air pollutants and odorants;
- Verification of the correct installation and the function as well as the calibration of continuous operating emission measuring systems including systems for data evaluation and remote monitoring of emissions;
- Suitability testing of measuring systems for continuous monitoring of emissions and immissions as well as for electronic systems for data evaluation and remote monitoring of emissions

The accreditation is valid up to 01/31/2013. DAR registriation number: DAP-PL-3856.99.

Akkreditiertes Prüfinstitut

Deutscher Akkreditierungs Rat
DAR

DAP-PL-3856.99

Translation of the report on the suitability test of the multi-component air measuring system airpointer of the company recordum Messtechnik GmbH for the components NO, NO_2, NO_x, SO_2, O_3, and CO

Measuring system tested:	airpointer
Manufacturer of the instrument:	recordum Messtechnik GmbH Jasmirgottgasse 5 A-2340 Mödling Austria
Time period of testing:	April 2008 to January 2009
Date of report:	01/15/2009
Report number:	936/21209700/A
Editor:	Dipl.-Ing. Martin Schneider martin.schneider@de.tuv.com Tel.: ++49 221 806-1614
Liable for the contents:	Dr. Peter Wilbring
Scope of the report:	In total 85 pages (this excerpt). Complete report with 468 pages.

Table of contents

1. Summary and Proposal for Declaration of Suitability

Abstract

By order of recordum Messtechnik GmbH the TÜV Rheinland Immissionsschutz und Energiesysteme GmbH has accomplished the suitability test of the measuring system airpointer for the components NO_x, SO_2, O_3, and CO.

The testing was performed in accordance with the following guidelines and requirements:

- VDI 4202 Part 1: Minimum requirements for suitability tests of automated ambient air quality measuring systems; Point-related measurement methods of gaseous and particulate pollutants, from June 2002
- VDI 4203 Part 3: Testing of automated measuring systems; Test procedures for point-related ambient air quality measuring systems of gaseous and particulate pollutants, from August 2004
- DIN EN 14211 Ambient air quality – Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence, from June 2005
- DIN EN 14212 Ambient air quality – Standard method for the measurement of the concentration of sulphur dioxide by ultraviolet fluorescence, from June 2005
- DIN EN 14625 Ambient air quality – Standard method for the measurement of the concentration of ozone by ultraviolet photometry, from July 2005
- DIN EN 14626 Ambient air quality – Standard method for the measurement of the concentration of carbon monoxide, from July 2005

The measuring system tested operates using the respective EU reference methods. The tests took place in a laboratory and during a field test with a duration of three months as an endurance test. The tested measuring ranges are:

Components		Ranges	
		VDI 4202	EN standards
Nitrogen monoxide	NO	-	1200 µg/m³ *
Nitrogen dioxide	NO_2	400 µg/m³	500 µg/m³ *
Sulphur dioxide	SO_2	700 µg/m³	1000 µg/m³ **
Ozone	O_3	360 µg/m³	500 µg/m³ ***
Carbon monoxide	CO	60 mg/m³	100 mg/m³ ****

* DIN EN 14211; ** DIN EN 14212; *** DIN EN 14625; **** DIN EN 14626

The minimum requirements have been fulfilled in the suitability test.

Therefore, the TÜV Rheinland Immissionsschutz und Energiesysteme GmbH proposes the publication as suitability-tested measuring system for continuous monitoring of nitrogen oxides, sulphur dioxide, ozone, and carbon monoxide in ambient air.

The measuring system is a multi-component analyzer for monitoring NO, NO_2, NO_x, SO_2, O_3, and CO. To provide an improved overview, the report is structured as follows:

Chapter 1 contains a summary and the declaration of suitability.

Chapter 2 describes the terms of reference and the objective of the suitability test.

Chapter 3 provides a description of the tested system.

Chapter 4 contains the test program.

Chapter 5 describes the reference method.

Chapter 6 sums up the test results and the total uncertainty calculation as follows:

Paragraph 6.1 contains the test results according to VDI 4202 for the components NO_2, SO_2, O_3, and CO.

Paragraph 6.2 contains the test results and the uncertainty calculation according to DIN EN 14211 for the component NO.

Paragraph 6.3 contains the test results and the uncertainty calculation according to DIN EN 14212 for the component SO_2.

Paragraph 6.4 contains the test results and the uncertainty calculation according to DIN EN 14625 for the component O_3.

Paragraph 6.5 contains the test results and the uncertainty calculation according to DIN EN 14626 for the component CO.

Chapter 7 contains recommendations for the use in practice.

Chapter 8 provides the literature.

1.1 Proposal for Declaration of Suitability

Due to the postive results, the following recommendation for declaration of suitability as suitability-tested measuring system is given:

1.2 Device designation : airpointer

1.2.1 Software revision 1.001 (analytical module)

1.3 Measured components : NO, NO_2, NO_x, SO_2, O_3, and CO

1.4 Manufacturer : recordum Messtechnik GmbH
Jasomirgottgasse 5
A-2340 Mödling
Austria

1.5 Suitability : Continuous immission measurement of nitrogen oxide, sulphur dioxide, ozone, and carbon monoxide

1.6 Measuring ranges during the suitability test :

Measuring ranges according to VDI 4202

Component	Range	Unit
NO_2	0 - 400	µg/m³
SO_2	0 - 700	µg/m³
O_3	0 - 360	µg/m³
CO	0 - 60	mg/m³

Measuring ranges according to EN standards

Component	Range	Unit
NO	0 - 1200	µg/m³
NO_2	0 - 500	µg/m³
SO_2	0 - 1000	µg/m³
O_3	0 - 500	µg/m³
CO	0 - 100	mg/m³

1.7 Restrictions : -

1.8 Remarks : 1. The airpointer measures NO, NO_2, NO_x, SO_2, O_3, and CO independently from each other. Thus the declaration of suitability comprises the following models:

Product name	Model	Component 1	Component 2	Component 3	Component 4
airpointer	1000	NO_x			
airpointer	0100	SO_2			
airpointer	0010	CO			
airpointer	0001	O_3			
airpointer	1100	NO_x	SO_2		
airpointer	1010	NO_x	CO		
airpointer	1001	NO_x	O_3		
airpointer	0110	SO_2	CO		
airpointer	0011	CO	O_3		
airpointer	0101	SO_2	O_3		
airpointer	1110	NO_x	SO_2	CO	
airpointer	1101	NO_x	SO_2	O_3	
airpointer	1011	NO_x	CO	O_3	
airpointer	0111	SO_2	CO	O_3	
airpointer	1111	NO_x	SO_2	CO	O_3

1.9 Test institute : TÜV Rheinland Immissionsschutz und Energiesysteme GmbH, Köln
TÜV Rheinland Group

1.10 Test report : 936/21209700/A of 01/15/2009

2. Terms of Reference

2.1 Kind of Testing

On behalf of the company recordum Messtechnik GmbH, TÜV Rheinland Immissionsschutz und Energiesysteme GmbH performed a complete suitability test for the multi-component measuring system airpointer for defining NO, NO_2, NO_x, SO_2, O_3, and CO. Additionally, the measuring sytem can be equipped with modules for monitoring PM2.5, PM10, NH_3, H_2S, VOC, electrochemical cells, traffic counting modules and modules for recording meteorological data, none of which is influencing the actual measurement.

2.2 Objective

The goal of the test was to show that the measuring system fulfills the German minimum requirements according to VDI 4202 part 1 and the requirements according to DIN EN 14211, DIN EN 14212, DIN EN 14625, and DIN EN 14626. For this purpose, the measuring system has been tested in the following measuring ranges (Table 1):

Table 1: Tested measuring ranges

Component		Measuring Range	
		VDI 4202	EN Standards
Nitrogen monoxide	NO	-	1200 µg/m³ *
Nitrogen dioxide	NO_2	400 µg/m³	500 µg/m³ *
Sulphur dioxide	SO_2	700 µg/m³	1000 µg/m³ **
Ozone	O_3	360 µg/m³	500 µg/m³ ***
Carbon monoxide	CO	60 mg/m³	100 mg/m³ ****

* DIN EN 14211; ** DIN EN 14212; *** DIN EN 14625; **** DIN EN 14626

3. Description of the Tested System

3.1 Measuring Principle

The airpointer gas modules utilize different types of optical detection principles. The following sections provide an overview of the underlying optical principles and contribute to a better understanding of the results provided by the airpointer. Figure 1 depicts a diagram of the wavelengths used by each gas module detector.

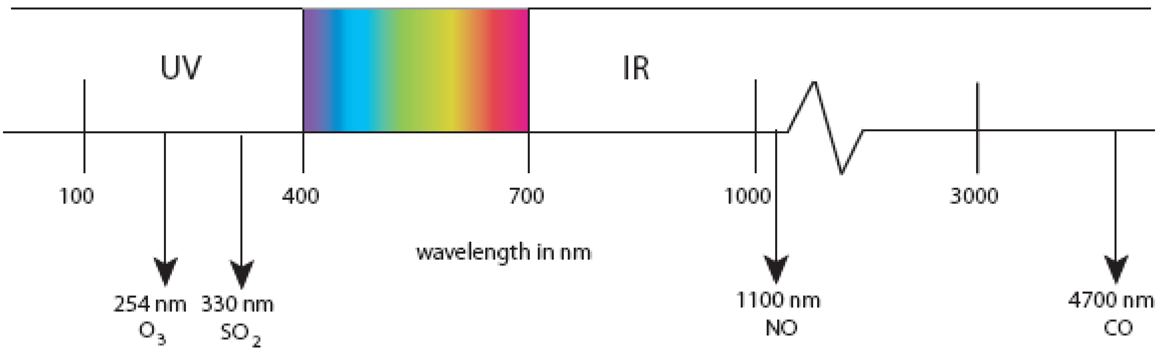

Figure 1: Wavelengths of the measured pollutants

3.1.1 Chemiluminescence (NO_x Module)

Chemiluminescence is energy release in the form of electromagnetic radiation during a chemical reaction. The initial reaction results in electrically exited molecules which release their excess energy by emitting a photon and dropping to a lower energy level. The light intensity produced is directly proportional to the concentration of excited molecules. The related processes are similar to those of light absorption and scattering but are using chemical energy as the exciting source instead of an external light.

3.1.2 UV Fluorescence (SO_2 Module)

Fluorescence is an optical phenomenon in cold bodies in which a molecule absorbs a high-energy photon by exciting an electron and reemitting it as a then lower-energy (longer wavelength) photon. The electron does not fall back into its initial state. The energy difference between the absorbed and emitted photons ends up as molecular vibrations (heat) and the electron returns to the ground state (see Figure 2). Usually, the absorbed photon is in the ultraviolet and the emitted light is in the visible range. The process of an uptake of electromagnetic radiation followed by an immediate release of energy in the form of directionally spread light intensity is called 'light scattering'. Normally, this process does not change the wavelength of light, this is called ’elastic light scattering’. In this respect, fluorescence is a special kind of light scattering with a change of wavelength involved (a so-called ’inelastic scattering’).

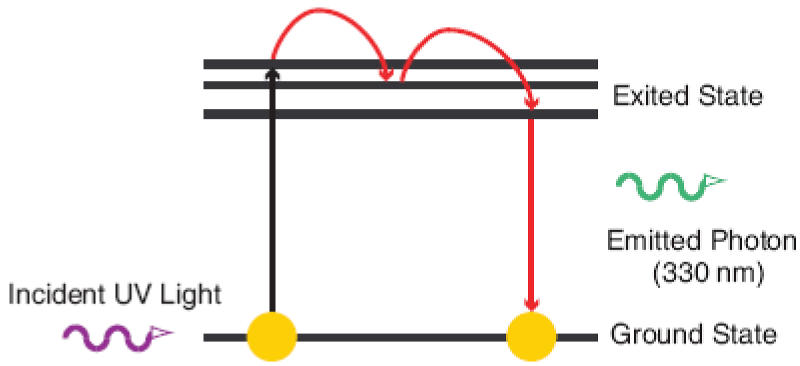

Figure 2: Fluorescence

3.1.3 UV Absorption (O_3 Module)

Every atom consists of positive charges (protons) in its core and the same number of negative charges (electrons) in its shell. The atom as a whole is therefore electrically neutral. Each electron is on a separated level (orbital). The orbitals of several atoms superpose each other in a way to get into an advantageous energetic state and form a molecule. By exciting the electrons with external energy they can be lifted to a higher level from where they actually are. Energetic excitation may be possible by UV light. Their amount of energy is described by the following formula:

$$E = hc / \lambda = h\nu$$

h Planck's constant ($6.6261 \cdot 10^{-34}$ Js)
c Speed of light ($3 \cdot 10^{8}$ m/s)
λ Wavelength of the UV light
ν Frequency of the UV light

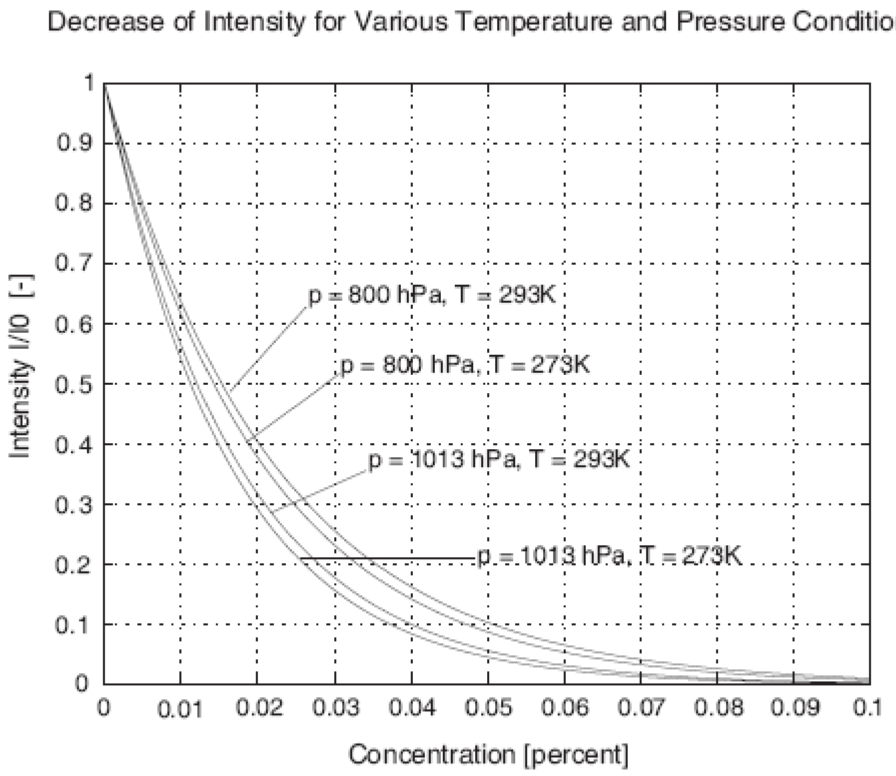

Figure 3: The law of absorption by Lambert and Beer

Because this excited state is not stable, this electron returns to its original state immediately and emits a photon to get rid of its additional energy. The gaps between the energetic levels vary depending on the kind of molecule. This leads to characteristic spectra of the emitted radiation and to an easy distinguishing between various compounds by measuring the emitted light (photons).

3.1.4 IR Absorption (CO Module)

From a macroscopic point of view, molecules are – just like the atoms – electrically neutral. The free electrons of the atoms form an 'electron cloud' that spreads all over the molecule and compounds the atoms. However, the electrons do not spread evenly but accumulate in centers of charge. The reason for this is the different electro-negativity of the elements, i.e. the negative charges are variably attracted.

Therefore, with microscopic dimensions at the scale of the atoms, most molecules have an electrical polarization and this leads to the development of a dipole momentum. For example, water molecules (H_2O) have their negative center of charge on the side of the oxygen atom because oxygen has a higher electro-negativity than hydrogen. Symmetric molecules do not have such a permanent dipole momentum. However, infrared (IR) rays may force them to vibrate so that the centers of charge start to shift and cause a temporary dipole momentum. IR rays are too weak to excite electrons like UV rays. Absorption in the IR spectrum usually is not caused by transitions of electrons but by the induction of dipole momenta. The molecules in gases vibrate and rotate. Therefore, the dipole momentum is continuously changing and an electromagnetic wave develops just like an open oscillating circuit (i.e an antenna).

If the incidental IR ray is just an opposite phase to the excited ray, the two waves annihilate each other (destructive interference) which means that the incident rays are absorbed.

The masses of the atoms have to be taken into account as well. To illustrate this, one can imagine the molecule as a compound of punctiform masses attached to each other by scroll springs. The heavier the atoms are, the slower they vibrate and hence absorb in the long wave IR spectrum. Any remaining radiation may be measured with a detector. The spectrum yields information about the constitution of the molecule.

3.2 System Gas Flow

The gas flow diagrams in Figures 4 to 7 illustrate the gas flow inside each single airpointer module.
The ambient air to be monitored enters the airpointer through the sample inlet above. The sample gas passes the inlet filter and is led to the modules where the various measurements are done. It then passes the system pump (double piston pump) and exits the device.

3.2.1 Gas Flow Through the NO_x Module

1. The sample gas reaches valve D which switches between sample and zero.

2. Valve A and auto zero valve C in 'normal open (NO)' mode for NO measurement:

   a) The sample gas passes valve D and the perma pure dryer. It is then led through the valve A and the auto zero valve C into the NO_x reaction cell.
   b) Ambient air is drawn through the DFU filter and the inner line of the perma pure dryer.
   c) One part of this ambient air is returned through the capillary 2 to the outer line of the dryer and further on to the system pump.
   d) The dried air from the inner line of the dryer passes a flow sensor and runs through the O_3 generator and the cleanser and finally enters the NO_x reaction cell where it then reacts with the sample gas (NO measurements).
   e) Afterwards the gas passes the ozone destroyer to keep the exhaust gas free of O_3.
   f) The gas from the dryers and the reaction cell passes to the system pump and exits the airpointer.

3. At the same time a part of the original sample gas is drawn in to the delay loop and saved there for the NO_x measurements.

4. Valve A in NC mode (normal closed) for NO_x measurement:

   a) The sample air passes the auto zero valve D, the sample dryer, and is drawn to the pump.
   b) The sample air is stored in the delay loop and is converted in the molybdenum converter. It then runs through the valve A and on through the auto zero valve C to the reaction cell (NO_x-measurement).

5. Auto zero valve C in NC mode (offset measurement):

    a) Sample gas can not reach the reaction cell. Only O_3 from the generator flows through the reation cell. This flow provides the zero offset measurement.

    b) The O_3 is drawn through the ozone destroyer to the system pump.

    c) At the same time the sample gas from the NO/NC valves is drawn to the system pump.

6. Flow, temperature, and pressure are monitored as well.

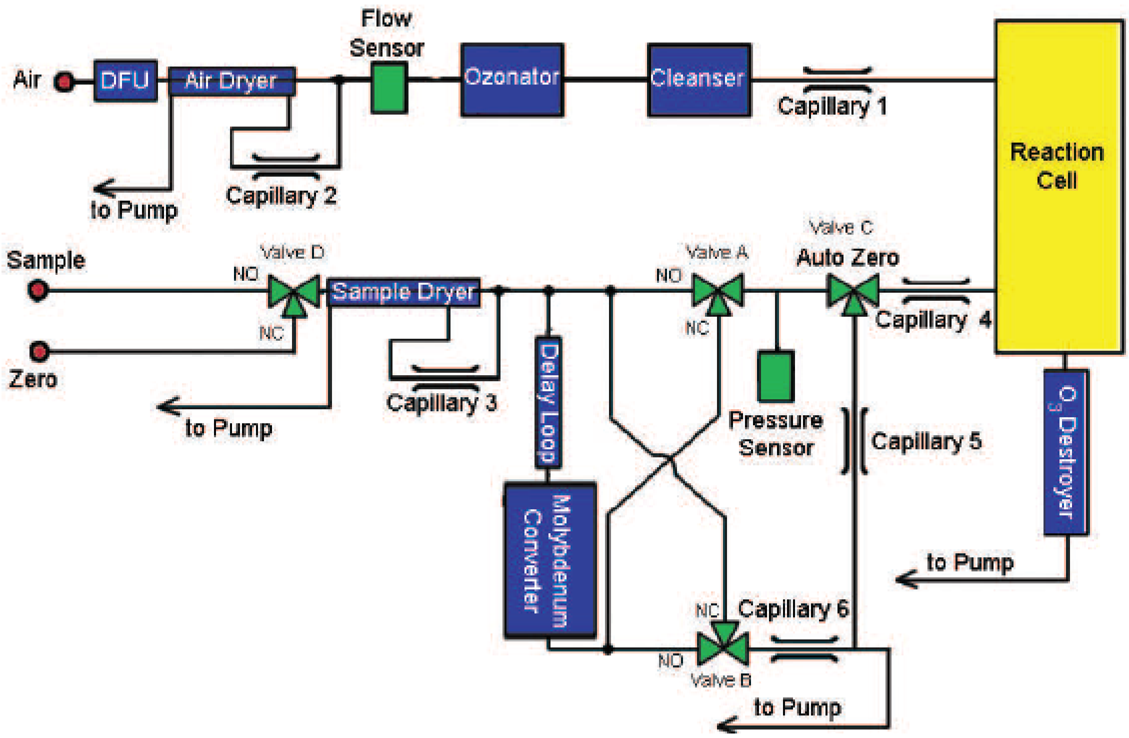

Figure 4: Flow diagram of NO_x modules

3.2.2 Gas Flow Through the SO_2 Module

1. The sample gas reaches the scrubber, which removes hydrocarbons from the sample air. The scrubber works similarly to the perma pure dryer of the NO_x module with simply a different membrane.

2. The gas flows from the scrubber to the SO_2 reaction cell, then back through the capillaries to the 'shell side' of the scrubber and then to the system pump.

3. Temperature, flow, and pressure are monitored as well.

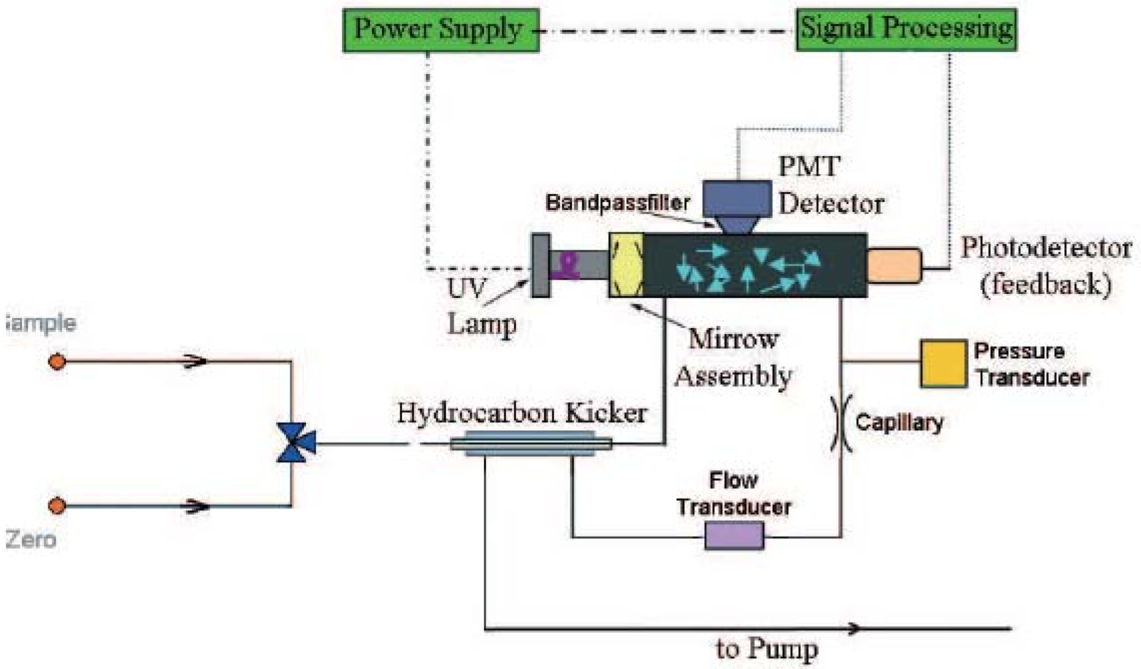

Figure 5: Flow diagram of the SO_2 module

3.2.3 Gas Flow Through the O_3 Module

1. The sample gas stream is split into two gas streams a and b:
2. First part of the cycle

   a) Gas stream a is led directly to switch valve A.

   b) Gas stream b flows through the O_3 scrubber and then to the switch valve B.

   c) The switch valves lead the gas stream a to measuring cell A of the optical bench and gas stream b to measuring cell B.

   d) Afterwards they are drawn through the capillaries to the system pump.

3. Second part of the cycle

   a) Gas stream a passes the O_3 scrubber and then to the switch valve B and further to measuring cell B.

   b) Gas stream b is led directly to switch valve A and further to measuring cell A.

   c) Afterwards they are drawn through the capillaries to the system pump.

4. Flow and pressure are monitored.

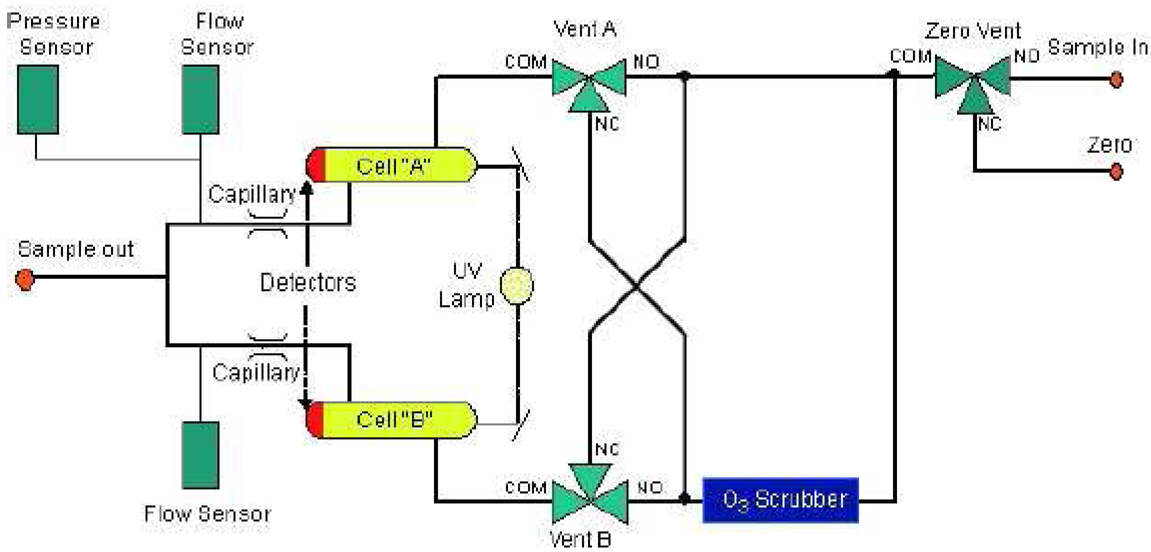

Figure 6: Flow diagram of the O_3 module

3.2.4 Gas Flow Through the CO Module

1. The sample air flows through the NO/NC valve to the optical bench.
2. From there it is drawn through the capillaries to the system pump.
3. Temperature and pressure are measured as well.
4. Zero air measurement
   a) First, zero air flows through a CO scrubber and then through the NO/NC valve to the optical bench.
   b) From there it is drawn through the capillary to the system pump.

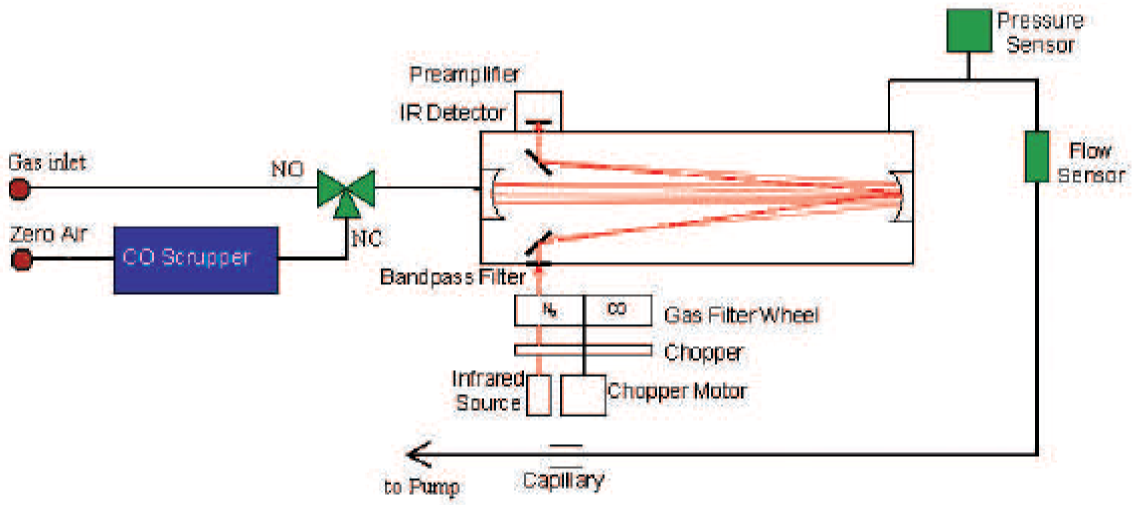

Figure 7: Flow diagram of the CO module

3.3 Extent and Set-Up of the Measuring System

The airpointer consists of the basic device with 4 drawers for up to 4 gas modules. The device is available with 2 drawers for up to 2 gas modules as well. The basic device provides the connection for power supply, the enclosure with pump, air conditioning, the data logger plus software, and two Ethernet interfaces.

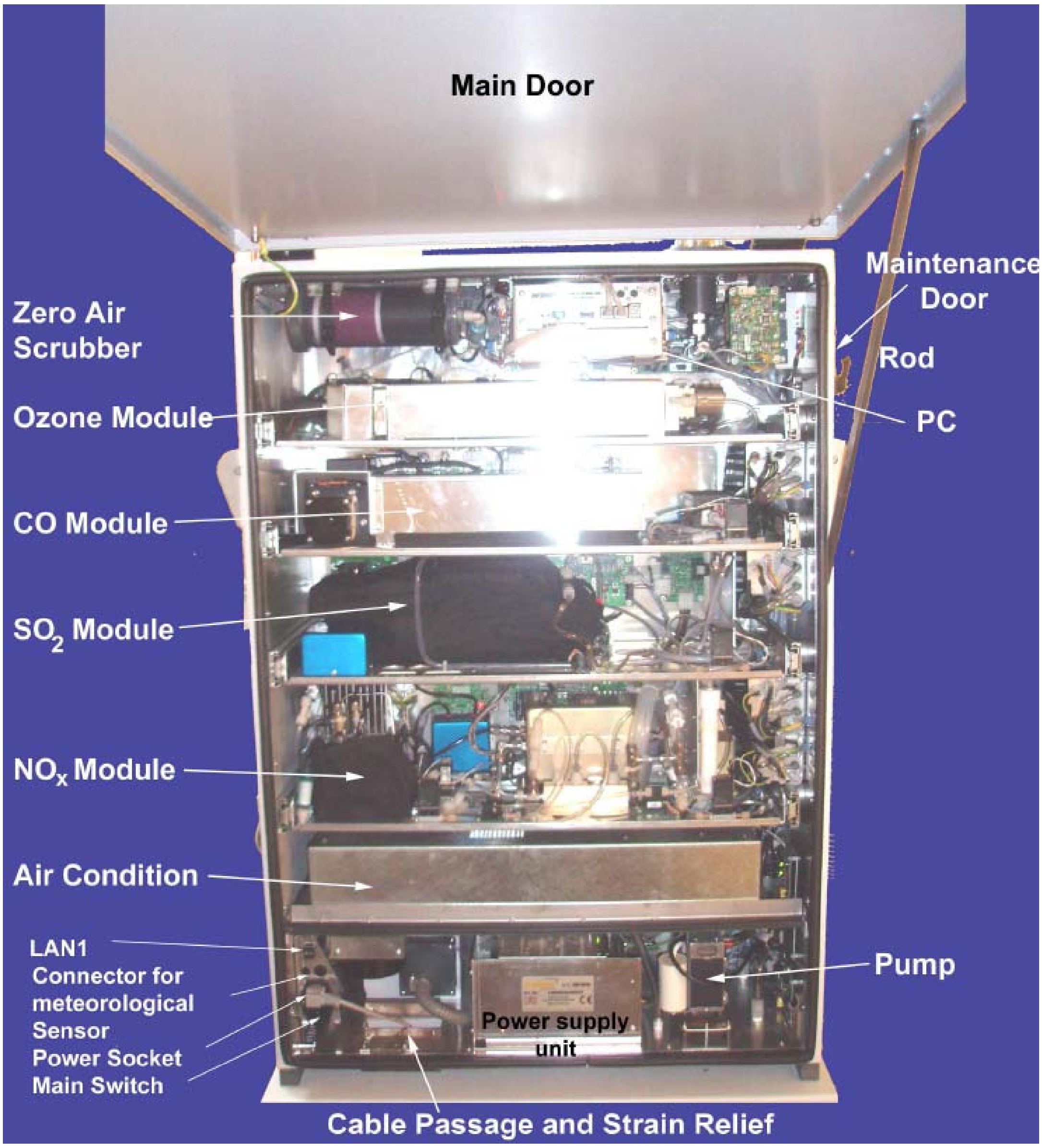

Figure 8: Interior view of the basic airpointer with the various measuring modules

The basic airpointer leads the sample gas to the various measuring modules connected parallel to the same sample air line. Details for the various compounds can be found in the respective chapters.

3.3.1 The NO_x Module

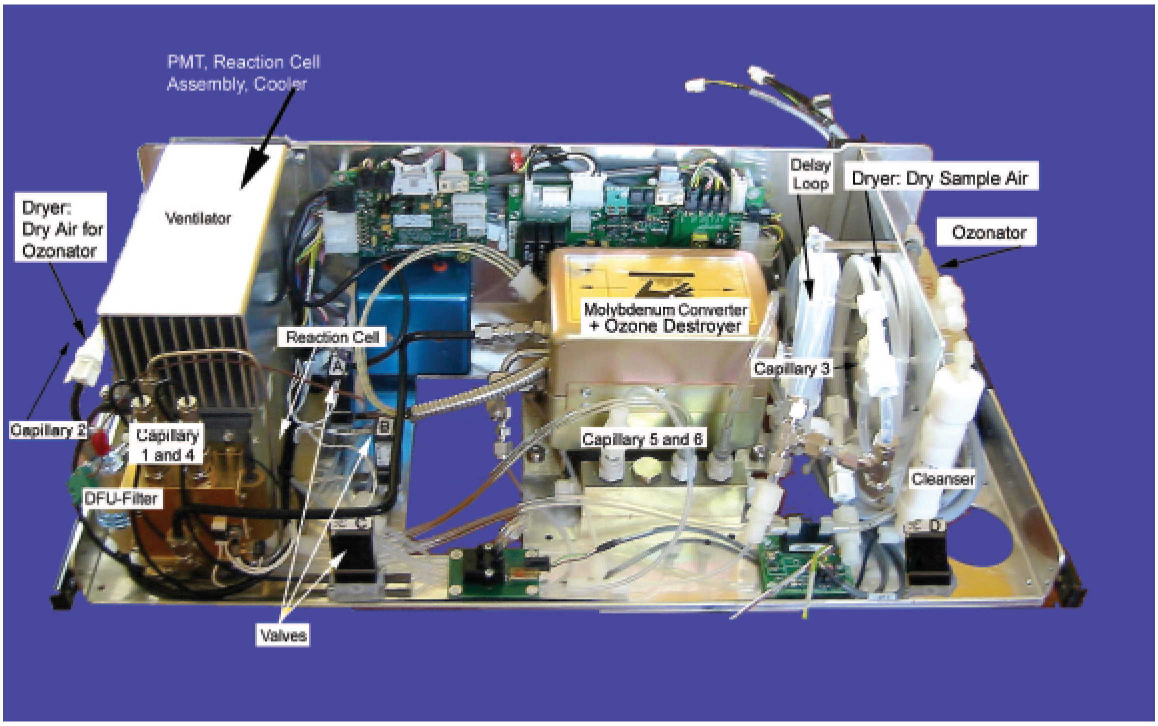

Figure 9: The NO_x module

Chemiluminescence

The device measures the concentration of NO and NO_x in a gas sample and is able to calculate the concentration of NO_2. In this case, the gas phase titration is used and the analyzer is measuring the chemiluminescence of nitrogen monoxide when it reacts with ozone:

$$NO + O_3 \rightarrow NO_2^* + O_2$$

An oxygen molecule and an excited NO_2 molecule are generated. The last one will emit its energy as a light pulse with a characteristic wavelength λ =c/v of 1100 nm:

$$NO_2^* \rightarrow NO_2 + h\nu$$

The intensity can be measured with a photomultiplier (PMT) and so the concentration can be calculated.
Any NO_2 contained in the gas is not detected in the process described above since NO_2 does not react with O_3 to undergo chemiluminescence. In order to measure the concentration of NO_2 or NO_x (which is the sum of NO and NO_2 in the sample gas), the device periodically switches the sample gas stream through a converter cartridge filled with molybdenum chips heated to a temperature of 325° C. The heated molybdenum reacts with NO_2 in the sample gas and produces a variety of molybdenum oxides and NO.

$$Mo + 3NO_2 \rightarrow 3NO + MoO_3$$

Once the NO_2 in the sample gas has been converted to NO, it is routed to the reaction cell where it undergoes the chemiluminescence reaction. By converting NO_2 in the sample gas into NO, the analyzer measures the total NO_x ($NO+NO_2$) content of the sample gas. By switching the NO_2 converter on and off in the sample gas stream every 8 seconds, the airpointer is able to continuously measure both the NO and the total NO_x content. The NO_2 concentration is not measured but calculated by subtracting the known NO content of the sample gas from the known NO_x content. The optical filter placed between the reaction cell and the PMT is another significant component of the method by which the airpointer detects chemiluminescence. This so called high pass filter is transparent only for wavelenths with a value higher than 645 nm. In connection with the response characteristics of the PMT, this filter creates a very narrow window of wavelengths to which the device will respond.

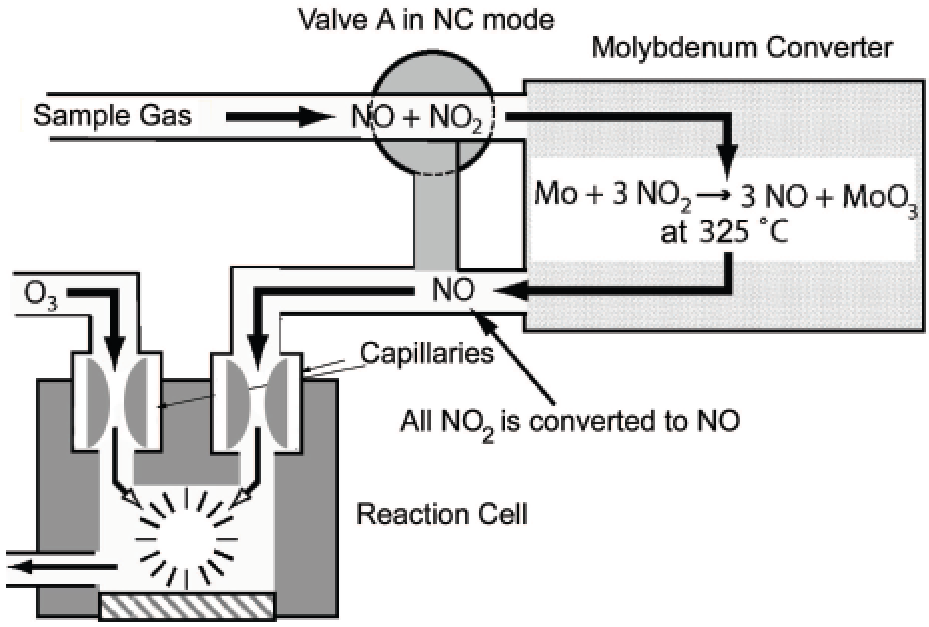

Figure 10: NO_2 conversion principle

Auto Zero Cycle

The operation of any PMT implies a certain amount of noise. This is due to a variety of factors such as black body infrared radiation given off by the metal components of the reaction cell, variations from device to device in the PMT units, and even the constant background radiation. In order to reduce this amount of noise and offset, the PMT is kept at a constant temperature of -2° C by a thermo-electric cooler. To determine how much noise remains, the device diverts the sample gas flow directly to the vacuum manifold without passing the reaction cell once every minute for about 10 seconds (see Figure 11). During this time, only ozone is present in the reaction chamber, so there will be no chemiluminescence. Once the chamber is completely dark, the airpointer records the output of the PMT and keeps a running average of these values ('PMTSigAutoZero'). To provide a revised reading, this average offset value is subtracted from the PMT raw readings while the instrument is measuring NO and NO_x.

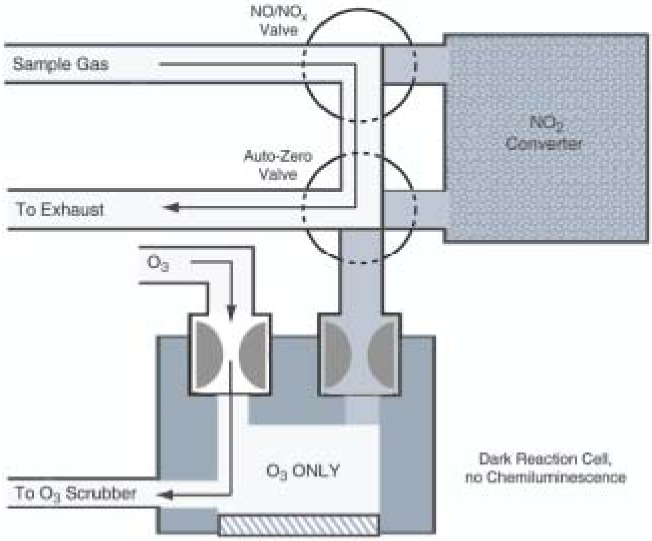

Figure 11: Reaction cell during the auto zero cycle

Ozonator

The airpointer uses a corona discharge tube for generating its ozone. Corona discharge is capable of efficiently producing high concentrations of ozone with low excess heat. Despite numerous cell designs, the fundamental principle remains the same. The device utilizes a dual di-electric design with a glass tube and hollow walls. The outermost and innermost surfaces are coated with electrically conductive material. The air flows through the glass tube between the two conductive coatings, thus generating a capacitor with the air and glass acting as the di-electric. The layers of glass separate the conductive surfaces from the air stream to prevent a reaction with the ozone. As the capacitor charges and discharges, electrons are generated and accelerated across the air gap and collide with the O_2 molecules in the air stream splitting them into elemental oxygen. Some of these oxygen atoms recombine with O_2 to O_3. The amount of ozone produced is dependent on factors such as the voltage and frequency of the alternating current applied to the cells. When enough high energy electrons are produced to ionize the O_2 molecules, a light emitting and gaseous plasma is formed, which is commonly referred to as a corona, hence the term corona discharge. There is a cleanser behind the ozonator to remove radicals from the ozone gas.

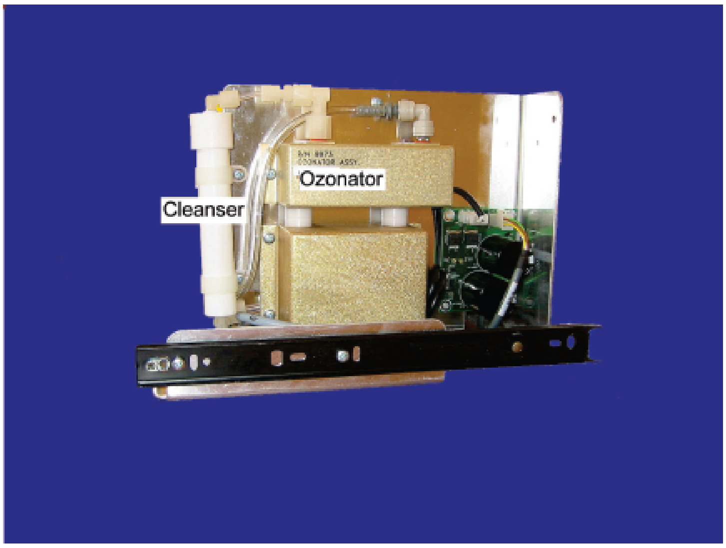

Figure 12: Cleanser and Ozonator

PermaPure Dryer

The air supplied to the O_3 generator has to be as dry as possible. Normal room air contains a certain amount of water vapor, which largely diminishes the yield of ozone produced by the ozone generator. Furthermore, water can react with other chemicals inside the O_3 generator to produce chemicals that damage the optical filter located in the reaction cell such as ammonium sulfate or highly corrosive nitric acid. To accomplish this task, the airpointer uses a Perma Pure single tube permeation dryer. The dryer consists of a single Nafion tube, a DuPont co-polymer similar to Teflon that indeed absorbs water very well but no other chemicals. The Nafion tube is located within an outer flexible plastic tube. As gas flows through the inner Nafion tube, water vapor is absorbed into the membrane walls. The absorbed water is transported through the membrane wall and evaporates into the dry purge gas flowing through the outer tube, countercurrent to the gas in the inner tube (Figure 13).

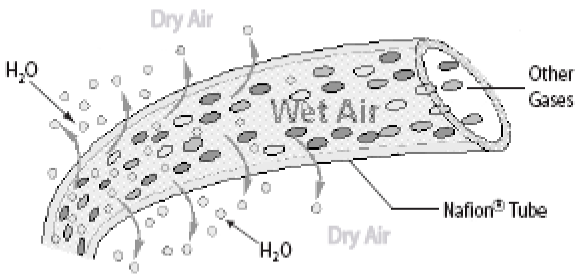

Figure 13: Semi-permeable membrane drying process

This process is called per-evaporation and is determined by the humidity gradient between the inner and outer tubes and their differences concerning flow and pressure. Unlike microporous membrane permeation which transfers water through a relatively slow diffusion process, per-evaporation is a simple kinetic reaction. Therefore, the drying process occurs quickly, typically within milliseconds. The first step in this process is a chemical reaction be-

tween the molecules of the Nafion material and water, other chemical components of the gases to be dried are usually unaffected. The chemical reaction is based on hydrogen bonds between the water molecule and the Nafion material. Other small polar gases that are capable of hydrogen bonds can thus be absorbed as welll, for example ammonia (NH_3) and some low molecular amines. To provide a dry purge gas for the external side of the Nafion tube, the device returns some of the dried air from the internal to the external tube (see Fi-gure 14). When the analyzer is first started, the humidity gradient between the inner and outer tubes is not very high and the dryer´s efficiency is low at first. However, it improves as this cycle reduces the moisture in the sample gas and settles at a minimum humidity.
If the analyzer has been off for more than 30 minutes, it takes a certain amount of time for the humidity gradient to become high enough for the Perma Pure dryer to adequately dry the air. The Perma Pure dryer used in the airpointer is capable of adequately drying ambient air to a dew point of ≤ -5° C with a flow rate of 1 standard litre per minute (slpm) or down to ≤ -15° C with 0.5 slpm. The Perma Pure dryer is also capable of removing ammonia from the sample gas with concentrations up tp approximately 1 ppm.

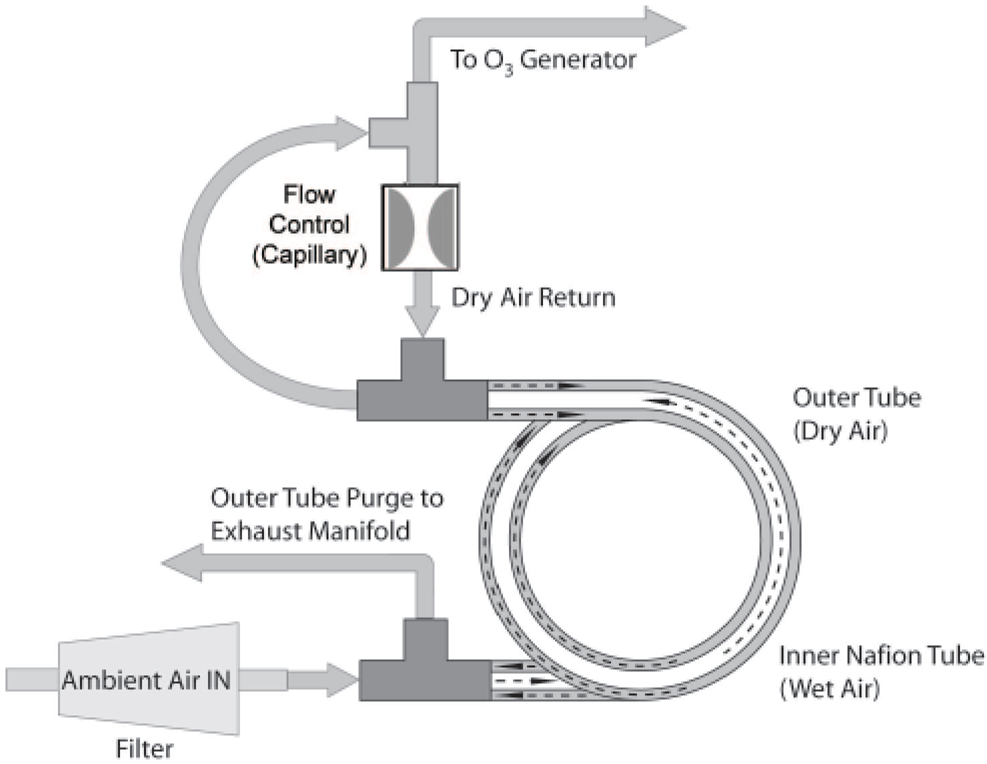

Figure 14: Diagram of a Perma Pure Dryer

PMT (Photomultiplier)

The airpointer uses a photomultiplier to detect specific emission spectra of the pollutants. The only differences between the PMTs in the various modules are the optical filters to detect the specific wavelength of the emitted light. A typical PMT is a vacuum tube containing a variety of specially designed electrodes (Figure 15). Photons of the reaction are filtered by an optical high-pass filter, enter the PMT and strike a negatively charged photo cathode causing it to emit electrons. A high voltage potential across these focusing electrodes directs the electrons toward an array of high voltage electrodes, the so called dynodes. The dynodes in this electron multiplier array are designed in a way that each stage multiplies the number of emited electrons by emitting multiple new electrons. The largely increased number of electrons emitted from one end of the electron multiplier is collected by a positively charged anode at the other end generating a suitable current signal. This signal is amplified by the preamplifier board and then reported to the RDPP. A significant performance characteristic of the PMT is the voltage potential across the electron multiplier. The higher the voltage, the greater the number of electrons emitted from each dynode of the electron multiplier, making

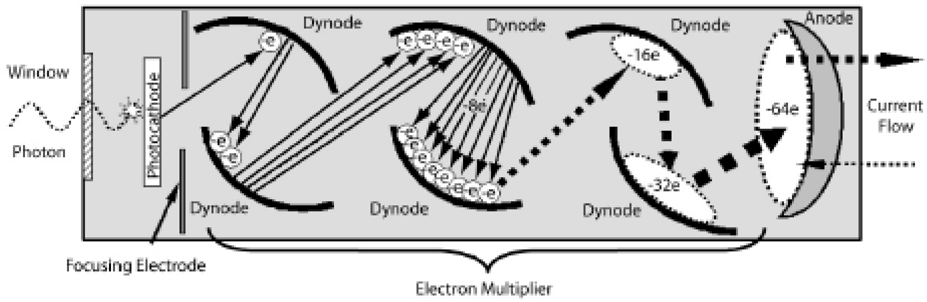

Figure 15: Diagram of a Photomultiplier Tube

the PMT more sensitive and responsive to small variations in light intensity, nevertheless, it also increases dark noise.

3.3.2 The SO_2 Module

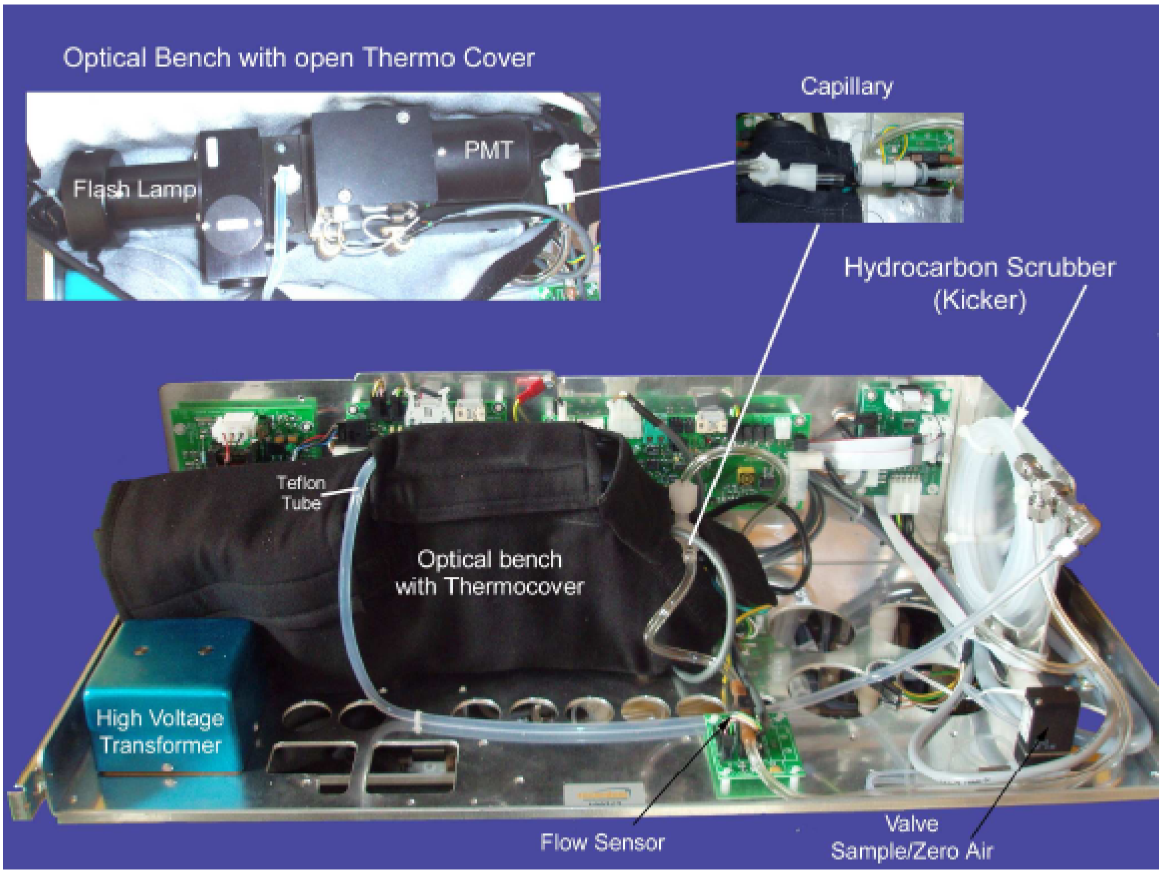

Figure 16: The SO_2 Module

SO_2- Ultraviolet Fluorescence

The SO_2 module of the airpointer measures the amount of sulphur dioxide in a sample. This is done by exciting the SO_2 molecules by ultraviolet light with a wavelength of 214 nm and then measuring their fluorescence.

$$SO_2 + h\nu \rightarrow SO_2^*$$

The use of UV light causes the molecules to absorb energy which is emitted as a light pulse (photon) shortly afterwards. The photons have a wavelength of 330 nm and can be recorded with a detector.

$$SO_2^* \rightarrow SO_2 + h\nu'$$

UV Light Path

The optical design of the components´ sample chamber optimizes the fluorescent reaction between SO_2 and UV light (see Figure 17). Furthermore, it guarantees that only UV light resulting from the decay of SO_2* to SO_2 is sensed by the fluorescence detector.
UV radiation is generated by a lamp specifically designed to produce a maximum amount of light with a wavelength of 214 nm. This is needed to excite SO_2 to SO_2*. A special reference detector circuit constantly measures the lamp intensity. The photomultilpier (PMT) detects the UV emitted by the SO_2* decay and outputs an analog signal. Several lenses and optical filters guarantee both detectors being exposed to the optimal amount of the designated UV wavelenghts. To further guarantee a light incident of decaying SO_2* only, the pathway of the excited UV and field of view of the PMT are perpendicular to each other. The inner surfaces of the sample chamber are coated with black teflon to ensure absorption of stray light.

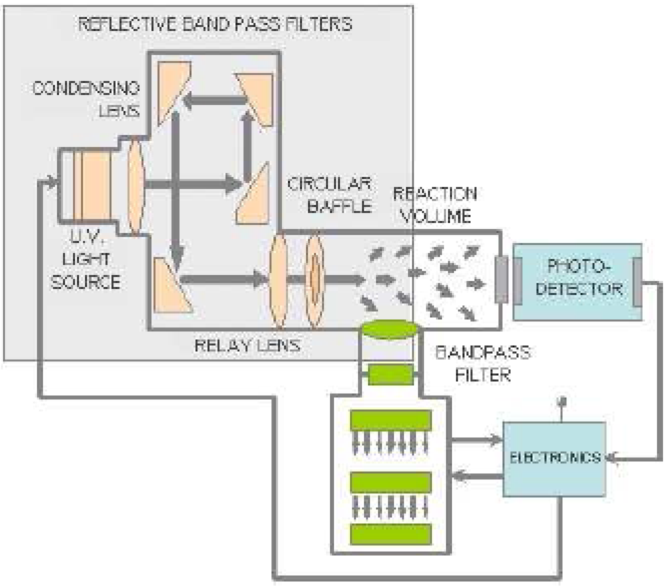

Figure 17: UV Light Path

UV Flash Lamp

The pulsing of the UV source serves to increase the optical intensity whereas a larger UV energy throughput and lower detectable SO_2 concentration are realised. Reflective bandpass filters as compared to commonly used transmission filters are less subject to photochemical degradation and more selective in wavelength isolation. This results in both increased detection capability and long-term stability.

Reference Detector

The detector at the back of the fluorescence chamber continuously monitors the intensity of the pulsating UV light source. It is connected to a circuit compensating for fluctuations of lamp intensity.

Optical Filter

The analyzer uses two stages of optical filters to enhance precision. The first stage conditions the UV light essential to excite SO_2 by removing frequencies of light that are not needed to produce SO_2^*. The second stage defends the PMT detector from exposure to light apart from that light just now emitted by the SO_2^*.

UV Source Optical Filter

A condenser lens and a mirror assembly, compared to commonly used transmission filters, are less prone to photochemical degradation and more selective in wavelength isolation. Both of which leads to increased detection specificity and long-term stability.

PMT Optical Filter

The PMT reacts to a wide spectum of light including a large part of the visible spectrum and most of the UV spectrum. Even though the 214 nm light used to excite the SO_2 is focused away from the PMT, some of it scatters in the direction of the PMT as it interacts with the sample gas. A second optional bandpass filter placed between the sample chamber and the PMT strips away light outside of the fluorescence spectrum of decaying SO_2^* including reflected UV from the source lamp and other stray light.

Hydrocarbon Scrubber (Kicker)

It is very important to ensure the air supplied to the sample chamber being clean of various gases that may influence the measurement (e.g. hydrocarbons in the SO_2 module). To accomplish this task, the airpointer uses a single tube permeation scrubber. The scrubber consists of a single tube of a special plastic which absorbs hydrocarbons very well. This tube is located within an outer flexible plastic tube shell. As gas flows through the inner tube, hydrocarbons are transported through the membrane wall into the hydrocarbon-free purge gas that is flowing through the outer tube. This process is defined by the hydrocarbon concentration gradient between the inner and outer tube. Some of the cleansed air of the inner tube is returned to be used as purge gas in the outer tube (Figure 18). So when the analyzer is first started, the concentration gradient between the inner and outer tubes is not very high and the scrubber efficiency is relatively low.

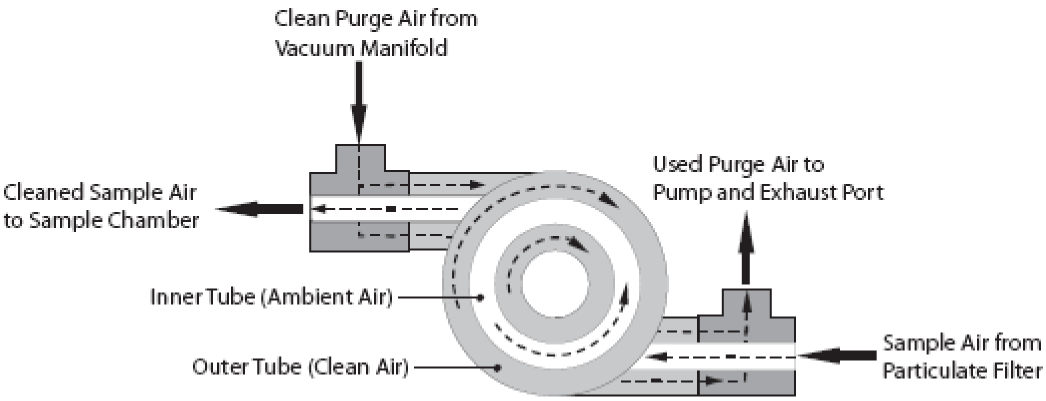

Figure 18: Hydrocarbon Scrubber

When the instrument is turned on after having been off for more than 30 minutes, it takes a little time for the gradient to become high enough fort he scrubber to efficiently remove hydrocarbons from the sample air.

The O_3 Module

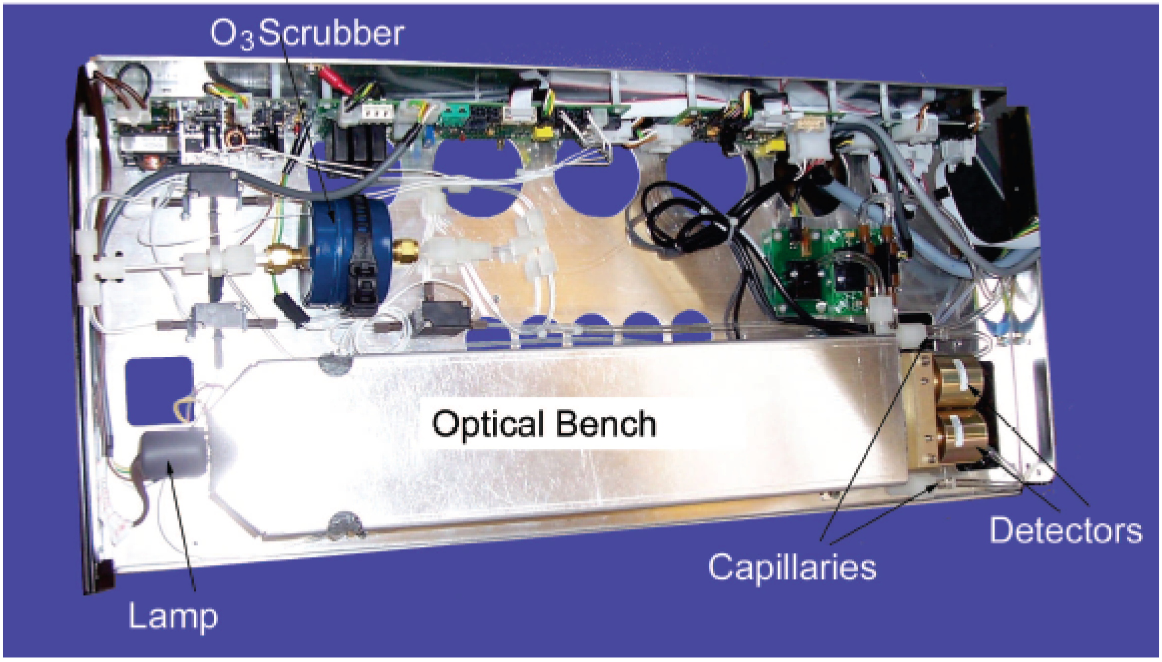

Figure 19: The O_3 Module

The Absorption Path

The compact ozone analyzer of the airpointer:

- Measures sample temperature, sample pressure, intensity of the UV light beam with and without O_3,
- Inserts known values for the length of the absorption path and the absorption coefficient, and
- Calculates the concentration of O_3 in the sample gas.

Basically, the airpointer uses a high energy mercury vapor lamp to generate a beam of UV light. This beam passes through a window made of specifically selected material to be both non-reactive to O_3 and transparent to UV radiation at 254 nm and into an absorption tube filled with sample gas. Because ozone is a very efficient absorber of UV radiation, the absorption path length required to generate a measurable decrease in UV intensity is short enough (approximately 38 cm) to pass the light beam only once through the absorption tube. Therefore, no complex mirror system is needed to lengthen the effective path by bouncing the beam back and forth.

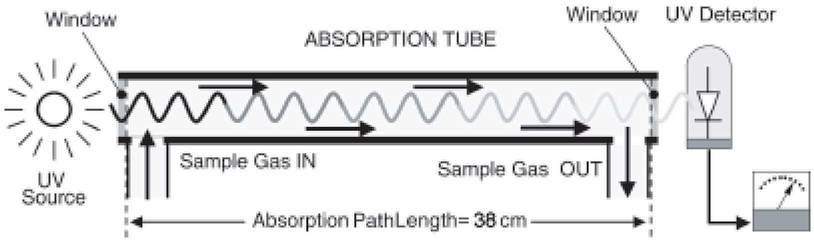

Figure 20: O_3 Absorption Path

Finally, the UV passes through a similar window at the other end of the absorption tube and is detected by a specially designed vacuum diode that detects radiation only at or very close to a wavelength of 254 nm. The sensitivity of the detector is sufficient, so no additional optical filtering of the UV light is needed. The detector assembly reacts to the UV light and outputs a voltage that varies in direct relationship to the light intensity. This voltage is digitized and sent to the CPU for reasons of computing the O_3 concentration in the absorption tube.

Reference / Measurement Cycle

In order to resolve the Lambert-Beer equation, it is necessary to know the intensity of the light passing through the absorption path both with O_3 present and not. This is accomplished by splitting the sample stream. One part flows through an ozone scrubber, thus becoming the reference gas I0. The reference gas flows to the reference solenoid valve. The sample gas flows directly to the sample solenoid valve. The solenoid valve switches the reference and sample streams between cell A and B every 10 seconds. When cell A contains reference gas, cell B contains sample gas and vice versa.
The UV intensity of each cell is measured by detector A or B. When the solenoid valve switches, reference gas and sample gas take different cells. Light intensity is ignored during switching to flush the cell. See Table 2 for temporal resolution of reference and measurement cycle. The measurement results of one cycle are averaged.

Table 2: Measurement / Reference Cycle

Time Index	Status
0 seconds	Solenoid valve opens Reference gas to cell A and sample gas to cell B
0–6 seconds	Wait Period. Ensures that the absorption tubes have been adequately flushed of any previously present gases.
6–9 seconds	Detector A measures the UV light intensity I_0 and detector B the light intensity I during this period.
10 seconds	The Solenoid Valves switch. The reference gas flows in cell B and the sample gas in cell A
10–16 seconds	Wait Period. Ensures that the Absorption tube has been adequately flushed of of any previously present gases
16–19 seconds	Detector A measures the UV light intensity I and detector B the light intensity I_0 during this period.
CYCLE REPEAT EVERY 20 SECONDS	

3.3.4 The CO Module

IR absorption is measured by the airpointer using a photoconductive sensor. Utilizing NDIR (Non-Dispersive Infra-Red Detection), the wavelength of 4.6 µm is precisely identified. Thus, an optical filter in front of the detector allows the better part of the 4.6 µm beams to pass.
The sensor consists of a semiconductor. With IR beams meeting the sensor surface, positive or negative charges (depending on the kind of semiconductor) are excited into movement and continuous flow. This becomes apparent by a decreasing resistance and is measured by a multiplier with a constant value. When the resistance decreases, the current increases with a constant voltage (ohmic law). This current is measured allowing for the calculation of resistance and concentration of the IR absorbing molecules in the sample chamber.

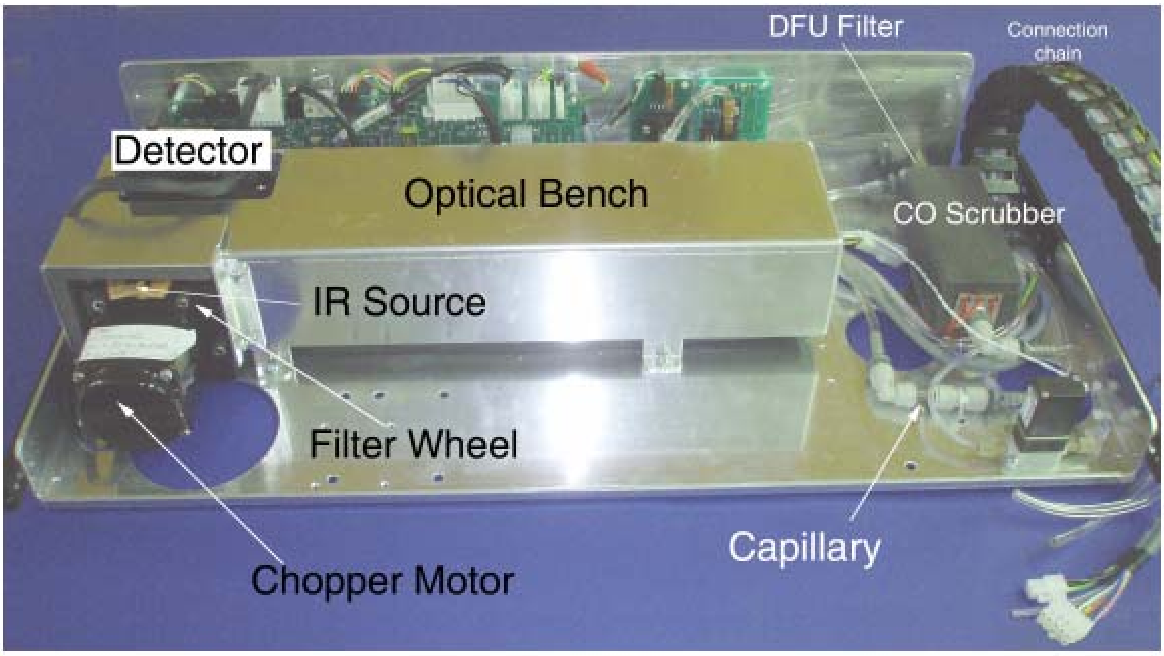

Figure 21: The CO Module

This module uses an element heated with high energy to generate a beam of broad-band IR light with a known intensity of 4.6 µm (measured during calibration). This beam is directed through a multi-pass cell filled with sample gas. The sample cell uses mirrors at each end to reflect the IR beam back and forth through the sample gas to generate a long absorption path (Figure 22). The length was chosen to give the analyzer maximum sensitivity to fluctuations in CO density. Upon exciting the sample cell, the beam runs through a narrow band-pass filter allowing only light with a wavelength of 4.6 µm to pass. Here, the light signal is converted into a modulated voltage signal representing the reduced intensity of the beam. The CO module uses an internal calibration curve to accurately linearize the instrument output.

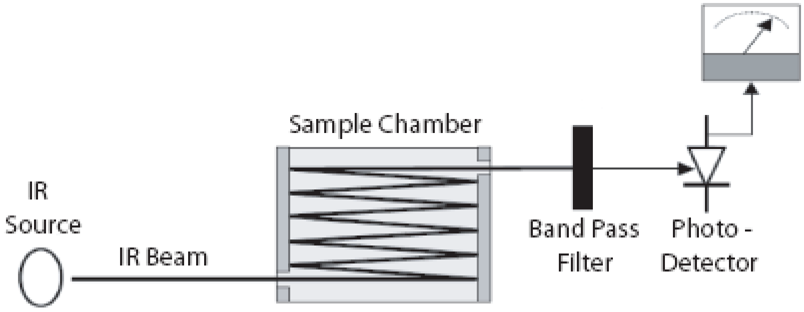

Figure 22: Measurement Fundamentals

Gas Filter Correlation

Unfortunately, a variety of gases also absorb light at 4.6 µm. Among them are water and CO_2, both of which are much more common than CO. To overcome these interfering influences and those of other gases, there is a gas filter correlation wheel in the light path between IR sources and sample chamber (see Figure 23).

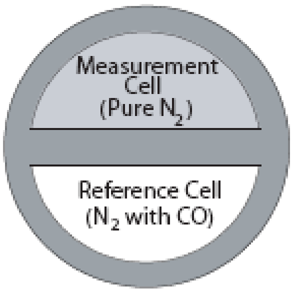

Figure 23: GFC Wheel

A GFC wheel consists of a metallic housing with two chambers. The chambers are sealed on both sides with material transparent to 4.6 µm IR radiation, thus generating two airtight cavities. Each cavity is filled with specially composed gases. One cell is filled with pure N_2 (the sample cell). The other is filled with a combination of N_2 and a high concentration of CO (the reference cell). As the GFC wheel spins, the IR light alternately passes through the two cavities. When the beam is exposed to the reference cell, the CO in the gas filter wheel strips the beam of most of the IR at 4.6 µm. When the light beam is exposed to the measurement cell, the N_2 in the filter wheel does not absorb IR light. This results in a fluctuation of the IR intensity (see Figure 24). Thus, you will obtain a signal resembling a square wave.

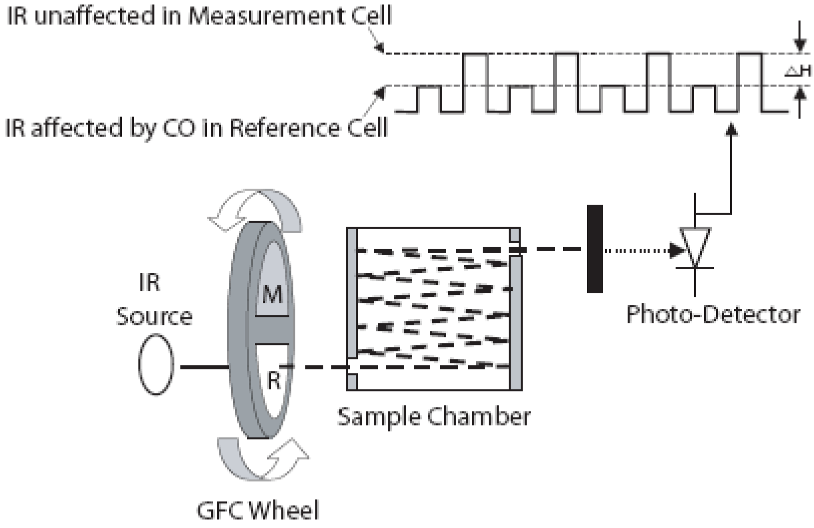

Figure 24: Measurement Fundamentals (GFC Wheel)

The device determines the CO content in the sample chamber by computing the ratio between the peak of the measurement pulse (CO MEAS) and the peak of the reference pulse (CO REF). If there are no gases in the sample chamber absorbing light at 4.6, the high concentration of CO in the gas mixture of the reference cell will decrease the intensity of the IR beam by approximately 20 % with a given M/R ratio of 1.2 : 1. Adding CO to the sample chamber causes the peaks of both cells to further decrease by percentage (see Figure 25).

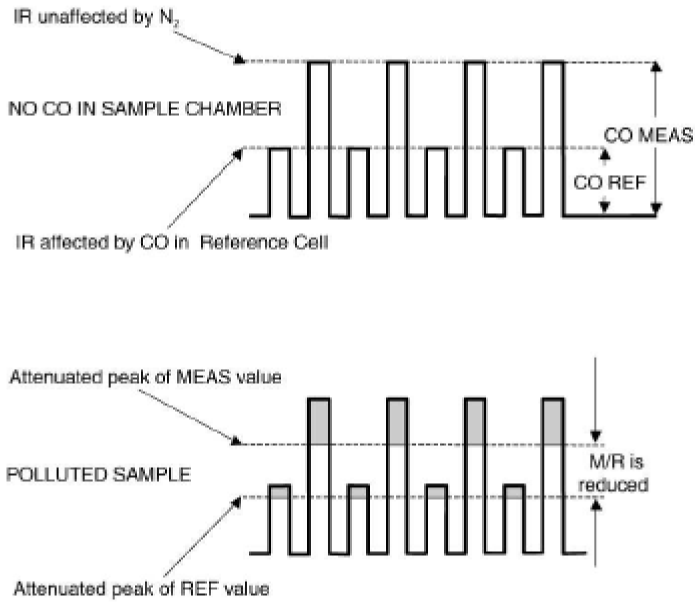

Figure 25: Effect of CO in the Sample on CO MEAS and CO REF

With the light intensity in the sample cell being higher, the effect of this additional decrease will be larger. This causes CO MEAS to be more sensitive to the presence of CO in the sample chamber than CO REF. The ratio between them (M/R) moves closer to 1:1 as the concentration of CO in the sample chamber increases. After having computed this ratio, the response is linearised by using a look-up table. This linearised concentration value is combined with 'SLOPE' and offset values to obtain the CO concentration. This value is then normalised for changes in sample pressure.
If an interfering gas (such as CO_2 or H_2O vapor) is introduced into the sample chamber, the spectrum of the IR beam changes in a way that is identical for both the reference and measurement cells, leaving the ratio between the CO MEAS and CO REF peaks unaltered. Actually, the difference between the peaks remains the same. Thus, the difference of the peak heights and the resulting M/R ratio is only due to CO and not to interfering gases. In this way, gas filter correlation rejects the effects of interfering gases and so the analyzer responds only to the presence of CO.

To improve the signal-to-noise performance of the IR photo-detector, the GFC includes an optical mask dividing the IR beam into alternating pulses of light and dark impulses at six times a frequency of the measurement/reference signal. This narrows the detection bandwidth and helps to reject interfering signals outside this bandwidth, thus improving the signal to noise ratio.

3.4 General System Specifications

The measuring system airpointer is a multi-component immission measuring device. It consists of the base unit and up to four gas modules depending on the configuration. Two different base units are available.

Base unit 4D: This base unit contains 4 drawers and up to 4 main gas modules.

Base unit 2D: This base unit contains 2 drawers and up to 2 main gas modules.

The base module contains the housing including pump, air-conditioning, and the data-logger. Up to 4 gas modules can be included.

Additionally, the measuring system can be equipped with modules for monitoring PM2.5, PM 10, NH_3, H_2S, VOC, electrochemical cells, traffic counting modules and modules for recording meteorological data, none of which is influencing the actual measurement.

The modules for the measurement of NO, NO_2, NOx, SO_2, O_3, and CO were part of the suitability test and installed in the base unit 4D (4 drawers).

Type	Compact air-conditioned measurement container
Sample Flow Rate	Approx. 3.0 l/min
Dimensions	Base unit 2D (two drawers) 740 x 352 x 831 mm / 29.1 x 13.9 x 32.7 inches Base unit 4D (four drawers) 740 x 352 x 1067 mm / 29.1 x 13.9 x 42 inches
Weight	Approx. 74 kg
Relative Humidity	0 – 95 %, non-condensing
Power	115V / 60Hz oder 230V / 50Hz 10A fused Consumption during continuous operation: Approx. 350 watt with 5° C ambient temperature Approx. 530 watt with 20° C ambient temperature Approx. 560 watt with 40° C ambient temperature
Protection	IP54 (range), IP44 (pump compartment)
Units	ppm or ppb
Digital Outputs	2 x Ethernet 10/100 MBits/s interface
Software Version	1.001

4. Test Program

The laboratory and field tests have been accomplished with two identical analysers with the following serial numbers:

Unit 1: S/N 188

Unit 2: S/N 208

The laboratory test was conducted in the laboratories of the TÜV Rheinland Immissionsschutz und Energiesysteme GmbH in Cologne, Germany. The field test was conducted on a big parking lot of the TÜV Rheinland in Cologne, Germany. The respective measuring modules are located in an air-conditioned basic module appropriate for outdoor installation. Therefore, unlike former field tests, the units had not been installed in an air-conditioned container but directly outdoors.

The long-term test was conducted from 08/25/2008 to 12/10/2008. No adjustments were made during the entire field test.

The analysis of the laboratory and the field test was based on the certification ranges indicated in Table 1.

Figure 26: Units during Laboratory and Field Test

4.1 Test Program According to VDI 4202, For Results See Appendix A

The following laboratory test program resulted from the regulations of VDI 4202, Part 1:

- Review of the general analyser functions
- Determination of the characteristic line with span gases
- Determination of the cross-sensitivity of the measuring system versus sample impurities
- Review of the stability of zero and reference point in the acceptable ambient temperature range
- Determination of the influence of changes in mains voltage on the measuring signal
- Determination of the detection limit
- Determination of the set-up time
- Determination of the converter efficiency for NO_x
- Determination of the overall uncertainty

The following field test program resulted from the regulations of VDI 4202, Part 1:

- Review of the general analyser functions
- Performance test of the measuring device at the beginning and the end of the field test
- Determination of the detection limits
- Determination of the reproducibility
- Determination of the drift of zero and reference point
- Determination of the maintenance interval
- Determination of the availability
- Determination of the overall uncertainty

4.2 Test Program According to DIN EN 14211, DIN EN 14212, DIN EN 14625 and DIN EN 14626, For Results See Appendices B to E

The following laboratory test program resulted from the regulations of DIN EN 14211, DIN EN 14212, DIN EN 14625, and DIN EN 14626:

- Review of the general analyser functions
- Determination of repeatability of standard deviation for zero
- Determination of repeatability of standard deviation for concentration c_t
- Determination of „lack of fit“
- Determination of the sensitivity coefficient of the sample pressure
- Determination of the sensitivity coefficient of the sample temperature
- Determination of the sensitivity coefficient of the ambient temperature
- Determination of the sensitivity coefficient of the electric voltage
- Determination of the influence of interferences
- Determination of the influence of the averages
- Determination of the short-time drifts
- Determination of the set-up times
- Difference between sample in and calibration in
- Determination of the overall uncertainty
- Determination of the converter efficiency for NO_x
- Determination of the increase of NO_2 by retention time in the unit

The following field test program resulted from the regulations of DIN EN 14211, DIN EN 14212, DIN EN 14625 and DIN EN 14626:

- Performance test of the measuring device at the beginning and the end of the field test
- Determination of the comparative standard deviation on field conditions
- Determination of the control interval
- Determination of the drift of zero and reference point
- Determination of the availability
- Determination of the overall uncertainty

5 Reference Method

5.1 Component NO_2

A permeation oven manufactured by MCZ has been utilized for generating NO_2 span gas during the laboratory test as well as the field test. The mass change of the tube being inserted in the oven and facing constant temperature and purge flow conditions has been determined during defined time intervals for the validation of the generated NO_2 concentration and the determination of the permeation rate of the permeation tube in the oven.

This gravimetric determination of the permeation rate has been continued for control purposes during the whole suitability test.

Furthermore, several comparative measurements have been conducted according to VDI 2453, Part 1, with the Saltzman method at various levels of concentration in which at a time the preset concentration at the permeation oven has been compared with the recorded concentrations by the Saltzman method and the values recorded by the analysers.

5.2 Component NO

For applying NO span gas a cylinder (with the number 10420) of span gas of the manufacturer Praxair with a precision of ± 2 % had been utilized. The concentration of the span gas cylinder had been reviewed by the standard reference method according to VDI 2456.

The various concentration levels were generated by means of mass flow controllers and by using synthetic air as dilution air.

Span gas NO:	12.6 mg/m³ in N_2
Number of cylinder:	10420
Manufacturer / Date of manufacturing:	Praxair
Guarantee of stability / Certified:	36 months
Certificate review by / on:	In-house laboratory / 01/31/2006
Relative uncertainty according to certificate:	± 2 %

5.3 Component SO_2

A permeation oven manufactured by MCZ has been utilized for generating SO_2 span gas during the laboratory test as well as the field test. The mass change of the tube being inserted in the oven and facing constant temperature and purge flow conditions has been determined during defined time intervals for the validation of the generated SO_2 concentration and the determination of the permeation rate of the permeation tube in the oven.

This gravimetric determination of the permeation rate has been continued for control purposes during the whole suitability test. These regular gravimetric controls showed an uncertainty of the span gas of ± 1 % of the final value of the range.

Furthermore, several comparative measurements have been conducted according to VDI 2451, Part 3, with the TCM method at various levels of concentration in which at a time the preset concentration at the permeation oven has been compared with the recorded concentrations by the TCM method and the values recorded by the analyser.

5.4 Component Ozone

An ozone generator manufactured by MCZ has been used for generating the ozone span gas concentration. For reviewing the generated ozone concentrations, the method has been analysed according to the guidelines DIN ISO 13964 "Determination of ozone in ambient air" and VDI 2468, Part 6, "Measuring of ozone concentrations, direct UV photometric method (basic method)". The ozone generator had been previously validated against a primary UV calibration photometer traceable to the national reference laboratory.

Regardless of this, comparative measurements had been conducted with the KJ method according to VDI 2468; Part 1, "Measuring of ozone and peroxide concentrations – Manual photometric method; potassium iodide method". Although the applicability of this method for immission measurements is possible only to a limited extent, it is well suitable for independent validation of span gases.

5.3 Component CO

Span gas was applied in both the laboratory and field test by using certified span gas in cylinders diluted by mass flow controllers. The concentration of undiluted span gas as well as several dilution concentrations were reviewed by utilizing gas chromatography according to VDI 2459, Part 1, "Measuring of gaseous emissions – Measuring of carbon monoxide concentrations using a flame ionisation detector after reduction to methane".

Span gases in compressed gas cylinders have been used in the test. The listed span gases have been used during the whole test and diluted by a separator or a mass flow controller, if necessary.

Span gas CO:	256 mg/m³ in N_2
Number of cylinder:	10654
Manufacturer / Date of manufacturing:	Praxair
Guarantee of stability / Certified:	36 months
Certificate review by / on:	In-house laboratory / 10/10/2007
Relative uncertainty according to certificate:	± 2 %

6. Test Results

The overall uncertainties as well as the test results of each individual measurement component are specified in the following chapter. A detailed description of each test item is provided in appendices A to E.

Chapter 6.1 summarises the test results according to VDI 4202 for the components NO_2, SO_2, O_3, and CO.

Chapter 6.2 summarises the test results and the uncertainty computation according to DIN EN 14211 for the component NO.

Chapter 6.3 summarises the test results and the uncertainty computation according to DIN EN 14212 for the component SO_2.

Chapter 6.4 summarises the test results and the uncertainty computation according to DIN EN 14625 for the component O_3.

Chapter 6.5 summarises the test results and the uncertainty computation according to DIN EN 14626 for the component CO.

6.1 Summary of Test Results According to VDI 4202

Minimum Requirement	Test Result	Assessment
Legend:	Minimum requirement fulfilled Minimum requirement not fulfilled Minimum requirement not applicable	+ – x
A 4.1.1 Data Display The measurement device must be equipped with a data display.	Data evaluation of the measurement device is effected exclusively via the web browser by means of a cross patch cable or an external PC.	+
A 4.1.2 Ease of maintenance Maintenance of the measurement device should be possible without any larger effort from outside.	Maintenance of the measurement device is possible without any larger effort.	+
A 4.1.3 Function Control If special equipment should be necessary for operation or function control of the measurement device, they have to be considered as being part of the device, have to be utilized for the respective component testing and to be considered in its evaluation. Span gas units included in the measurement device shall indicate their operational readiness by a status signal and shall provide direct as well as remote control via the measurement device. The uncertainty of the span gas shall not exceed 1 % of the reference value B_2 within three months.	The measurement device can be optionally equipped with internal span gas generating systems for each single component. These systems have not been part of the test.	x
A 4.1.4 Set-Up Times / Warm-Up Times Set-up times and warm-up times have to be indicated in the operation manual.	Set-up time comes to 0.5 hours. A warm-up time of 3 hours was established by our test.	+

Minimum Requirement	**Test Result**	**Assessment**
A 4.1.5 Design The operation manual has to include manufacturer information on the design of the device. Essentially, these are: Design (e.g. table-top unit, built-in unit, stand-alone unit) Installation position (e.g. horizontal or vertical position) Safety requirements Dimensions Weight Power requirements	Design and general technical requirements are described in detail in the operation manual.	+
A 4.1.6 Unauthorized Adjustment It must be possible to secure the measurement device against unintended and unauthorized adjustment.	The measurement device is password protected against unauthorized adjustment.	+
A 4.1.7 Measurement Signal Output Digital (e.g. RS-232) and/or analog (e.g. 4 mA to 20 mA) measurement signals have to be provided.	Measurement signals and operating conditions are recognized correctly by the downstram evaluation systems.	+
A 4.2 Requirements for the Mobile Application Mobile measurement devices have to comply with the requirements for stationary measurement devices even in mobile operation. In mobile operation, e.g. measurements of moving traffic, temporary measurements at different places or in aeroplanes, a constant operational readiness has to be secured.	The measurement device is not designated for mobile application.	-
A 5.2.1 Measuring Range The limit value of the measurement device has to be larger than or equal to the reference value B_2. (B_2 for NO_2 = 400 µg/m³) (B_2 for SO_2 = 700 µg/m³) (B_2 for O_3 = 360 µg/m³) (B_2 for CO = 60 mg/m³)	The required limit values according to VDI 4202 can be monitored.	+
A 5.2.2 Negative Signals Negative measurement signals / measurement values may not be suppressed (live zero).	Digital data output provides the output of negative measurement data and range overflows.	+

Minimum Requirement	**Test Result**	**Assessment**
A 5.2.3 Analysis Function The relationship between the output signal and the value of the air quality characteristic has to be presentable by means of the analysis function and to be determined by the regression analysis.	The connection between output signal and measurand is presentable statistically secured by the analysis function and determined by the regression analysis.	+
A 5.2.4 Linearity Linearity is considered to be secured if the deviation of the group averages of the measurement values of the calibration function (see 5.2.1) in the range of zero to B_1 is no more than 5 % of B_1 and no more than 1 % of B_2 in the range of zero to B_2. (B_1 for NO_2 = 60 µg/m³)(B_2 for NO_2 = 400 µg/m³) (B_1 for SO_2 = 40 µg/m³)(B_2 for SO_2 = 700 µg/m³) (B_1 for O_3 = 80 µg/m³)(B_2 for O_3 = 360 µg/m³) (B_1 for CO = 20 mg/m³)(B_2 for CO = 60 mg/m³)	The tests did not show any exceeding of the allowable deviations. The greater of both values are used as a basis for computing the overall uncertainty. For the component NO_2 1.7 µg/m³ for unit 1 (188) and -1.6 µg/m³ for unit 2 (208). For the component SO_2 4,2 µg/m³ for unit 1 (188) and 2.9 µg/m³ for unit 2 (208). For the component O_3 2.7 µg/m³ for unit 1 (188) and 3.2 µg/m³ for unit 2 (208). For the component CO 0.33 mg/m³ for unit 1 (188) and -0.48 mg/m³ for unit 2 (208).	+
A 5.2.5 Detection Limit The detection limit may not exceed the reference value B_0. The detection limit has to be determined in the field test. (B_0 for NO_2 = 3 µg/m³) (B_0 for SO_2 = 2 µg/m³) (B_0 for O_3 = 4 µg/m³) (B_0 for CO = 1 mg/m³)	The detection limit of all tested components is within the minimum requirements.	+
A 5.2.6 Response Time The response time (90 % time) of the measurement device may not be more than 5 % of the averaging time (180 s).	The maximum allowable response time of 180 s is underrun with all tested components.	+
A 5.2.7 Dependence of the Zero Point On Ambient Temperature With a change in ambient temperature of 15 K in the range from +5° C to +20° C and of 20 K in the range from +20° C to +40° C, the temperature dependence of the zero value may not exceed the reference value B_0. (B_0 for NO_2 = 3 µg/m³) (B_0 for SO_2 = 2 µg/m³) (B_0 for O_3 = 4 µg/m³) (B_0 für CO = 1 mg/m³)	With all examined ambient temperatures, the change of the zero point is significantly better than the maximum allowable deviation.	+

Minimum Requirement	**Test Result**	**As-sess-ment**
A 5.2.8 Dependence of the Zero Point On Ambient Temperature With a change in ambient temperature of 15 K in the range from +5° C to +20° C and of 20 K in the range from +20° C to +40° C, the temperature dependence of the zero value may not exceed the reference value B_1. (B_1 for NO_2 = 60 µg/m³) (B_1 for SO_2 = 40 µg/m³) (B_1 for O_3 = 80 µg/m³) (B_1 for CO = 20 mg/m³)	With all examined ambient temperatures, the change of the zero point is significantly better than the maximum allowable deviation.	+
A 5.2.9 Zero Point Drift The temporal variation of the zero point value may not exceed the reference value B_0 neither in 24 h nor during the maintenance interval. (B_0 for NO_2 = 3 µg/m³) (B_0 for SO_2 = 2 µg/m³) (B_0 for O_3 = 4 µg/m³) (B_0 for CO = 1 mg/m³)	Zero point drifts for NO_2 in 24 h and during the maintenance interval show a value of 0.0061 µg/(m³*d) and 0.183 µg/(m³*month) fur unit 1 (188), and 0.0064 µg/(m³*d) and 0.192 µg/(m³*month) for unit 2 (208), thus remaining significantly below the requirement of 3 µg/m³. Zero point drifts for SO_2 in 24 h and during the maintenance interval show a value of 0.0078 µg/(m³*d) and 0.234 µg/(m³*month) for unit 1 (188), and 0.0102 µg/(m³*d) and 0.306 µg/(m³*month) for unit 2 (208), thus remaining significantly below the requirement of 2 µg/m³. Zero point drifts for O_3 in 24 h and during the maintenance interval show a value of 0.0172 µg/(m³*d) and 0.516 µg/(m³*month) for unit 1 (188), and 0.0010 µg/(m³*d) and 0.030 µg/(m³*month) for unit 2 (208), thus remaining significantly below the requirement of 4 µg/m³. Zero point drifts for CO in 24 h and during the maintenance interval show a value of 0.0043 mg/(m³*d) and 0.129 mg/(m³*month) for unit 1 (188), and 0.0032 mg/(m³*d) and 0.096 mg/(m³*month) for unit 2 (208), thus remaining significantly below the requirement of 1 mg/m³.	+

Minimum Requirement	**Test Result**	**Assessment**
A 5.2.10 Measurement Reading Drift The temporal variation of the measurement reading in the range of the reference value B_1 may not exceed ± 5 % of B_1 neither in 24 h nor during the maintenance interval. (B_1 for NO_2 = 60 µg/m³) (B_1 for SO_2 = 40 µg/m³) (B_1 for O_3 = 80 µg/m³) (B_1 for CO = 20 mg/m³)	Reference point drifts for NO_2 in 24 h and during the maintenance interval show a value of 0.0028 µg/(m³*d) and 0.084 µg/(m³*month) for unit 1 (188), and 0.0078 µg/(m³*d) and 0.234 µg/(m³*month) for unit 2 (208), thus remaining significantly below the requirement of 3 µg/m³. Reference point drifts for SO_2 in 24 h and during the maintenance interval show a value of -0.0034 µg/(m³*d) and -0.102 µg/(m³*month) for unit 1 (188), and -0.0010 µg/(m³*d) and -0.030 µg/(m³*month) for unit 2 (208), thus remaining significantly below the requirement of 2 µg/m³. Reference point drifts for O_3 in 24 h and during the maintenance interval show a value of 0.0060 µg/(m³*d) and 0.180 µg/(m³*month) for unit 1 (188), and 0.0269 µg/(m³*d) and 0.807 µg/(m³*month) for unit 2 (208), thus remaining significantly below the requirement of 4 µg/m³. Reference point drifts for CO in 24 h and during the maintenance interval show a value of -0.0029 mg/(m³*d) and -0.087 mg/(m³*month) for unit 1 (188), and 0.0049 mg/(m³*d) and 0.147 mg/(m³*month) for unit 2 (208), thus remaining significantly below the requirement of 1 mg/m³.	+
A 5.2.11 Cross Sensitivities In the range of the zero point, the absolute values of the sums of positive and negative deviations caused by interferences due to cross sensitivities related to sample impurities may not be more than B_0, and not more than 3 % in the range of B_2. The concentration of the impurity is utilized in the range of the respective B_2 value of the impurity. In case of no reference value being known, an applicable reference value has to be defined and indicated by the testing institute in consultation with the other testing institutes. (B_0 for NO_2 = 3 µg/m³) (B_1 for NO_2 = 60 µg/m³) (B_2 for NO_2 = 400 µg/m³) (B_0 for SO_2 = 2 µg/m³) (B_1 for SO_2 = 40 µg/m³) (B_2 for SO_2 = 700 µg/m³) (B_0 for O_3 = 4 µg/m³) (B_1 for O_3 = 80 µg/m³) (B_2 for O_3 = 360 µg/m³) (B_0 for CO = 1 mg/m³) (B_1 for CO = 20 mg/m³) (B_2 for CO = 60 mg/m³)	The cross sensitivities of the measurement device fulfill the minimum requirements. For the computation of the overall uncertainty, the largest total value per unit is utilized. This is for the component NO_2 7.5 µg/m³ for unit 1 (188) and 8.4 µg/m³ for unit 2 (208). This is for the component SO_2 -12.9 µg/m³ for unit 1 (188) and 9.7 µg/m³ for unit 2 (208). This is for the component O_3 9.1 µg/m³ for unit 1 (188) and 10.1 µg/m³ for unit 2 (208). This is for the component CO -0.88 mg/m³ for unit 1 (188) and -0.77 mg/m³ for unit 2 (208).	+
A 5.2.12 Reproducibility The reproducibility R_D of the measurement device has to be defined by repeat determinations with two identical devices. It may not exceed a value of 10. B_1 has to be utilized as reference value.	The value of 10, required for reproducibility in VDI 4202, Part 1, is kept by all tested components. Therefore, the minimum requirements are fulfilled. For computing the overall uncertainty, the reproducibility with B_1 is utilized (= 25 for NO_2, 52 for SO_2, 25 for O_3, and 48 for CO).	+

Minimum Requirement	**Test Result**	**Assessment**
A 5.2.13 Hourly Averages The measurement device must provide hourly averages.	The measurement device provides hourly averages.	+
A 5.2.14 Power Supply Voltage and Power Frequency The variation of the measured value with the reference value B_1 caused by common voltage changes in an interval (230 V +15 V/-20 V) may not exceed B_0. Furthermore, variations of the measured value caused by variations of the power frequency (50Hz ± 2Hz) during mobile application may not exceed B_0. (B_0 for NO_2 = 3 µg/m³) (B_0 for SO_2 = 2 µg/m³) (B_0 for O_3 = 4 µg/m³) (B_0 for CO = 1 mg/m³)	The measurement device fulfills the minimum requirements concerning power frequency.	+
A 5.2.15 Power Failure In case of malfunctions and power failure, uncontrolled emission of sample and calibration gas has to be avoided. A buffer must be used to protect the instrument parameters against loss caused by power failure. When the power returns, the instrument automatically has to achieve the operation modus and has to start the measurement according to the operating instruction.	A power failure causes no negative effect on the measurement device. After restoration of the power supply the device returned to the normal operation modus.	+
A 5.2.16 Operating Modi The essential operating modi must have to be monitored by telemetric transmittable status signals.	Telemetrical monitoring of the status signals (operating states, failures) is provided.	+
A 5.2.17 Switching Switching between measurement and function control and/or calibration must have to be telemetrically triggered by computer control and/or manually.	Switching between operating modi (measurement, maintenance) is provided manually and telemetrically.	+
A 5.2.18 Availability The availability of the measurement device has to be at least 90 %.	The availability is 96.3 %, the minimum requirement is fulfilled.	+
A 5.2.19 Converter Efficiency Measurement devices with a converter must provide a converter efficiency of at least 95 %.	The converter efficiency of both measurement devices is above 95 % before the laboratory and after the field test.	+

Minimum Requirement	**Test Result**	**Assessment**
A 5.2.20 Maintenance Interval The maintenance interval has to be determined and to be indicated. The maintenance interval should be preferably 28 days, yet 14 days at least.	The maintenance interval is 4 weeks.	+
A 5.2.21 Overall Uncertainty The expanded measurement uncertainty has to be determined. The value may not exceed the requirements of the EU Air Quality Daughter Guideline.	The overall uncertainties are 6.12 respectively 6.49 for NO_2 6.02 respectively 5.24 for SO_2 7.54 respectively 8.14 for O_3 10.42 respectively 10.22 für CO and therefore are lower than the required overall uncertainties of 15 %.	+
A 5.4 Requirements for Multi-Component Measurement Devices Multi-component measurement devices have to fulfill the requirements of each single component even with simultaneous operation of all measuring channels. The generation of hourly averages must be secured with sequential operation.	When assessing the minimum requirements, the results of all channels were provided simultaneously.	+

6.2 Test Results and Approval of Suitability According to DIN EN 14211 for the Component NO

The approval of suitability consists of the following steps:

***1)** The value of every single performance parameter tested in the laboratory has to fulfill the criterion in Table 1 (see 8.2 in DIN EN 14211).*

***2)** The extended measurement uncertainty, computed from the standard uncertainties of the specific performance parameters determined in the laboratory test, fulfills the criterion of guideline 2002/3/EG. This criterion is the maximum allowable uncertainty of individual measurements for continuous measurements of the 1-h-average. The relevant performance parameters and the method of computation are indicated in Appendix G of guideline DIN EN 14211.*

***3)** The value of every single performance parameter tested in the field has to fulfill the criterion in Table 1 (see 8.2 in DIN EN 14211).*

***4)** The extended measurement uncertainty, computed from the standard uncertainties of the specific performance parameters determined in the laboratory test and field test, fulfills the criterion of guideline 2002/3/EG. This criterion is the maximum allowable uncertainty of individual measurements for continuous measurements of the 1-h-average. The relevant performance parameters and the method of computation are indicated in Appendix G of guideline DIN EN 14211.*

Test Instructions

Computation according to appendix G of guideline DIN EN 14211

Test Procedure

The test was conducted according to DIN EN 14211. A detailed description of each test item plus results is listed in Appendix B. The required uncertainties were computed with the test values at the end of the test.

Analysis

On 1) The value of every single performance parameter tested in the laboratory fulfills the criterion in Table 1 of DIN EN 14211.

On 2) The extended measurement uncertainty, computed from the standard uncertainties of the specific performance parameters determined in the laboratory test, fulfills the required criterion.

On 3) The value of every single performance parameter tested in the field fulfills the criterion in Table 1 of DIN EN 14211.

On 4) The extended measurement uncertainty, computed from the standard uncertainties of the specific performance parameters determined in the laboratory test and field test, fulfills the required criterion.

Assessment

A detailed description of each test item plus results is listed in Appendix B. The minimum requirements are fulfilled.

Minimum requirements fulfilled? Yes

Detailed Description

A detailed description of each test item plus results is listed in Appendix B.

The results of items 1 and 3 are combined in Table 1.

The results of item 2 are indicated in Table 4 and Table 6.

The results of item 4 are indicated in Table 5 and Table 7.

Table 3: Performance Requirements According to DIN EN 14211 for the Component NO

Performance Parameter	Performance Criterion	Test Result	Com-plied
8.4.5 Repeat standard deviation for zero	≤ 1.0 nmol/mol	S_r unit 188: 0.2 ppb S_r unit 208: 0.1 ppb	yes
8.4.5 Repeat standard deviation for concentration ct	≤ 3.0 nmol/mol	S_r unit 188: 1.2 ppb S_r unit 208: 1.1 ppb	yes
8.4.6 „lack of fit“ (Deviation of the linear regression)	Largest deviation of the linear regression function for concentration larger than zero ≤ 4 % of the measurement reading Deviation for zero ≤ 5.0 nmol/mol	$X_{l,z}$ unit 188: NP 0.1 ppb X_l unit 188: RP 0.5 % $X_{l,z}$ unit 208: NP 0.1 ppb X_l unit 208: RP 0.7 %	yes
8.4.7 Sensitivity coefficient of sample pressure	≤ 8.0 nmol/mol/kPa	b_{gp} unit 188: 0.01 b_{gp} unit 208: 0.02	yes
8.4.8 Sensitivity coefficient of sample temperature	≤ 3.0 nmol/mol/K	b_{gt} unit 188: 0.053 ppb b_{gt} unit 208: 0.017 ppb	yes
8.4.9 Sensitivity coefficient of ambient temperature	≤ 3.0 nmol/mol/K	b_{st} unit 188: -0.26 ppb b_{st} unit 208: 0.13 ppb	yes
8.4.10 Sensitivity coefficient of voltage	≤ 0.3 nmol/mol/V	b_v unit 188: RP 0.140 ppb b_v unit 208: RP 0.210 ppb	yes
8.4.11 Interference components for zero and concentration ct	H_2O ≤ 5.0 nmol/mol CO_2 ≤ 5.0 nmol/mol O_3 ≤ 2.0 nmol/mol NH_3 ≤ 5.0 nmol/mol	H_2O $X_{int,z}$ unit 188: NP 0.1 ppb / RP -1.3 ppb $X_{int,ct}$ unit 208: NP 0.1 ppb / RP -2.0 ppb CO_2 $X_{int,z}$ unit 188: NP 0.1 ppb / RP 0.8 ppb $X_{int,ct}$ unit 208: NP 0.1 ppb / RP 0.1 ppb O_3 $X_{int,z}$ unit 188: NP 0.0 ppb / RP -1.8 ppb $X_{int,ct}$ unit 208: NP 0.1 ppb / RP -2.0 ppb NH_3 $X_{int,z}$ unit 188: NP 0.1 ppb / RP 0.5 ppb $X_{int,ct}$ unit 208: NP 0.0 ppb / RP 0.8 ppb	yes

Performance Parameter	Performance Criterion	Test Result	Complied
8.4.12 Influence of averaging	≤ 7.0 % of measurement reading	X_{av} unit 188: 5.6 % X_{av} unit 208: 4.0 %	yes
8.4.13 Difference between sample in / calibration in	≤ 1.0 %	D_{SC} unit 188: 0.21 % D_{SC} unit 208: 0.18 %	yes
8.4.3 Set-up time (Rise)	≤ 180 s	t_r unit 188: max. 44 s (NO) t_r unit 208: max. 43 s (NO) t_r unit 188: max. 27 s (NO_2) t_r unit 208: max. 31 s (NO_2)	yes
8.4.3 Set-up time (Fall)	≤ 180 s	t_f unit 188: max. 42 s (NO) t_f unit 208: max. 42 s (NO) t_f unit 188: max. 26 s (NO_2) t_f unit 208: max. 27 s (NO_2)	yes
8.4.3 Difference between rise and fall time (Slope)	≤ 10 % relative difference or 10 s, whichever is greater	t_d unit 188: 3.7 % or 5 s (NO) t_d unit 208: -2.5 % or 4 s (NO) t_d unit 188: 5.7 % or 3 s (NO_2) t_d unit 208: 6.3 % or 4 s (NO_2)	yes
8.4.14 Converter efficiency	≥ 98%	E_{conv} unit 188: 99.4 % E_{conv} unit 208: 99.1 %	yes
8.5.6 Control interval	3 months or less if indicated by the manufacturer, but never less than 2 weeks	Unit 188: 4 weeks Unit 208: 4 weeks	yes
8.5.7 Availability of the measuring device	> 90 %	A_a unit 188: 96 % A_a unit 208: 96 %	yes
8.5.5 Comparison standard deviation under field conditions	≤ 5.0 % of average over a period of three months	$S_{r,f}$ unit 188: 2.59 % $S_{r,f}$ unit 208: 2.59 %	yes
8.5.4 Long-term drift for zero	≤ 5.0 nmol/mol	$D_{l,z}$ unit 188: 0.63 ppb $D_{l,z}$ unit 208: 0.84 ppb	yes
8.5.4 Long-term drift for span	≤ 5.0 % of maximum of certification range	$D_{l,s}$ unit 188: max. 1.03 % $D_{l,s}$ unit 208: max. 0.95 %	yes
8.4.4 Short-term drift for zero	≤ 2.0 nmol/mol for 12 h	$D_{s,z}$ unit 188: 0.0 ppb $D_{s,z}$ unit 208: -0.3 ppb	yes
8.4.4 Short-term drift for span	≤ 6.0 nmol/mol for 12 h	$D_{s,s}$ unit 188: 1.5 ppb $D_{s,s}$ unit 208: -0.9 ppb	yes

Table 4: Extended Uncertainty from the Results of the Laboratory Test According to DIN EN 14211 (Component NO) for Unit 188

Device:	airpointer				Serial.-no.:	Device 1 (188)	
Component:	NO				1h-limit value:	505	nmol/mol
No.	**Performance characteristic**	**Performance criteria**	**Result**	**Partial uncertainty**		**Square of uncertainty**	
1	Repeatability at zero	≤ 1,0 nmol/mol	0,200	$u_{r,Z}$	0,02	0,0005	
2	Repeatability at concentration ct	≤ 3,0 nmol/mol	1,200	$u_{r,lh}$	0,13	0,0172	
3	"lack of fit"	≤ 4,0% of measurement	0,500	$u_{l,lh}$	1,46	2,1252	
4	Sensitivity coefficient of sample gas pressure	≤ 8,0 nmol/mol/kPa	0,010	u_{gp}	0,17	0,0300	
5	Sensitivity coefficient of sample gas temperature	≤ 3,0 nmol/mol/K	0,053	u_{gt}	0,62	0,3821	
6	Sensitivity coefficient of surrounding temperature	≤ 3,0 nmol/mol/K	-0,260	u_{st}	-3,03	9,1945	
7	Sensitivity coefficient of electrical voltage	≤ 0,30 nmol/mol/V	0,140	u_V	2,18	4,7393	
8a	H20 with concentration 21 mmol/mol	≤ 5,0 nmol/mol	-0,077	u_{H2O}	-1,09	1,1810	
8b	CO2 with concentration 500 µmol/mol	≤ 5,0 nmol/mol	0,002	$u_{int,pos}$ or $u_{int,neg}$	1,85	3,4133	
8c	O3 with concentration 200 nmol/mol	≤ 2,0 nmol/mol	-0,016				
8d	NH3 with concentration 200 nmol/mol	≤ 5,0 nmol/mol	0,003				
9	Averaging effect	≤ 7,0% of measurement	5,600	u_{av}	16,33	266,5861	
18	Difference sample/calibration port	≤ 1,0%	0,210	$u_{\Delta sc}$	1,06	1,1247	
21	Converter efficiency	≥ 98%	99,400	u_{CE}	3,03	9,1809	
22	Increase of NO2 concentration due to residence time	≤ 4,0 nmol/mol	0,050	u_{ctr}	0,25	0,0638	
23	Uncertainty calibration gas	≤ 3,0%	2,000	u_{cg}	5,05	25,5025	
			combined standard uncertainty	u_c		17,9877	nmol/mol
			expanded uncertainty	U_c		35,9755	nmol/mol
			expanded uncertainty actual	$U_{c,rel}$		**7,12**	%
			expanded uncertainty required	$U_{req,rel.}$		15	%

Table 5: Extended Uncertainty from the Results of the Laboratory Test and Field Test According to DIN EN 14211 (Component NO) for Unit 188

Device:	airpointer				Serial-no.:		Device 1 (188)	
Component:	NO				1h-limit value:		505	nmol/mol
No.	**Performance characteristic**		**Performance criteria**	**Result**	**Partial uncertainty**		**Square of uncertainty**	
1	Repeatability at zero	≤	1,0 nmol/mol	0,200	$u_{r,Z}$	0,02	0,0005	
2	Repeatability at concentration ct	≤	3,0 nmol/mol	1,200	$u_{r,lh}$	not considered because ur,lh = 0,131 < ur,f	-	
3	"lack of fit"	≤	4,0% of measurement	0,500	$u_{l,lh}$	1,46	2,1252	
4	Sensitivity coefficient of sample gas pressure	≤	8,0 nmol/mol/kPa	0,010	u_{gp}	0,17	0,0300	
5	Sensitivity coefficient of sample gas temperature	≤	3,0 nmol/mol/K	0,053	u_{gt}	0,62	0,3821	
6	Sensitivity coefficient of surrounding temperature	≤	3,0 nmol/mol/K	-0,260	u_{st}	-3,03	9,1945	
7	Sensitivity coefficient of electrical voltage	≤	0,30 nmol/mol/V	0,140	u_V	2,18	4,7393	
8a	H20 with concentration 21 mmol/mol	≤	5,0 nmol/mol	-0,077	u_{H2O}	-1,09	1,1810	
8b	CO2 with concentration 500 µmol/mol	≤	5,0 nmol/mol	0,002	$u_{int,pos}$ or $u_{int,neg}$	1,85	3,4133	
8c	O3 with concentration 200 nmol/mol	≤	2,0 nmol/mol	-0,016				
8d	NH3 with concentration 200 nmol/mol	≤	5,0 nmol/mol	0,003				
9	Averaging effect	≤	7,0% of measurement	5,600	u_{av}	16,33	266,5861	
10	Reproducibility under field conditions	≤	5,0% of the average of 3 month	2,590	$u_{r,f}$	2,71	7,3394	
11	Long term drift at zero level	≤	5,0 nmol/mol	0,630	$u_{d,l,z}$	0,36	0,1323	
12	Long term drift at span level	≤	5,0% of range	1,030	$u_{d,l,lh}$	3,00	9,0185	
18	Difference sample/calibration port	≤	1,0%	0,210	$u_{\Delta sc}$	1,06	1,1247	
21	Converter efficiency	≥	98%	99,400	u_{CE}	3,03	9,1809	
22	Increase of NO2 concentration due to residence time	≤	4,0 nmol/mol	0,050	u_{ctr}	0,25	0,0638	
23	Uncertainty calibration gas	≤	3,0%	2,000	u_{cg}	5,05	25,5025	
				combined standard uncertainty	u_c		18,6374	nmol/mol
				expanded uncertainty	U_c		37,2749	nmol/mol
				expanded uncertainty actual	$U_{c,rel}$		**7,38**	%
				expanded uncertainty required	$U_{req,rel.}$		15	%

Table 6: Extended Uncertainty from the Results of the Laboratory Test According to DIN EN 14211 (Component NO) for Unit 208

Device:	airpointer				Serial.-no.:		Device 2 (208)	
Component:	NO				1h-limit value:		505	nmol/mol
No.	**Performance characteristic**		**Performance criteria**	**Result**	**Partial uncertainty**		**Square of uncertainty**	
1	Repeatability at zero	≤	1,0 nmol/mol	0,100	$u_{r,Z}$	0,01	0,0001	
2	Repeatability at concentration ct	≤	3,0 nmol/mol	1,100	$u_{r,lh}$	0,12	0,0143	
3	"lack of fit"	≤	4,0% of measurement	0,700	$u_{l,lh}$	2,04	4,1654	
4	Sensitivity coefficient of sample gas pressure	≤	8,0 nmol/mol/kPa	0,020	u_{gp}	0,35	0,1200	
5	Sensitivity coefficient of sample gas temperature	≤	3,0 nmol/mol/K	0,017	u_{gt}	0,20	0,0393	
6	Sensitivity coefficient of surrounding temperature	≤	3,0 nmol/mol/K	0,130	u_{st}	1,52	2,2986	
7	Sensitivity coefficient of electrical voltage	≤	0,30 nmol/mol/V	0,210	u_V	3,27	10,6634	
8a	H20 with concentration 21 mmol/mol	≤	5,0 nmol/mol	-0,118	u_{H2O}	-1,67	2,8016	
8b	CO2 with concentration 500 µmol/mol	≤	5,0 nmol/mol	0,000	$u_{int,pos}$	1,44	2,0833	
8c	O3 with concentration 200 nmol/mol	≤	2,0 nmol/mol	-0,013	or			
8d	NH3 with concentration 200 nmol/mol	≤	5,0 nmol/mol	0,004	$u_{int,neg}$			
9	Averaging effect	≤	7,0% of measurement	4,000	u_{av}	11,66	136,0133	
18	Difference sample/calibration port	≤	1,0%	0,180	$u_{\Delta sc}$	0,91	0,8263	
21	Converter efficiency	≥	98%	99,000	u_{CE}	5,05	25,5025	
22	Increase of NO2 concentration due to residence time	≤	4,0 nmol/mol	0,050	u_{ctr}	0,25	0,0638	
23	Uncertainty calibration gas	≤	3,0%	2,000	u_{cg}	5,05	25,5025	
			combined standard uncertainty		u_c		14,4951	nmol/mol
			expanded uncertainty		U_c		28,9903	nmol/mol
			expanded uncertainty actual		$U_{c,rel}$		**5,74**	%
			expanded uncertainty required		$U_{req,rel.}$		15	%

Table 7: Extended Uncertainty from the Results of the Laboratory Test and Field Test According to DIN EN 14211(Component NO) for Unit 208

Device:	airpointer				Serial-no.:	Device 2 (208)	
Component:	NO				1h-limit value:	505	nmol/mol
No.	**Performance characteristic**	**Performance criteria**	**Result**	**Partial uncertainty**		**Square of uncertainty**	
1	Repeatability at zero	≤ 1,0 nmol/mol	0,100	$u_{r,Z}$	0,01	0,0001	
2	Repeatability at concentration ct	≤ 3,0 nmol/mol	1,100	$u_{r,lh}$	not considered because ur,lh = 0,119 < ur,f	-	
3	"lack of fit"	≤ 4,0% of measurement	0,700	$u_{l,lh}$	2,04	4,1654	
4	Sensitivity coefficient of sample gas pressure	≤ 8,0 nmol/mol/kPa	0,020	u_{gp}	0,35	0,1200	
5	Sensitivity coefficient of sample gas temperature	≤ 3,0 nmol/mol/K	0,017	u_{gt}	0,20	0,0393	
6	Sensitivity coefficient of surrounding temperature	≤ 3,0 nmol/mol/K	0,130	u_{st}	1,52	2,2986	
7	Sensitivity coefficient of electrical voltage	≤ 0,30 nmol/mol/V	0,210	u_V	3,27	10,6634	
8a	H20 with concentration 21 mmol/mol	≤ 5,0 nmol/mol	-0,118	u_{H2O}	-1,67	2,8016	
8b	CO2 with concentration 500 µmol/mol	≤ 5,0 nmol/mol	0,000	$u_{int,pos}$ or $u_{int,neg}$	1,44	2,0833	
8c	O3 with concentration 200 nmol/mol	≤ 2,0 nmol/mol	-0,013				
8d	NH3 with concentration 200 nmol/mol	≤ 5,0 nmol/mol	0,004				
9	Averaging effect	≤ 7,0% of measurement	4,000	u_{av}	11,66	136,0133	
10	Reproducibility under field conditions	≤ 5,0% of the average of 3 month	2,590	$u_{r,f}$	2,71	7,3394	
11	Long term drift at zero level	≤ 5,0 nmol/mol	0,840	$u_{d,l,z}$	0,48	0,2352	
12	Long term drift at span level	≤ 5,0% of range	0,950	$u_{d,l,lh}$	2,77	7,6720	
18	Difference sample/calibration port	≤ 1,0%	0,180	$u_{\Delta sc}$	0,91	0,8263	
21	Converter efficiency	≥ 98%	99,000	u_{CE}	5,05	25,5025	
22	Increase of NO2 concentration due to residence time	≤ 4,0 nmol/mol	0,050	u_{ctr}	0,25	0,0638	
23	Uncertainty calibration gas	≤ 3,0%	2,000	u_{cg}	5,05	25,5025	
				combined standard uncertainty	u_c	15,2534	nmol/mol
				expanded uncertainty	U_c	30,5068	nmol/mol
				expanded uncertainty actual	$U_{c,rel}$	**6,04**	%
				expanded uncertainty required	$U_{req,rel.}$	15	%

6.3 Test Results and Approval of Suitability According to DIN EN 14212 for the Component SO_2

The approval of suitability consists of the following steps:

***1)** The value of every single performance parameter tested in the laboratory has to fulfill the criterion in Table 1 (see 8.2 in DIN EN 14212).*

***2)** The extended measurement uncertainty, computed from the standard uncertainties of the specific performance parameters determined in the laboratory test, fulfills the criterion of guideline 2002/3/EG. This criterion is the maximum allowable uncertainty of individual measurements for continuous measurements of the 1-h-average. The relevant performance parameters and the method of computation are indicated in Appendix G of guideline DIN EN 14212.*

***3)** The value of every single performance parameter tested in the field has to fulfill the criterion in Table 1 (see 8.2 in DIN EN 14212).*

***4)** The extended measurement uncertainty, computed from the standard uncertainties of the specific performance parameters determined in the laboratory test and field test, fulfills the criterion of guideline 2002/3/EG. This criterion is the maximum allowable uncertainty of individual measurements for continuous measurements of the 1-h-average. The relevant performance parameters and the method of computation are indicated in Appendix G of guideline DIN EN 14212.*

Test Instructions

Computation according to appendix G of guideline DIN EN 14212

Test Procedure

The test was conducted according to DIN EN 14212. A detailed description of each test item plus results are listed in Appendix C. The required uncertainties were computed with the test values at the end of the test.

Analysis

On 1) The value of every single performance parameter tested in the laboratory fulfills the criterion in Table 1 of DIN EN 14212.

On 2) The extended measurement uncertainty, computed from the standard uncertainties of the specific performance parameters determined in the laboratory test, fulfills the required criterion.

On 3) The value of every single performance parameter tested in the field fulfills the criterion in Table 1 of DIN EN 14212.

On 4) The extended measurement uncertainty, computed from the standard uncertainties of the specific performance parameters determined in the laboratory test and field test, fulfills the required criterion.

Assessment

A detailed description of each test item plus results is listed in Appendix C. The minimum requirements are fulfilled.

Minimum requirements fulfilled? Yes

Detailed Description

A detailed description of each test item plus results is listed in Appendix C.

The results of items 1 and 3 are combined in Table 8.

The results of item 2 are indicated in Table 9 and Table 11.

The results of item 4 are indicated in Table 10 und Table 12.

Table 8: Performance Requirements According to DIN EN 14212 for the Component SO_2

Performance Parameter	Performance Criterion	Test Result	Complied
8.4.5 Repeat standard deviation for zero	≤ 1.0 nmol/mol	S_r unit 188: 0.1 ppb S_r unit 208: 0.1 ppb	yes
8.4.5 Repeat standard deviation for concentration ct	≤ 3.0 nmol/mol	S_r unit 188: 0.5 ppb S_r unit 208: 0.4 ppb	yes
8.4.6 „lack of fit" (Deviation of the linear regression)	Largest deviation of the linear regression function for concentrations larger than zero ≤ 4 % of the measurement reading Deviation for zero ≤ 5.0 nmol/mol	$X_{l,z}$ unit 188: NP 0.2 ppb X_l unit 188: RP 0.1 % $X_{l,z}$ unit 208: NP 0.2 ppb X_l unit 208: RP -0.7 %	yes
8.4.7 Sensitivity coefficient of sample pressure	≤ 2.0 nmol/mol/kPa	b_{gp} unit 188: 0.02 ppk/kPa b_{gp} unit 208: 0.02 ppb/kPa	yes
8.4.8 Sensitivity coefficient of sample temperature	≤ 1.0 nmol/mol/K	b_{gt} unit 188: 0.037 ppb/K b_{gt} unit 208: 0.008 ppb/K	yes
8.4.9 Sensitivity coefficient of ambient temperature	≤ 1.0 nmol/mol/K	b_{st} unit 188: 0.11 ppb/K b_{st} unit 208: 0.10 ppb/K	yes
8.4.10 Sensitivity coefficient of voltage	≤ 0.3 nmol/mol/V	b_v unit 188: NP 0.02 ppb/V b_v unit 208: RP 0.01 ppb/V	yes
8.4.11 Interference components for zero and concentration ct	H_2O ≤ 10 nmol/mol H_2S ≤ 5 nmol/mol NH_3 ≤ 5 nmol/mol NO ≤ 5 nmol/mol NO_2 ≤ 5 nmol/mol m-xylene ≤ 10 nmol/mol	H_2O Unit 188: NP 0.1 ppb / RP -1.7 ppb Unit 208: NP 0.1 ppb / RP -1.3 ppb H_2S Unit 188: NP 0.1 ppb / RP 0.4 ppb Unit 208: NP 0.1 ppb / RP 0.2 ppb NH_3 Unit 188: NP 0.3 ppb / RP 0.8 ppb Unit 208: NP 0.1 ppb / RP 1.1 ppb NO Unit 188: NP 0.0 ppb / RP 0.4 ppb Unit 208: NP -0.1 ppb / RP 0.4 ppb NO_2 Unit 188: NP 0.0 ppb / RP 0.4 ppb Unit 208: NP 0.0 ppb / RP 0.5 ppb m-xylene Unit 188: NP 0.1 ppb / RP 0.5 ppb Unit 208: NP 0.1 ppb / RP 1.0 ppb	yes

Performance Parameter	Performance Criterion	Test Result	Complied
8.4.12 Influence of averaging	≤ 7.0 % of measurement reading	X_{av} unit 188: -4.8 % X_{av} unit 208: -3.4 %	yes
8.4.13 Difference between sample in / calibration in	≤ 1.0 %	D_{SC} unit 188: 0.02 D_{SC} unit 208: 0.04	yes
8.4.3 Set-up time (Rise)	≤ 180 s	t_r unit 188: max. 40 s t_r unit 208: max. 41 s	yes
8.4.3 Set-up time (Fall)	≤ 180 s	t_f unit 188: max. 37 s t_f unit 208: max. 42 s	yes
8.4.3 Difference between rise and fall time (Slope)	≤ 10 % relative difference or 10 s, whichever is greater	t_d unit 188: 0.7 % or 3 s t_d unit 208: 2.6 % or 5 s	yes
8.5.6 Control interval	3 months or less if indicated by the manufacturer, but never less than 2 weeks	Unit 188: 4 weeks Unit 208: 4 weeks	yes
8.5.7 Availability of the measuring device	> 90 %	A_a unit 188: 96 % A_a unit 208: 96 %	yes
8.5.5 Comparison standard deviation under field conditions	≤ 5.0 % of average over a period of three months	$S_{r,f}$ unit 188: 4.87 % $S_{r,f}$ unit 208: 4.87 %	yes
8.5.4 Long-term drift for zero	≤ 5.0 nmol/mol	$D_{l,z}$ unit 188: 0.42 ppb $D_{l,z}$ unit 208: 0.57 ppb	yes
8.5.4 Long-term drift for span	≤ 5.0 % of maximum of certification range	$D_{l,s}$ unit 188: max. 0.88 % $D_{l,s}$ unit 208: max. 1.37 %	yes
8.4.4 Short-term drift for zero	≤ 2.0 nmol/mol for 12 h	$D_{s,z}$ unit 188: 0.0 ppb $D_{s,z}$ unit 208: -0.1 ppb	yes
8.4.4 Short-term drift for span	≤ 6.0 nmol/mol for 12 h	$D_{s,s}$ unit 188: 0.0 ppb $D_{s,s}$ unit 208: 0.0 ppb	yes

Table 9: Extended Uncertainty from the Results of the Laboratory Test According to DIN EN 14212 (Component SO_2) for Unit 188

Device:	airpointer				Serial-no.:		Device 1 (188)	
Component:	SO2				1h-limit value:		132	nmol/mol
No.	**Performance characteristic**		**Performance criteria**	**Result**	**Partial uncertainty**		**Square of uncertainty**	
1	Repeatability at zero	≤	1,0 nmol/mol	0,100	$u_{r,Z}$	0,01	0,0001	
2	Repeatability at concentration ct	≤	3,0 nmol/mol	0,500	$u_{r,lv}$	0,05	0,0027	
3	"lack of fit"	≤	4,0% of measurement	0,100	$u_{l,lv}$	0,08	0,0058	
4	Sensitivity coefficient of sample gas pressure	≤	3,0 nmol/mol/kPa	0,020	u_{gp}	0,41	0,1713	
5	Sensitivity coefficient of sample gas temperature	≤	1,0 nmol/mol/K	0,037	u_{gt}	0,28	0,0790	
6	Sensitivity coefficient of surrounding temperature	≤	1,0 nmol/mol/K	0,110	u_{st}	0,84	0,7028	
7	Sensitivity coefficient of electrical voltage	≤	0,30 nmol/mol/V	0,020	u_V	0,20	0,0413	
8a	H20 with concentration 21 mmol/mol	≤	10 nmol/mol	-1,944	u_{H2O}	1,31	1,7218	
8b	H2S with concentration 200 nmol/mol	≤	5,0 nmol/mol	0,404	$u_{int,pos}$			
8c	NH3 with concentration 200 nmol/mol	≤	5,0 nmol/mol	0,805				
8d	NO with concentration 500 nmol/mol	≤	5,0 nmol/mol	0,405	or	1,51	2,2950	
8e	NO2 with concentration 200 nmol/mol	≤	5,0 nmol/mol	0,506				
8f	m-Xylol with concentration 1 µmol/mol	≤	10 nmol/mol	0,505	$u_{int,neg}$			
9	Averaging effect	≤	7,0% of measurement	-4,800	u_{av}	-3,66	13,3816	
18	Difference sample/calibration port	≤	1,0%	0,020	u_{Dsc}	0,02	0,0002	
23	Uncertainty calibration gas	≤	3,0%	2,000	ucg	1,32	1,7424	
				combined standard uncertainty	u_c		4,4882	nmol/mol
				expanded uncertainty	U_c		8,9764	nmol/mol
				expanded uncertainty actual	$U_{c,rel}$		**6,80**	%
				expanded uncertainty required	$U_{req,rel.}$		15	%

Table 10: Extended Uncertainty from the Results of the Laboratory Test and Field Test According to DIN EN 14212 (Component SO_2) for Unit 188

Device:	airpointer				Serial-no.:		Device 1 (188)	
Component:	SO2				1h-limit value:		132	nmol/mol
No.	**Performance characteristic**		**Performance criteria**	**Result**	**Partial uncertainty**		**Square of uncertainty**	
1	Repeatability at zero	≤	1,0 nmol/mol	0,100	$u_{r,Z}$	0,01	0,0001	
2	Repeatability at concentration ct	≤	3,0 nmol/mol	0,500	$u_{r,lv}$	not considered because ur,lv = 0,05 < ur,f	-	
3	"lack of fit"	≤	4,0% of measurement	0,100	$u_{l,lv}$	0,08	0,0058	
4	Sensitivity coefficient of sample gas pressure	≤	3,0 nmol/mol/kPa	0,020	u_{gp}	0,41	0,1713	
5	Sensitivity coefficient of sample gas temperature	≤	1,0 nmol/mol/K	0,037	u_{gt}	0,28	0,0790	
6	Sensitivity coefficient of surrounding temperature	≤	1,0 nmol/mol/K	0,110	u_{st}	0,84	0,7028	
7	Sensitivity coefficient of electrical voltage	≤	0,30 nmol/mol/V	0,020	u_V	0,20	0,0413	
8a	H20 with concentration 21 mmol/mol	≤	10 nmol/mol	-1,944	u_{H2O}	1,31	1,7218	
8b	H2S with concentration 200 nmol/mol	≤	5,0 nmol/mol	0,404	$u_{int,pos}$ or $u_{int,neg}$	1,51	2,2950	
8c	NH3 with concentration 200 nmol/mol	≤	5,0 nmol/mol	0,805				
8d	NO with concentration 500 nmol/mol	≤	5,0 nmol/mol	0,405				
8e	NO2 with concentration 200 nmol/mol	≤	5,0 nmol/mol	0,506				
8f	m-Xylol with concentration 1 µmol/mol	≤	10 nmol/mol	0,505				
9	Averaging effect	≤	7,0% of measurement	-4,800	u_{av}	-3,66	13,3816	
10	Reproducibility under field conditions	≤	5,0% of average of 3 month	4,870	$u_{r,f}$	6,43	41,3243	
11	Long term drift at zero level	≤	5,0 nmol/mol	0,420	$u_{d,l,z}$	0,24	0,0588	
12	Long term drift at span level	≤	5,0% of range	0,880	$u_{d,l,lv}$	0,67	0,4498	
18	Difference sample/calibration port	≤	1,0%	0,020	u_{Dsc}	0,02	0,0002	
23	Uncertainty calibration gas	≤	3,0%	2,000	ucg	1,32	1,7424	
				combined standard uncertainty	u_c		7,8724	nmol/mol
				expanded uncertainty	U_c		15,7447	nmol/mol
				expanded uncertainty actual	$U_{c,rel}$		**11,93**	%
				expanded uncertainty required	$U_{req,rel.}$		15	%

Table 11: Extended Uncertainty from the Results of the Laboratory Tests According to DIN EN 14212 (Component SO_2) for Unit 208

Device:	airpointer				Serial-no:		Device 2 (208)	
Component:	SO2				1h-limit value:		132	nmol/mol
No.	**Performance characteristic**		**Performance criteria**	**Result**	**Partial uncertainty**		**Square of uncertainty**	
1	Repeatability at zero	≤	1,0 nmol/mol	0,100	$u_{r,Z}$	0,01	0,0001	
2	Repeatability at concentration ct	≤	3,0 nmol/mol	0,400	$u_{r,lv}$	0,04	0,0019	
3	"lack of fit"	≤	4,0% of measurement	-0,700	$u_{l,lv}$	-0,53	0,2846	
4	Sensitivity coefficient of sample gas pressure	≤	3,0 nmol/mol/kPa	0,010	u_{gp}	0,21	0,0446	
5	Sensitivity coefficient of sample gas temperature	≤	1,0 nmol/mol/K	0,008	u_{gt}	0,06	0,0037	
6	Sensitivity coefficient of surrounding temperature	≤	1,0 nmol/mol/K	0,100	u_{st}	0,76	0,5808	
7	Sensitivity coefficient of electrical voltage	≤	0,30 nmol/mol/V	0,010	u_V	0,10	0,0103	
8a	H20 with concentration 21 mmol/mol	≤	10 nmol/mol	-1,487	u_{H2O}	1,00	1,0074	
8b	H2S with concentration 200 nmol/mol	≤	5,0 nmol/mol	0,201	$u_{int,pos}$			
8c	NH3 with concentration 200 nmol/mol	≤	5,0 nmol/mol	1,107				
8d	NO with concentration 500 nmol/mol	≤	5,0 nmol/mol	0,406	or	1,80	3,2570	
8e	NO2 with concentration 200 nmol/mol	≤	5,0 nmol/mol	0,405				
8f	m-Xylol with concentration 1 µmol/mol	≤	10 nmol/mol	1,007	$u_{int,neg}$			
9	Averaging effect	≤	7,0% of measurement	-3,400	u_{av}	-2,59	6,7140	
18	Difference sample/calibration port	≤	1,0%	0,040	u_{Dsc}	0,03	0,0009	
23	Uncertainty calibration gas	≤	3,0%	2,000	0	1,32	1,7424	
				combined standard uncertainty	u_c		3,6943	nmol/mol
				expanded uncertainty	U_c		7,3886	nmol/mol
				expanded uncertainty actual	$U_{c,rel}$		**5,60**	%
				expanded uncertainty required	$U_{req,rel.}$		15	%

Table 12: Extended Uncertainty from the Results of the Laboratory Test and Field Test According to DIN EN 14212 (Component SO_2) for Unit 208

Device:	airpointer				Serial-no.:		Device 2 (208)	
Component:	SO2				1h-limit value:		132	nmol/mol
No.	**Performance characteristic**		**Performance criteria**	**Result**	**Partial uncertainty**		**Square of uncertainty**	
1	Repeatability at zero	≤	1,0 nmol/mol	0,100	$u_{r,Z}$	0,01	0,0001	
2	Repeatability at concentration ct	≤	3,0 nmol/mol	0,400	$u_{r,lv}$	not considered because ur,lv = 0,04 < ur,f	-	
3	"lack of fit"	≤	4,0% of measurement	-0,700	$u_{l,lv}$	-0,53	0,2846	
4	Sensitivity coefficient of sample gas pressure	≤	3,0 nmol/mol/kPa	0,010	u_{gp}	0,21	0,0446	
5	Sensitivity coefficient of sample gas temperature	≤	1,0 nmol/mol/K	0,008	u_{gt}	0,06	0,0037	
6	Sensitivity coefficient of surrounding temperature	≤	1,0 nmol/mol/K	0,100	u_{st}	0,76	0,5808	
7	Sensitivity coefficient of electrical voltage	≤	0,30 nmol/mol/V	0,010	u_V	0,10	0,0103	
8a	H20 with concentration 21 mmol/mol	≤	10 nmol/mol	-1,487	u_{H2O}	1,00	1,0074	
8b	H2S with concentration 200 nmol/mol	≤	5,0 nmol/mol	0,201	$u_{int,pos}$ or $u_{int,neg}$	1,80	3,2570	
8c	NH3 with concentration 200 nmol/mol	≤	5,0 nmol/mol	1,107				
8d	NO with concentration 500 nmol/mol	≤	5,0 nmol/mol	0,406				
8e	NO2 with concentration 200 nmol/mol	≤	5,0 nmol/mol	0,405				
8f	m-Xylol with concentration 1 µmol/mol	≤	10 nmol/mol	1,007				
9	Averaging effect	≤	7,0% of measurement	-3,400	u_{av}	-2,59	6,7140	
10	Reproducibility under field conditions	≤	5,0% of average of 3 month	4,870	$u_{r,f}$	6,43	41,3243	
11	Long term drift at zero level	≤	5,0 nmol/mol	0,570	$u_{d,l,z}$	0,33	0,1083	
12	Long term drift at span level	≤	5,0% of range	1,370	$u_{d,l,lv}$	1,04	1,0901	
18	Difference sample/calibration port	≤	1,0%	0,040	u_{Dsc}	0,03	0,0009	
23	Uncertainty calibration gas	≤	3,0%	2,000	0	1,32	1,7424	
				combined standard uncertainty	u_c		7,4946	nmol/mol
				expanded uncertainty	U_c		14,9891	nmol/mol
				expanded uncertainty actual	$U_{c,rel}$		**11,36**	%
				expanded uncertainty required	$U_{req,rel.}$		15	%

6.4 Test Results and Approval of Suitability According to DIN EN 14625 for the Component O_3

The approval of suitability consists of the following steps:

***1)** The value of every single performance parameter tested in the laboratory has to fulfill the criterion in Table 1 (see 8.2 in DIN EN 14625).*

***2)** The extended measurement uncertainty, computed from the standard uncertainties of the specific performance parameters determined in the laboratory test, fulfills the criterion of guideline 2002/3/EG. This criterion is the maximum allowable uncertainty of individual measurements for continuous measurements of the 1-h-average. The relevant performance parameters and the method of computation are indicated in Appendix G of guide-line DIN EN 14625.*

***3)** The value of every single performance parameter tested in the field has to fulfill the criterion in Table 1 (see 8.2 in DIN EN 14625).*

***4)** The extended measurement uncertainty, computed from the standard uncertainties of the specific performance parameters determined in the laboratory test and field test, fulfills the criterion of guideline 2002/3/EG. This criterion is the maximum allowable uncertainty of individual measurements for continuous measurements of the 1-h-average. The relevant performance parameters and the method of computation are indicated in Appendix G of guideline DIN EN 14625.*

Test Instructions

Computation according to Appendix G of guideline DIN EN 14625

Test Procedure

The test was conducted according to DIN EN 14625. A detailed description of each test item plus results is listed in Appendix D. The required uncertainties were computed with the test values at the end of the test.

Analysis

On 1) The value of every single performance parameter tested in the laboratory fulfills the criterion in Table 1 of DIN EN 14625.

On 2) The extended measurement uncertainty, computed from the standard uncertainties of the specific performance parameters determined in the laboratory test, fulfills the required criterion.

On 3) The value of every single performance parameter tested in the field fulfills the criterion in Table 1 of DIN EN 14625.

On 4) The extended measurement uncertainty, computed from the standard uncertainties of the specific performance parameters determined in the laboratory test and field test, fulfills the required criterion.

Assessment

A detailed description of each test item plus results is listed in Appendix D. The minimum requirements are fulfilled.

Minimum requirements fulfilled? Yes

Detailed Description

A detailed description of each test item plus results is listed in Appendix D.

The results of items 1 and 3 are combined in Table 13.

The results of item 2 are indicated in Table 14 and Table 16.

The results of item 4 are indicated in Table 15 and Table 17.

Table 13: Performance Requirements According to DIN EN 14625 for the Component O_3

Performance Parameter	Performance Criterion	Test Result	Com-plied
8.4.5 Repeat standard deviation for zero	≤ 1.0 nmol/mol	S_r unit 188: 0.1 ppb S_r unit 208: 0.1 ppb	yes
8.4.5 Repeat standard deviation for concentration ct	≤ 3.0 nmol/mol	S_r unit 188: 1.0 ppb S_r unit 208: 0.9 ppb	yes
8.4.6 „lack of fit“ (Deviation of the linear regression)	Largest deviation of the linear regression function for concentration larger than zero ≤ 4 % Deviation for zero ≤ 5.0 nmol/mol	$X_{l,z}$ unit 188: NP 0.1 ppb X_l unit 188: RP 0.5 % $X_{l,z}$ unit 208: NP 0.1 ppb X_l unit 208: RP 1.4 %	yes
8.4.7 Sensitivity coefficient of sample pressure	≤ 2.0 nmol/mol/kPa	b_{gp} unit 188: 0.01 b_{gp} unit 208: 0.01	yes
8.4.8 Sensitivity coefficient of sample temperature	≤ 1.0 nmol/mol/K	b_{gt} unit 188: 0.022 ppb b_{gt} unit 208: 0.004 ppb	yes
8.4.9 Sensitivity coefficient of ambient temperature	≤ 1.0 nmol/mol/K	b_{st} unit 188: 0.11 ppb b_{st} unit 208: 0.09 ppb	yes
8.4.10 Sensitivity coefficient of voltage	≤ 1.0 nmol/mol/V	b_v unit 188: NP 0.02 ppb b_v unit 208: RP 0.05 ppb	yes
8.4.11 Interference components for zero and concentration ct	H_2O ≤ 10 nmol/mol Toluol ≤ 5.0 nmol/mol Xylene ≤ 5.0 nmol/mol	H_2O Unit 188: NP 0.1 ppb / RP 1.0 ppb Unit 208: NP 0.2 ppb / RP 0.4 ppb Toluol Unit 188: NP 0.1 ppb / RP 1.5 ppb Unit 208: NP 0.1 ppb / RP 1.3 ppb Xylene Unit 188: NP 0.2 ppb / RP 0.4 ppb Unit 208: NP 0.1 ppb / RP 1.0 ppb	yes
8.4.12 Influence of averaging	≤ 7.0 % of measurement reading	X_{av} unit 188: 0.8 % X_{av} unit 208: 2.5 %	yes
8.4.13 Difference between sample in / calibration in	≤ 1.0 %	D_{SC} unit 188: 0.02 D_{SC} unit 208: 0.01	yes

Performance Parameter	Performance Criterion	Test Result	Complied
8.4.3 Set-up time (Rise)	≤ 180 s	t_r unit 188: max. 43 s t_r unit 208: max. 43 s	yes
8.4.3 Set-up time (Fall)	≤ 180 s	t_f unit 188: max. 40 s t_f unit 208: max. 41 s	yes
8.4.3 Difference between rise and fall time (Slope)	≤ 10 % relative difference or 10 s, whichever is greater	t_d unit 188: 8.3 % or 5 s t_d unit 208: 3.8 % or 5 s	yes
8.5.6 Control interval	3 months or less if indicated by the manufacturer, but never less than 2 weeks	Unit 188: 4 weeks Unit 208: 4 weeks	yes
8.5.7 Availability of the measuring device	> 90 %	A_a unit 188: 96 % A_a unit 208: 96 %	yes
8.5.5 Comparison standard deviation under field conditions	≤ 5.0 % of average over a period of three months	$S_{r,f}$ unit 188: 3.27 % $S_{r,f}$ unit 208: 3.27 %	yes
8.5.4 Long-term drift for zero	≤ 5.0 nmol/mol	$D_{l,z}$ unit 188: 0.43 ppb $D_{l,z}$ unit 208: -0.57 ppb	yes
8.5.4 Long-term drift for span	≤ 5.0 % of maximum of certification range	$D_{l,s}$ unit 188: max. 1.53 % $D_{l,s}$ unit 208: max. 1.75 %	yes
8.4.4 Short-term drift for zero	≤ 2.0 nmol/mol for 12 h	$D_{s,z}$ unit 188: 0.0 ppb $D_{s,z}$ unit 208: 0.0 ppb	yes
8.4.4 Short-term drift for span	≤ 6.0 nmol/mol for 12 h	$D_{s,s}$ unit 188: -0.5 ppb $D_{s,s}$ unit 208: -0.9 ppb	yes

Table 14: Extended Uncertainty from the Results of the Laboratory Test According to DIN EN 14625 (Component O_3) for unit 188

Device:	Airpointer			Serial No.		Device 1 (188)	
Measured component:	O3			hourly alert threshold		120	nmol/mol
No.	**Performance characteristic**	**Criterion**	**Result**	**Uncertainty**		**Square of uncertainty**	
1	Repeatability standard deviation at zero	1,0 nmol/mol	0,100	$u_{r,Z}$	0,01	0,0001	
2	Repeatability standard deviation at ct	3,0 nmol/mol	1,000	$u_{r,lv}$	0,11	0,0115	
3	"lack of fit" at the hourly alert threshold value	4,0% of mesaurement	0,500	$u_{l,lv}$	0,35	0,1200	
4	Variations in sample gas pressure	2,0 nmol/mol/kPa	0,010	u_{gp}	0,11	0,0131	
5	Variations in sample gas temperature	1,0 nmol/mol/K	0,022	u_{gt}	0,23	0,0523	
6	Variations in surrounding temperature	1,0 nmol/mol/K	0,110	u_{st}	0,38	0,1452	
7	Variations in electrical voltage	0,30 nmol/mol/V	0,020	u_V	0,24	0,0588	
8a	Interference H20 mit 21 mmol/mol	10 nmol/mol	0,447	u_{H2O}	0,30	0,0912	
8b	Interference Toluol mit 0,5 µmol/mol	5,0 nmol/mol	1,470	$u_{int,pos}$ or $u_{int,neg}$	1,08	1,1652	
8c	Interference Xylol mit 0,5 µmol/mol	5,0 nmol/mol	0,399				
9	Averaging effect	7,0% of measurement	0,800	u_{av}	0,55	0,3072	
18	Difference sample/calibration port	1,0%	0,020	u_{Dsc}	0,01	0,0002	
23	Uncertainty test gas	3,0%	2,000	ucg	1,20	1,4400	
		Combined standard uncertainty			u_c	1,8452	nmol/mol
		Expanded uncertainty			U_c	3,6904	nmol/mol
		Expanded uncertainty actual			$U_{c,rel}$	**3,08**	%
		Expanded uncertainty required			$U_{req,rel.}$	15	%

Table 15 Extended Uncertainty from the Results of the Laboratory Test and Field Test According to DIN EN 14625 (component O_3) for Unit 188

Device:	Airpointer			Serial No.		Device 1 (188)	
Component:	O3			hourly alert threshold		120	nmol/mol
No.	**Performance characteristic**	**Criterion**	**Result**	**Uncertainty**		**Square of uncertainty**	
1	Repeatability standard deviation at zero	1,0 nmol/mol	0,100	$u_{r,Z}$	0,01	0,0001	
2	Repeatability standard deviation at ct	3,0 nmol/mol	1,000	$u_{r,lv}$	not considered because ur,lv = 0,1 < ur,f	-	
3	"lack of fit" at the hourly alert threshold value	4,0% of measurement	0,500	$u_{l,lv}$	0,35	0,1200	
4	Variations in sample gas pressure	2,0 nmol/mol/kPa	0,010	u_{gp}	0,11	0,0131	
5	Variations in sample gas temperature	1,0 nmol/mol/K	0,022	u_{gt}	0,23	0,0523	
6	Variations in surrounding temperature	1,0 nmol/mol/K	0,110	u_{st}	0,38	0,1452	
7	Variations in electrical voltage	0,30 nmol/mol/V	0,020	u_V	0,24	0,0588	
8a	Interference H20 mit 21 mmol/mol	10 nmol/mol	0,447	u_{H2O}	0,30	0,0912	
8b	Interference Toluol mit 0,5 µmol/mol	5,0 nmol/mol	1,470	$u_{int,pos}$ or $u_{int,neg}$	1,08	1,1652	
8c	Interference Xylol mit 0,5 µmol/mol	5,0 nmol/mol	0,399				
9	Averaging effect	7,0% of measurement	0,800	u_{av}	0,55	0,3072	
10	Reproducibility standard deviation in field	5,0% of average of 3 month	3,270	$u_{r,f}$	3,92	15,3978	
11	Long term drift at zero	5,0 nmol/mol	0,430	$u_{d,l,z}$	0,25	0,0616	
12	Long term drift at span level	5,0% of range	1,530	$u_{d,l,lv}$	1,06	1,1236	
18	Difference sample/calibration port	1,0%	0,020	u_{Dsc}	0,01	0,0002	
23	Uncertainty test gas	3,0%	2,000	ucg	1,20	1,4400	
		Combined standard uncertainty		u_c		4,4695	nmol/mol
		Expanded uncertainty		U_c		8,9390	nmol/mol
		Expanded uncertainty actual		$U_{c,rel}$		**7,45**	%
		Expanded uncertainty required		$U_{req,rel.}$		15	%

Table 16: Extended Uncertainty from the Results of the Laboratory Test According to DIN EN 14625 (component O_3) for Unit 208

Device:	Airpointer			Serial No.		Device 2 (208)	
Measured component:	O3			hourly alert threshold		120	nmol/mol
No.	**Performance characteristic**	**Criterion**	**Result**	**Uncertainty**		**Square of uncertainty**	
1	Repeatability standard deviation at zero	1,0 nmol/mol	0,100	$u_{r,z}$	0,01	0,0001	
2	Repeatability standard deviation at ct	3,0 nmol/mol	0,900	$u_{r,lv}$	0,10	0,0095	
3	"lack of fit" at the hourly alert threshold value	4,0% of measurement	1,400	$u_{l,lv}$	0,97	0,9408	
4	Variations in sample gas pressure	2,0 nmol/mol/kPa	0,010	u_{gp}	0,11	0,0130	
5	Variations in sample gas temperature	1,0 nmol/mol/K	0,004	u_{gt}	0,04	0,0017	
6	Variations in surrounding temperature	1,0 nmol/mol/K	0,090	u_{st}	0,31	0,0972	
7	Variations in electrical voltage	0,30 nmol/mol/V	0,050	u_V	0,61	0,3675	
8a	Interference H20 mit 21 mmol/mol	10 nmol/mol	1,122	u_{H2O}	0,76	0,5738	
8b	Interference Toluol mit 0,5 µmol/mol	5,0 nmol/mol	1,285	$u_{int,pos}$ oder $u_{int,neg}$	1,32	1,7294	
8c	Interference Xylol mit 0,5 µmol/mol	5,0 nmol/mol	0,993				
9	Averaging effect	7,0% of measurement	2,500	u_{av}	1,73	3,0000	
18	Difference sample/calibration port	1,0%	0,010	u_{Dsc}	0,01	0,0000	
23	Uncertainty test gas	3,0%	2,000	0	1,20	1,4400	
				Combined standard uncertainty	u_c	2,8589	nmol/mol
				Expanded uncertainty	U_c	5,7177	nmol/mol
				Expanded uncertainty actual	$U_{c,rel}$	**4,76**	%
				Expanded uncertainty required	$U_{req,rel.}$	15	%

Table 17 Extended Uncertainty from the Results of the Laboratory Test and Field Test According to DIN EN 14625 (Component O_3) for Unit 208

Device:	Airpointer			Serial No.		Device 2 (208)	
Component:	O3			hourly alert threshold		120	nmol/mol
No.	**Performance characteristic**	**Criterion**	**Result**	**Uncertainty**		**Square of uncertainty**	
1	Repeatability standard deviation at zero	1,0 nmol/mol	0,100	$u_{r,Z}$	0,01	0,0001	
2	Repeatability standard deviation at ct	3,0 nmol/mol	0,900	$u_{r,lv}$	not considered because ur,lv = 0,09 < ur,f	-	
3	"lack of fit" at the hourly alert threshold value	4,0% of measurement	1,400	$u_{l,lv}$	0,97	0,9408	
4	Variations in sample gas pressure	2,0 nmol/mol/kPa	0,010	u_{gp}	0,11	0,0130	
5	Variations in sample gas temperature	1,0 nmol/mol/K	0,004	u_{gt}	0,04	0,0017	
6	Variations in surrounding temperature	1,0 nmol/mol/K	0,090	u_{st}	0,31	0,0972	
7	Variations in electrical voltage	0,30 nmol/mol/V	0,050	u_V	0,61	0,3675	
8a	Interference H20 mit 21 mmol/mol	10 nmol/mol	1,122	u_{H2O}	0,76	0,5738	
8b	Interference Toluol mit 0,5 µmol/mol	5,0 nmol/mol	1,285	$u_{int,pos}$ or $u_{int,neg}$	1,32	1,7294	
8c	Interference Xylol mit 0,5 µmol/mol	5,0 nmol/mol	0,993				
9	Averaging effect	7,0% of measurement	2,500	u_{av}	1,73	3,0000	
10	Reproducibility standard deviation in field	5,0% of average of 3 month	3,270	$u_{r,f}$	3,92	15,3978	
11	Long term drift at zero	5,0 nmol/mol	-0,570	$u_{d,l,z}$	-0,33	0,1083	
12	Long term drift at span level	5,0% of range	1,750	$u_{d,l,lv}$	1,21	1,4700	
18	Difference sample/calibration port	1,0%	0,010	u_{Dsc}	0,01	0,0000	
23	Uncertainty test gas	3,0%	2,000	0	1,20	1,4400	
		Combined standard uncertainty			u_c	5,0139	nmol/mol
		Expanded uncertainty			U_c	10,0279	nmol/mol
		Expanded uncertainty actual			$U_{c,rel}$	**8,36**	%
		Expanded uncertainty required			$U_{req,rel.}$	15	%

6.5 Test Results and Approval of Suitability According to DIN EN 14626 for the Component CO

The approval of suitability consists of the following steps:

***1)** The value of every single performance parameter tested in the laboratory has to fulfill the criterion in Table 1 (see 8.2 in DIN EN 14626).*

***2)** The extended measurement uncertainty, computed from the standard uncertainties of the specific performance parameters determined in the laboratory test, fulfills the criterion of guideline 2002/3/EG. This criterion is the maximum allowable uncertainty of individual measurements for continuous measurements of the 1-h-average. The relevant performance parameters and the method of computation are indicated in Appendix G of guide-line DIN EN 14626.*

***3)** The value of every single performance parameter tested in the field has to fulfill the criterion in Table 1 (see 8.2 in DIN EN 14626).*

***4)** The extended measurement uncertainty, computed from the standard uncertainties of the specific performance parameters determined in the laboratory test and field test, fulfills the criterion of guideline 2002/3/EG. This criterion is the maximum allowable uncertainty of individual measurements for continuous measurements of the 1-h-average. The relevant performance parameters and the method of computation are indicated in Appendix G of guideline DIN EN 14626.*

Test Instructions

Computation according to Appendix G of guideline DIN EN 14626

Test Procedure

The test was conducted according to DIN EN 14626. A detailed description of each test item plus results is listed in Appendix E. The required uncertainties were computed with the test values at the end of the test.

Analysis

On 1) The value of every single performance parameter tested in the laboratory fulfills the criterion in Table 1 of DIN EN 14626.

On 2) The extended measurement uncertainty, computed from the standard uncertainties of the specific performance parameters determined in the laboratory test, fulfills the required criterion.

On 3) The value of every single performance parameter tested in the field fulfills the criterion in Table 1 of DIN EN 14626.

On 4) The extended measurement uncertainty, computed from the standard uncertainties of the specific performance parameters determined in the laboratory test and field test, fulfills the required criterion.

Assessment

The minimum requirements are fulfilled. A detailed description of each test item plus results is listed in Appendix E.

Minimum requirements fulfilled? Yes

Detailed description

A detailed description of each test item plus results is listed in Appendix E.

The results of items 1 and 3 are combined in Table 18.

The results of item 2 are indicated in Table 19 and Table 21.

The results of item 4 are indicated in Table 20 and Table 22.

Table 18: Performance Requirements According to DIN EN 14626 for the Component CO

Performance Parameter	Performance Criterion	Test Result	Complied
8.4.5 Repeat standard deviation for zero	≤ 1.0 µmol/mol	S_r unit 188: 0.0 ppm S_r unit 208: 0.1 ppm	yes
8.4.5 Repeat standard deviation for concentration ct	≤ 3.0 µmol/mol	S_r unit 188: 0.1 ppm S_r unit 208: 0.1 ppm	yes
8.4.6 „lack of fit“ (Deviation of the linear regression)	Largest deviation of the linear regression function for concentration larger than zero ≤ 4 % of the measurement reading Deviation for zero ≤ 0.2 µmol/mol	$X_{l,z}$ unit 188: NP 0.09 ppm X_l unit 188: RP 0.4 % $X_{l,z}$ unit 208: NP -0.02 ppm X_l unit 208: RP 0.4 %	yes
8.4.7 Sensitivity coefficient of sample pressure	≤ 0.70 µmol/mol/kPa	b_{gp} unit 188: 0.01 ppk/kPa b_{gp} unit 208: 0.01 ppm/kPa	yes
8.4.8 Sensitivity coefficient of sample temperature	≤ 0.30 µmol/mol/K	b_{gt} unit 188: 0.003 ppm/K b_{gt} unit 208: 0.000 ppm/K	yes
8.4.9 Sensitivity coefficient of ambient temperature	≤ 0.30 µmol/mol/K	b_{st} unit 188: 0.01 ppm/K b_{st} unit 208: 0.01 ppm/K	yes
8.4.10 Sensitivity coefficient of voltage	≤ 0.30 µmol/mol/V	b_v unit 188: 0.00 ppm/V b_v unit 208: 0.01 ppm/V	yes
8.4.11 Interference components for zero and concentration ct	H_2O ≤ 1.0 µmol/mol CO_2 ≤ 0.5 µmol/mol NO ≤ 0.5 µmol/mol N_2O ≤ 0.5 µmol/mol	H_2O Unit 188: NP 0.02 ppm / RP 0.03 ppm Unit 208: NP 0.02 ppm / RP 0.03 ppm CO_2 Unit 188: NP -0.01 ppm / RP -0.01 ppm Unit 208: NP -0.01 ppm / RP 0.01 ppm NO Unit 188: NP 0.00 ppm / RP 0.04 ppm Unit 208: NP 0.01 ppm / RP 0.03 ppm N_2O Unit 188: NP 0.02 ppm / RP -0.01 ppm Unit 208: NP 0.03 ppm / RP 0.03 ppm	yes

Performance Parameter	Performance Criterion	Test Result	Complied
8.4.12 Influence of averaging	≤ 7.0 % of measurement	X_{av} unit 188: -2.3 % X_{av} unit 208: 0.6 %	yes
8.4.13 Difference between sample in / calibration in	≤ 1.0 %	D_{SC} unit 188: -0.12 D_{SC} unit 208: -0.05	yes
8.4.3 Set-up time (Rise)	≤ 180 s	t_r unit 188: max. 92 s t_r unit 208: max. 93 s	yes
8.4.3 Set-up time (Fall)	≤ 180 s	t_f unit 188: max. 89 s t_f unit 208: max. 89 s	yes
8.4.3 Difference between rise and fall time (Slope)	≤ 10 % relative difference or 10 s, whichever is greater	t_d unit 188: 1.39 % or 4 s t_d unit 208: 3.31 % or 5 s	yes
8.5.6 Control interval	3 months or less if indicated by the manufacturer, but never less than 2 weeks	Unit 188: 4 weeks Unit 208: 4 weeks	yes
8.5.7 Availability of the measuring device	> 90 %	A_a unit 188: 96 % A_a unit 208: 96 %	yes
8.5.5 Comparison standard deviation under field conditions	≤ 5.0 % of average over a period of three months	$S_{r,f}$ unit 188: 4.80% $S_{r,f}$ unit 208: 4.80 %	yes
8.5.4 Long-term drift for zero	≤ 0.50 µmol/mol	$D_{l,z}$ unit 188: 0.25 ppm $D_{l,z}$ unit 208: 0.39 ppm	yes
8.5.4 Long-term drift for span	≤ 5.0 % of maximum of certification range	$D_{l,s}$ unit 188: max. 1.21 % $D_{l,s}$ unit 208: max. 1.27 %	yes
8.4.4 Short-term drift for zero	≤ 0.20 µmol/mol for 12 h	$D_{s,z}$ unit 188: 0.0 ppm $D_{s,z}$ unit 208: 0.0 ppm	yes
8.4.4 Short-term drft for span	≤ 0.60 µmol/mol for 12 h	$D_{s,s}$ unit 188: 0.0 ppm $D_{s,s}$ unit 208: 0.1 ppm	yes

Table 19: Extended Uncertainty from the Results of the Laboratory Test According to DIN EN 14626 (Component CO) for Unit 188

Device:	airpointer					Serial-no.:	Device 1 (188)	
Component:	CO					1h-limit value:	8,62	µmol/mol
No.	**Performance characteristic**		**Performance criteria**	**Result**	**Partial uncertainty**		**Square of uncertainty**	
1	Repeatability standard deviation at zero	≤	1,0 µmol/mol	0,000	$u_{r,Z}$	0,00	0,0000	
2	Repeatability standard deviation at ct	≤	3,0 µmol/mol	0,100	$u_{r,lv}$	0,02	0,0003	
3	"lack of fit" at the hourly alert threshold value	≤	4,0% of measurement	0,400	$u_{l,lv}$	0,02	0,0004	
4	Variations in sample gas pressure	≤	0,7 µmol/mol/kPa	0,010	u_{gp}	0,01	0,0002	
5	Variations in sample gas temperature	≤	0,3 µmol/mol/K	0,003	u_{gt}	0,01	0,0000	
6	Variations in surrounding temperature	≤	0,3 µmol/mol/K	0,010	u_{st}	0,02	0,0005	
7	Variations in electrical voltage	≤	0,3 µmol/mol/V	0,000	u_V	0,00	0,0000	
8a	Interference H20 mit 21 mmol/mol	≤	1,0 µmol/mol	0,033	u_{H2O}	0,02	0,0005	
8b	Interference CO2 mit 500 µmol/mol	≤	0,5 µmol/mol	-0,010	$u_{int,pos}$ or $u_{int,neg}$	0,02	0,0005	
8c	Interference NO mit 1 µmol/mol	≤	0,5 µmol/mol	0,038				
8d	Interference N2O mit 50 nmol/mol	≤	0,5 µmol/mol	-0,009				
9	Averaging effect	≤	7,0% of measurement	-2,300	u_{av}	-0,11	0,0131	
18	Difference sample/calibration port	≤	1,0%	-0,120	u_{Dsc}	-0,01	0,0000	
23	Uncertainty test gas	≤	3,0%	2,000	ucg	0,09	0,0074	
				Combined standard uncertainty	u_c		0,1515	µmol/mol
				Expanded uncertainty	U_c		0,3030	µmol/mol
				Expanded uncertainty actual	$U_{c,rel}$		3,52	%
				Expanded uncertainty required	$U_{req,rel.}$		15	%

Table 20: Extended Uncertainty from the Results of the Laboratory Test and Field Test According to DIN EN 14626 (Component CO) for Unit 188

Device:	airpointer				Serial-no.:		Device 1 (188)	
Component:	CO				1h-limit value:		8,62	µmol/mol
No.	**Performance characteristic**		**Performance criteria**	**Result**	**Partial uncertainty**		**Square of uncertainty**	
1	Repeatability standard deviation at zero	≤	1,0 µmol/mol	0,000	$u_{r,Z}$	0,00	0,0000	
2	Repeatability standard deviation at ct	≤	3,0 µmol/mol	0,100	$u_{r,lv}$	not considered because ur,lv = 0,01 < ur,f	-	
3	"lack of fit" at the hourly alert threshold value	≤	4,0% of measurement	0,400	$u_{l,lv}$	0,02	0,0004	
4	Variations in sample gas pressure	≤	0,7 µmol/mol/kPa	0,010	u_{gp}	0,01	0,0002	
5	Variations in sample gas temperature	≤	0,3 µmol/mol/K	0,003	u_{gt}	0,01	0,0000	
6	Variations in surrounding temperature	≤	0,3 µmol/mol/K	0,010	u_{st}	0,02	0,0005	
7	Variations in electrical voltage	≤	0,3 µmol/mol/V	0,000	u_V	0,00	0,0000	
8a	Interference H20 with 21 mmol/mol	≤	1,0 µmol/mol	0,033	u_{H2O}	0,02	0,0005	
8b	Interference CO2 with 500 µmol/mol	≤	0,5 µmol/mol	-0,010	$u_{int,pos}$ or $u_{int,neg}$	0,02	0,0005	
8c	Interference NO with 1 µmol/mol	≤	0,5 µmol/mol	0,038				
8d	Interference N2O with 50 nmol/mol	≤	0,5 µmol/mol	-0,009				
9	Averaging effect	≤	7,0% of measurement	-2,300	u_{av}	-0,11	0,0131	
10	Reproducibility standard deviation in field	≤	5,0% of average of 3 month	4,800	$u_{r,f}$	0,41	0,1712	
11	Long term drift at zero	≤	0,5 µmol/mol	0,250	$u_{d,l,z}$	0,14	0,0208	
12	Long term drift at span level	≤	5,0% of range	1,210	$u_{d,l,lv}$	0,06	0,0036	
18	Difference sample/calibration port	≤	1,0%	-0,120	u_{Dsc}	-0,01	0,0000	
23	Uncertainty test gas	≤	3,0%	2,000	ucg	0,09	0,0074	
					Combined standard uncertainty	u_c	0,4673	µmol/mol
					Expanded uncertainty	U_c	0,9346	µmol/mol
					Expanded uncertainty actual	$U_{c,rel}$	**10,84**	%
					Expanded uncertainty required	$U_{req,rel.}$	15	%

Table 21: Extended Uncertainty from the Results of the Laboratory Test According to DIN EN 14626 (Component CO) for Unit 208

Device:	airpointer				Serial-no.:		Device 2 (208)	
Component:	CO				1h-limit value:		8,62	µmol/mol
No.	**Performance characteristic**		**Performance criteria**	**Result**	**Partial uncertainty**		**Square of uncertainty**	
1	Repeatability standard deviation at zero	≤	1,0 µmol/mol	0,100	$u_{r,z}$	0,02	0,0003	
2	Repeatability standard deviation at ct	≤	3,0 µmol/mol	0,100	$u_{r,lv}$	0,02	0,0003	
3	"lack of fit" at the hourly alert threshold value	≤	4,0% of measurement	0,400	$u_{l,lv}$	0,02	0,0004	
4	Variations in sample gas pressure	≤	0,7 µmol/mol/kPa	0,010	u_{gp}	0,01	0,0002	
5	Variations in sample gas temperature	≤	0,3 µmol/mol/K	0,000	u_{gt}	0,00	0,0000	
6	Variations in surrounding temperature	≤	0,3 µmol/mol/K	0,010	u_{st}	0,02	0,0005	
7	Variations in electrical voltage	≤	0,3 µmol/mol/V	0,010	u_V	0,03	0,0009	
8a	Interference H20 mit 21 mmol/mol	≤	1,0 µmol/mol	0,033	u_{H2O}	0,02	0,0005	
8b	Interference CO2 mit 500 µmol/mol	≤	0,5 µmol/mol	0,014	$u_{int,pos}$ or $u_{int,neg}$	0,04	0,0018	
8c	Interference NO mit 1 µmol/mol	≤	0,5 µmol/mol	0,029				
8d	Interference N2O mit 50 nmol/mol	≤	0,5 µmol/mol	0,030				
9	Averaging effect	≤	7,0% of measurement	0,600	u_{av}	0,03	0,0009	
18	Difference sample/calibration port	≤	1,0%	-0,050	u_{Dsc}	0,00	0,0000	
23	Uncertainty test gas	≤	3,0%	2,000	0	0,09	0,0074	
				Combined standard uncertainty	u_c		0,1147	µmol/mol
				Expanded uncertainty	U_c		0,2293	µmol/mol
				Expanded uncertainty actual	$U_{c,rel}$		2,66	%
				Expanded uncertainty required	$U_{req,rel.}$		15	%

Table 22: Extended Uncertainty from the Results of the Laboratory Test and Field Test According to DIN EN 14626 (Component CO) for Unit 208

Device:	airpointer				Serial-no.:		Device 2 (208)	
Component:	CO				1h-limit value:		8,62	µmol/mol
No.	**Performance characteristic**		**Performance criteria**	**Result**	**Partial uncertainty**		**Square of uncertainty**	
1	Repeatability standard deviation at zero	≤	1,0 µmol/mol	0,100	$u_{r,Z}$	0,02	0,0003	
2	Repeatability standard deviation at ct	≤	3,0 µmol/mol	0,100	$u_{r,lv}$	not considered because ur,lv = 0,01 < ur,f	-	
3	"lack of fit" at the hourly alert threshold value	≤	4,0% of measurement	0,400	$u_{l,lv}$	0,02	0,0004	
4	Variations in sample gas pressure	≤	0,7 µmol/mol/kPa	0,010	u_{gp}	0,01	0,0002	
5	Variations in sample gas temperature	≤	0,3 µmol/mol/K	0,000	u_{gt}	0,00	0,0000	
6	Variations in surrounding temperature	≤	0,3 µmol/mol/K	0,010	u_{st}	0,02	0,0005	
7	Variations in electrical voltage	≤	0,3 µmol/mol/V	0,010	u_V	0,03	0,0009	
8a	Interference H20 with 21 mmol/mol	≤	1,0 µmol/mol	0,033	u_{H2O}	0,02	0,0005	
8b	Interference CO2 with 500 µmol/mol	≤	0,5 µmol/mol	0,014	$u_{int,pos}$ or $u_{int,neg}$	0,04	0,0018	
8c	Interference NO with 1 µmol/mol	≤	0,5 µmol/mol	0,029				
8d	Interference N2O with 50 nmol/mol	≤	0,5 µmol/mol	0,030				
9	Averaging effect	≤	7,0% of measurement	0,600	u_{av}	0,03	0,0009	
10	Reproducibility standard deviation in field	≤	5,0% of average of 3 month	4,800	$u_{r,f}$	0,41	0,1712	
11	Long term drift at zero	≤	0,5 µmol/mol	0,390	$u_{d,l,z}$	0,23	0,0507	
12	Long term drift at span level	≤	5,0% of range	1,270	$u_{d,l,lv}$	0,06	0,0040	
18	Difference sample/calibration port	≤	1,0%	-0,050	u_{Dsc}	0,00	0,0000	
23	Uncertainty test gas	≤	3,0%	2,000	0	0,09	0,0074	
					Combined standard uncertainty	u_c	0,4887	µmol/mol
					Expanded uncertainty	U_c	0,9773	µmol/mol
					Expanded uncertainty actual	$U_{c,rel}$	**11,34**	%
					Expanded uncertainty required	$U_{req,rel.}$	15	%

7 Recommendations for the Use in Practice

Besides routine calibration procedures it is important to regularly control the state of the internal Teflon filters which in case of an excessive load may cause a decrease of the drawn in sample volume. The duration of the filter exchange interval, the filters being intended to prevent the units from being contaminated by drawn in ambient air, depends entirely on the dust exposure on the respective site.

The airpointer should be inspected for obvious damages such as loose plugs and connections, cracked or blocked hose fittings, and exceptional high accumulation of dust and dirt.

Apart from that, the instructions and the maintenance schedule of the manufacturer have to be followed.

Immissionsschutz/Luftreinhaltung

Dipl.-Ing. Martin Schneider	Dipl.-Ing. Karsten Pletscher

Cologne, 01/15/2009
936/21209700/A

8 Literature

- VDI 4202 Blatt 1: Mindestanforderungen an automatische Immissionsmesseinrichtungen bei der Eignungsprüfung; Punktmessverfahren für gas- und partikelförmige Luftverunreinigungen, vom Juni 2002. Berlin: Beuth Verlag
- VDI 4203 Blatt 3: Prüfpläne für automatische Messeinrichtungen; Prüfprozeduren für Messeinrichtungen zur Punktförmigen Messung von - und partikelförmigen Immissionen, vom August 2004. Berlin: Beuth Verlag
- VDI 2453 Blatt 2: 2002-10 Messen gasförmiger Immissionen; Messen der Stickstoffmonoxid- und Stickstoffdioxidkonzentration; Kalibrierung von NO/NOx Chemolumineszenz-Messgeräten mit Hilfe der Gasphasentitration. Berlin: Beuth Verlag
- VDI 2453 Blatt 1: 1990-10 Messen gasförmiger Immissionen; Messen der Stickstoffdioxidkonzentration; Manuelles photometrisches Basisverfahren (Saltzman). Berlin: Beuth Verlag
- VDI 2451 Blatt 3: Messen der Schwefeldioxid-Konzentration –Photometrisches Verfahren (TCM - Verfahren), 1996
- DIN ISO 13964: Bestimmung von Ozon in der Außenluft – UV-photometrisches Verfahren, vom Dezember 1999
- VDI 2468 Blatt 1: Messen der Ozon- und Peroxid-Konzentration – Manuelles photometrisches Verfahren Kaliumjodid-Methode, vom Mai 1978
- VDI 2459 Blatt 1: Messen gasförmiger Emissionen - Messen von Kohlenmonoxid-Konzentrationen mittels Flammionisationsdetektor nach Reduktion zu Methan, vom Dezember 2000. Berlin: Beuth Verlag
- VDI 3490 Blatt 7: Messen von Gasen; Prüfgase; Dynamische Herstellung durch periodische Injektion, vom Dezember 1980. Berlin: Beuth Verlag
- Richtlinie 96/62/EG des Rates vom 27.September 1996 über die Beurteilung und die Kontrolle der Luftqualität ABl. L 208, S. 55
- Richtlinie 1999/30/EG des Rates vom 22. April 1999 über Grenzwerte für Schwefeldioxid, Stickstoffdioxid und Stickstoffoxide, Partikel und Blei in der Luft, ABl. L 163, S. 41
- DIN EN 14211 Luftqualität – Messverfahren zur Bestimmung der Konzentration von Stickstoffdioxid und Stickstoffmonoxid mit Chemilumineszenz, vom Juni 2005
- DIN EN 14212 Luftqualität – Messverfahren zur Bestimmung der Konzentration von Schwefeldioxid mit Ultraviolett-Fluoreszenz, vom Juni 2005
- DIN EN 14625 Luftqualität – Messverfahren zur Bestimmung der Konzentration von Ozon mit Ultraviolett-Photometrie, vom Juli 2005
- DIN EN 14626 Luftqualität – Messverfahren zur Bestimmung der Konzentration von Kohlenmonoxid mit nicht-dispersiver Infrarot-Photometrie, vom Juli 2005