TÜV RHEINLAND
ENERGIE UND UMWELT GMBH

Report on the performance testing of the ambient air monitor CO 12e by Environnement S.A. for the component CO

TÜV-report: 936/21228317/A
Cologne, 09 October 2015

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- Determination of air quality and emissions of air pollution and odour substances;
- Inspection of correct installation, function and calibration of continuously operating emission measuring instruments, including data evaluation and remote emission monitoring systems;
- Combustion chamber measurements;
- Performance testing of measuring systems for continuous monitoring of emissions and and ambient air, and of electronic data evaluation and remote emission monitoring systems;
- Determination of stack height and air quality projections for hazardous and odour substances;
- Determination of noise and vibration emissions and pollution, determination of sound power levels and execution of sound measurements at wind energy plants

according to EN ISO/IEC 17025.

The accreditation is valid up to 22-01-2018 DakkS-register number D-PL-11120-02-00.

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DAkkS Deutsche Akkreditierungsstelle D-PL-11120-02-00

Report on the performance testing of the ambient air monitor CO 12e by Environnement S.A. for the component CO

Instrumend tested: CO 12e

Manufacturer: Environnement S.A.
111, bd Robespierre
78304 Poissy cedex
France

Test period: April 2015 to October 2015

Date of report: 09 October 2015

Report number: 936/21228317/A

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Scope of report:

Report:		112	Pages
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Manual	of	80	Pages
Total		192	Pages

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1. Summary and certification proposal

1.1 Summary

Environnement S.A. have commissioned TÜV Rheinland Energie und Umwelt GmbH to carry out performance testing of CO 12e for CO.

Testing was performed in compliance with the following standards and performance criteria:

- VDI 4202 Part 1: Performance criteria for performance tests of automated ambient air measuring systems; Point-related measurement methods for gaseous and particulate air pollutants, September 2010
- VDI 4203 Part 3: Testing of automated measuring systems Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants, September 2010
- EN 14626: Ambient air quality - Standard method for the measurement of the concentration of carbon monoxide by non-dispersive infrared spectroscopy, December 2012

CO 12e uses the method of non-dispersive infrared spectroscopy to measure CO. The measurement principle complies with the EU reference method. Tests were performed in the laboratory as well as during a three months field test in Cologne. The measured range was:

Table 1: Measurement range tested

Measured component	Measurement range [mg/m³] [1)]	Measurement range [ppm] or [µmol/mol]
CO	0 – 100	0 - 86

[1)] Data refer to 20 °C and 101,3 kPa

Minimum requirements were met during performance testing.

TÜV Rheinland Energie und Umwelt GmbH therefore suggests its type approval for continuous measurement of carbon monoxide concentrations in ambient air.

1.2 Certification proposal

Due to the positive results achieved, the following recommendation is put forward for the notification of the AMS as a type-approved measuring system:

AMS designation:

CO 12e for CO

Manufacturer:

Environnement S.A., Poissy, Frankreich

Field of application:

Continuous measurement of carbon monoxide concentrations in ambient air from stationary sources.

Measured ranges during performance testing:

Component	Certification range	Unit
Carbon monoxide	0 - 100	mg/m³

Software version:

Firmware: 1.0.d

Restrictions:

none

Notes:

1. Version CO 12e* (without display) has also been performance tested. Measured values were displayed on a PC or laptop belonging to the AMS.
2. The test report on the performance test is available online at www.qal1.de.

Test report:

TÜV Rheinland Energie und Umwelt GmbH, Cologne

Report-No.: 936/21228317/A of 09 October 2015

1.3 Summary of test results

8.4 Requirements of Standard EN 14626				
Performance criterion	**Minimum requirement**	**Test result**	**Met**	**Page**
Fehler! Verweisquelle konnte nicht gefunden werden.	Neither the response time (rise) nor the response time (fall) shall exceed 180 s. The difference between rise and fall response time shall not exceed 10 s or 10 % relative difference, depending on which value is greater.	The maximum permissible response time is significantly below 180 s in all cases. The maximum response time determined for system 1 is 50, 25 s and 51 s for system 2.	yes	**Fehler! Textmarke nicht definiert.**
8.4.4 Short-term drift	The short-term drift at zero shall not exceed 0.10 µmol/mol/12h (=0.116 mg/m³/12h). The short-term drift at span level shall not exceed 6.0 µmol/mol/12h (=0.696 mg/m³/12h).	Short-term drift at zero point is 0.02 µmol/mol for system 1 and 0.01 µmol/mol for system 2. Short-term drift at the reference point is -0.24 µmol/mol for system 1 and -0.18 µmol/mol for system 2.	yes	64
8.4.5 Repeatability standard deviation	The repeatability standard deviation shall meet the performance characteristics at zero ≤ 0.3 µmol/mol (= 0.348 mg/m³) and at a test gas concentration at reference point ≤ 0.4 µmol/mol (= 0.464 mg/m³).	Repeatability standard deviation at zero point is 0.00 µmol/mol for system 1 and 0.03 µmol/mol for system 2. Repeatability standard deviation at reference point is 0.03 µmol/mol for system 1 and 0.05 µmol/mol for system 2.	yes	68
8.4.6 Lack of fit of linearity of the calibration function	The lack of fit of linearity of the calibration function shall not exceed 0.5 µmol/mol (= 0.58 mg/m³) at zero point and 4 % of the measured value at concentrations above zero.	For system 1, the deviation from the regression line is 0.11 µmol/mol at zero point and max. 1.94 % of the target value for concentrations greater than zero. For system 2, the deviation from the regression line is 0.04 µmol/mol at zero point and max. 2.06 % of the target value for concentrations greater than zero.	yes	71
8.4.7 Sensitivity coefficient of sample gas pressure	The sensitivity coefficient of the sample gas pressure shall not exceed 0.70 µmol/mol/kPa (=0.81 mg/m³/kPa).	The sensitivity coefficient of sample gas pressure for system 1 is 0.05 µmol/mol/kPa. The sensitivity coefficient of sample gas pressure for system 2 is 0.05 µmol/mol/kPa.	yes	76

Performance criterion	Minimum requirement	Test result	Met	Page
8.4.8 Sensitivity coefficient of sample gas temperature	The sensitivity coefficient of the sample gas temperature shall not exceed 0.3 µmol/mol/K (=0.35 mg/m³/K).	The sensitivity coefficient of sample gas temperature for system 1 is 0.00 µmol/mol/K. The sensitivity coefficient of sample gas temperature for system 2 is 0.00 µmol/mol/K.	yes	78
8.4.9 Sensitivity coefficient of ambient temperature	The sensitivity coefficient of the ambient temperature shall not exceed 0.3 µmol/mol/K (=0.35 mg/m³/K).	The sensitivity coefficient bst of the ambient temperature does not exceed the performance criteria of max. 3.0 µmol/mol/K. For both systems, the greatest sensitivity coefficient value bst is used for the purpose of evaluating uncertainty. For system it is 1 0.019 µmol/mol/K and for system 2 it is 0.019 µmol/mol/K.	yes	80
8.4.10 Sensitivity coefficient of supply voltage	The sensitivity coefficient of the supply voltage shall not exceed 0.30 µmol/mol/V (=0.35 mg/m³/V).	The sensitivity coefficient of supply voltage bv does not exceed the performance criteria of 0.30 µmol/mol/V specified in EN 14626. The greatest value bv is used for the purpose of evaluating uncertainty for both systems. For system 1 it is 0.00 µmol/mol/V and for system 2 it is 0.01 µmol/mol/V.	yes	83
8.4.11 Interferents	Interferents at zero concentration and at a concentration c_t (at the level of the hourly limit = 10 mg/m³ for CO). Maximum responses allowed for the interferents CO_2, NO und NO_2 are ≤ 0.5 µmol/mol (= 0.58 mg/m³), for H_2O ≤ 1.0 µmol/mol (= 1.16 mg/m³).	Cross-sensitivity at zero point is 0.29 µmol/mol for system 1 and 0.22 µmol/mol for system 2 at H2O, -0.15 µmol/mol for system 1 and -0.21 µmol/mol for system 2 at CO2, -0.06 µmol/mol for system 1 and -0.03 µmol/mol for system 2 at NO, -0.05 µmol/mol for system 1 and -0.16 µmol/mol for system 2 at N2O. Cross-sensitivity at limit value ct is 0.33 µmol/mol for system 1 and 0.32 µmol/mol for system 2 at H2O, -0.14 µmol/mol for system 1 and -0.09 µmol/mol for system 2 at CO2, -0.04 µmol/mol for system 1 and -0.00 µmol/mol for system 2 at NO, -0.06 µmol/mol for system 1 and -0.01 µmol/mol for system 2 at N2O.	yes	85

Performance criterion	Minimum requirement	Test result	Met	Page
8.4.12 Averaging test	The averaging effect shall not exceed 7 % of the measured value.	The performance characteristics stipulated in EN 14626 are met with -2.56% for system 1 and -2.61% for system 2.	yes	88
8.4.13 Difference sample/calibration port	The difference sample port and calibration port shall not exceed 1 %.	The performance characteristics stipulated in EN 14626 are met with 0.39% for system 1 and 0.22% for system 2.	yes	91
8.5.4 Long-term drift	The long-term drift at zero shall not exceed 0.5 µmol/mol (=0.58 mg/m³). The long-term drift at span level shall not exceed 5 % of the certification range (= 4.3 µmol/mol at a measurement range of 0 to 86 µmol/mol).	Maximum short-term drift at zero point $Dl_{,z}$ is 0.23 µmol/mol for system 1 and 0.16 µmol/mol for system 2. Maximum long-term drift at reference point $Dl_{,s}$ is 0.70 µmol/mol for system 1 and 0.89 µmol/mol for system 2.	yes	93
8.5.6 Period of unattended operation	Maintenance interval must be at least two weeks.	The maintenance interval is four weeks as determined by the necessary maintenance tasks.	yes	98
8.5.5 Reproducibility standard deviation for CO under field conditions	The reproducibility standard deviation under field conditions shall not exceed 5 % of the average over a period of three months.	The reproducibility standard deviation for CO under field conditions was 1.79% of the average over a period of three months in the field. The requirements of EN 14626 are fulfilled.	yes	96
8.5.7 Availability of AMS	AMS availability shall be at least 90 %	The AMS' availability is 100%. The requirements of Standard EN 14626 are fulfilled.	yes	105

2. Task definition

2.1 Nature of test

Environnement S.A. have commissioned TÜV Rheinland Energie und Umwelt GmbH to carry out performance testing of CO 12e. The test was a complete performance test.

2.2 Objective

The AMS is designed to measure the concentration of carbon monoxidein ambient air in the following concentration ranges:

Component	Certification range	Unit
Carbon monoxide	0 - 100	mg/m³

CO 12e uses the method of non-dispersive infrared spectroscopy to measure CO.

Performance testing was to be carried out in accordance with current standards taking into consideration the latest developments.

Testing was performed in compliance with the following standards and performance criteria:

- VDI 4202 Part 1: Performance criteria for performance tests of automated ambient air measuring systems; Point-related measurement methods for gaseous and particulate air pollutants, September 2010
- VDI 4203 Part 3: Testing of automated measuring systems Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants, September 2010
- EN 14626: Ambient air quality - Standard method for the measurement of the concentration of carbon monoxide by non-dispersive infrared spectroscopy, December 2012

3. Description of AMS tested

CO 12e is a continuous carbon monoxide analyser. The measuring principle is based on non-dispersive infrared spectroscopy. The AMS is designed for continuous measurement of carbon monoxide in ambient air.

Figure 1: CO 12e

Figure 2: CO 12e*

3.1 Measuring principle

CO 12e uses the method of infrared absorption according to the Beer-Lambert Law.

The maximum of the absorption spectrum of carbon monoxide is at a wavelength of 4,67 µm, which corresponds to the spectrum chosen for the optical filter. The correlation wheel proceeds the optical filter. In this way, interferences by gases which absorption spectrum is close to CO is eliminated. This leads to a highly selective measurement of the gas being analysed.

The sample air flows through a normalised air supply system. Dust protection is ensured by an easily accessible Teflon dust filter at the sample gas inlet. Sample air is drawn to the measurement chamber by a pump that is located at the outer end of the fluid loop. At the pump inlet the sample gas flow is limited to approx. 60 l/h.

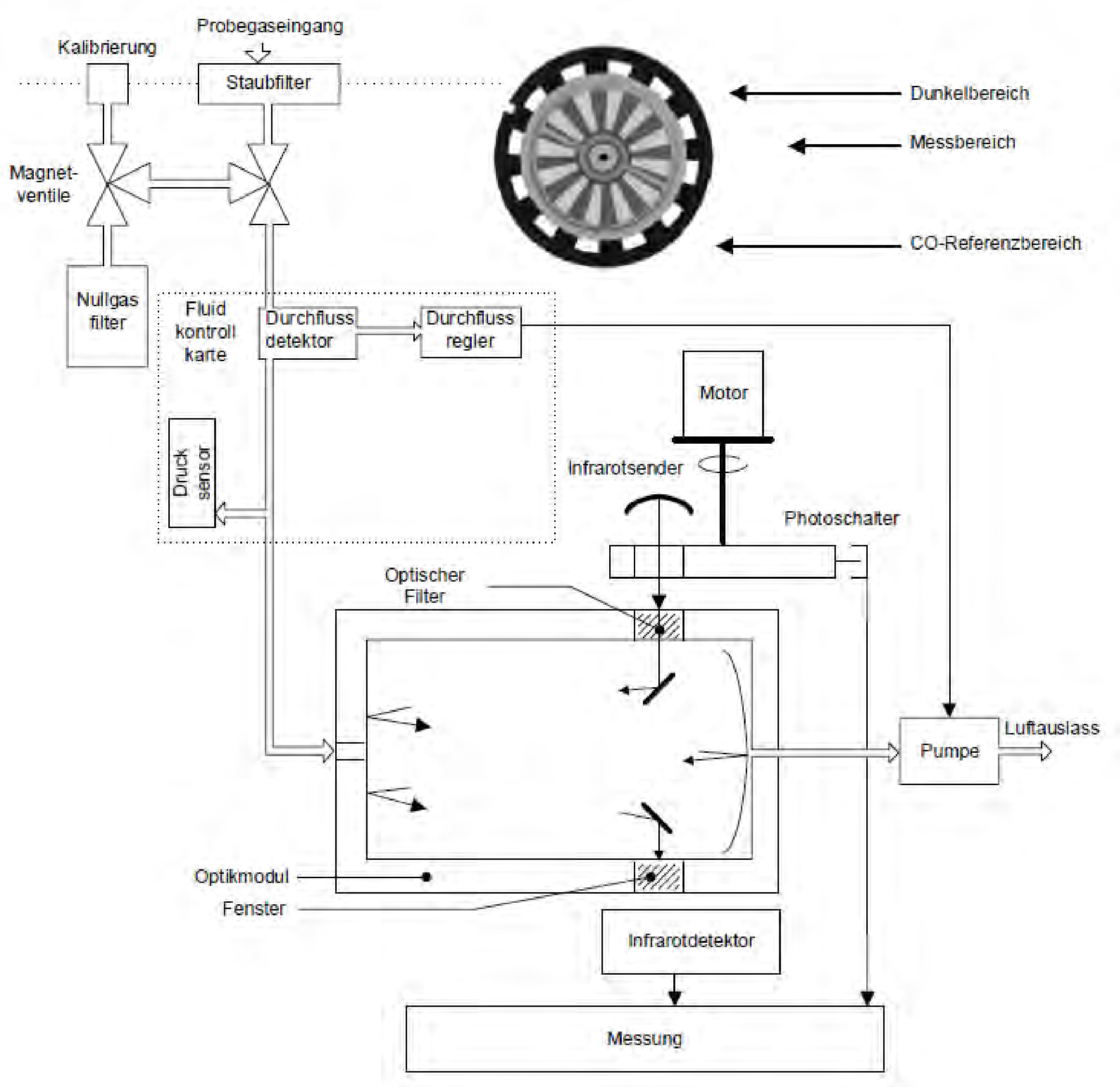


Figure 3: General functional schematic of CO 12e*

The light beam coming from the infrared source passes the correlation wheel, which consists of on cell with two sealed chambers and identical volume. One chamber is filled with carbon monoxide, the other is filled with nitrogen. 12 choppers are arranged above the chambers. Smooth rotation of the correlation wheel is ensured by a brushless motor.

With each rotation of the correlation wheel the infrared beam is absorbed if it passes the chamber filled with carbon monoxide. If it passes the chamber filled with N_2 the infrared beam is not absorbed. At the same time, the beam is cut up by the chopper in which way the signal is modulated. The beam then passes the interference filter, which only lets the CO sensitive part of the infrared radiation pass through the infrared detector (4.7 µm). This prevents noise and interferences. After that, the beam passes the analysis chamber with a long optical path in order to detect traces of CO. According to the Beer-Lambert Law, the longer the path through which the beam passes in the sample gas, the greater the absorption of the beam. This is why the measurement beam is transmitted through the analysis chamber several times before it hits the detector.

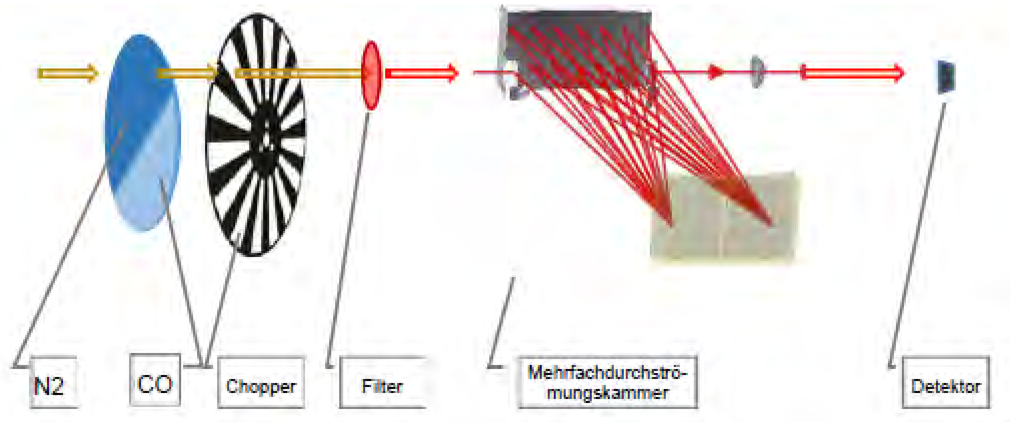


Figure4: Function of correlation wheel

3.2 AMS scope and set-up

The analyser's front side is fitted with the main switch as well as a TFT LCD coloured display with backlight and a touch screen display. The analyser CO 12e for CO is operated via the touch screen display. Version CO 12e* is identical to version CO 12e, expect for the facts that it is not fitted with a display and the front side design is different. CO 12e* can only be operated via Ethernet using an external PC.

Fluid inputs and outputs as well as electrical connections are located on the rear side of the analyser.

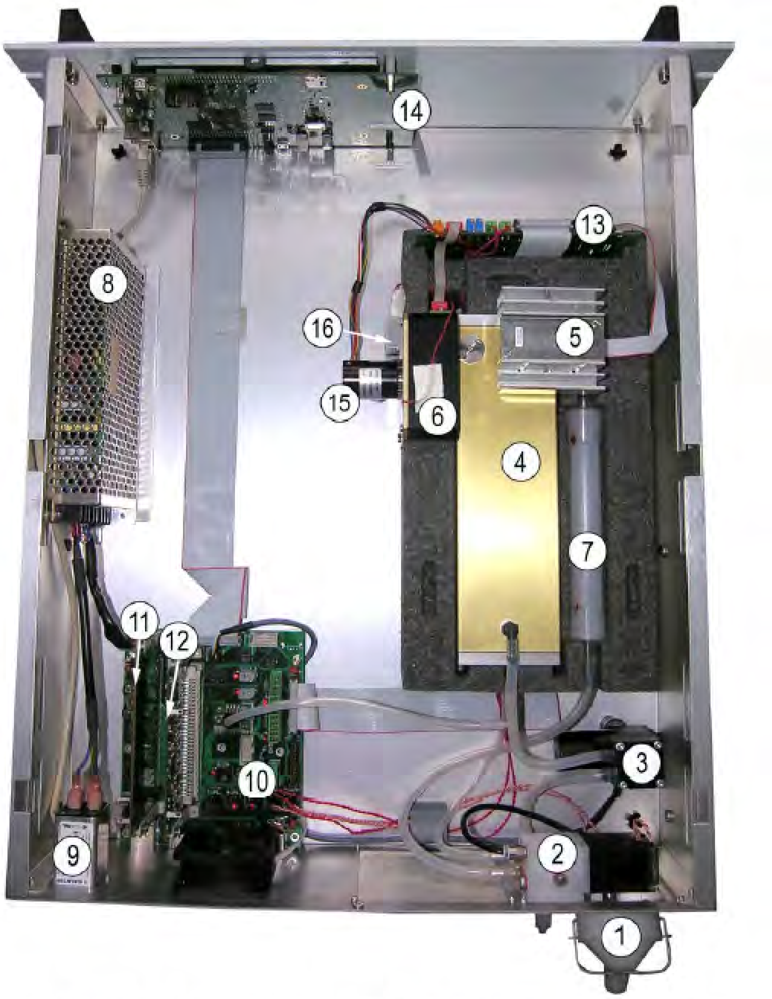
(1) Probegaseingang, (2) Pumpenausgang, (3) Nullufteingang, (4) Prüfgaseingang, (5) dreipoliger Netzanschluss, (6) Hauptsicherung, (7) Ethernet-Ausgang, (8) zwei USB-Anschlüsse, (9) Ventilator, (10) Rückmeldung MV Nullluft und Prüfgas für das optionale externe Kalibrier-MV, (11) 24-V-Versorgung für optionale ESTEL-Karte, (12) not used.

Figure 5: Rear side of CO12e / CO12e*

The analyser's inside can be roughly divided in two components:

The **mechanical** component consists of an electro valve filter unit as well as the measuring cell. The sample to be analysed is led through a dust filter (1) to the module which consists of two magnet valves (2). The pump (3) draws the sample over the measurement cell (4) in which the CO molecules selectively absorb infrared radiation centered to a wavelength of 4.67 µm. An optical sensor (5) as well as a light source (6) are located within the measurement cell. A selective CO filter (7) allows for zero point correction.

The electronic components consists of a power supply (8) providing a supply voltage of 24 V. It is connected to the outlet (9) as well as the connection card (10). The supply card (11) provides additional internal supply voltage (24 V, 15 V, 5 V, 3.3 V). The control card (12) controls general operation of the analyser (magnet valves, pressure and temperature control). The measurement card (13) processes the measurement data and controls the motor (15) and the infrared source (16). The HMI card controls the data output as well as the visualisation on the touch screen display.



(1) Staubfilter des Probeneingangs, (2) Magnetventileinheit, (3) Pumpe, (4) Messkammer, (5) optischer Sensor, (6) Quelle, (7) selektiver CO-Filter, (8) 24-Volt-Versorgung, (9) Netzfilter, (10) Verbindungskarte, (11) Speisekarte, (12) Steuerungskarte, (13) Messkarte, (14) HMI-Karte, (15) Motor, (16) IR-Quelle.

Figure 6: Interior view CO 12e

Table Table 2 lists all important equipment characteristics of CO 12e.

Table 2: Equipment characteristics CO 12e (provided by manufacturer)

Measurement range:	Other measuring ranges of max. 0 – 300 ppm are possible.
Units:	ppm or mg/m³
Measured components:	CO
Sample flow rate:	approx. 1 litre/min
Output signals:	• USB port on the rear side • TCP/IP Ethernet network connection • RJ45 port • 4 analogue outputs (optional)
Power supply	Voltage: 230 V or 115 V Frequency: 50 Hz or 60 Hz
Consumption	approx. 50 W
Dimentions (l x w x h) / weight:	581 x 483 x 133 mm / 7.1 kg

4. Test programme

4.1 General

Performance testing was carried out with two complete and identical instruments with the serial numbers:

System 1: SN 11
System 2: SN 12

During the test software version 1.0.d was implemented.

Performance testing consisted of a laboratory test which aimed to specify performance characteristics and a field test over a period of three months.

This report presents a heading for each test criterion along with the number and description as stipulated in the respective standard [1.2.3.4].

Figure 7: CO 12e test equipment

4.2 Laboratory test

The laboratory test was performed with two identical systems CO 12e with the serial numbers SN: 11 and SN: 12. In compliance with the standards [2.3] the following test criteria were tested:

- Description of operating states
- General requirements
- Adjustment of calibration line
- Short-time drift
- Repeatability standard deviation
- Sensitivity to the sample gas pressure
- Sensitivity to sample gas temperature
- Sensitivity to ambient air temperature
- Sensitivity to supply voltage
- Cross-sensitivities
- Response times
- Difference sample/calibration port

Measured values were recorded using an external data logger.

Results obtained during the laboratory tests are reported in section 6.

4.3 Field test

The field test was carried out with two identical systems from 06-05-2015 until 12-08-2015. The measuring systems under test were identical to those used during laboratory testing. Serial numbers:

System 1: SN 11
System 2: SN 12

The following criteria were tested in the field:

- Long-term drift
- Maintenance interval
- Availability
- Reproducibility standard deviation under field conditions

5. Reference Measurement Method

Test gases used to adjust the AMS during the test (tested systems and TÜV-measuring systems)

(The mentioned test gases were used during the entire test and, where necessary, diluted using a sample divider or a mass flow control station.)

Zero gas:	Synthetic air
Test gas CO:	**66.5 ppm in synt. air**
Number of test gas cylinder:	15674
Manufacturer/date of manufacture	Praxair/12 March 2013
Stability guatantee/certified:	60 months
Check of certificate on/by	6. May 2013/in-house
Rel. uncertainty according to certificate:	2%
Test gas CO:	**203 mg/m³ in Synt. air**
Number of test gas cylinder:	15892
Manufacturer/date of manufacture	Praxair/16 June 2014
Stability guatantee/certified:	60 months
Check of certificate on/by	24 September/in-house
Rel. uncertainty according to certificate:	2%

6. Test results according to VDI 4203 part 3

6.1 4.1.1 Measured value display

The measuring system shall be fitted with measured value display.

6.2 Equipment

No additional equipment is required.

6.3 Testing

It was checked whether the measuring system has a measured value display.

6.4 Evaluation

The AMS is available in two versions. Version CO 12e is fitted with an LED measured value display. Version CO 12e* is not fitted with a value display. Value display and operation is carried out using an external PC via Ethernet connection.

6.5 Assessment

The measuring system is fitted with a measured value display in the version CO 12. Version CO 12e* is not fitted with a value display and must be operated via an external PC.

Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 4.1.2 Easy maintenance

Maintenance should be possible to perform with reasonable effort and from the outside.

6.2 Equipment

No additional equipment is required.

6.3 Testing

The necessary regular maintenance tasks were performed in accordance with the instruction manual.

6.4 Evaluation

The user shall perform the following maintenance tasks:

1. Check of instrument status
   The status of the instrument can be checked and monitored by visual inspection on the display or via PC.
2. Check and replace the particle filter at the sample gas inlet. The frequency of which particle filters need to be replaced depends on the dust concentration in the ambient air.

6.5 Assessment

Maintenance can be performed with usual tools in a reasonable time from the outside.

Requirement fulfilled? yes

6.6 Test results in detail

Maintenance tasks were performed during the test and in accordance with the tasks and procedures described in the manuals. Complying with these procedures, no difficulties were identified. All maintenance tasks could be performed easily by using conventional tools.

6.1 4.1.3 Functional check

Particular instruments required shall be considered as part of the measuring system and be applied in the corresponding sub-tests and included in the assessment.
Test gas units included in the measuring system shall indicate their operational readiness to the measuring system by a status signal and shall provide direct as well as remote control via the measuring system.

6.2 Equipment

Manual

6.3 Testing

The instrument tested does not have a particular device for functional checks. The instrument tested does not have a particular device for functional checks. The operating status of the AMS is continually monitored; potential problems will be displayed via an array of different error messages.

The functional check was performed with external test gases.

6.4 Evaluation

The instrument tested does not have a particular device for functional checks. The operational status of the AMS is continually monitored and potential problems are displayed via an array of different error messages.

It is possible to perform external zero point and reference point checks by means of test gases.

6.5 Assessment

The instrument tested does not have a particular device for functional checks.

Requirement fulfilled? not applicable

6.6 Test results in detail

Not applicable.

6.1 4.1.4 Set-up times and warm-up times

The set-up times and warm-up times shall be specified in the instruction manual.

6.2 Equipment

The testing of this performance criterion required the additional provision of a clock.

6.3 Testing

The measuring systems were put into operation in accordance with the specifications provided by the manufacturer. The set-up times and warm-up times needed were recorded separately.

Required structural measures prior to AMS installation such as the setup of a sampling system in the analytical chamber were not assessed here.

6.4 Evaluation

The manual does not provide information on the set-up times. It is evident that this would depend on the specific conditions of the measurement site as well as on the voltage supply available. As CO 12e is a compact analyser, the set-up time is mainly comprised of:

- Establishing the voltage supply
- Connecting necessary tubes (sampling, exhaust air)

A set-up time of approx. 0.5 h was determined for various changes in positions in the laboratory (i.e. installation/dismounting in the climate chamber) and installation in the field.

When switched on from a completely cold state the instrument requires approx. 60 minutes until the reading stabilises.

The measuring system has to be mounted at a place where it is protected from changes in the weather, for instance in an air conditioned measuring container.

6.5 Assessment

Set-up times and warm-up times were determined.

The measuring system can be operated at different measurement points without great effort. The time required for setting up the system is approx. 0.5 h and the warm-up time amounts to 1–2 h depending on the time required for stabilisation.

Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 4.1.5 Instrument design

The instruction manual shall include specifications of the manufacturer regarding the design of the measuring system. The main elements are:
Instrument shape (e.g. bench mounting, rack mounting, free mounting)
Mounting position (e.g. horizontal or vertical mounting)
Safety requirements
Dimensions
Weight
Power consumption

6.2 Equipment

Testing was performed using a measuring instrument for the determination of the power consumption as well as weighing scales.

6.3 Testing

The set-up of the provided instruments was compared to the description in the instruction manuals. The power consumption was determined for 24 h during normal operation in the field test.

6.4 Evaluation

The measuring system has to be mounted horizontally (e.g. on a table or in a rack) and protected against weather. The temperature at the installation site may not exceed the range of 0 °C to 30 °C.

The dimensions and weight of the measuring system correspond to the specifications in the instruction manual.

According to the manufacturer, the power consumption of the measuring system is approx. 50 W. The manufacturer’s specification could be confirmed by the 24 h test. During warm-up consumption temporary values of 160 W were determined.

6.5 Assessment

Specifications made in the instruction manual with regard to the instrument’s design are complete and correct.

Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 4.1.6 Unauthorized adjustment

It shall be possible to secure the adjustment of the measuring system against illicit or unintended adjustment during operation.

6.2 Equipment

No further equipment required.

6.3 Testing

The measuring system may be operated using the display and control panel on the front side of the instrument or from an external computer connected to the RS232 or Ethernet ports.

The instrument does not have a built-in mechanism (password protection) to protect it against unintended or unauthorized re-adjustment. Changing parameters or adjusting sensors is only possible by pushing several sequences of keys.

6.4 Evaluation

Instrument parameters which affect measurement characteristics can only be changed via the display manual or an external PC using the correct password.

6.5 Assessment

The measuring system itself is not protected against the unintended or unauthorised adjustment of instrument parameters.

Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 4.1.7 Data output

The output signals shall be provided digitally (e.g. RS232) and/or as analogue signals (e.g. 4 mA to 20 mA).

6.2 Equipment

PC with network connection, analogue data logger

6.3 Testing

The measuring system is equipped with the following transmission paths: RS232, USB, digital and analogue in- and outputs (optional), TCP/IP Ethernet network connection. Moreover, it has a means to output analogue signals (optional).

6.4 Evaluation

Measures signal are provided on the system's rear side as follows:

Analogue:	4-20 mA or 0-10 V), selectable concentration range
Digitally	RS232, USB, digital in and outputs, TCP/IP network

6.5 Assessment

Measured signals are provided analogue (4-20 mA or 0-10 V) and digitally (via TCP/IP, RS 232, USB).

It is possible to connect additional measuring systems or peripheral devices via the respective ports (e.g. analogue inputs).

Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 5.1 General

The manufacturer's specifications in the instruction manual shall not contradict the results of the performance test.

6.2 Equipment

Not applicable.

6.3 Testing

The test results were compared to the specifications in the instruction manual.

6.4 Evaluation

Discrepancies between the first draft of the manual and the actual instrument design have been corrected.

6.5 Assessment

No discrepancies between the actual instrument design and the instruction manuals were observed.

Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 5.2.1 Certification ranges

The certification range intended for testing shall be determined.

6.2 Equipment

No further equipment required.

6.3 Testing

The certification range intended for testing shall be determined.

6.4 Evaluation

VDI 4202 Part 1 and EN 14626 stipulate the following minimum requirements for the certification ranges of continuous ambient air monitoring systems for carbon monoxide:

Table 3: Certification range VDI 4202 Sheet 1 and EN 14626

Measured component	Lower limit CR	Upper limit CR	Limit value	Assessment period
	in mg/m³	in mg/m³	in mg/m³	
Carbon monoxide	0	100	10	8 h

6.5 Assessment

The measuring system can be assessed in the range of the relevant limit values.

Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 5.2.2 Measurement range

The upper limit of measurement of the measuring systems shall be greater than or equal to the upper limit of the certification range.

6.2 Equipment

No further equipment required.

6.3 Testing

It was tested whether the upper limit of measurement of the measuring systems shall be greater than or equal to the upper limit of the certification range.

6.4 Evaluation

The measuring system allows for measuring ranges from max. 0 – 200 ppm.

Possible measuring range:	0 – 300 ppm
Upper limit of the certification range for CO:	100 mg/m³ (86 ppm or µmol/mol)

6.5 Assessment

By default the measuring range is set to 0 – 100 µg/m³ for CO. Other measuring ranges of max. 0 – 300 ppm are possible.

The upper limit of the measuring range is greater than the upper limit of the certification range.

Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 5.2.3 Negative signals

Negative signals shall be displayed (life zero).

6.2 Equipment

No further equipment required.

6.3 Testing

In the laboratory and field test was tested whether the AMS displays negative signals.

6.4 Evaluation

The measuring system also displays negative signals.

6.5 Assessment

The measuring system also displays negative signals.
Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 5.2.4 Failure in the mains voltage

In case of malfunction of the measuring system or failure in the mains voltage for a period of up to 72 h, uncontrolled emission of operation and calibration gas shall be avoided. The instrument parameters shall be secured by buffering against loss caused by failure in the mains voltage. When mains voltage returns, the instrument shall automatically reach the operation mode and start the measurement according to the operating instructions.

6.2 Equipment

Not applicable.

6.3 Testing

A failure in the mains voltage was simulated in order to check whether the instrument remains intact and is ready to measure when mains voltage returns.

6.4 Evaluation

The measuring system does not require any operation or calibration gases. Thus, there is no uncontrolled emission of gases in the case of failure in the mains voltage.

In the event of power failure the measuring system will switch to warm-up mode when the power supply is re-established. It will remain in this mode until an appropriate and stable temperature for operation is reached. The time required for warm-up depends on the ambient conditions at the installation site and on the thermal condition of the instrument itself when switched on again. After warm-up the instrument automatically switches back to the same mode that was active when the power failure occurred. The warm-up phase is indicated by a number of status alarms.

6.5 Assessment

In the event of power failure, the measuring system will be ready to be operated again and will automatically resume measurement when reconnected.

Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 5.2.5 Operating states

The measuring system shall allow the control of important operating states by telemetrically transmitted status signals.

6.2 Equipment

PC for data acquisition.

6.3 Testing

The analyser is fitted with various connectivity ports, such as RS232, USB, digital and analogue in- and outputs (optional), TCP/IP Ethernet network connection. The analyser can be connected to an external PC using a web browser. Via telemetrical data transmission the analyser can be adjusted and the analyser's display can be transferred and indicated on the PC. In this mode, all information and functions shown on the analyser display can be accessed and controlled. Moreover, the “Remote Terminal” is a useful tool to check operation and parameter values.

6.4 Evaluation

The measuring system allows for extensive telemetrical monitoring and control via various connectivity options.

6.5 Assessment

By means of various connectivity options the AMS can be monitored and controlled from an external PC.

Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 5.2.6 Switch-over

Switch-over between measurement and functional check and/or calibration shall be possible telemetrically or manual intervention.

6.2 Equipment

Not applicable.

6.3 Testing

The measuring system may be monitored or controlled via the control panel of the analyser or telemetrically via remote control.

6.4 Evaluation

All control functions which do not require direct on-site intervention may be performed by operating staff on-site or telemetrically via remote control.

6.5 Assessment

In general, all tasks related to functional checks may be performed directly on-site or monitored telemetrically using the remote control functions.

Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 5.2.7 Maintenance interval

Maintenance interval shall be determined in the field test. Maintenance interval should preferably be three months, but at least two weeks.

6.2 Equipment

Not applicable.

6.3 Testing

In testing this performance criterion, the types of maintenance work and the corresponding maintenance intervals needed to ensure proper functioning of the measuring system were determined. Moreover, drift behaviour for zero and reference point according 7.1 8.5.4 Long-term drift was taken into consideration in determining the maintenance interval.

6.4 Evaluation

During the entire field test period, no andue drift behaviour was observed in the measuring systems. The maintenance interval is therefore determined by the necessary maintenance tasks.

During operation, maintenance tasks are generally limited to contamination and plausibility checks as well as checking for potential status signals and error warnings. Notes for works during the maintenance interval can be referred to in Chapter 8.

6.5 Assessment

The maintenance interval is four weeks as determined by the necessary maintenance tasks.

Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

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6.5 Assessment

See Chapter 7.1 8.4.6 Deviation from linearity of the calibration function.
Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 5.2.8 Availability

The AMS' Availability shall be determined in the field test and must be at least 95 %.

6.2 Equipment

Not applicable.

6.3 Testing

The start and end time of the availability test are determined by the start and end time at the field test site. To this effect any interruptions of the test, for instance due to malfunctions or maintenance work, are recorded.

6.4 Evaluation

The field test was carried out from 06-5-015 until 12-8-15. Thus, the measuring systems were tested in the field for 98 days of measuring in total. Table 4 lists periods of operation, maintenance and malfunction.

No malfunctions were observed.

6.5 Assessment

Availability for both systems was 100% incl. maintenance times during testing.

Requirement fulfilled? yes

6.6 Test results in detail

Table 4: Determination of availability

		System 1 (SN 11)	System 2 (SN 12)
Operating time	h	2352	2352
Down time	h	0	0
Maintenance time	h	8	8
Effective operating time	h	2344	2344
Effective operating time incl. maintenance		2352	2352
Availability	%	100	100

6.1 5.2.9 Instrument software

The version of the instrument software to be tested shall be displayed during switch-on of the measuring system. The test institute shall be informed about changes in the instrument software, which influence the performance of the measuring system.

6.2 Equipment

Not applicable.

6.3 Testing

It was checked whether the measuring system does indicate the software version. The manufacturer is aware that all changes to the AMS software shall be communicated to the test institute.

6.4 Evaluation

The current software version is indicated on the display. The information can also be referred to any time in the menu under “Information”.

During the test software version 1.0.d was implemented.

6.5 Assessment

The instrument’s software version is indicated on the display. Changes to the software will be communicated to the test institute.

Requirement fulfilled? yes

6.6 Test results in detail

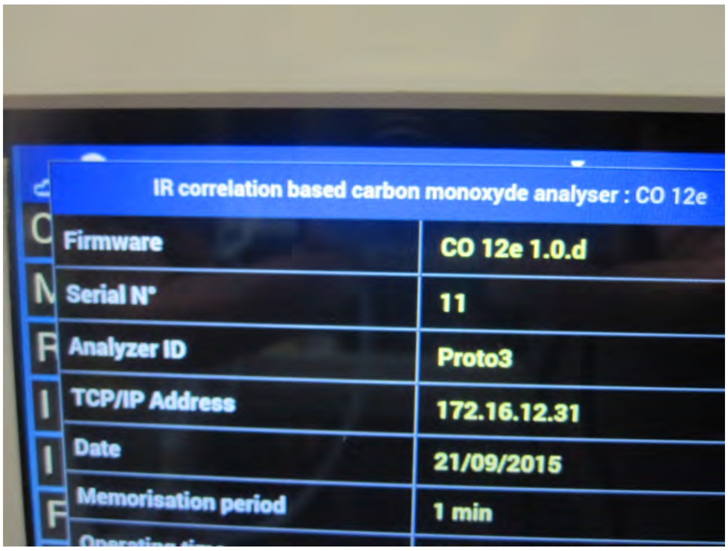


Figure 8: Display of the software version (1.0.d) on the info screen

6.1 5.3.1 General

The test is performed on the basis of minimum requirements as stipulated in VDI 4202 part 1 (September 2010).

6.2 Equipment

Not applicable.

6.3 Testing

The test is performed on the basis of minimum requirements as stipulated VDI 4202 part 1 (September 2010) as well as standard EN 14626 (2012).

6.4 Evaluation

VDI 4202 Part 1 and VDI 4203 Part 3 were revised extensively and re-published in an amended version in September 2010. Minimum requirements as listed in Table 2 a/b of said standard were used for evaluation.

6.5 Assessment

The tests were performed on the basis of minimum requirements as stipulated VDI 4202 part 1 (September 2010) as well as standard EN 14626 (2012).

Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 5.3.2 Repeatability standard deviation at zero point.

The repeatability standard deviation at zero point shall not exceed the requirements listed in Table 1 of VDI 4202 part 1 (September 2010) and in table 2 of standard VDI 4202 part 1 (September 2010) in the certification range.

In case of deviating certification ranges, the repeatability standard deviation at zero point shall not exceed 2 % of the upper limit of this certification range.

The repeatability standard deviation at zero point shall not exceed 1.0 µmol/mol (i.e. 1.16 mg/m³).

6.2 Equipment

Not applicable.

6.3 Testing

Performance and evaluation of the steps taken to determine the repeatability standard deviation at zero point are in line with the requirements stipulated in Standard EN 14626 (2012). See Chapter 7.1 8.4.5 Repeatability standard deviation.

6.4 Evaluation

See Chapter 7.1 8.4.5 Repeatability standard deviation.

6.5 Assessment

See Chapter 7.1 8.4.5 Repeatability standard deviation.

Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 5.3.3 Repeatability standard deviation at reference point.

The repeatability standard deviation at reference point in the certification range shall not exceed the requirements stipulated in table 1 of VDI 4202 part 1 (September 2010) and Table 2 of standard VDI 4202 part 1 (September 2010) in the certification range. The limit value or the alert threshold shall be used as reference point.

In case of deviating certification ranges, the repeatability standard deviation at reference point shall not exceed 2 % of the upper limit of this certification range. In this case a value c_t at 70 % to 80 % of the upper limit of this certification range shall be used as reference point.

The repeatability standard deviation at reference point shall not exceed 3 µmol/mol (i.e. 3.48 mg/m³).

6.2 Equipment

Not applicable.

6.3 Testing

Performance and evaluation of the steps taken to determine the repeatability standard deviation at reference point are in line with the requirements stipulated in EN 14626 (2012). See Chapter 7.1 8.4.5 Repeatability standard deviation.

6.4 Evaluation

See Chapter 7.1 8.4.5 Repeatability standard deviation.

6.5 Assessment

See Chapter 7.1 8.4.5 Repeatability standard deviation.

Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 5.3.4 Linearity (Lack-of-fit)

The analytical function describing the relationship between the output signal and the value of the air quality characteristic shall be linear.

Reliable linearity is given, if deviations of the group averages of measured values about the calibration function meet the requirements of Table 2 of VDI 4202, Part 1 (September 2010) in the certification range according to Table 1 of VDI 4202, Part 1 (September 2010).

For all other certification ranges the group averages of measured values about the calibration function shall not exceed 5 % of the upper limit of the corresponding certification range.

The deviation from the linear regression shall not exceed 4 %.

6.2 Equipment

Not applicable.

6.3 Testing

Performance and evaluation of the steps taken to determine Lack of fit are in line with the requirements stipulated in EN 14626 (2012). 7.1 8.4.6 Lack of fit of linearity of the calibration function

6.4 Evaluation

See chapter 7.1 8.4.6 Deviation from linearity of the calibration function.

6.5 Assessment

See chapter 7.1 8.4.6 Deviation from linearity of the calibration function.

Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 5.3.5 Sensitivity coefficient of sample gas pressure

The sensitivity coefficient of sample gas pressure at reference point shall not exceed the requirements stipulated in table 2 of standard VDI 4202 part 1 (September 2010). A value c_t at 70 % to 80 % of the upper limit of this certification range shall be used as reference point.
The sensitivity coefficient of the sample gas pressure shall not exceed 0.7 µmol/mol/kPa (=0.81 mg/m³/kPa).

6.2 Equipment

Not applicable.

6.3 Testing

Performance and evaluation of the steps taken to determine the sensitivity coefficient of sample gas pressure are identical with those in determining the sensitivity coefficient of sample gas pressure according to EN 14626 (2012). 7.1 8.4.7 Sensitivity coefficient of sample gas pressure.

6.4 Evaluation

See Chapter 7.1 8.4.7 Sensitivity coefficient of sample gas pressure.

6.5 Assessment

See Chapter 7.1 8.4.7 Sensitivity coefficient of sample gas pressure.

Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 5.3.6 Sensitivity coefficient of sample gas temperature

The sensitivity coefficient of sample gas temperature at reference point shall not exceed the requirements stipulated in table 2 of standard VDI 4202 part 1 (September 2010). A value c_t at 70 % to 80 % of the upper limit of this certification range shall be used as reference point.
The sensitivity coefficient of the sample gas temperature shall not exceed 0.3 µmol/mol/kPa (=0.35 mg/m³/K).

6.2 Equipment

Not applicable.

6.3 Testing

Performance and evaluation of the steps taken to determine the sensitivity coefficient of sample gas temperature are identical with those in determining the sensitivity coefficient of sample gas temperature according to EN 14626 (2012). See chapter 7.1 8.4.8 Sensitivity coefficient of sample gas temperature.

6.4 Evaluation

See chapter 7.1 8.4.8 Sensitivity coefficient of sample gas temperature.

6.6 Assesment

See chapter 7.1 8.4.8 Sensitivity coefficient of sample gas temperature.
Requirement fulfilled? Yes

6.6 Test results in detail

Not applicable

6.1 5.3.7 Sensitivity coefficient of ambient temperature

The sensitivity coefficient of the ambient temperature at reference point and zero point shall not exceed the requirements stipulated in table 2 of standard VDI 4202 part 1 (September 2010). A value c_t at 70 % to 80 % of the upper limit of this certification range shall be used as reference point.

The sensitivity coefficient of the ambient shall not exceed 0.3 (µmol/mol)/K (=(0.35 mg/m³)/K).

6.2 Equipment

Not applicable.

6.3 Testing

Performance and evaluation of the steps taken to determine the sensitivity coefficient of ambient temperature are identical with those in determining the sensitivity coefficient of ambient temperature according to EN 14626 (2012). See Chapter 7.1 8.4.9 Sensitivity coefficient of ambient temperature.

6.4 Evaluation

See Chapter 7.1 8.4.9 Sensitivity coefficient of ambient temperature.

6.5 Assessment

See Chapter 7.1 8.4.9 Sensitivity coefficient of ambient temperature.

Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 5.3.8 Sensitivity coefficient of supply voltage

The sensitivity coefficient of supply voltage shall not exceed the requirements specified in table 2 of standard VDI 4202 part 1 (September 2010). A value c_t at 70 % to 80 % of the upper limit of this certification range shall be used as reference point.

The sensitivity coefficient of supply voltage shall not exceed 0.3 (µmol/mol)/V (=(0.35 mg/m³)/V).

6.2 Equipment

Not applicable.

6.3 Testing

Performance and evaluation of the steps taken to determine the sensitivity coefficient of supply voltage are identical with those in determining the sensitivity coefficient of supply voltage according to EN 14626 (2012). See Chapter 7.1 8.4.10 Sensitivity coefficient of supply voltage.

6.4 Evaluation

See Chapter 7.1 8.4.10 Sensitivity coefficient of supply voltage

6.5 Assessment

See Chapter 7.1 8.4.10 Sensitivity coefficient of supply voltage.

Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 5.3.9 Cross-sensitivity

The change in the measured value caused by cross-sensitivity to interfering components in the sample gas shall not exceed the requirements specified in table 2 of standard VDI 4202 part 1 (September 2010) at zero and reference point. The limit value (8-h limit value for CO = 8.6 µmol/mol) shall be used as reference point.
For measuring principles deviating from EN standards the absolute values of the sum of the positive and the sum of negative deviations caused by interfering components in the sample gas shall not exceed 3 % of the upper limit of the certification range at zero and reference point. A value c_t at 70 % to 80 % of the upper limit of this certification range shall be used as reference point.

6.2 Equipment

Not applicable.

6.3 Testing

Performance and evaluation of the steps taken to determine cross-sensitivity are identical with those in determining cross-sensitivity according to EN 14626 (2012). See Chapter 7.1 8.4.11 Interferents.

6.4 Evaluation

See Chapter 7.1 8.4.11 Interferents.

6.5 Assessment

See Chapter 7.1 8.4.11 Interferents.

Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 5.3.10 Averaging effect

For gaseous components the measuring system shall allow the formation of hourly averages.

The averaging effect shall not exceed the requirements specified in table 2 of standard VDI 4202 part 1 (September 2010).
The averaging effect shall not exceed 7 % of the measured value.

6.2 Equipment

Not applicable.

6.3 Testing

Performance and evaluation of the steps taken to determine the averaging effect are identical with those in determining the averaging effect according to EN 14626 (2012). See Chapter 7.1 8.4.12 Averaging test.

6.4 Evaluation

See Chapter 7.1 8.4.12 Averaging test.

6.5 Assessment

See Chapter 7.1 8.4.12 Averaging test

Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 5.3.11 Standard deviation from paired measurements

The standard deviation from paired measurements shall be determined with two identical measuring systems by paired measurements in the field test. It shall not exceed the requirements specified in table 2 of standard VDI 4202 part 1 (September 2010).
The standard deviation under field conditions shall not exceed 5 % of the average over a period of 3 months.

6.2 Equipment

Not applicable.

6.3 Testing

Performance and evaluation of the steps taken to determine standard deviation from paired measurements are identical with those in determining standard deviation from paired measurements according to EN 14626 (2012). See Chapter 7.1 8.5.5 Reproducibility standard deviation for CO under field conditions.

6.4 Evaluation

See Chapter 7.1 8.5.5 Reproducibility standard deviation for CO under field conditions.

6.5 Assessment

See Chapter 7.1 8.5.5 Reproducibility standard deviation for CO under field conditions.

Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 5.3.12 Long-term drift

The long-term drift at zero point and reference point shall not exceed the requirements specified in Table 2 of standard VDI 4202 part 1 (September 2010) in die field test. A value c_t at 70 % to 80 % of the upper limit of this certification range shall be used as reference point.
The long-term drift at zero shall not exceed 0.5 µmol/mol (=0.58 mg/m³).
The long-term drift at span point shall not exceed 5 % of the upper limit of the certification range.

6.2 Equipment

Not applicable.

6.3 Testing

Performance and evaluation of the steps taken to determine the long-term drift are identical with those in determining the long-term drift according to EN 14626 (2012). See Chapter 7.1 8.5.4 Long-term drift.

6.4 Evaluation

See Chapter 7.1 8.5.4 Long-term drift.

6.5 Assessment

See Chapter 7.1 8.5.4 Long-term drift.

Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 5.3.13 Short-term drift

The short-term drift at zero point and reference point shall not exceed the requirements of Table 2 of standard VDI 4202 part 1 (September 2010) within 12 h (for benzene 24 h) in the laboratory test and within 24 h in the field test. A value c_t at 70 % to 80 % of the upper limit of this certification range shall be used as reference point.
The short-term drift at zero shall not exceed 0.1 µmol/mol/12h (=0.12 mg/m³).
The short-term drift at span value not exceed 0.60 µmol/mol/12h (=0.70 mg/m³).

6.2 Equipment

Not applicable.

6.3 Testing

Performance and evaluation of the steps taken to determine the short-term drift are identical with those in determining the short-term drift according to EN 14626 (2012). See Chapter 7.1 8.4.4 Short-term drift.

6.4 Evaluation

See Chapter 7.1 8.4.4 Short-term drift.

6.5 Assessment

See Chapter 7.1 8.4.4 Short-term drift.

Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 5.3.14 Response times

The response time (rise) of the measuring system shall not exceed 180 s.

The response time (fall) of the measuring system shall not exceed 180 s.

The difference between the response time (rise) and response time (fall) of the measuring system shall not exceed 10% of response time (rise) or 10 s, whatever value is larger.

6.2 Equipment

Not applicable.

6.3 Testing

Performance and evaluation of the steps taken to determine the response time are identical with those in determining the response time according to EN 14626 (2012). See Chapter 7.1 8.4.3 Response time.

6.4 Evaluation

See Chapter 7.1 8.4.3 Response time

6.5 Assessment

See Chapter 7.1 8.4.3 Response time

Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 5.3.15 Difference sample/calibration port

The difference between the measured values obtained by feeding gas at the sample and calibration port shall not exceed the requirements Table 2 of standard VDI 4202 part 1 (September 2010). A value c_t at 70 % to 80 % of the upper limit of this certification range shall be used as reference point.
The difference between sample port and calibration port shall not exceed 1 %.

6.2 Equipment

Not applicable.

6.3 Testing

Performance and evaluation of the steps taken to determine the difference between sample and calibration port are identical with those in determining the difference between sample and calibration port according to EN 14626 (2012). See Chapter 7.1 8.4.13 Difference sample/calibration port.

6.4 Evaluation

See Chapter 7.1 8.4.13 Difference sample/calibration port.

6.5 Assessment

See Chapter 7.1 8.4.13 Difference sample/calibration port.
Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

6.1 5.3.16 Converter efficiency

In the case of measuring systems with a converter, the converter efficiency shall be at least 98%.

6.2 Equipment

Not applicable.

6.3 Testing

The analyser tested is not equipped with a converter due to its measuring principle.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable, AMS does not use a converter.
Requirement fulfilled? Not applicable

6.6 Test results in detail

Not applicable.

6.1 5.3.17 Increase of NO_2 concentrations due to residence in the measuring system

In case of NO_x measuring systems the increase of NO_2 concentration due to residence in the measuring system shall not exceed the requirements specified in table 2 of standard VDI 4202 part 1 (September 2010).

The requirements of Table 2 of VDI 4202, Part 1 (September 2010) apply to certification ranges according to Table 1 of VDI 4202, Part1 (September 2010). For deviating certification ranges the requirements shall be proportionally converted.

6.2 Equipment

Not applicable.

6.3 Testing

AMS does not measure NO_x. Not applicable.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable, AMS does not measure NO_x.
Requirement fulfilled? Not applicable

6.6 Test results in detail

Not applicable.

6.1 5.3.18 Total uncertainty

The expanded uncertainty of the measuring system shall be determined. The value determined shall not exceed the corresponding data quality objectives in the applicable EU Directives on air quality listed in Annex A, Table A1 of standard VDI 4202 part 1 (September 2010).

6.2 Equipment

Not applicable.

6.3 Testing

The determination of uncertainty was performed in accordance with EN 14626 (2012) and is detailed in Chapter7.1 8.6 Total uncertainty in accordance with Annex E of EN 14262 (2012).

6.4 Evaluation

The determination of uncertainty was performed in accordance with EN 14626 (2012) and is detailed in Chapter7.1 8.6 Total uncertainty in accordance with Annex E of EN 14262 (2012).

6.5 Assessment

The determination of uncertainty was performed in accordance with EN 14626 (2012) and is detailed in Chapter7.1 8.6 Total uncertainty in accordance with Annex E of EN 14262 (2012).

Requirement fulfilled? yes

6.6 Test results in detail

Not applicable.

7. Test results according to EN 14626 (2012)

7.1 8.4.3 Response times

Neither the response time (rise) nor the response time (fall) shall exceed 180 s. The difference between rise and fall response time shall not exceed 10 s.

7.2 Test program

The determination of the response time shall be carried out by applying to the analyser a step function in the concentration from less than 20 % to about 80 % of the maximum of the certification range of carbon monoxide and vice versa.

The change from zero gas to span gas must be carried out instantaneously, using of a suitable valve. The valve outlet shall be mounted directly to the inlet of the analyser, and both zero gas and span gas shall have the same amount of gas in excess, which is vented by the use of a tee. The gas flows of both zero gas and span gas shall be chosen in such a way that the dead time in the valve and tee can be neglected compared to the lag time of the analyser system. The step change is made by switching the valve from zero gas to span gas. This event needs to be timed and is the start (t = 0) of the (rise) lag time according to **Fehler! Verweisquelle konnte nicht gefunden werden.**. When the reading is stable to 98 % of the concentration applied, the span gas can be changed to zero gas again; this event is the start (t = 0) of the (fall) lag time. When the reading is stable to 2 % of the concentration applied, the whole cycle as shown in **Fehler! Verweisquelle konnte nicht gefunden werden.** is complete.

The elapsed time (response time) between the start of the step change and reaching 90 % of the analyser final stable reading of the applied concentration shall be measured. The whole cycle shall be repeated four times. The average of the four response times (rise) and the average of the four response times (fall) shall be calculated.

The difference in response times shall be calculated according to:

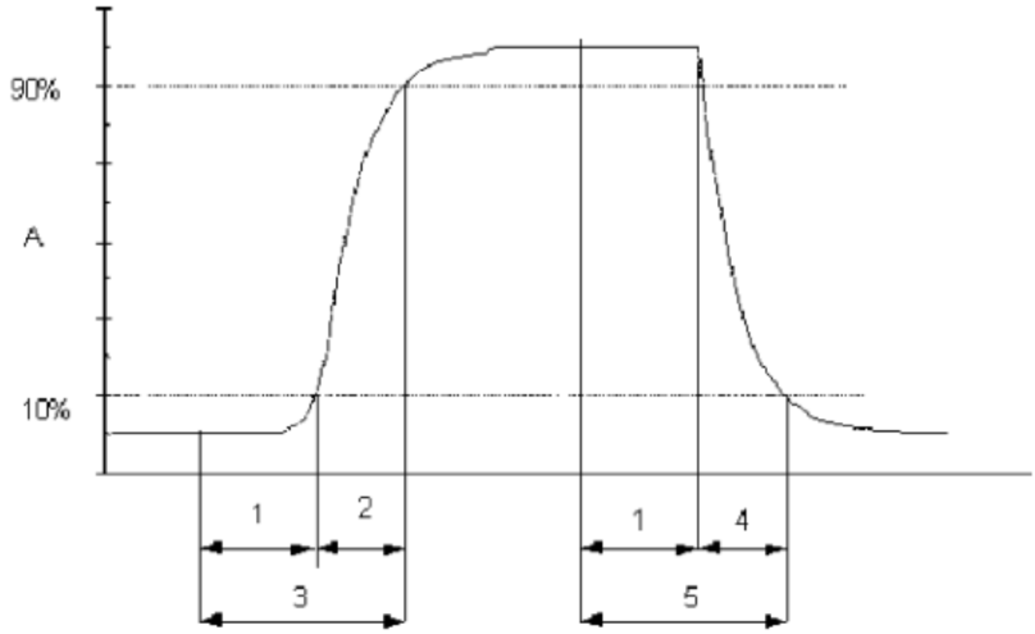
$$t_d = \bar{t}_r - \bar{t}_f$$

Mit t_d is the difference between response time (rise) and response time (fall), in s

t_r is the response time (rise) (average of the four response times – rise), in s

t_f is the response time (fall) (average of the four response times – fall), in s

t_r, t_f and t_d shall comply with the performance criteria as specified above.



Legende
A Signal des Messgeräts
1 Totzeit
2 Anstiegszeit
3 Einstellzeit (Anstieg)
4 Abfallzeit
5 Einstellzeit (Abfall)

Figure 9: Illustration of response time

7.3 Testing

Testing was carried out in accordance with the requirements stipulated in EN 14626. Data were recorded using a Yokogawa DX2000 data logger with its averaging time set to 1 s.

7.4 Evaluation

Table 5: Response times of the two CO 12e measuring systems for CO

	requirements	device 1		device 2	
average rise t_r [s]	≤ 180 s	50,25	✓	50	✓
average fall t_f [s]	≤ 180 s	50	✓	51	✓
difference t_d [s]	≤ 10 s	0,25	✓	-1	✓

For system 1 this results in a maximum t_r of 50, 25 s, a maximum t_f of 50 s and a t_d of 0.25 s for CO.

For system 2 this results in a maximum t_r of 50, a maximum t_f of 51 s and a t_d of -1 s for CO.

7.5 Assessment

The maximum permissible response time is significantly below 180 s in all cases. The maximum response time determined for system 1 is 50, 25 s and 51 s for system 2.

Requirement fulfilled? yes

7.6 Test results in detail

Table 6: Individual readings of the response time for CO

		device 1					
	80%		rise			fall	
measuring range	68,97	0,0 0,00	0,9 62,07	1,0 68,97	1,0 68,97	0,1 6,90	0,0 0,00
cycles 1	t = 0	13:44:00	13:44:49	13:46:00	13:49:00	13:49:50	13:50:00
	delta t		00:00:49			00:00:50	
	delta t [s]		49			50	
cycles 2	t = 0	13:53:00	13:53:50	13:54:00	13:57:00	13:57:50	13:58:00
	delta t		00:00:50			00:00:50	
	delta t [s]		50			50	
cycles 3	t = 0	14:01:00	14:01:50	14:02:00	14:05:00	14:05:49	14:06:00
	delta t		00:00:50			00:00:49	
	delta t [s]		50			49	
cycles 4	t = 0	14:09:00	14:09:52	14:10:00	14:13:00	14:13:51	14:14:00
	delta t		00:00:52			00:00:51	
	delta t [s]		52			51	

		device 2					
	80%		rise			fall	
measuring range	68,97	0,0 0,00	0,9 62,07	1,0 68,97	1,0 68,97	0,1 6,90	0,0 0,00
cycles 1	t = 0	13:44:00	13:44:50	13:46:00	13:49:00	13:49:53	13:50:00
	delta t		00:00:50			00:00:53	
	delta t [s]		50			53	
cycles 2	t = 0	13:53:00	13:53:51	13:54:00	13:57:00	13:57:51	13:58:00
	delta t		00:00:51			00:00:51	
	delta t [s]		51			51	
cycles 3	t = 0	14:01:00	14:01:50	14:02:00	14:05:00	14:05:50	14:06:00
	delta t		00:00:50			00:00:50	
	delta t [s]		50			50	
cycles 4	t = 0	14:09:00	14:09:49	14:10:00	14:13:00	14:13:50	14:14:00
	delta t		00:00:49			00:00:50	
	delta t [s]		49			50	

7.1 8.4.4 Short-term drift

The short-term drift at zero shall not exceed 0.10 µmol/mol/12h (=0.12 mg/m³/12h).

The short-term drift at span level shall not exceed 6.0 µmol/mol/12h (=0.70 mg/m³/12h).

7.2 Test program

After the required stabilisation period, the analyser shall be adjusted at zero and span level (around 70 % to 80 % of the maximum of the certification range). After waiting the time equivalent to one independent reading, 20 individual measurements are recorded, first at zero and then at span concentration. From these 20 measurements, the average is calculated for zero and span level.

The analyser shall be kept running under the laboratory conditions while analysing ambient air. After a period of 12 h, zero and span gas is fed to the analyser. After waiting the time equivalent to one independent reading, 20 individual measurements are recorded, first at zero and then at span concentration. The averages for zero and span level shall be calculated.

The short-term drift at zero and span level shall be calculated as follows:

$$D_{S,Z} = (C_{Z,2} - C_{Z,1})$$

Where

$D_{S,Z}$ is the 12 h drift at zero

$C_{Z,1}$ is the average concentration of the measurements at zero at the beginning of the drift period

$C_{Z,2}$ is the average concentration of the zero gas measurements at the end of the drift period

$D_{S,Z}$ shall comply with the performance criterion as specified above.

$$D_{S,S} = (C_{S,2} - C_{S,1}) - D_{S,Z}$$

Where

$D_{S,S}$ is the 12 h drift at span level

$C_{S,1}$ is the average concentration of the span gas measurements at the beginning of the drift period

$C_{S,2}$ is the average concentration of the span gas measurements at the end of the drift period

$D_{S,S}$ shall comply with the performance criterion as specified above.

7.3 Testing

Testing was carried out in accordance with the requirements stipulated in EN 14626. Testing must be carried out using the component CO. According to this standard, the test shall be performed using carbon monoxide at a concentration level of 70 % to 80 % of the certification range for carbon monoxide.

7.4 Evaluation

Table Table 6 lists the readings obtained for the short-term drift.

Table 6: Results for the short-term drift

	requirements	device 1		device 2	
averange at zero at the beginning [µmol/mol]	-	0.00		0.09	
averange at zero at the end [µmol/mol]	-	0.02		0.11	
averange at span at the beginning [µmol/mol]	-	64.03		63.24	
averange at span at the end [µmol/mol]	-	63.81		63.44	
12-hour drift at zero $D_{s,z}$ [µmol/mol]	≤ 0,1	0.02	✓	0.01	✓
12-hour drift at span $D_{s,s}$ [µmol/mol]	≤ 0,6	-0.24	✓	0.18	✓

7.5 Assessment

Short-term drift at zero point is 0.02 µmol/mol for system 1 and 0.01 µmol/mol for system 2.

Short-term drift at the reference point is -0.24 µmol/mol for system 1 and -0.18 µmol/mol for system 2.

Requirement fulfilled? yes

7.6 Test results in detail

Individual test results are provided in Table 7 and Table 8.

Table 7: Individual test results for the short-term drift (initial values)

at beginning		
zero level		
	device 1	device 2
time	[µmol/mol]	[µmol/mol]
17:30:00	0.0	0.1
17:31:00	0.0	0.1
17:32:00	0.0	0.1
17:33:00	0.0	0.1
17:34:00	0.0	0.1
17:35:00	0.0	0.1
17:36:00	0.0	0.1
17:37:00	0.0	0.1
17:38:00	0.0	0.1
17:39:00	0.0	0.1
17:40:00	0.0	0.1
17:41:00	0.0	0.1
17:42:00	0.0	0.1
17:43:00	0.0	0.1
17:44:00	0.0	0.1
17:45:00	0.0	0.1
17:46:00	0.0	0.1
17:47:00	0.0	0.1
17:48:00	0.0	0.1
17:49:00	0.0	0.1
average	**0.0**	**0.1**

at beginning		
span level		
	device 1	device 2
time	[µmol/mol]	[µmol/mol]
17:55:00	63.5	63.3
17:56:00	63.5	63.3
17:57:00	63.5	63.3
17:58:00	63.5	63.3
17:59:00	63.6	63.3
18:00:00	63.7	63.4
18:01:00	63.9	63.4
18:02:00	63.9	63.4
18:03:00	64.1	63.3
18:04:00	64.1	63.2
18:05:00	64.2	63.2
18:06:00	64.3	63.2
18:07:00	64.3	63.1
18:08:00	64.4	63.1
18:09:00	64.4	63.2
18:10:00	64.4	63.2
18:11:00	64.4	63.2
18:12:00	64.3	63.2
18:13:00	64.3	63.3
18:14:00	64.2	63.3
average	**64.0**	**63.2**

Table 8: Individual test results for the short-term drift (final values)

after 12h		
zero level		
	device 1	device 2
time	[µmol/mol]	[µmol/mol]
05:30:00	0.1	0.1
05:31:00	0.1	0.1
05:32:00	0.1	0.1
05:33:00	0.1	0.1
05:34:00	0.0	0.1
05:35:00	0.0	0.1
05:36:00	0.0	0.1
05:37:00	0.0	0.1
05:38:00	0.0	0.1
05:39:00	0.1	0.1
05:40:00	0.1	0.1
05:41:00	0.1	0.1
05:42:00	0.0	0.1
05:43:00	0.0	0.1
05:44:00	0.1	0.1
05:45:00	0.0	0.1
05:46:00	0.0	0.1
05:47:00	0.0	0.1
05:48:00	0.0	0.1
05:49:00	0.0	0.1
average	**0.0**	**0.1**

after 12h		
span level		
	device 1	device 2
time	[µmol/mol]	[µmol/mol]
05:55:00	64.5	63.5
05:56:00	64.4	63.3
05:57:00	64.2	63.4
05:58:00	64.0	63.4
05:59:00	63.9	63.5
06:00:00	63.9	63.5
06:01:00	63.9	63.6
06:02:00	63.8	63.6
06:03:00	63.7	63.6
06:04:00	63.7	63.5
06:05:00	63.7	63.5
06:06:00	63.7	63.5
06:07:00	63.6	63.5
06:08:00	63.6	63.5
06:09:00	63.6	63.5
06:10:00	63.6	63.4
06:11:00	63.6	63.3
06:12:00	63.6	63.3
06:13:00	63.6	63.3
06:14:00	63.6	63.2
average	**63.8**	**63.4**

7.1 8.4.5 Repeatability standard deviation

The repeatability standard deviation shall meet the performance characteristics at zero ≤ 0.3 µmol/mol (= 0.35 mg/m³) and at a test gas concentration at reference point ≤ 0.4 µmol/mol (= 0.46 mg/m³).

7.2 Test program

After waiting the time equivalent of one independent reading, 20 individual measurements both at zero concentration and at a test concentration (c_t) similar to the 8-hour limit value shall be performed.

From these measurements, the repeatability standard deviation at zero concentration and at concentration c_t shall be calculated according to:

$$s_r = \sqrt{\frac{\sum \left(x_i - \bar{x}\right)^2}{n-1}}$$

Where

s_r is the repeatability standard deviation

x_i is the i-th measurement

$\bar{x}$ is the average of the 20 measurements

n is the number of measurements

The repeatability standard deviation shall be calculated separately for both series of measurements (zero gas and concentration c_t).

s_r shall comply with the performance criterion as specified above, both at zero and at the test concentration ct (8-hour limit value).

The repeatability standard deviation at zero is used in combination with the slope of the calibration function determined in 8.4.6 to calculate the detection limit of the analyser as:

$$l_{\det} = 3{,}3 \cdot \frac{s_{r,z}}{B}$$

Where

$l_{\det}$ is the detection limit of the analyser, in µmol/mol

$s_{r,z}$ is the repeatability standard deviation at zero, in µmol/mol

B is the slope of the calibration function determined according to Annex A using the data from 8.4.6.

7.3 Testing

Testing was carried out in accordance with the requirements stipulated in EN 14626. Testing must be carried out using the component CO. According to this standard, the test shall be performed using carbon monoxide at a concentration level of approx.8.6 µmol/mol. According to VDI 4202 Part 1, the test of the repeatability standard deviation at reference point shall be performed using the limit value.

7.4 Evaluation

Table 9 details the test results for the repeatability standard deviation.

Table 9: Repeatability standard deviation at zero and reference point

	requirements	device 1		device 2	
repeatability standard deviation $s_{r,z}$ at zero [µmol/mol]	≤ 0,3	0.00	✓	0.03	✓
repeatability standard deviation $s_{r,ct}$ at c_t [µmol/mol]	≤ 0,4	0.03	✓	0.05	✓
detection limit [µmol/mol]		0.00		0.09	

7.5 Assessment

Repeatability standard deviation at zero point is 0.00 µmol/mol for system 1 and 0.03 µmol/mol for system 2. Repeatability standard deviation at reference point is 0.03 µmol/mol for system 1 and 0.05 µmol/mol for system 2.

Requirement fulfilled? yes

7.6 Test results in detail

Table 10 lists the results of the individual measurements.

Table 10: Individual test results for the repeatability standard deviation

zero level		
	device 1	device 2
time	[µmol/mol]	[µmol/mol]
15:20:00	0.0	0.1
15:21:00	0.0	0.1
15:22:00	0.0	0.0
15:23:00	0.0	0.0
15:24:00	0.0	0.1
15:25:00	0.0	0.0
15:26:00	0.0	0.0
15:27:00	0.0	0.0
15:28:00	0.0	0.0
15:29:00	0.0	0.0
15:30:00	0.0	0.0
15:31:00	0.0	0.0
15:32:00	0.0	0.0
15:33:00	0.0	0.0
15:34:00	0.0	0.0
15:35:00	0.0	0.0
15:36:00	0.0	0.1
15:37:00	0.0	0.1
15:38:00	0.0	0.1
15:39:00	0.0	0.1
average	0.0	0.0

c_t level		
	device 1	device 2
time	[µmol/mol]	[µmol/mol]
15:45:00	8.7	8.7
15:46:00	8.7	8.7
15:47:00	8.7	8.7
15:48:00	8.6	8.7
15:49:00	8.6	8.8
15:50:00	8.6	8.8
15:51:00	8.7	8.8
15:52:00	8.7	8.8
15:53:00	8.7	8.8
15:54:00	8.7	8.8
15:55:00	8.7	8.8
15:56:00	8.7	8.8
15:57:00	8.7	8.8
15:58:00	8.7	8.8
15:59:00	8.7	8.8
16:00:00	8.7	8.8
16:01:00	8.7	8.8
16:02:00	8.7	8.8
16:03:00	8.7	8.9
16:04:00	8.7	8.8
average	8.7	8.8

7.1 8.4.6 Lack of fit of linearity of the calibration function

The lack of fit of linearity of the calibration function shall not exceed 0.5 µmol/mol (= 0.58 mg/m³) at zero point and 4 % of the measured value at concentrations above zero.

7.2 Test program

The lack of fit of linearity of the calibration function of the analyser shall be tested over the range of 0 % to 95% of the maximum of the certification range, using at least six concentrations (including the zero point). The analyser shall be adjusted at a concentration of about 90% of the maximum of the certification range. At each concentration (including zero) at least five individual measurements shall be performed.

The concentrations shall be applied in the following sequence: 80%, 40%, 0%, 60%, 20% and 95%. After each change in concentration, at least a time equivalent to four response times shall be elapse before the next measurement is performed.

The linear regression function and the deviation are established on in accordance with Annex A of standard EN 14626. Deviations from the linear regression function must comply with the performance characteristics stated above.

Establishing the regression line:

A linear regression line in the form of $Y_i = A + B * X_i$ is established through calculation of the following formula:

$$Y_i = a + B(X_i - X_z)$$

For the regression calculation, all measuring points (including zero) are taken into account. The total number of measuring points is equal to the number of concentration levels (at least six including zero) multiplied with the number of repetitions (at least five) at each concentration level.

The coefficient a is obtained from:

$$a = \sum Y_i / n$$

Where

a is the average of the Y-values
Y_i is the individual Y-value
N is the number of calibration points

The coefficient B is obtained from:

$$B = \left(\sum Y_i (X_i - X_z)\right) / \sum (X_i - X_z)^2$$

Where:

X_z is the average of the X-values $\left(= \sum (X_i / n)\right)$
X_i is the individual X-value

The function $Y_i = a + B (X_i – X_z)$ is converted to $Y_i = A + B * X_i$ through the calculation of A.

$A = a – B * X_z$

The residuals of the averages of each calibration point (including the zero point) are calculated as follows.
The average of each calibration point (including the zero point) at one and the same concentration c is calculated according to:

$$(Y_a)_c = \sum (Y_i)_c / m$$

Where:

$(Y_a)_c$ is the average Y-value at concentration level c
$(Y_i)_c$ is the individual Y-value at concentration level c
M is the number of repetitions at one and the same concentration level c

The deviation of each average (r_c) at each concentration level is calculated according to:

$$r_c = (Y_a)_c - (A + B \times c)$$

Each deviation to a value relative to its own concentration level c is expressed in % as:

$$r_{c,rel} = \frac{r_c}{c} \times 100\%$$

7.3 Testing

Testing was carried out in accordance with the requirements stipulated in EN 14626.

7.4 Evaluation

The following linear regressions where determined:

Figure 10 and Figure *11* illustrate the results of the determination of the group averages for CO.

Table 11: Deviations of the analytical function for CO

	requirements	device 1		device 2	
largest value of the relative residuals r_{max} [%]	≤ 4,0	1.94	✓	2.06	✓
residual at zero r_z [µmol/mol]	≤ 0,5	0.11	✓	0.04	✓

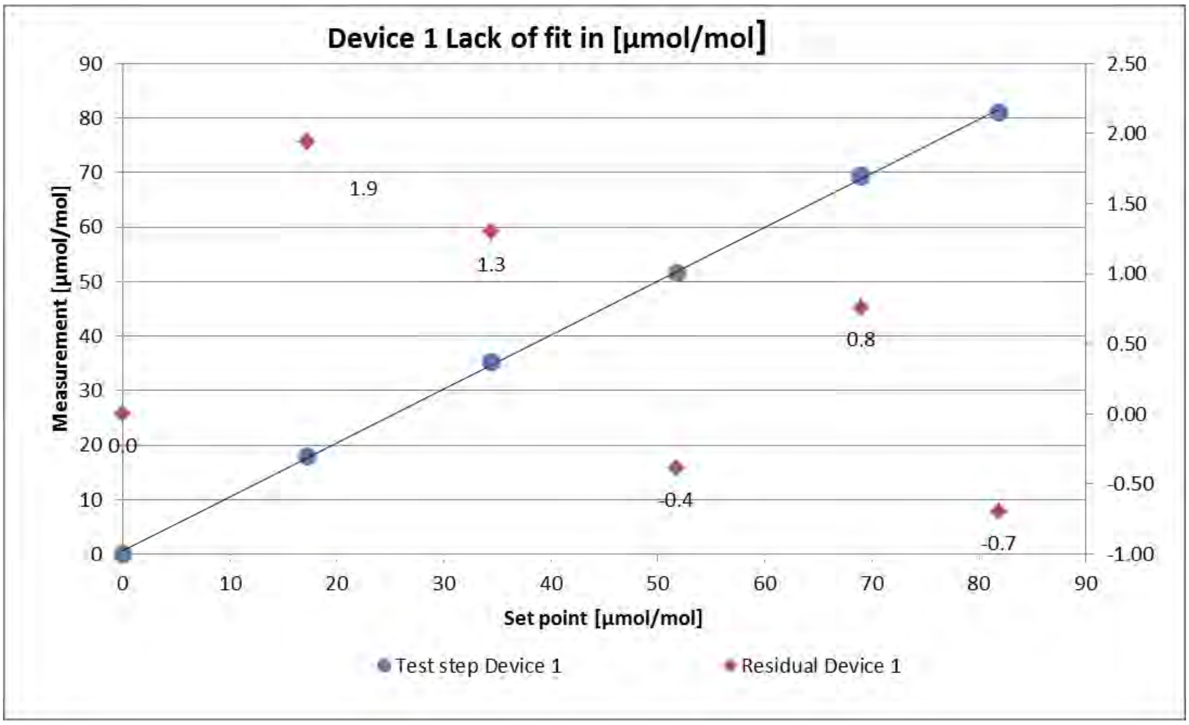


Figure 10: Analytical function established from group averages for system 1

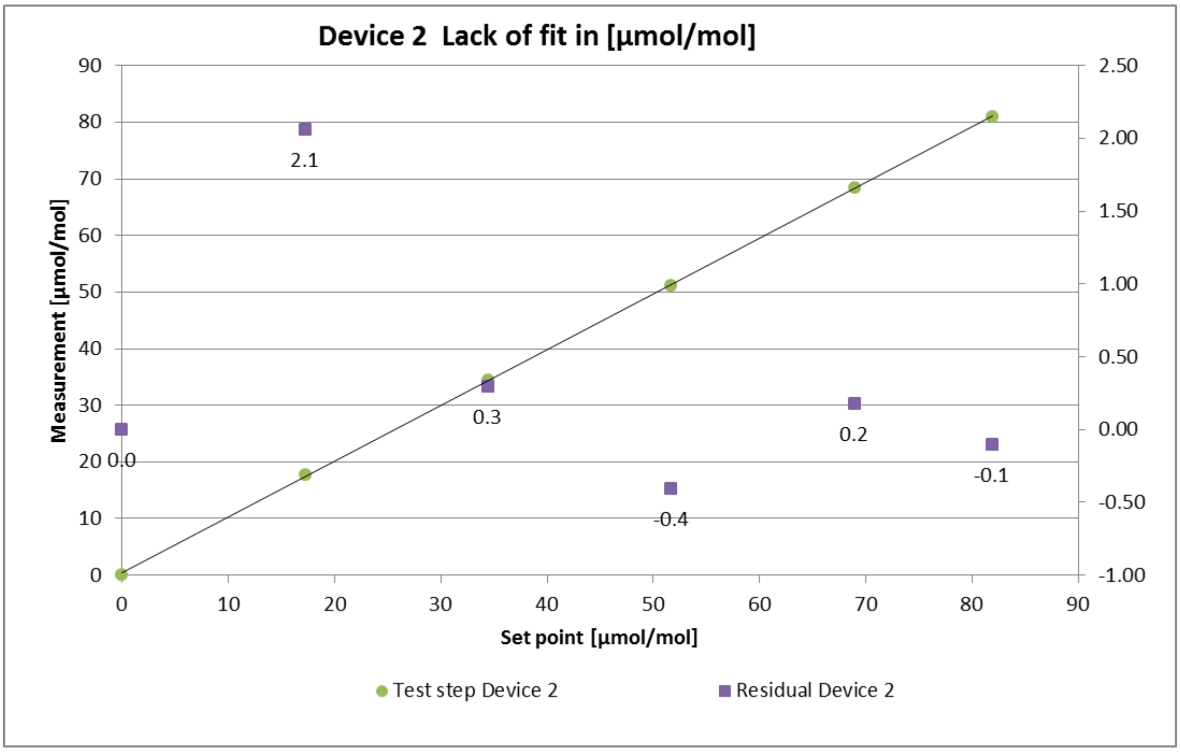


Figure 11: Analytical function established from group averages for system 2

7.5 Assessment

For system 1, the deviation from the regression line is 0.11 µmol/mol at zero point and max. 1.94 % of the target value for concentrations greater than zero. For system 2, the deviation from the regression line is 0.04 µmol/mol at zero point and max. 2.06 % of the target value for concentrations greater than zero.

Deviations from the ideal regression line do not exceed the limit values stipulated in EN 14626.

Requirement fulfilled? yes

7.6 Test results in detail

Individual test results are provided in Table 12.

Table 12: Individual values of the “lack of fit”-test.

		device 1 [µmol/mol]		device 2 [µmol/mol]	
time	level [%]	actual value y_i	set value x_i	actual value y_i	set value x_i
14:22:00	80	69.22	68.97	68.59	68.97
14:23:00	80	69.31	68.97	68.55	68.97
14:24:00	80	69.38	68.97	68.45	68.97
14:25:00	80	69.43	68.97	68.40	68.97
14:26:00	80	69.44	68.97	68.38	68.97
average		69.36		68.47	
$r_{c,rel}$		0.76		0.17	
14:32:00	40	35.19	34.48	34.44	34.48
14:33:00	40	35.18	34.48	34.43	34.48
14:34:00	40	35.19	34.48	34.44	34.48
14:35:00	40	35.19	34.48	34.44	34.48
14:36:00	40	35.18	34.48	34.44	34.48
average		35.19		34.44	
$r_{c,rel}$		1.30		0.30	
14:42:00	0	0.11	0.00	0.05	0.00
14:43:00	0	0.10	0.00	0.03	0.00
14:44:00	0	0.10	0.00	0.03	0.00
14:45:00	0	0.11	0.00	0.04	0.00
14:46:00	0	0.14	0.00	0.04	0.00
average		0.11		0.04	
r_z					
14:52:00	60	51.67	51.72	51.08	51.72
14:53:00	60	51.62	51.72	51.11	51.72
14:54:00	60	51.57	51.72	51.14	51.72
14:55:00	60	51.55	51.72	51.16	51.72
14:56:00	60	51.53	51.72	51.17	51.72
average		51.59		51.13	
$r_{c,rel}$		-0.38		-0.41	
15:02:00	20	18.04	17.24	17.67	17.24
15:03:00	20	18.04	17.24	17.68	17.24
15:04:00	20	18.02	17.24	17.68	17.24
15:05:00	20	18.01	17.24	17.69	17.24
15:06:00	20	18.02	17.24	17.69	17.24
average		18.03		17.68	
$r_{c,rel}$		1.94		2.06	
15:12:00	95	81.08	81.90	81.06	81.90
15:13:00	95	81.08	81.90	81.07	81.90
15:14:00	95	81.02	81.90	81.03	81.90
15:15:00	95	81.01	81.90	80.98	81.90
15:16:00	95	81.05	81.90	80.99	81.90
average		81.05		81.03	
$r_{c,rel}$		-0.70		-0.10	

7.1 8.4.7 Sensitivity coefficient of sample gas pressure

The sensitivity coefficient of the sample gas pressure shall not exceed 0.7 µmol/mol/kPa (=0.81 mg/m³/kPa).

7.2 Test program

Measurements are taken at a concentration of about 70% to 80% of the maximum of the certification range at an absolute pressure of about (80 ± 0.2) kPa and at an absolute pressure of about (110 ± 0.2) kPa. At each pressure after waiting the time equivalent to one independent reading, three individual measurements are recorded. From these three measurements, the averages at each pressure are calculated.

Measurements at different pressures shall be separated by at least four response times.

The sample gas pressure influence is calculated by:

$$b_{gp} = \left| \frac{(C_{P2} - C_{P1})}{(P_2 - P_1)} \right|$$

Where:

b_{gp} is the sensitivity coefficient of sample gas pressure

C_{P1} is the average concentration of the measurements at sampling gas pressure P_1

C_{P2} is the average concentration of the measurements at sample gas pressure P_2

P_1 is the sample gas pressure P_1

P_2 is the sample gas pressure P_2

b_{gp} shall comply with the performance criterion as specified above.

7.3 Testing

Testing was carried out in accordance with the requirements stipulated in EN 14626.

Negative pressure was created by lowering the volume of inserted test gas by restricting the sampling line. For testing excess pressure, the analyser was connected to a test gas source. The generated test gas volume was greater than the sample gas volume sucked in by the analysers. Remaining gas is discharged via a T piece. To generate excess pressure, the bypass line was restricted. The test gas pressure was determined by a pressure sensor within the test gas line.

Independent measurements are taken at concentrations of about 70 % to 80 % of the maximum of the certification range and at pressures of 80 kPa and 110 kPa.

7.4 Evaluation

The following sensitivity coefficients were determined for the sample gas pressure.

Table 13: Sensitivity coefficient of sample gas pressure

	requirements	device 1		device 2	
sensitivity coeff. sample gas pressure b_{gp} [µmol/mol/kPa]	≤ 0,7	0.05	✓	0.05	✓

7.5 Assessment

The sensitivity coefficient of sample gas pressure for system 1 is 0.05 µmol/mol/kPa.
The sensitivity coefficient of sample gas pressure for system 2 is 0.05 µmol/mol/kPa.
Requirement fulfilled? yes

7.6 Test results in detail

Table 14: Individual values from the test of sensitivity to changes ihn sample gas pressure

time	pressure [kPa]	concentration	device 1 [µmol/mol]	device 2 [µmol/mol]
10:22:00	80	64.66	64.58	64.12
10:23:00	80	64.66	64.72	64.13
10:24:00	80	64.66	64.75	64.15
average C_{P1}			64.68	64.13
10:32:00	110	64.66	66.23	65.67
10:33:00	110	64.66	66.25	65.68
10:34:00	110	64.66	66.18	65.68
average C_{P2}			66.22	65.68

7.1 8.4.8 Sensitivity coefficient of sample gas pressure

The sensitivity coefficient of the sample gas temperature shall not exceed 0.3 µmol/mol/K.

7.2 Test program

Measurements to determine the influence of the sample gas temperature shall be performed at sample gas temperatures T_1 = 0 °C und T_2 = 30 °C. A concentration around 70% to 80% of the maximum of the certification range is applied. After waiting the time equivalent to one independent measurement, three individual measurements at each temperature are recorded.

The sample gas temperature, measured at the inlet of the analyser, is held constant for at least 30 min.

The influence of sample gas temperature is calculated from:

$$b_{gt} = \frac{(C_{GT,2} - C_{GT,1})}{(T_{G,2} - T_{G,1})}$$

Where:

b_{gt}	is the sensitivity coefficient of sample gas temperature
$C_{GT,1}$	is the average concentration of the measurements at sample gas temperature $T_{G,1}$
$C_{GT,2}$	is the average concentration of the measurements at sample gas temperature $T_{G,2}$
$T_{G,1}$	is the sample gas temperature $T_{G,1}$
$T_{G,2}$	is the sample gas temperature $T_{G,2}$
b_{gt}	shall comply with the performance criterion as specified above.

7.3 Testing

Testing was carried out in accordance with the requirements stipulated in EN 14626.

The sample gas was transported to the analyser via a tube bundle of 30 m length which was placed in a climatic chamber. The analysers were placed directly in front of the climatic chamber. The tube bundle's ending was connected to the analyser outside the climatic chamber. The lead on the outside of the climate chamber was insulated and the sample gas temperature directly at the analyser was monitored with a thermocouple. The climate chamber's temperature was adjusted so that the gas temperature directly at the anlayser was 0 °C. In order to check the 30 °C gas temperature, the gas was led to the analysers through a conditioned heating line instead of the tube bundle in the climate chamber.

Independent measurements are taken at concentrations of about 70 % to 80 % of the maximum of the certification range and at sample gas temperatures of 0 °C and 3°C.

7.4 Evaluation

Table 15: Sensitivity coefficient of sample gas temperature

	requirements	device 1		device 2	
sensitivity coeff. sample gas pressure b_{gt} [µmol/mol/K]	≤ 0,3	0.00	✓	0.00	✓

7.5 Assessment

The sensitivity coefficient of sample gas temperature for system 1 is 0.00 µmol/mol/K.
The sensitivity coefficient of sample gas temperature for system 2 is 0.00 µmol/mol/K.
Requirement fulfilled? yes

7.6 Test results in detail

Table 16: Individual values determined for the influence of sample gas temperature for CO

time	temp [ºC]	concentration	device 1 [µmol/mol]	device 2 [µmol/mol]
09:55:00	0	64.66	65.12	65.20
09:56:00	0	64.66	65.11	65.18
09:57:00	0	64.66	65.14	65.18
average $C_{GT,1}$			65.12	65.19
16:15:00	30	64.66	65.06	65.15
16:16:00	30	64.66	65.07	65.18
16:17:00	30	64.66	65.07	65.17
average $C_{GT,1}$			65.07	65.17

7.1 8.4.9 Sensitivity coefficient of ambient temperature

The sensitivity coefficient of the ambient temperature shall not exceed 0.3 µmol/mol/K.

7.2 Test program

The sensitivity of the analyser readings to the ambient temperature in the range specified by the manufacturer shall be determined by performing measurements at the following temperatures:

1) at the minimum temperature T_{min} = 0 °C
2) at the temperature in the laboratory T_l = 20 °C
3) at the maximum temperature T_{max} = 30 °C

For these tests, a climate chamber is required.

The influence is determined at a concentration of zero and a concentration around 70% to 80% of the maximum of the certification range. At each temperature setting after waiting the time equivalent to one independent measurement, three individual measurements at zero and at span concentration shall be recorded.

The sequence of test temperatures is as follows:

T_l, T_{min}, T_l and T_l, T_{max}, T_l

At the first temperature (T_l), the analyser shall be adjusted at zero and at span level (70 % to 80 % of the maximum of the certification range). Then three individual measurements are recorded after waiting the time equivalent to one independent reading at T_l, T_{min} and again at T_l. This measurement procedure shall be repeated at the temperature sequence T_l, T_{max} and T_l.

In order to exclude any possible drift due to factors other than temperature, the measurements at T_l are averaged, which is taken into account in the following formula for calculation of the sensitivity coefficient for ambient temperature dependence:

$$b_{st} = \left| \frac{x_T - \frac{x_1 + x_2}{2}}{T_S - T_{S,0}} \right|$$

Where:

b_{st}	is the sensitivity coefficient of the ambient temperature
x_T	is the average concentration of the measurements at T_{min} or T_{max}
x_1	is the first average of the measurements at T_1
x_2	is the second average of the measurements at T_1
T_S	is the ambient temperature in the laboratory
$T_{S,0}$	is the average of the ambient temperatures at set point

For reporting the ambient temperature dependence the higher value is taken of the two calculations of the temperature dependence at $T_{S,1}$ or $T_{S,2}$.

b_{st} shall comply with the performance criterion as specified above.

7.3 Testing

Testing was carried out in accordance with the requirements stipulated in EN 14626.

7.4 Evaluation

The following sensitivity coefficients were determined for the influence of the ambient temperature.

Table 17: Sensitivity coefficient to the ambient temperature at zero point and at span point, systems 1 and 2

	requirements	device 1		device 2	
sensitivity coefficient at 0 ºC for zero level [µmol/mol/K]	≤ 0.3	0.015	✓	0.003	✓
sensitivity coefficient at 30 ºC for zero level [µmol/mol/K]	≤ 0.3	0.019	✓	0.003	✓
sensitivity coefficient at 0 ºC for span level [µmol/mol/K]	≤ 0.3	0.017	✓	0.012	✓
sensitivity coefficient at 30 ºC for span level [µmol/mol/K]	≤ 0.3	0.008	✓	0.019	✓

As illustrated in Table 18, the sensitivity coefficient to the ambient temperature at zero point and at reference point complies with the performance criteria.

7.5 Assessment

The sensitivity coefficient b_{st} of the ambient temperature does not exceed the performance criteria of max. 3.0 µmol/mol/K. For both systems, the greatest sensitivity coefficient value b_{st} is used for the purpose of evaluating uncertainty. For system it is 1 0.019 µmol/mol/K and for system 2 it is 0.019 µmol/mol/K.

Requirement fulfilled? yes

7.6 Test results in detail

Individual test results are provided in Table 18.

Table 18: Individual values for the test of the sensitivity coefficient of the ambient temperature for CO

	zero level				span level			
			device 1	device 2			device 1	device 2
date	time	temp [ºC]	[µmol/mol]	[µmol/mol]	time	temp [ºC]	[µmol/mol]	[µmol/mol]
20.04.2015	09:05:00	20	0.5	0.1	09:15:00	20	64.7	63.7
20.04.2015	09:06:00	20	0.5	0.1	09:16:00	20	64.6	63.7
20.04.2015	09:07:00	20	0.5	0.1	09:17:00	20	64.4	63.7
average ($X_{1(TS1)}$)			0.5	0.1			64.6	63.7
20.04.2015	15:35:00	0	0.0	-0.1	15:45:00	0	64.1	63.8
20.04.2015	15:36:00	0	0.0	-0.1	15:46:00	0	64.1	63.8
20.04.2015	15:37:00	0	0.0	-0.1	15:47:00	0	64.1	63.8
average($X_{Ts,1}$)		0	0.0	-0.1			64.1	63.8
21.04.2015	07:15:00	20	0.1	-0.2	07:25:00	20	64.2	63.5
21.04.2015	07:16:00	20	0.1	-0.1	07:26:00	20	64.3	63.5
21.04.2015	07:17:00	20	0.1	-0.2	07:27:00	20	64.3	63.5
average ($X_{2(TS1)}$) = ($X_{1(TS2)}$)			0.1	-0.2			64.3	63.5
21.04.2015	15:30:00	30	0.4	-0.1	15:40:00	30	64.4	63.7
21.04.2015	15:31:00	30	0.4	-0.1	15:41:00	30	64.4	63.7
21.04.2015	15:32:00	30	0.4	-0.1	15:42:00	30	64.5	63.7
average($X_{Ts,2}$)			0.4	-0.1			64.4	63.7
22.04.2015	07:35:00	20	0.4	-0.1	07:45:00	20	64.5	63.5
22.04.2015	07:36:00	20	0.4	-0.1	07:46:00	20	64.5	63.6
22.04.2015	07:37:00	20	0.4	-0.1	07:47:00	20	64.5	63.6
average ($X_{2(TS2)}$)			0.4	-0.1			64.5	63.5

7.1 8.4.10 Sensitivity coefficient of supply voltage

The sensitivity coefficient of the supply voltage shall not exceed 0.30 µmol/mol/V (=0.35 mg/m³/V).

7.2 Test program

The sensitivity coefficient of electrical voltage shall be determined at both ends of the voltage range specified by the manufacturer and at a concentration around 70% to 80% of the maximum of the certification range. After waiting the time equivalent to one independent measurement, three individual measurements at each voltage and concentration level shall be recorded.

The sensitivity coefficient of supply voltage in accordance with EN 14626 is calculated from:

$$b_v = \left| \frac{(C_{V2} - C_{V1})}{(V_2 - V_1)} \right|$$

Where:

b_v is the sensitivity coefficient of supply voltage

C_{V1} is the average of the measurement at voltage V_1

C_{V2} is the average of the measurement at voltage V_2

V_1 is the minimum voltage V_{min}

V_2 is the maximum voltage V_{max}

For reporting the dependence on voltage, the higher value of the result at zero and span level shall be taken.

b_v shall comply with the performance criterion as specified above.

7.3 Testing

For the purpose of testing the voltage sensitivity coefficient, a transformer was interposed between the analyser and the voltage supply. Sample gas was fed at various voltages at zero and reference point.

7.4 Evaluation

The following sensitivity coefficients to supply voltage resulted from the tests:

Table 19: Sensitivity coefficient of supply voltage at zero and reference point

	requirements	device 1		device 2	
sensitivity coeff. of voltage bv at 0 level [µmol/mol/V]	≤ 0.3	0.00	✓	0.00	✓
sensitivity coeff. of voltage bv at span level [µmol/mol/V]	≤ 0.3	0.00	✓	0.01	✓

7.5 Assessment

The sensitivity coefficient of supply voltage b_v does not exceed the performance criteria of 0.30 µmol/mol/V specified in EN 14626. The greatest value b_v is used for the purpose of evaluating uncertainty for both systems. For system 1 it is 0.00 µmol/mol/V and for system 2 it is 0.01 µmol/mol/V.

Requirement fulfilled? yes

7.6 Test results in detail

Table 20: Individual values of the sensitivity coefficient of supply voltage

time	voltage [V]	concentration	device 1 [µmol/mol]	device 2 [µmol/mol]
15:05:00	190	0	0.19	0.01
15:06:00	190	0	0.18	0.01
15:07:00	190	0	0.19	0.04
average C_{V1} at 0			0.19	0.02
15:15:00	250	0	0.21	0
15:16:00	250	0	0.2	-0.01
15:17:00	250	0	0.21	-0.01
average C_{V2} at 0			0.21	-0.01
15:25:00	190	63.50	63.6	63.61
15:26:00	190	63.50	63.63	63.67
15:27:00	190	63.50	63.64	63.7
average C_{V1} at Span			63.62	63.66
15:35:00	250	63.50	63.52	63.3
15:36:00	250	63.50	63.53	63.35
15:37:00	250	63.50	63.53	63.37
average C_{V2} at Span			63.53	63.34

7.1 8.4.11 Interferents

Interferents at zero concentration and at a concentration c_t (at the level of the 8-hour limit = 8.6 mg/m³ for CO). Maximum responses allowed for the interferents CO_2, NO and N_2O are ≤ 5.0 µmol/mol (= 5.8 mg/m³), for H_2O ≤ 10.0 µmol/mol (= 11.6 mg/m³).

7.2 Test program

The analyser response to certain interferents, which are to be expected to be present in ambient air, shall be tested. The interferents can cause a positive as well as a negative response. The test shall be performed at zero concentration and at a test concentration (c_t) similar to the 8-hour limit value (8.6 µmol/mol for CO shall be performed.

The concentration of the mixtures of the test gases with the interferent shall have an uncertainty of ≤ 5 % and shall be traceable to nationally accepted standards. The interferents to be tested and their respective concentrations are given in Table 21. The influence of each interferent shall be determined individually. A correction on the concentration of the measurement parameter shall be made for the dilution effect due to addition of an interferent (e.g. water vapour).

After adjustment of the analyser at zero and span level, the analyser shall be fed with a mixture of zero gas and the interferent to be investigated with the concentration as given in Table 21. With this mixture, one independent measurement followed by two individual measurements shall be carried out. This procedure shall be repeated with a mixture of the measurement parameter at concentration c_t and the interferent to be investigated. The influence quantity at zero and concentration c_t is calculated from:

$$X_{\text{int},z} = x_z$$

$$X_{\text{int},ct} = x_{ct} - c_t$$

Where:

$X_{\text{int},z}$ is the interferent's effect at zero

x_z is the average of the measurements at zero

$X_{\text{int},ct}$ is the interferent's effect at concentration c_t

x_{ct} is the average of the measurement at concentration c_t

c_t is the concentration of the applied gas at the 8-hour limit value level

The interferent's effect shall comply with the performance criterion as specified above, both at zero and at the test concentration c_t.

7.3 Testing

Testing was carried out in accordance with the requirements stipulated in EN 14626. The systems were adjusted to zero concentration and to the concentration c_t (approx. 8.6 µmol/mol). Zero and test gas with various interferents were then applied. Interferents and their respective concentrations used during testing are provided in Table 22.

Table 21: Interferents according to EN 14626

Interferent	Concentration
H_2O	19 mmol/mol
CO_2	500 µmol/mol
NO	1 µmol/mol
N_2O	50 nmol/mol

7.4 Evaluation

The following table lists the influence quantities of individual interferents. The dilution effect was factored into the test gas generating system when determining the influence of humidity.

Table 22: Influence of the interferents tested (c_t = 8.6 µmol/mol)

	requirements	**device 1**		**device 2**	
influence quantity interferent H_2O at cero [nmol/mol/V]	≤ 1.0 µmol/mol	0.29	✓	0.22	✓
influence quantity interferent H_2O at c_t [nmol/mol/V]	≤ 1.0 µmol/mol	0.33	✓	0.32	✓
influence quantity interferent CO_2 at cero [nmol/mol/V]	≤ 0.5 µmol/mol	-0.15	✓	-0.21	✓
influence quantity interferent CO_2 at c_t [nmol/mol/V]	≤ 0.5 µmol/mol	-0.14	✓	-0.09	✓
influence quantity interferent NO at cero [nmol/mol/V]	≤ 0.5 µmol/mol	-0.06	✓	-0.03	✓
influence quantity interferent NO at c_t [nmol/mol/V]	≤ 0.5 µmol/mol	0.04	✓	0.00	✓
influence quantity interferent N_2O at cero [nmol/mol/V]	≤ 0.5 µmol/mol	-0.05	✓	-0.16	✓
influence quantity interferent N_2O at c_t [nmol/mol/V]	≤ 0.5 µmol/mol	0.06	✓	0.01	✓

7.5 Assessment

Cross-sensitivity at zero point is 0.29 µmol/mol for system 1 and 0.22 µmol/mol for system 2 at H_2O, -0.15 µmol/mol for system 1 and -0.21 µmol/mol for system 2 at CO_2, -0.06 µmol/mol for system 1 and -0.03 µmol/mol for system 2 at NO, -0.05 µmol/mol for system 1 and -0.16 µmol/mol for system 2 at N_2O.

Cross-sensitivity at limit value c_t is 0.33 µmol/mol for system 1 and 0.32 µmol/mol for system 2 at H_2O, -0.14 µmol/mol for system 1 and -0.09 µmol/mol for system 2 at CO_2, -0.04 µmol/mol for system 1 and -0.00 µmol/mol for system 2 at NO, -0.06 µmol/mol for system 1 and -0.01 µmol/mol for system 2 at N_2O.

Requirement fulfilled? yes

7.6 Test results in detail

Table 23 details the individual test results.

Table 23: Individual test results for the interferents

	without interferents			with interferents		
	time	device 1	device 2	time	device 1	device 2
zero gas + H_2O (19 mmol/mol)	10:05:00	0.19	0.07	0.43	0.49	0.29
	10:06:00	0.18	0.06	0.43	0.46	0.29
	10:07:00	0.18	0.07	0.43	0.46	0.27
	average x_z	0.18	0.07	average x_z	0.47	0.28
test gas c_t + H_2O (19 mmol/mol)	10:25:00	8.82	8.68	0.44	9.18	8.99
	10:26:00	8.84	8.68	0.44	9.16	8.99
	10:27:00	8.84	8.67	0.44	9.16	9.01
	average x_{ct}	8.83	8.68	average x_{ct}	9.17	9.00
zero gas + CO_2 (500 µmol/mol)	10:25:00	0.14	0.01	0.44	-0.04	-0.23
	10:26:00	0.11	-0.01	0.44	-0.05	-0.23
	10:27:00	0.08	-0.05	0.44	-0.03	-0.22
	average x_z	0.11	-0.02	average x_z	-0.04	-0.23
test gas c_t + CO_2 (500 µmol/mol)	10:45:00	8.64	8.34	0.45	8.48	8.25
	10:46:00	8.64	8.35	0.46	8.50	8.25
	10:47:00	8.62	8.34	0.46	8.50	8.26
	average x_{ct}	8.63	8.34	average x_{ct}	8.49	8.25
zero gas + NO (1 µmol/mol)	09:45:00	0.25	0.09	0.41	0.18	0.05
	09:46:00	0.24	0.08	0.41	0.18	0.05
	09:47:00	0.22	0.06	0.41	0.17	0.05
	average x_z	0.24	0.08	average x_z	0.18	0.05
test gas c_t + NO (1 µmol/mol)	10:05:00	8.69	8.47	0.43	8.71	8.47
	10:06:00	8.68	8.47	0.43	8.73	8.47
	10:07:00	8.68	8.47	0.43	8.73	8.47
	average x_{ct}	8.68	8.47	average x_{ct}	8.72	8.47
zero gas + N_2O (50 nmol/mol)	08:55:00	0.10	0.01	0.38	0.03	-0.18
	08:56:00	0.09	-0.04	0.38	0.04	-0.19
	08:57:00	0.09	-0.06	0.38	0.05	-0.21
	average x_z	0.09	-0.03	average x_z	0.04	-0.19
test gas c_t + N_2O (50 nmol/mol)	09:15:00	8.52	8.53	0.39	8.59	8.54
	09:16:00	8.52	8.54	0.39	8.59	8.52
	09:17:00	8.51	8.54	0.39	8.54	8.59
	average x_{ct}	8.52	8.54	average x_{ct}	8.57	8.55

7.1 8.4.12 Averaging test

The averaging effect shall not exceed 7 % of the measured value.

7.2 Test program

The averaging test gives a measure of the uncertainty in the averaged values caused by short-term concentration variations in the sampled air shorter than the time scale of the measurement process in the analyser. In general, the output of an analyser is a result of the determination of a reference concentration (normally zero) and the actual concentration which takes a certain time.

For the determination of the uncertainty due to the averaging, the following concentrations are applied to the analyser and readings are taken at each concentration:

- a stepwise variable CO concentration between zero and the concentration c_t similar to the 8-hour limit value (8.6 µmol/mol).

The time period (t_c) of the constant CO concentration shall be at least equal to a period required to obtain four independent readings (16 response times minimum). The time period (t_v) of the varying NO concentration shall be at least equal to a period to obtain four independent readings. The time period (t_{CO}) for the CO concentration shall be 45 s followed by a period (t_{zero}) of 45 s zero concentration. Where:

c_t is the test gas concentration

t_v is the total number of t_{CO}- and t_{zero}-pairs (minimum 3 pairs)

The change from t_{CO} to t_{zero} shall be within 0.5 s. The change from t_c to t_v shall be within one response time of the analyser tested.

The averaging effect (E_{av}) is:

$$E_{av} = \frac{C_{const}^{av} - 2C_{var}^{av}}{C_{const}^{av}} * 100$$

Where:

E_{av} is the averaging effect (%)

C_{const}^{av} is the average of the at least four independent measurements during the constant concentration period

C_{var}^{av} is the average of the at least four independent measurements during the variable concentration period

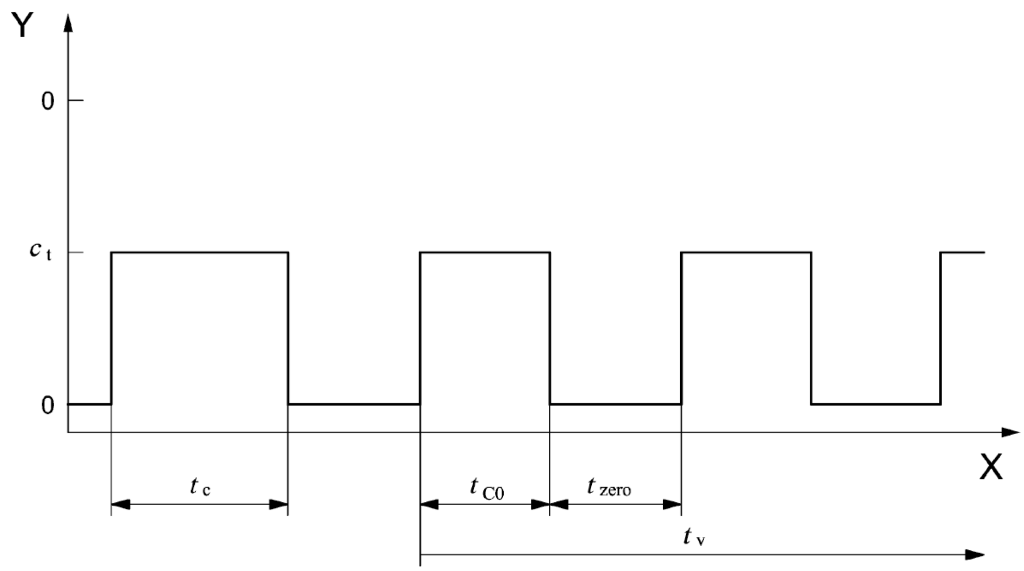


Figure 12: Concentration variation for the averaging test *(t_{CO} = t_{zero} = 45 s)*

7.3 Testing

The averaging test was carried out in accordance with the requirements stipulated in EN 14626. Since the analyser measures CO, the test was carried out with a volatile concentration between zero and concentration c_t (8.6 µmol/mol). First, the average was calculated at a constant concentration of test gas. Then, an alternating change between zero and test gas every 45 s was established using a three-way valve. For the period of alternating test gas application, the average was calculated as well.

7.4 Evaluation

Following average values were determined in the test:

	requirements	device 1		device 2	
averaging effect E_{av} [%]	≤ 7%	-2.56	✓	-2.61	✓

This results in the following averaging effects:

System 1: -2.56%

System 2: -2.61%

7.5 Assessment

The performance characteristics stipulated in EN 14626 are met with -2.56% for system 1 and -2.61% for system 2.

Requirement fulfilled? yes

7.6 Test results in detail

Table 24 details the test results for the test of the averaging effect.

Table 24: Individual test results of the test of the averaging effect

		device 1	device 2
	time	[µmol/mol]	[µmol/mol]
average constant concentration $C_{av,c}$	13:10:00 till 13:25:00	8.43	8.65
average variable concentration $C_{av,c}$	13:25:00 till 13:40:00	4.35	4.45

		device 1	device 2
	time	[nmol/mol]	[nmol/mol]
average constant concentration $C_{av,c}$	13:40:00 till 13:55:00	8.49	8.48
average variable concentration $C_{av,c}$	13:55:00 till 14:10:00	4.43	4.34

		device 1	device 2
	time	[nmol/mol]	[nmol/mol]
average constant concentration $C_{av,c}$	14:10:00 till 14:25:00	8.69	8.54
average variable concentration $C_{av,c}$	14:25:00 till 14:40:00	4.35	4.38

7.1 8.4.13 Difference sample/calibration port

The difference between sample port and calibration port shall not exceed 1.0 %.

7.2 Test program

If the analyser has different ports for feeding sample gas and calibration gas, the difference in response of the analyser to feeding through the sample or calibration port shall be tested. The test shall be carried out by feeding the analyser with a test gas with a concentration of 70 % to 80 % of the maximum of the certification range through the sample port. The test shall consist of one independent measurement followed by two individual measurements. After a period of at least four response times, the test shall be repeated using the calibration port. The difference shall be calculated according to: The difference is calculated according to:

$$\Delta_{SC} = \frac{x_{sam} - x_{cal}}{c_t} \times 100$$

Where:

Δ_{SC} is the difference sample/calibration port

x_{sam} is the average of the measurements via the sample port

x_{cal} is the average of the measurements via the calibration port

c_t is the test gas concentration

Δ_{SC} shall comply with the performance criterion as specified above.

7.3 Testing

Testing was carried out in accordance with the requirements stipulated in EN 14626. For test gas feeding the path was controlled by means of a three-way valve between sample and span gas port.

7.4 Evaluation

The following differences between sample port and calibration port were determined:

	requirements	device 1		device 2	
difference sample/calibration port Δx_{cs} [%]	≤ 1%	0.39	✓	0.22	✓

7.5 Assessment

The performance characteristics stipulated in EN 14626 are met with 0.39% for system 1 and 0.22% for system 2.

Requirement fulfilled? yes

7.6 Test results in detail

Individual values can be referred to in Table *26.*

Table 25: Individual values for the test of the difference between sample port and calibration port

		device 1	device 2
	time	[µmol/mol]	[µmol/mol]
calibration port	15:45:00	63.9	63.8
	15:46:00	63.9	63.7
	15:47:00	63.9	63.7
sample port	15:55:00	63.7	63.6
	15:56:00	63.6	63.6
	15:57:00	63.6	63.6

7.1 8.5.4 Long-term drift

The long-term drift at zero shall not exceed 0.50 µmol/mol (=0.58 mg/m³).
The long-term drift at span level shall not exceed 5 % of the certification range (= 4.3 µmol/mol at a measurement range of 0 to 86 µmol/mol).

7.2 Test program

After each bi-weekly calibration, the drift of the analysers under test shall be calculated at zero and at span level following the procedures as given underneath. If the drift compared to the initial calibration exceeds one of the performance criteria for drift at zero or span level the "period of unattended operation" equals the number of weeks until the observation of the infringement, minus two weeks. For further (uncertainty) calculations, the values for "long term drift" are the values for zero and span drift over the period of unattended operation.

At the beginning of the drift period, five individual measurements are taken immediately after the calibration at zero and span level.

Long-term drift is calculated according to:

$$D_{L,Z} = (C_{Z,1} - C_{Z,0})$$

Where:

$D_{L,Z}$ is the drift at zero

$C_{Z,0}$ is the average concentration at zero at the beginning of the drift period

$C_{Z,1}$ is the average concentration of the zero gas measurements at the end of the drift period

$D_{L,Z}$ shall comply with the performance criterion as specified above.

$$D_{L,S} = \frac{(C_{S,1} - C_{S,0}) - D_{L,Z}}{C_{S,1}} \times 100$$

Where:

$D_{L,S}$ is the drift at span concentration

$C_{S,0}$ is the average concentration at span level at the beginning of the drift period

$C_{S,1}$ is the average concentration at span level at the the end of the drift period

$D_{L,S}$ shall comply with the performance criterion as specified above.

7.3 Testing

Test gas was applied every two weeks. Table 26 and Table 27 list the results of this bi-weekly test gas application.

7.4 Evaluation

Table 26: Long-term drift results at zero point for CO

		Device 1 (SN 11) [µmol/mol]	Device 2 (SN 12) [µmol/mol]
$C_{Z,0}$	06.05.2015	0.05	0.13
$C_{Z,1}$	20.05.2015	0.08	0.01
$D_{L,Z}$	**20.05.2015**	**0.03**	**-0.12**
$C_{Z,1}$	03.06.2015	0.13	0.21
$D_{L,Z}$	**03.06.2015**	**0.08**	**0.08**
$C_{Z,1}$	17.06.2015	0.21	0.29
$D_{L,Z}$	**17.06.2015**	**0.16**	**0.16**
$C_{Z,1}$	01.07.2015	0.25	0.22
$D_{L,Z}$	**01.07.2015**	**0.20**	**0.09**
$C_{Z,1}$	15.07.2015	0.26	0.25
$D_{L,Z}$	**15.07.2015**	**0.21**	**0.12**
$C_{Z,1}$	29.07.2015	0.27	0.28
$D_{L,Z}$	**29.07.2015**	**0.22**	**0.15**
$C_{Z,1}$	12.08.2015	0.28	0.27
$D_{L,Z}$	**12.08.2015**	**0.23**	**0.14**

Table 27: Long-term drift results at reference point for CO

		Device 1 (SN 11) [µmol/mol]	Device 2 (SN 12) [µmol/mol]
$C_{S,0}$	06.05.2015	65.1	65.2
$C_{S,1}$	20.05.2015	65.1	65.3
$D_{L,S}$	**20.05.2015**	**-0.06%**	**0.32%**
$C_{S,1}$	03.06.2015	65.3	65.3
$D_{L,S}$	**03.06.2015**	**0.11%**	**0.08%**
$C_{S,1}$	17.06.2015	65.4	65.5
$D_{L,S}$	**17.06.2015**	**0.18%**	**0.21%**
$C_{S,1}$	01.07.2015	65.4	65.5
$D_{L,S}$	**01.07.2015**	**0.19%**	**0.41%**
$C_{S,1}$	15.07.2015	65.6	65.6
$D_{L,S}$	**15.07.2015**	**0.36%**	**0.52%**
$C_{S,1}$	29.07.2015	65.6	65.8
$D_{L,S}$	**29.07.2015**	**0.41%**	**0.72%**
$C_{S,1}$	12.08.2015	65.8	65.9
$D_{L,S}$	**12.08.2015**	**0.70%**	**0.89%**

7.5 Assessment

Maximum short-term drift at zero point $D_{l,z}$ is 0.23 µmol/mol for system 1 and 0.16 µmol/mol for system 2. Maximum long-term drift at reference point $D_{l,s}$ is 0.70 µmol/mol for system 1 and 0.89 µmol/mol for system 2.

Requirement fulfilled? yes

7.6 Test results in detail

Individual test results for the long-term drift are provided in Table 28.

Table 28: Individual test results of the drift tests

Date	Time	Device 1 (SN 11)	Device 2 (SN 12)	Time	Device 1 (SN 11)	Device 2 (SN 12)
	zero point			span point		
	[hh:mm]	[µmol/mol]	[µmol/mol]	[hh:mm]	[µmol/mol]	[µmol/mol]
06.05.2015	12:27	0.02	0.11	12:45	65.1	65.2
06.05.2015	12:28	0.05	0.17	12:46	65.1	65.2
06.05.2015	12:29	0.05	0.14	12:47	65.1	65.2
06.05.2015	12:30	0.07	0.12	12:48	65.2	65.2
06.05.2015	12:31	0.08	0.12	12:49	65.2	65.3
Average		**0.05**	**0.00**		**0.0**	**65.2**
20.05.2015	9:12	0.08	0.01	9:22	65.1	65.3
03.06.2015	14:14	0.13	0.21	14:26	65.3	65.3
17.06.2015	9:05	0.21	0.29	9:18	65.4	65.5
01.07.2015	10:16	0.25	0.22	10:29	65.4	65.5
15.07.2015	10:12	0.26	0.25	10:26	65.6	65.6
29.07.2015	9:11	0.27	0.28	9:23	65.6	65.8
12.08.2015	9:58	0.28	0.27	10:12	65.8	65.9

The values given are the average of one independent measurement and four individual measurements.

7.1 8.5.5 Reproducibility standard deviation for CO under field conditions

The standard deviation under field conditions shall not exceed 5 % of the average over a period of 3 months.

7.2 Test program

Reproducibility standard deviation under field conditions is determined from the averages of the 8-hour measurements during a period of 2 months.

The difference for the i-th parallel measurement is:

$$\Delta x_{f,i} = x_{f,1,i} - x_{f,2,i}$$

Where:

$\Delta x_{f,i}$	is the i-th difference of the parallel measurement
$x_{f,1,i}$	is the i-th measured signal from system 1
$x_{f,2,i}$	is the i-th measured signal from system 2

Reproducibility standard deviation (under field conditions) is:

$$s_{r,f} = \frac{\left(\sqrt{\frac{\sum_{i=1}^{n} \Delta x_{f,i}^2}{2 * n}}\right)}{c_f} \times 100$$

Where:

$s_{r,f}$	is the reproducibility standard deviation under field conditions (%)
n	is the number of parallel measurements
c_f	CO concentration measured during the field test

The reproducibility standard deviation $s_{r,f}$ shall comply with the performance criterion as specified above.

7.3 Testing

Using the equations given above, the reproducibility standard deviation under field conditions was calculated from the data averaged 8-hour during the field test.

Since the CO concentration in the ambient air in Germany is normally near zero, the sample air was occasionally enriched with CO (for approx. 21 days in total). Hereby, it could be demonstrated that the analysers operate reliably at higher concentrations as well. The sample air was enriched using low doses of a highly concentrated CO test gas at the collective sample device of the measurement container.

7.4 Evaluation

Table 29: Determination the reproducibility standard deviation based on all date acquired in the field test

Reproducibility standard deviation under field conditions				
Sample size	n	=	293	
Average of both systems		=	19.00	µmol/mol
Standard deviation from paired measurements	sd	=	0.340	µmol/mol
Reproducibility standard deviation (%)	**Sr, f**	**=**	**1.79**	**%**

Reproducibility standard deviation under field conditions of 1.79% of the average value.

7.5 Assessment

The reproducibility standard deviation for CO under field conditions was 1.79% of the average over a period of three months in the field. The requirements of EN 14626 are fulfilled.

Requirement fulfilled? yes

7.6 Test results in detail

Figure 13 illustrates the reproducibility standard deviation in the field.

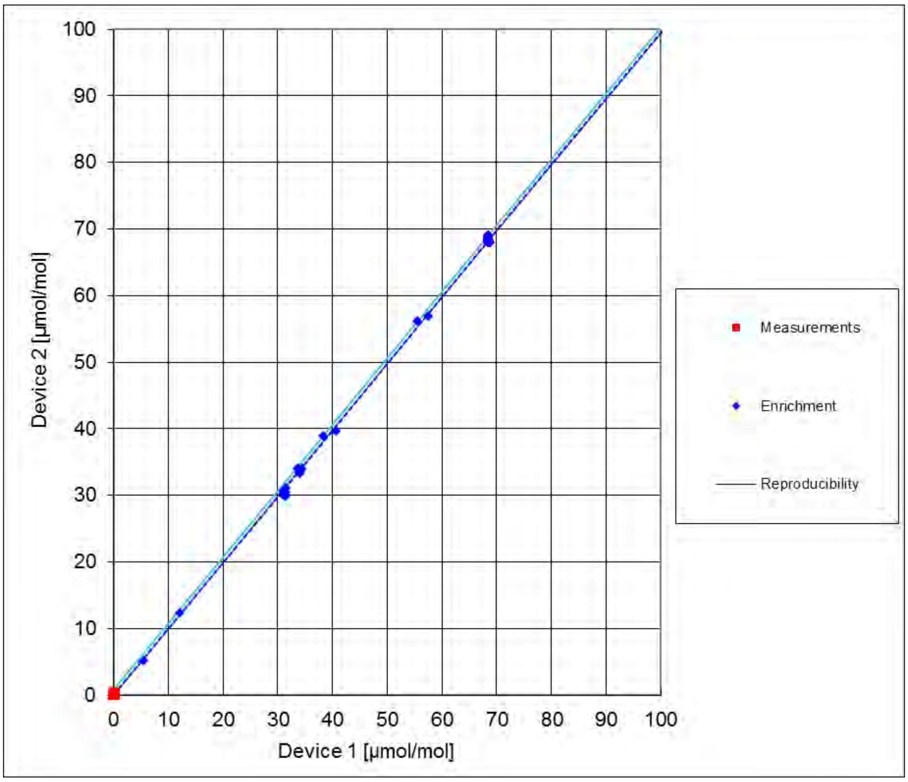


Figure 13: Illustration of reproducibility standard deviation in the field

7.1 8.5.6 Period of unattended operation

Maintenance interval must be at least two weeks.

7.2 Equipment

Not applicable.

7.3 Testing

In testing this performance criterion, the types of maintenance work and the corresponding maintenance intervals needed to ensure proper functioning of the measuring system were determined. Moreover, drift behaviour for zero and reference point according to 7.1 8.5.4 Long-term drift was taken into consideration in determining the maintenance interval.

7.4 Evaluation

During the entire field test period, no undue drift behavior was observed in the measuring systems. The maintenance interval is therefore determined by the necessary maintenance tasks.

During operation, maintenance tasks are generally limited to contamination and plausibility checks as well as checking for potential status signals and error warnings. Notes for works during the maintenance interval can be referred to in Chapter 8.

7.5 Assessment

The maintenance interval is four weeks as determined by the necessary maintenance tasks.

Requirement fulfilled? yes

7.6 Test results in detail

Not applicable.

7.1 8.5.7 Availability

AMS availability shall be at at least 90%.

7.2 Test program

The correct operation of the analysers shall be checked at least every fourteen days. It is recommended to perform this check every day during the first fourteen days. These checks consists of plausibility checks on the measured values, as well as, when available, on status signals and other relevant parameters. Time, duration and nature of any malfunctioning shall be logged.

The total time period with useable measuring data is the period during the field test during which valid measuring data of the ambient air concentrations are obtained. In this time period, the time needed for calibrations, conditioning of sample systems and filters and maintenance shall not be included.

The availability of the analyser is:

$$A_a = \frac{t_u}{t_t} * 100$$

Where:

A_a is the availability of the analyser (%)

t_u is the total period of time with valid measurement values

t_t is the total duration of the field test, excluding time spent on calibration and maintenance

t_u and t_t must be given in the same unit.

Availability shall comply with the performance criterion as specified above.

7.3 Testing

Availability was calculated on the basis of periods for the field test and any outage times based on the equation stated above.

Evaluation

Table 30 lists down times during the field test.

Table 30: Availability of CO 12e

		System 1	System 2
Operating time	h	2352	2352
Down time	h	0	0
Maintenance time	h	8	8
Effective operating time	h	2344	2344
Effective operating time incl. maintenance		2352	2352
Availability	%	100	100

Maintenance times result from daily test gas feeding for the purpose of determining the drift behavior and the maintenance interval as well as times required to change internal Teflon filters in the sample gas line.

7.5 Assessment

The availability is 100%. The requirements of Standard EN 14626 are fulfilled.

Requirement fulfilled? yes

7.6 Test results in detail

Not applicable.

7.1 8.6 Total uncertainty in accordance with Annex E of EN 14262 (2012).

The type approval of the analyser consists of the following steps:

***1)** The value of each individual performance characteristic tested in the laboratory shall fulfil the criterion stated in Table E.1 of EN 14626.*

***2)** The expanded uncertainty calculated from the standard uncertainties due to the values of the specific performance characteristics obtained in the laboratory tests shall fulfil the criterion as stated in Annex I of Directive 2008/50/EC (15% for fixed measurements or 25% for indicative measurements). This criterion is the maximum uncertainty of hourly values of continuous measurements at the hourly limit value. The relevant specific performance characteristics and the calculation procedure are given in Annex E of EN 14626.*

***3)** The value of each individual performance characteristic tested in the laboratory shall fulfil the criterion stated in Table E.1 of EN 14626.*

***4)** The expanded uncertainty calculated from the standard uncertainties due to the values of the specific performance characteristics obtained in the laboratory tests shall fulfil the criterion as stated in Annex I of Directive 2008/50/EC (15% for fixed measurements or 25% for indicative measurements). This criterion is the maximum uncertainty of hourly values of continuous measurements at the hourly limit value. The relevant specific performance characteristics and the calculation procedure are given in Annex E of EN 14626.*

7.2 Equipment

Determination of total uncertainty in accordance with Annex E of EN 14262 (2012).

7.3 Testing

At the end of the tests for type approval, total uncertainty was calculated using the values obtained from each individual test.

7.4 Evaluation

1) The value of each individual performance characteristic tested in the laboratory fulfils the criterion stated Table E.1 of EN 14626.
2) The expanded uncertainty calculated from the standard uncertainties due to the values of the specific performance characteristics obtained fulfils the criterion.
3) The value of each of the individual performance characteristics tested in the field fulfils the criterion stated in Table E.1 of standard EN 14626.
4) The expanded uncertainty calculated from the standard uncertainties due to the values of the specific performance characteristics obtained in the laboratory and field tests fulfils the criterion.

7.5 Assessment

The total uncertainty complies with the performance criteria.

Requirement fulfilled? yes

7.6 Test results in detail

The results to criterions 1 and 3 are given in Table 31.

The results to criterion 2 are given in Table 32 and Table 34Table 34.

The results to criterion 4 are given in Table 33 and Table 35.

Table 31: Performance criteria according to EN 14626

Performance characteristic	**Criterion**	**Test result**	**Met**	**Page**
8.4.5 Repeatability standard deviation at zero	≤ 0.3 µmol/mol	S_r system 1: 0.00 µmol/mol S_r system 2: 0.03 µmol/mol	yes	68
8.4.5 Repeatability standard deviation at concentration ct	≤ 0.4 µmol/mol	S_r system 1: 0.03 µmol/mol S_r system 2: 0.05 µmol/mol	yes	68
8.4.6 "lack of fit" (deviation from the linear regression)	Largest deviation from the linear regression line at concentrations above zero ≤ 4.0 % of the reading Deviation at zero ≤ 0.5 µmol/mol	$X_{l,z}$ system 1: ZP 0.11 µmol/mol X_l system 1: RP 1.94% $X_{l,z}$ system 2: ZP 0.04 µmol/mol X_l system 2: RP 2.06%	yes	71
8.4.7 Sensitivity coefficient of sample gas pressure	≤ 0.70 µmol/mol/kPa	b_{gp} system 1: 0.05 µmol/mol/kPa b_{gp} system 2: 0.05 µmol/mol/kPa	yes	76
8.4.8 Sensitivity coefficient of sample gas temperature	≤ 0.3 µmol/mol/K	b_{gt} system 1: 0.00 µmol/mol/K b_{gt} system 2 0.00 µmol/mol/K	yes	78
8.4.9 Sensitivity coefficient of ambient temperature	≤ 0.3 µmol/mol/K	b_{st} system 1: 0.019 µmol/mol/K b_{st} system 2: 0.019 µmol/mol/K	yes	80
8.4.10 Sensitivity coefficient of supply voltage	≤ 0.3 µmol/mol/V	b_v system 1: RP 0.00 µmol/mol/V b_v system 2: RP 0.01 µmol/mol/V	yes	83
8.4.11 Interferents at zero and concentration ct	H_2O ≤ 1.0 µmol/mol CO_2 ≤ 0.5 µmol/mol NO ≤ 0.5 µmol/mol NO_2 ≤ 0.5 µmol/mol	H_2O System 1: ZP 0.29 µmol/mol / RP 0.33 µmol/mol System 2: ZP 0.22 µmol/mol / RP 0.32 µmol/mol CO_2 System 1: ZP -0.15 µmol/mol / RP -0.14 µmol/mol System 2: ZP -0.21 µmol/mol / RP -0.09 µmol/mol NO System 1: ZP -0.06 µmol/mol / RP 0.04 µmol/mol System 2: ZP -0.03 µmol/mol / RP 0.00 µmol/mol NO_2 System 1: ZP -0.05 µmol/mol / RP 0.06 µmol/mol System 2: ZP -0.16 µmol/mol / RP 0.01 µmol/mol	yes	85

Performance characteristic	**Criterion**	**Test result**	**Met**	**Page**
8.4.12 Averaging effect	≤ 7,0 % of measured value	E_{av} system 1: -2.56 % E_{av} system 2: -2.61 %	yes	85
8.4.13 Difference sample/calibration port	≤ 1.0 %	Δ_{SC} system 1: 0.39% Δ_{SC} system 2: 0.22%	yes	91
8.4.3 Response time	≤ 180 s	t_r system 1: 50.25 s t_r system 2: 50 s	yes	**Fehler! Textmarke nicht definiert.**
8.4.3 Response time	≤ 180 s	t_f system 1: 50 s t_f system 2: 51 s	yes	**Fehler! Textmarke nicht definiert.**
8.4.3 Difference between response time (rise) and response time (fall)	≤ 10 % relative difference or 10 s, depending on which value is greater	t_d system 1: 0.25 s t_d system 2: -1 s	yes	**Fehler! Textmarke nicht definiert.**
8.5.6 Period of unattended operation	3 months or less according to manufacturer specifications, not less than 2 weeks	System 1: 4 weeks System 2: 4 weeks	yes	98
8.5.7 Availability of AMS	> 90 %	A_a system 1: 100 % A_a system 2: 100 %	yes	99
8.5.5 Reproducibility standard deviation under field conditions	≤ 5.0 % of average over a period of three months	$S_{r,f}$ system 1: 1.79 % $S_{r,f}$ system 2: 1.79 %	yes	96
8.5.4 Long-term drift at zero	≤ 0.50 µmol/mol	$C_{,z}$ system 1: 0.23 µmol/mol $C_{,z}$ system 2: 0.16 µmol/mol	yes	93
8.5.4 Long-term drift at span level	≤ 5.0 % of maximum of certification range	$C_{,s}$ system 1: max. 0.70 % $C_{,s}$ system 2: max. 0.89 %	yes	93
8.4.4 Short-term drift	≤ 0.10 µmol/mol over 12 h	$D_{s,z}$ system 1: 0.02 µmol/mol $D_{s,z}$ system 2: 0.01 µmol/mol	yes	64
8.4.4 Short-term drift at span level	≤ 0.60 µmol/mol over 12 h	$D_{s,s}$ system 1: -0.24 µmol/mol $D_{s,s}$ system 2: 0.18 µmol/mol	yes	64

Table 32: Expanded uncertainty from the laboratory test results for system 1

Measuring device:	CO 12e				Serial-No.:	SN 11	
Measured component:	CO				8h-limit value:	8.62	µmol/mol

No.	Performance characteristic		Performance criterion	Result	Partial uncertainty		Square of partial uncertainty
1	Repeatability standard deviation at zero	≤	0.3 µmol/mol	0.000	$u_{r,z}$	0.00	0.0000
2	Repeatability standard deviation at 8h-limit value	≤	0.4 µmol/mol	0.030	u_r	0.01	0.0001
3	"lack of fit" at 8h-limit value	≤	4.0% of measured value	1.940	u_l	0.10	0.0093
4	Sensitivity coefficient of sample gas pressure at 8h-limit value	≤	0.7 µmol/mol/kPa	0.050	u_{gp}	0.11	0.0128
5	Sensitivity coefficient of sample gas temperature at 8h-limit value	≤	0.3 µmol/mol/K	0.000	u_{gt}	0.00	0.0000
6	Sensitivity coefficient of surrounding temperature at 8h-limit value	≤	0.3 µmol/mol/K	0.019	u_{st}	0.04	0.0020
7	Sensitivity coefficient of electrical voltage at 8h-limit value	≤	0.3 µmol/mol/V	0.000	u_V	0.00	0.0000
8a	Interferent $H_2$0 with 21 mmol/mol	≤	1.0 µmol/mol (Zero)	0.290	u_{H2O}	0.25	0.0607
		≤	1.0 µmol/mol (Span)	0.330			
8b	Interferent CO_2 with 500 µmol/mol	≤	0.5 µmol/mol (Zero)	-0.150	$u_{int,pos}$	0.08	0.0065
		≤	0.5 µmol/mol (Span)	-0.140			
8c	Interferent NO with 1 µmol/mol	≤	0.5 µmol/mol (Zero)	-0.060	or		
		≤	0.5 µmol/mol (Span)	0.040			
8d	Interferent N_2O with 50 nmol/mol	≤	0.5 µmol/mol (Zero)	-0.050			
		≤	0.5 µmol/mol (Span)	0.060	$u_{int,neg}$		
9	Averaging effect	≤	7.0% of measured value	-2.560	u_{av}	-0.13	0.0162
18	Difference sample/calibration port	≤	1.0%	0.390	$u_{\Delta sc}$	0.03	0.0011
21	Uncertainty of test gas	≤	3.0%	2.000	u_{cg}	0.09	0.0074

Combined standard uncertainty	u_c	0.3408	µmol/mol
Expanded uncertainty	U	0.6815	µmol/mol
Relative expanded uncertainty	W	7.91	%
Maximum allowed expanded uncertainty	W_{req}	15	%

Table 33: Expanded uncertainty from the laboratory and field test results for system 1

Measuring device:	CO 12e				Serial-No.:	SN 11	
Measured component:	CO				8h-limit value:	8.62	µmol/mol

No.	Performance characteristic		Performance criterion	Result	Partial uncertainty		Square of partial uncertainty
1	Repeatability standard deviation at zero	≤	0.3 µmol/mol	0.000	$u_{r,z}$	0.00	0.0000
2	Repeatability standard deviation at 8h-limit value	≤	0.4 µmol/mol	0.030	u_r	not considered, as ur = 0 < ur,f	-
3	"lack of fit" at 8h-limit value	≤	4.0% of measured value	1.940	u_l	0.10	0.0093
4	Sensitivity coefficient of sample gas pressure at 8h-limit value	≤	0.7 µmol/mol/kPa	0.050	u_{gp}	0.11	0.0128
5	Sensitivity coefficient of sample gas temperature at 8h-limit value	≤	0.3 µmol/mol/K	0.000	u_{gt}	0.00	0.0000
6	Sensitivity coefficient of surrounding temperature at 8h-limit value	≤	0.3 µmol/mol/K	0.019	u_{st}	0.04	0.0020
7	Sensitivity coefficient of electrical voltage at 8h-limit value	≤	0.3 µmol/mol/V	0.000	u_V	0.00	0.0000
8a	Interferent $H_2$0 with 21 mmol/mol	≤	1.0 µmol/mol (Zero)	0.290	u_{H2O}	0.25	0.0607
		≤	1.0 µmol/mol (Span)	0.330			
8b	Interferent CO_2 with 500 µmol/mol	≤	0.5 µmol/mol (Zero)	-0.150	$u_{int,pos}$	0.08	0.0065
		≤	0.5 µmol/mol (Span)	-0.140			
8c	Interferent NO with 1 µmol/mol	≤	0.5 µmol/mol (Zero)	-0.060	or		
		≤	0.5 µmol/mol (Span)	0.040			
8d	Interferent N_2O with 50 nmol/mol	≤	0.5 µmol/mol (Zero)	-0.050			
		≤	0.5 µmol/mol (Span)	0.060	$u_{int,neg}$		
9	Averaging effect	≤	7.0% of measured value	-2.560	u_{av}	-0.13	0.0162
10	Reproducibility standard deviation under field conditions	≤	5.0% of average over 3 months	1.790	$u_{r,f}$	0.15	0.0238
11	Long term drift at zero level	≤	0.5 µmol/mol	0.230	$u_{d,l,z}$	0.13	0.0176
12	Long term drift at span level	≤	5.0% of max. of certification range	0.700	$u_{d,l,8h}$	0.03	0.0012
18	Difference sample/calibration port	≤	1.0%	0.390	$u_{\Delta sc}$	0.03	0.0011
21	Uncertainty of test gas	≤	3.0%	2.000	u_{cg}	0.09	0.0074

Combined standard uncertainty	u_c	0.3984	µmol/mol
Expanded uncertainty	U	0.7968	µmol/mol
Relative expanded uncertainty	W	9.24	%
Maximum allowed expanded uncertainty	W_{req}	15	%

Table 34: Expanded uncertainty from the laboratory test results for system 2

Measuring device:	CO 12e				Serial-No.:		SN 12	
Measured component:	CO				8h-limit value:		8.62	µmol/mol
No.	**Performance characteristic**		**Performance criterion**	**Result**	**Partial uncertainty**		**Square of partial uncertainty**	
1	Repeatability standard deviation at zero	≤	0.3 µmol/mol	0.030	$u_{r,z}$	0.01	0.0001	
2	Repeatability standard deviation at 8h-limit value	≤	0.4 µmol/mol	0.050	u_r	0.01	0.0001	
3	"lack of fit" at 8h-limit value	≤	4.0% of measured value	2.060	u_l	0.10	0.0105	
4	Sensitivity coefficient of sample gas pressure at 8h-limit value	≤	0.7 µmol/mol/kPa	0.050	u_{gp}	0.11	0.0128	
5	Sensitivity coefficient of sample gas temperature at 8h-limit value	≤	0.3 µmol/mol/K	0.000	u_{gt}	0.00	0.0000	
6	Sensitivity coefficient of surrounding temperature at 8h-limit value	≤	0.3 µmol/mol/K	0.019	u_{st}	0.05	0.0020	
7	Sensitivity coefficient of electrical voltage at 8h-limit value	≤	0.3 µmol/mol/V	0.010	u_V	0.03	0.0008	
8a	Interferent H_20 with 21 mmol/mol	≤	1.0 µmol/mol (Zero)	0.220	u_{H2O}	0.24	0.0571	
		≤	1.0 µmol/mol (Span)	0.320				
8b	Interferent CO_2 with 500 µmol/mol	≤	0.5 µmol/mol (Zero)	-0.210	$u_{int,pos}$			
		≤	0.5 µmol/mol (Span)	-0.090				
8c	Interferent NO with 1 µmol/mol	≤	0.5 µmol/mol (Zero)	-0.030		0.05	0.0027	
		≤	0.5 µmol/mol (Span)	0.000	or			
8d	Interferent N_2O with 50 nmol/mol	≤	0.5 µmol/mol (Zero)	-0.160				
		≤	0.5 µmol/mol (Span)	0.010	$u_{int,neg}$			
9	Averaging effect	≤	7.0% of measured value	-2.610	u_{av}	-0.13	0.0169	
18	Difference sample/calibration port	≤	1.0%	0.220	$u_{\Delta sc}$	0.02	0.0004	
21	Uncertainty of test gas	≤	3.0%	2.000	u_{cg}	0.09	0.0074	
				Combined standard uncertainty	u_c		0.3327	µmol/mol
				Expanded uncertainty	U		0.6655	µmol/mol
				Relative expanded uncertainty	W		7.72	%
				Maximum allowed expanded uncertainty	W_{req}		15	%

Table 35: Expanded uncertainty from the laboratory and field test results for system 2

Measuring device:	CO 12e				Serial-No.:		SN 12	
Measured component:	CO				8h-limit value:		8.62	µmol/mol
No.	**Performance characteristic**		**Performance criterion**	**Result**	**Partial uncertainty**		**Square of partial uncertainty**	
1	Repeatability standard deviation at zero	≤	0.3 µmol/mol	0.030	$u_{r,z}$	0.01	0.0001	
2	Repeatability standard deviation at 8h-limit value	≤	0.4 µmol/mol	0.050	u_r	not considered, as ur = 0,01 < ur,f	-	
3	"lack of fit" at 8h-limit value	≤	4.0% of measured value	2.060	u_l	0.10	0.0105	
4	Sensitivity coefficient of sample gas pressure at 8h-limit value	≤	0.7 µmol/mol/kPa	0.050	u_{gp}	0.11	0.0128	
5	Sensitivity coefficient of sample gas temperature at 8h-limit value	≤	0.3 µmol/mol/K	0.000	u_{gt}	0.00	0.0000	
6	Sensitivity coefficient of surrounding temperature at 8h-limit value	≤	0.3 µmol/mol/K	0.019	u_{st}	0.05	0.0020	
7	Sensitivity coefficient of electrical voltage at 8h-limit value	≤	0.3 µmol/mol/V	0.010	u_V	0.03	0.0008	
8a	Interferent H_20 with 21 mmol/mol	≤	1.0 µmol/mol (Zero)	0.220	u_{H2O}	0.24	0.0571	
		≤	1.0 µmol/mol (Span)	0.320				
8b	Interferent CO_2 with 500 µmol/mol	≤	0.5 µmol/mol (Zero)	-0.210	$u_{int,pos}$			
		≤	0.5 µmol/mol (Span)	-0.090				
8c	Interferent NO with 1 µmol/mol	≤	0.5 µmol/mol (Zero)	-0.030		0.05	0.0027	
		≤	0.5 µmol/mol (Span)	0.000	or			
8d	Interferent N_2O with 50 nmol/mol	≤	0.5 µmol/mol (Zero)	-0.160				
		≤	0.5 µmol/mol (Span)	0.010	$u_{int,neg}$			
9	Averaging effect	≤	7.0% of measured value	-2.610	u_{av}	-0.13	0.0169	
10	Reproducibility standard deviation under field conditions	≤	5.0% of average over 3 months	1.790	$u_{r,f}$	0.15	0.0238	
11	Long term drift at zero level	≤	0.5 µmol/mol	0.160	$u_{d,l,z}$	0.09	0.0085	
12	Long term drift at span level	≤	5.0% of max. of certification range	0.890	$u_{d,l,8h}$	0.04	0.0020	
18	Difference sample/calibration port	≤	1.0%	0.220	$u_{\Delta sc}$	0.02	0.0004	
21	Uncertainty of test gas	≤	3.0%	2.000	u_{cg}	0.09	0.0074	
				Combined standard uncertainty	u_c		0.3806	µmol/mol
				Expanded uncertainty	U		0.7613	µmol/mol
				Relative expanded uncertainty	W		8.83	%
				Maximum allowed expanded uncertainty	W_{req}		15	%

8. Recommendations for use

Tasks during maintenance interval (4 weeks)

The following checks are required on a regular basis:

- Regular visual inspections / telemetric monitoring
- System status
- Error warnings
- Replacement of the Teflon filter in the sample gas inlet
- Zero and span point checks with appropriate test gas

For all intents and purposes consider the manufacturer’s instructions.

Further details are specified in the manual.

Immission control/Air pollution control

Dipl.-Ing. Martin Schneider	Dipl.-Ing. Guido Baum

Cologne, 09 October 2015
936/21228317/A

9. Literature

[1] VDI 4202 Part 1 "Performance criteria for performance tests of automated ambient air measuring systems; Point-related measurement methods for gaseous and particulate air pollutants", September 2010

[2] VDI 4203 Part 3 "Testing of automated measuring systems; Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants", September 2010

[3] EN 14626 Ambient air quality - Standard method for the measurement of the concentration of carbon monoxide by non-dispersive infrared spectroscopy, December 2012

[4] Directive 2008/50/EC of European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe

10. Annex

Annex 1 Weather data field test

Table 36: Weather data (daily mean values), May

May 2015	Date	Atmospheric pressure [hPa]	Average ambient temperature [°C]	Rel. humidity [%]
1	01-05-2015	1003	7.8	84.9
2	02-05-2015	1002	10.3	62.5
3	03-05-2015	1000	14.4	58.3
4	04-05-2015	998	15.4	84.8
5	05-05-2015	994	19.8	65.1
6	06-05-2015	1001	15.6	63.9
7	07-05-2015	1007	13.6	62.5
8	08-05-2015	1010	14.5	56.7
9	09-05-2015	1007	17.2	57.8
10	10-05-2015	1015	15.2	67.8
11	11-05-2015	1017	17.5	56.4
12	12-05-2015	1010	21.8	56.6
13	13-05-2015	1012	15.7	59.6
14	14-05-2015	1007	15.5	53.5
15	15-05-2015	1004	15.2	62.5
16	16-05-2015	1013	13.8	61.0
17	17-05-2015	1017	12.1	76.7
18	18-05-2015	1011	14.9	60.2
19	19-05-2015	999	15.7	57.3
20	20-05-2015	1003	12.1	65.7
21	21-05-2015	1013	12.0	65.2
22	22-05-2015	1019	15.7	55.7
23	23-05-2015	1015	17.7	55.0
24	24-05-2015	1012	16.4	65.7
25	25-05-2015	1009	16.3	62.0
26	26-05-2015	1009	13.8	65.8
27	27-05-2015	1015	13.6	57.0
28	28-05-2015	1010	16.2	53.1
29	29-05-2015	1005	14.8	64.9
30	30-05-2015	1003	13.5	67.7
31	31-05-2015	1007	13.7	65.4

Table 37: Weather data (daily mean values), June

June 2015	Date	Atmospheric pressure [hPa]	Average ambient temperature [°C]	Rel. humidity [%]
1	01-06-2015	1006	15.4	74.4
2	02-06-2015	1006	15.8	63.8
3	03-06-2015	1009	19.0	64.0
4	04-06-2015	1019	16.8	59.4
5	05-06-2015	1013	22.5	50.0
6	06-06-2015	1011	23.9	63.0
7	07-06-2015	1020	18.5	50.5
8	08-06-2015	1020	17.7	51.4
9	09-06-2015	1020	15.7	53.3
10	10-06-2015	1018	17.3	50.0
11	11-06-2015	1014	20.4	51.7
12	12-06-2015	1006	22.2	50.6
13	13-06-2015	1002	20.8	77.0
14	14-06-2015	1003	20.4	55.5
15	15-06-2015	1006	19.2	61.5
16	16-06-2015	1014	16.2	54.2
17	17-06-2015	1017	15.5	57.8
18	18-06-2015	1010	20.2	64.0
19	19-06-2015	1010	14.8	66.8
20	20-06-2015	1012	12.3	82.3
21	21-06-2015	1011	15.1	72.5
22	22-06-2015	1004	16.5	73.7
23	23-06-2015	1001	11.9	87.1
24	24-06-2015	1012	13.6	78.8
25	25-06-2015	1014	17.7	66.4
26	26-06-2015	1013	21.4	58.5
27	27-06-2015	1009	22.1	66.8
28	28-06-2015	1013	19.1	59.6
29	29-06-2015	1012	22.8	54.2
30	30-06-2015	1014	22.5	56.8

Table 38: Weather data (daily mean values), July

July 2015	Date	Atmospheric pressure [hPa]	Average ambient temperature [°C]	Rel. humidity [%]
1	01-07-2015	1011	25.9	46.4
2	02-07-2015	1009	30.0	44.4
3	03-07-2015	1013	29.1	56.0
4	04-07-2015	1012	30.7	54.9
5	05-07-2015	1010	28.8	54.5
6	06-07-2015	1011	21.4	69.7
7	07-07-2015	1007	23.9	52.4
8	08-07-2015	1002	19.3	69.1
9	09-07-2015	1008	16.8	69.3
10	10-07-2015	1016	15.9	59.0
11	11-07-2015	1010	21.2	47.3
12	12-07-2015	1010	22.8	52.3
13	13-07-2015	1010	18.0	75.6
14	14-07-2015	1008	18.9	83.9
15	15-07-2015	1011	20.8	73.0
16	16-07-2015	1011	22.9	70.8
17	17-07-2015	1006	27.4	56.4
18	18-07-2015	1007	26.8	51.6
19	19-07-2015	1005	21.4	63.7
20	20-07-2015	1005	19.7	77.5
21	21-07-2015	1006	23.3	77.2
22	22-07-2015	1006	24.0	67.3
23	23-07-2015	1008	21.9	57.8
24	24-07-2015	1006	21.1	57.7
25	25-07-2015	996	21.2	69.3
26	26-07-2015	1007	15.2	71.5
27	27-07-2015	997	17.3	72.3
28	28-07-2015	998	17.1	70.4
29	29-07-2015	1001	15.8	65.9
30	30-07-2015	1006	15.3	68.4
31	31-07-2015	1012	13.8	78.2

Table 39: Weather data (daily mean values), August

August 2015	Date	Atmospheric pressure [hPa]	Average ambient temperature [°C]	Rel. humidity [%]
1	01-08-2015	1008	18.3	53.3
2	02-08-2015	1010	20.9	53.8
3	03-08-2015	1008	24.4	49.0
4	04-08-2015	1004	25.5	53.1
5	05-08-2015	1010	17.7	77.9
6	06-08-2015	1006	24.3	54.2
7	07-08-2015	1007	26.8	54.6
8	08-08-2015	1010	25.2	69.8
9	09-08-2015	1013	21.2	73.9
10	10-08-2015	1010	21.0	73.0
11	11-08-2015	1010	17.7	87.3
12	12-08-2015	1012	23.9	68.2
13	13-08-2015	1010	24.1	70.3
14	14-08-2015	-	-	-
15	15-08-2015	-	-	-
16	16-08-2015	-	-	-
17	17-08-2015	-	-	-
18	18-08-2015	-	-	-
19	19-08-2015	-	-	-
20	20-08-2015	-	-	-
21	21-08-2015	-	-	-
22	22-08-2015	-	-	-
23	23-08-2015	-	-	-
24	24-08-2015	-	-	-
25	25-08-2015	-	-	-
26	26-08-2015	-	-	-
27	27-08-2015	-	-	-
28	28-08-2015	-	-	-
29	29-08-2015	-	-	-
30	30-08-2015	-	-	-
31	31-08-2015	-	-	-

Annex 2

Manual

GENERAL CHARACTERISTICS

PRINCIPLE OF OPERATION

OPERATING INSTRUCTIONS

PREVENTIVE MAINTENANCE

CORRECTIVE MAINTENANCE

TECHNICAL MANUAL

CO12e

GAS FILTER CORRELATION

CARBON MONOXIDE ANALYZER

- APRIL 2016 -

Environnement S.A
L'instrumentation de l'environnement

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http://www.environnement-sa.com

WARNING

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Warranty

Defects that fall under warranty

The seller shall undertake to remedy any operational malfunction resulting from a manufactured or material defect within the limits of the provision below.

The seller shall not be liable in the case of a defect caused either by materials supplied by the buyer or by a design imposed by the buyer.

Any warranty is also invalid in the case of damage resulting from normal wear and tear, accident, disaster, misuse, fault or negligence of or by Buyer, causes external to the Products such as, but not limited to, unauthorized repairs or part replacement, electrical power surges, improper storage of the Product, use of the Product in a manner for which it was not designed.

Duration and starting point of the warranty

Unless otherwise stipulated, the warranty period shall have a duration of twelve months from the date of delivery within the meaning of article 6 paragraph 2 of the «Environnement S.A: 2013 INTERNATIONAL GENERAL TERMS AND CONDITIONS OF SALES», even if the shipment or assembly is postponed for any reason outside the seller's control.

Unless agreed upon by both parties, the repair, modification or replacement of parts during the warranty period will not extend or renew the original equipment warranty period.

Buyer's obligation

In order to file a claim under warranty, the buyer must notify the seller immediately in writing of any defect in the equipment and supply evidence in proof thereof. The buyer must provide the seller with the opportunity to observe and remedy the said defects. In addition, the buyer must not carry out any repairs or have repairs made by a third party without the written agreement of the seller.

The buyer is required to check the equipment as soon as possible upon receipt and acceptance and no later than eight days following receipt. Failing to do so might invalidate any claims made later regarding a declared defect.

Any installation, maintenance, repair, service of the product performed by any person or entity other than seller without seller's prior written approval, or any use of replacement parts not supplied by seller, shall immediately void and cancel all warranties with respect to the affected product.

Exercising the warranty

Once notified of a defect, the seller shall be responsible for remedying the defect at its own expense. The seller, however, reserves the right to modify the mechanisms of the equipment as needed to comply with its obligations.

The work to satisfy the warranty obligation shall be carried out, principally, in the seller's workshop after the buyer has returned the equipment or the defective parts to the seller for the purposes of repair or replacement, whichever the seller deems best.

However, if the nature of the equipment is such that the repair has to be carried out at the location where it was installed, the seller shall only be responsible for the on-site labor costs involved in direct service of the analyzer itself. The buyer is responsible for the cost of any additional measures needed to provide unrestricted access.

The cost of transport of the equipment or the defective parts, as well as the return of the repaired or replaced equipment or part, shall be borne by the buyer. In the case of on-site repair, the buyer shall be responsible for any travelling and accommodation expenses of the seller's representative.

Defective parts replaced free of charge, under warranty, must be returned to the seller and shall become its property once again.

SUMMARY

CHAPTER 1. GENERAL – CHARACTERISTICS

CHAPTER 2. PRINCIPLE OF OPERATION

CHAPTER 3. OPERATING INSTRUCTIONS

CHAPTER 4. PREVENTIVE MAINTENANCE

CHAPTER 5. CORRECTIVE MAINTENANCE

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GENERAL – CHARACTERISTICS

1 GENERAL – CHARACTERISTICS

Figure 1–1 – ENVIRONNEMENT S.A CO12e (with screen).

Figure 1–2 – ENVIRONNEMENT S.A CO12e∗ (without screen)

1.1 GENERAL

1.1.1 INTRODUCTION

The CO12e is a continuous carbon monoxide analyzer (with a detection limit of 0.05 ppm).

Its measurement principle is based on carbon monoxide detection by absorption in infrared light.

With the incorporation of recent optical and electronic technologies, the analyzer offers many advantages while requiring only limited maintenance.

The sample is taken using a Teflon tube (6 mm external diameter) connected to the rear panel of the analyzer. The sample is aspirated by an internal pump.

The measurement is displayed on a color display equipped with a touch screen located on the front panel.

This analyzer is also available in CO12e∗ (without screen) version.

1.1.2 DESCRIPTION

1.1.2.1 Front panel

The front panel includes the following:

– General switch.

– Backlit color TFT LCD (Thin Film Transistor Liquid Crystal Display):

- Resolution of 800 x 480 (pixels), 7" screen,
- The display provides the measurement values and other system parameters, as desired.

– Capacitive touch-screen projected on glass.

– Two-color LED as operation indicator, placed above the switch.

Figure 1–3 – Color screen fitted with touch-screen

1.1.2.2 Rear panel

All of the CO12e electrical connectors and gas inlets/outlets are located on the rear panel. Refer to Figure 1–4.

Gas inlets / outlets (right-hand side):

- The inlet for the sample to be analyzed (1) is composed of 4 mm (I.D.) and 6 mm (O.D.) Teflon tube fittings, attached to the dust filter holder. The dust filter holder is equipped with a Teflon filtering diaphragm.
- The pump outlet (2), to exhaust the analyzed sample, consists of 4 mm (I.D.) and 6 mm (O.D.) Teflon fitting.
- A fan (9).

The following internal options are also located on the rear panel:

- The "zero / span" optional inlets, (3) and (4), are composed of 4 mm (I.D.) and 6 mm (O.D.) pneumatic tube fitting. They are used either to connect a "ZERO AIR" external supply free of carbon monoxide, or to connect a device enabling carbon monoxide generation (both gases are always at atmospheric pressure).

Electrical equipment and connections (left-hand side of the rear panel):

- One main power supply block consisting of a three-contact socket (5) to connect a standard power cable and the general fuse (6): 3.15 A/230 V or 3.15 A/115 V.
- One Ethernet output (7) and two USB ports (8).
- One 4-points BL connection to connect the optional solenoid valve for external calibration (10),
- One connection for the 24 V power supply for ESTEL board option (11).

(1) sample inlet, (2) pump outlet, (3) zero inlet and (4) span inlet, (5) three-contact socket for main power supply, (6) general fuse, (7) Ethernet output, (8) two USB ports, (9) fan, (10) duplicate zero and span solenoid valves for the optional solenoid valve of external calibration, (11) 24 V power supply for ESTEL board option, (12) not used.

Figure 1–4 – Rear panel

1.1.2.3 Internal view

The internal components of the analyzer are accessed by simply unscrewing the single knurled screw at the rear panel and sliding the upper cover.

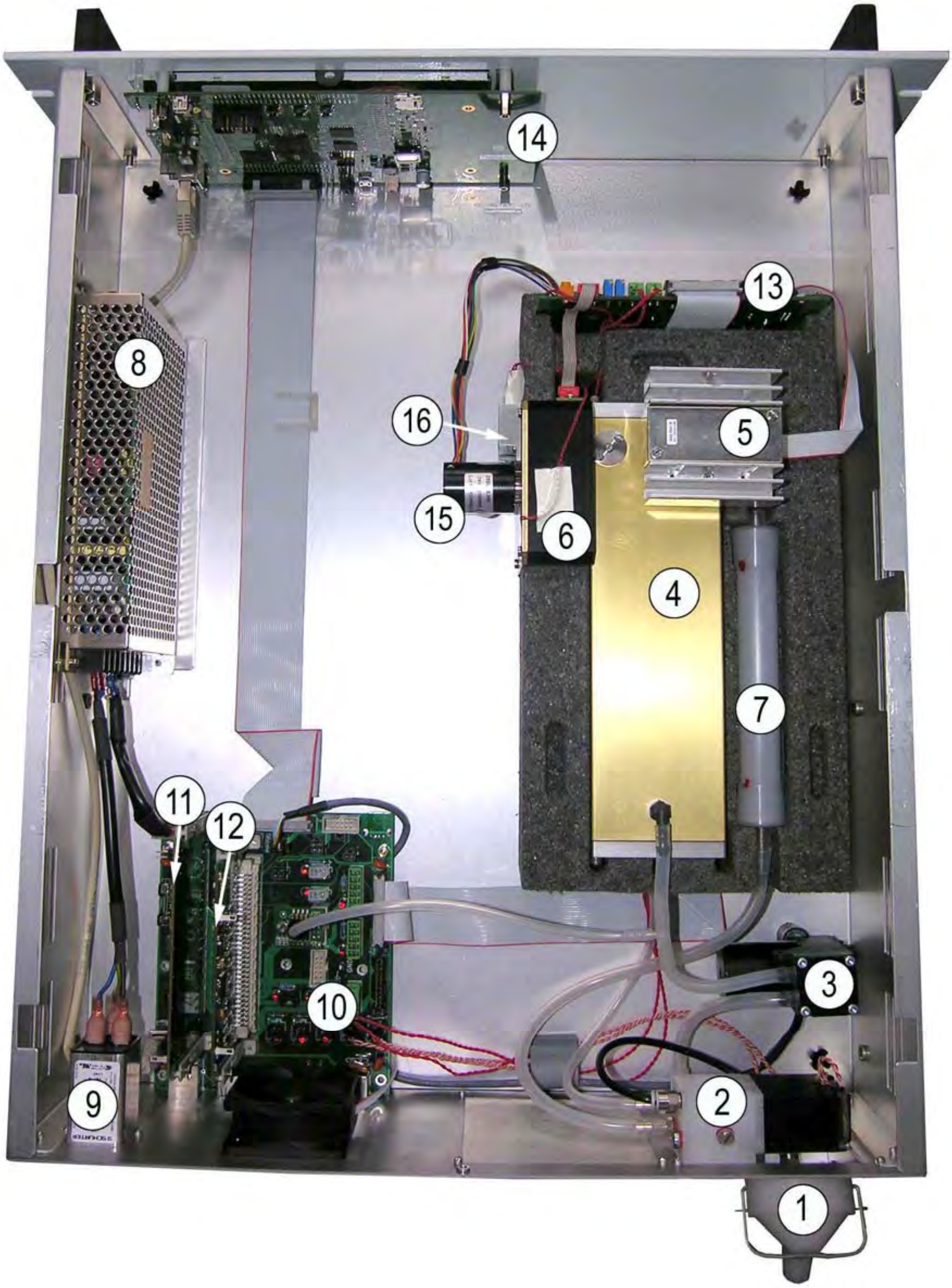
The internal elements include (refer to Figure 1–5):

- Sample inlet dust filter mounted on the rear panel (1),
- Solenoid valve-filter assembly (2),
- Measurement chamber (4),
- Optical sensor (5),
- Source block (6),
- Motor (15),
- IR source (16),
- Selective CO filter (7),
- Pump (3),
- ARM20 board (14)
- Interconnection board (10)
- 24 VDC power supply unit (8), which also includes 230 V to 115 V switch.
- Mains filter (9),
- Power supply board (11),
- Measurement board (13) that uses the + 12 V, – 12 V, + 5 V, – 5 V, + 3 V, - 3 V power supplies. That supports temperature regulations, acquisitions and digital processing.
- Automaton board (12),

After passing through the dust filter (1), sample to be analyzed moves towards a block consisting of two solenoid valves (2). A pump (3) aspirates sample through the measurement chamber (4) where CO molecules selectively absorb infrared radiation centered on 4.67 µm.

The measurement chamber holds optical sensor (5) and source block (6).

The selective CO filter (7) resets analyzer "zero" reading.



(1) sample inlet dust filter, (2) solenoid valve-filter assembly, (3) pump, (4) measurement chamber, (5) optical sensor, (6) source block, (7) selective CO filter, (8) 24 volts power supply, (9) mains filter, (10) Interconnection board, (11) power supply board, (12) automaton board, (13) measurement board, (14) ARM20 board, (15) motor, (16) IR source.

Figure 1–5 – Internal view of CO12e

1.1.3 VARIOUS OPERATING MODES

1.1.3.1 Standard

- Programmable measurement range from 0 to 300 ppm, with a detection limit of 0.05 ppm for 35 second response time.
- Automated monitoring of parameters influencing metrology (infrared energy, gas flow, temperature and pressure) and correct operation tests.
- Measurement values in ppm or mg/m^3 (integrated conversion coefficient).
- Memory storage of average measurements in programmable periods.

1.1.3.2 Options

The following analyzer options are available:

- One to two ESTEL board case(s), as accessories, and to be directly connected to USB ports on rear panel,
- One RS case delivered as an accessory and to be directly connected to USB ports on rear panel.

1.1.4 ASSOCIATED EQUIPMENT (OPTIONAL)

- Analog recorders and data loggers,
- Digital data acquisition system.

1.2 CHARACTERISTICS

1.2.1 TECHNICAL CHARACTERISTICS

Measurement range :	–	Programmable by user (0 to 300 ppm)
Units :	–	Selected by user (default ppm)
Noise (σ) :	–	0.025 ppm (response time: 35 sec)
Minimum detectable limit (2 σ) :	–	0.05 ppm (response time: 35 sec)
Response time (0-90 %) :	–	20-90 sec (programmable)
Zero drift :	–	< 0.2 ppm /7 days.
Span drift :	–	< 0.5 % FS / 7 days – FS = 50 ppm
Linearity :	–	± 1 %
Pressure influence :	–	< 0.1 ppm/kPa
Sample flow-rate :	–	Approximately 1 liter/min.
Display :	–	TFT LCD color screen, resolution : 800 (RGB) x 480, size : 7 inches
Control :	–	Touch screen
Output signals (option) :	–	4 analog outputs (0-1 V, 0-10 V, 0-20 mA, 4-20 mA)
Power supply :	–	90-230 V, 50-60 Hz + ground
Consumption :	–	50 W
Working temperature :	–	+5 °C to +40 °C
Memory storage of measurement values :	–	Capacity : 1 year
Alarm checks :	–	Detection and identification of irregularities in continuous: temperature, flow rate, pressure, IR energy, out of CO programmable measurement thresholds.
Test and diagnostics of maintenance :	–	Direct selection with the touch screen and/or remote selection on the embedded Web server.
Backup saving time for the real-time clock and RAM-stored data :	–	1 year maximum.
Ethernet output :	–	RJ45 socket, UDP protocol.
USB port :	–	Type A USB socket: 2.0 (3.0 compliant)
Zero/span external SV control :	–	Contact connector with screw terminals

SV : Solenoid valve

FS : Full scale

1.2.2 STORAGE CHARACTERISTICS

Temperature: – 10 to 60 °C.

1.2.3 INSTALLATION CHARACTERISTICS

1.2.3.1 Links between units

The CO12e analyzer connections are illustrated in Figure 1–6:

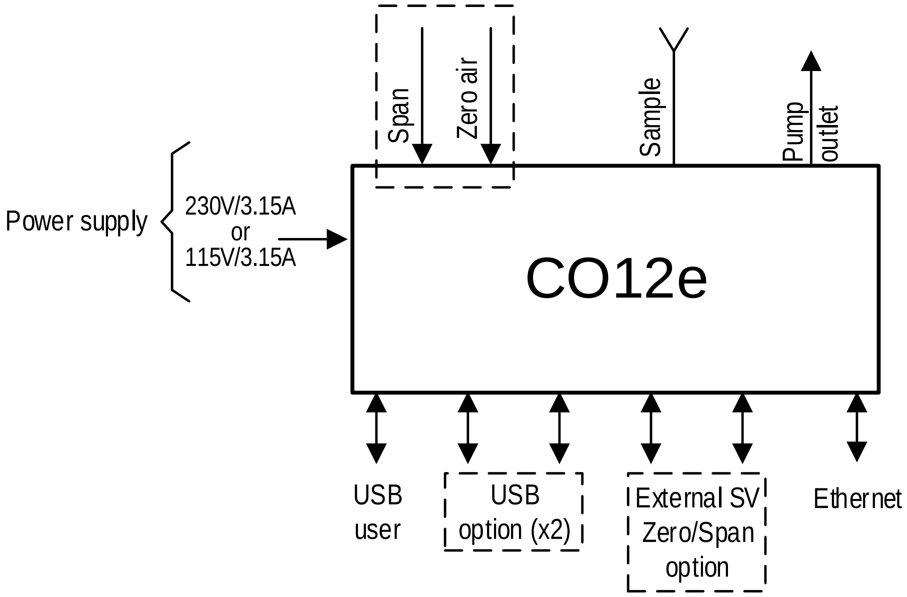


Figure 1–6 – Links between units

1.2.3.2 Dimensions and weight

The analyzer comes in a standard 19-inch, three-unit high rack.

Length : 581 mm
Width : 483 mm
Height : 133 mm
Weight : 7.1 Kg

1.2.3.3 Handling and storage

The CO12e analyzer must be handled with care to avoid damage to the various connectors and fittings on the rear panel.

Make sure that the analyzer fluid inlets and outlets are protected with caps during handling.

1.2.4 STORAGE

The unit should be stored in the foam-packed case provided for this purpose.

Make sure that the analyzer fluid inlets and outlets are protected with caps during storage.

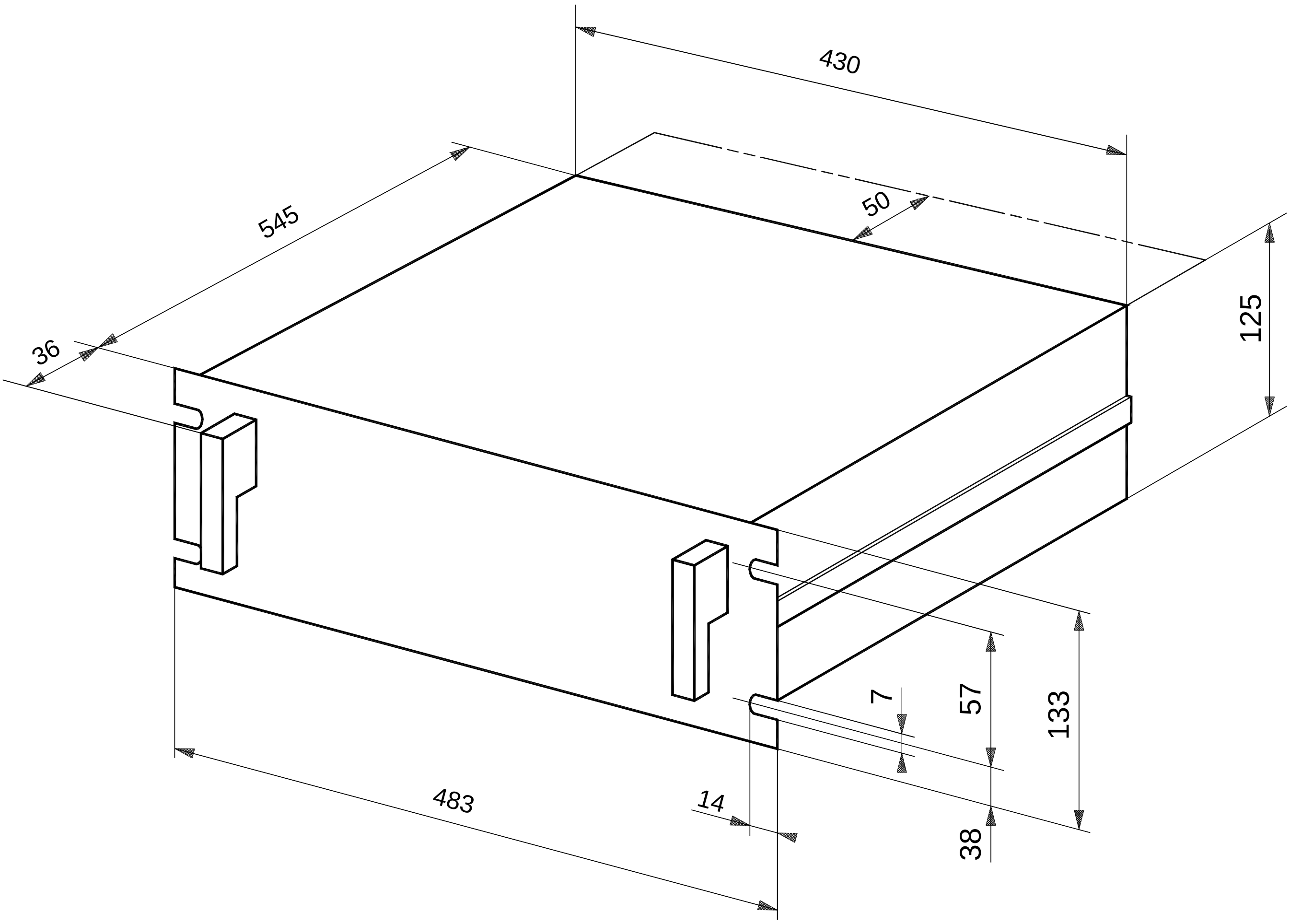


Figure 1–7 – CO12e dimensions (in mm)

CHAPTER 2

PRINCIPLE OF OPERATION

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2 PRINCIPLE OF OPERATION

2.1 MEASUREMENT PRINCIPLE

Refer to Figure 2–1.

CO12e measurement principle is based on the Beer-Lambert law related to infrared absorption.

The maximum carbon monoxide absorption spectrum is reached at a wavelength of 4.67 micrometers (µm). That corresponds to the selected optical filter spectrum.

As absorption spectrum is not continuous, a gas filter, "correlation wheel", is used in conjunction with the optical filter, it allows highly selective sample gas measurement by eliminating gas interference with a very-close CO absorption spectra.

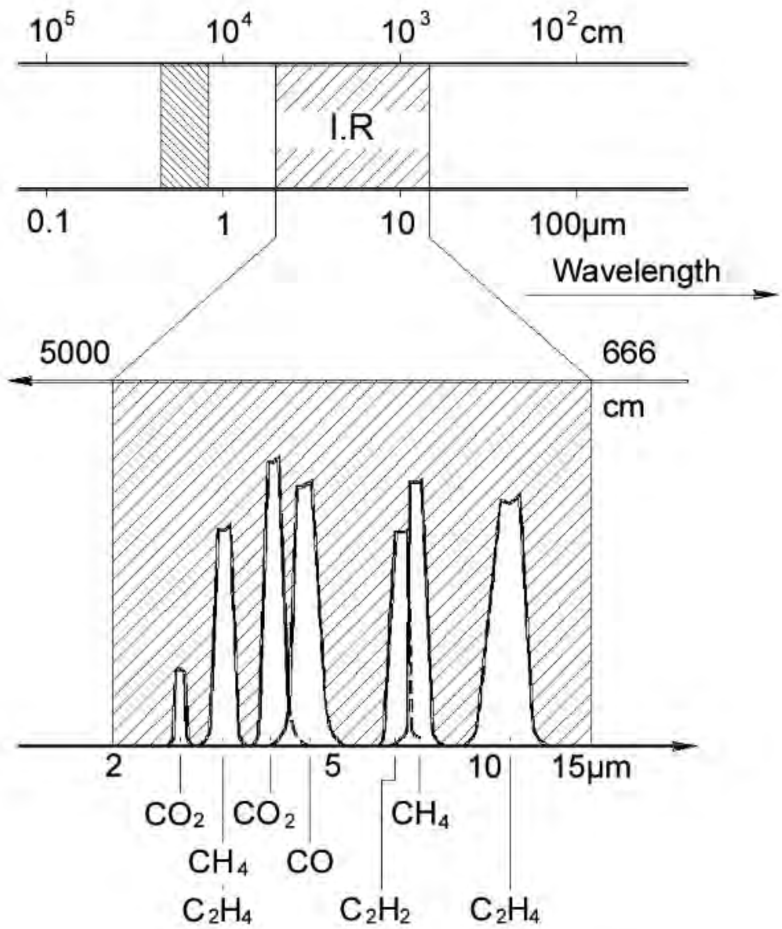


Figure 2–1 – Various infrared gas absorption spectra

Refer to measurement principle diagram represented in Figure 2–2.

The sample is drawn through a standardized air inlet system (sampling tube, funnel, Teflon tube) with a pump connected to the analyzer rear panel. Dust protection is provided by the dust filter holder equipped with a Teflon filter diaphragm.

A sample pump draws the sample through a restrictor placed at the sample chamber outlet which provides a constant flow of approximately 60 liters/hour.

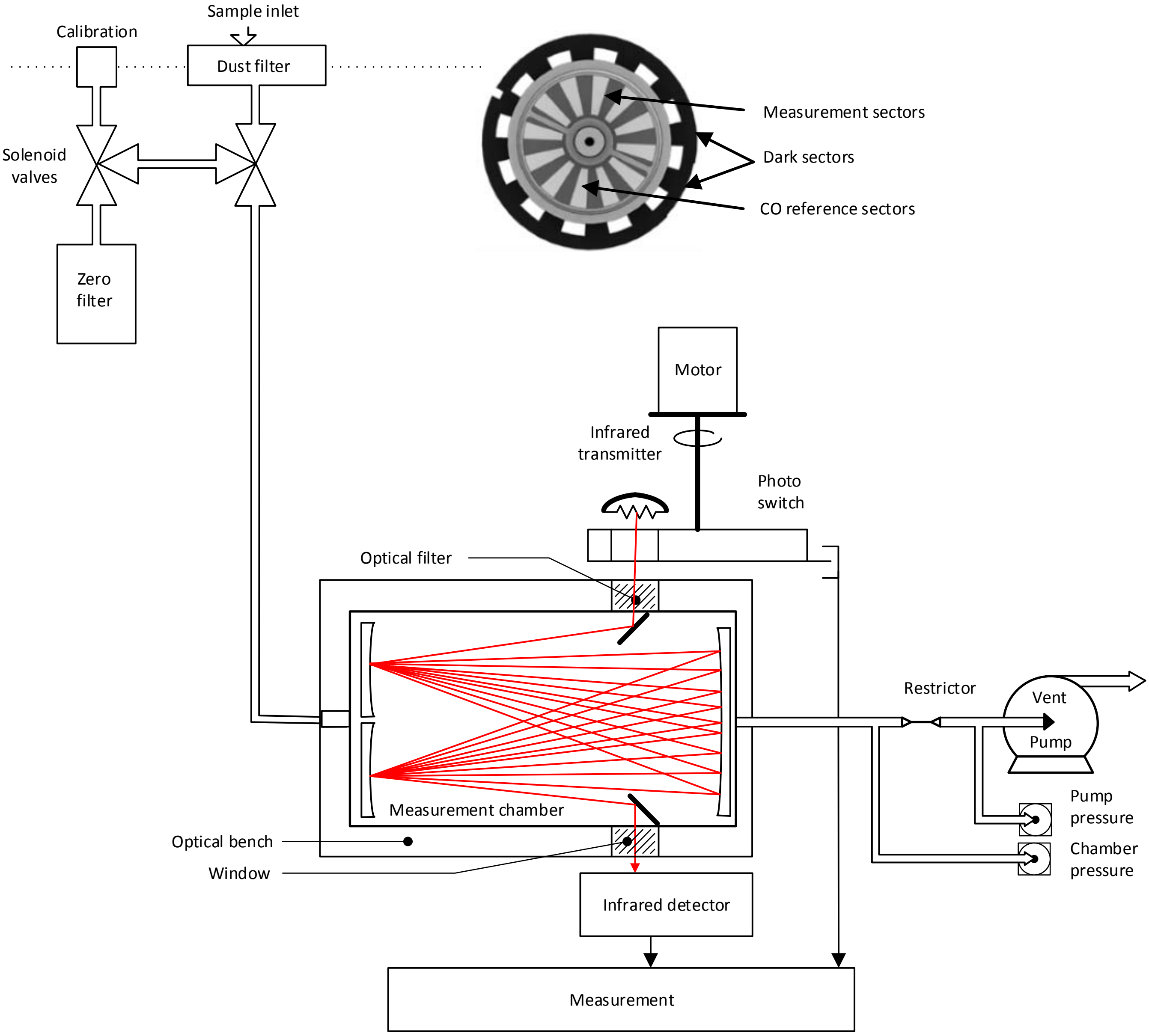


Figure 2–2 – Measurement principle diagram

2.2 PHYSICAL SIGNAL MODULATION

2.2.1 DESCRIPTION OF OPTICAL SIGNAL MODULATION

The beam coming from the IR source passes through a correlation wheel consisting of two-sealed compartment cells mounted on a 12-spoke wheel also called a "chopper". The two cells have equal volume, one is filled with carbon monoxide (CO), the other with nitrogen (N_2), and a "brushless" motor rotates the correlation wheel.

At every correlation wheel turn, during the first wheel half-turn the IR beam passes through the N_2-containing cell, and during the second wheel half-turn the IR beam passes through the CO-containing cell. For each of the half-turns, the beam is chopped by a chopper which modulates the light energy.

The IR beam passes through an interference filter to select the "useful" metrology wavelengths.

Then the IR beam passes through a long optical path measurement chamber to detect traces of CO. Beer-Lambert's Law states that the length of the optical path will determine the amount of IR that will be absorbed by the gases that are being measured, That is why the IR beam performs many back-and-forth passes in the measurement chamber before being focused on the detector.

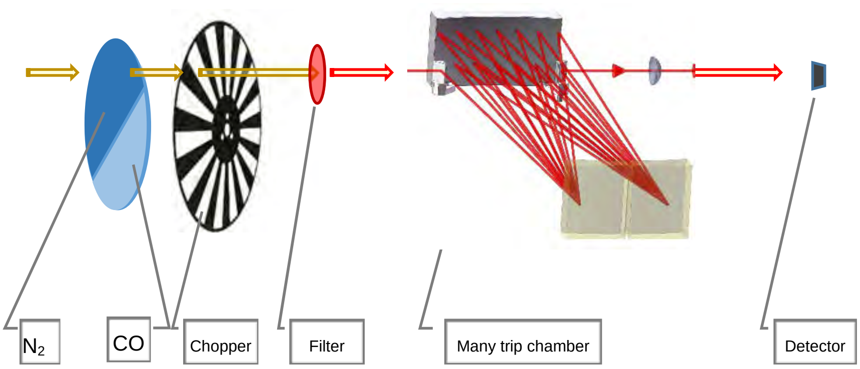


Figure 2–3 – CO analysis principle diagram by NDIR absorption

2.2.2 DESCRIPTION OF ACQUIRED ELECTRIC SIGNAL

At each wheel turn, the chopper modulates the IR signal inducing an f1 frequency oscillation which is called the chopper frequency. The chopper frequency is equal to twelve-time motor speed.

At each wheel half-turn, the correlation wheel modulates the IR signal at f2 frequency which is called the CO/N_2 frequency. The CO/N_2 frequency is equal to the motor speed.

When the wheel selects the CO filter all the IR energy is absorbed for the CO wavelength. The CO molecules present in the measurement chamber no longer contribute to the CO absorption because all IR-radiation to which CO is sensitive has been absorbed.

The maximum IR absorption occurs in the N_2 position. During this position, all CO wavelength energy is projected to the detector. Only the CO molecules in the sample chamber will absorb.

The measurement board compares the signal between N_2-position and CO-position (Reference).

Chopper modulation signal and CO/N_2 modulation signal allow signal synchronization by the measurement board, in order to determine measurement signal and reference signal amplitudes.

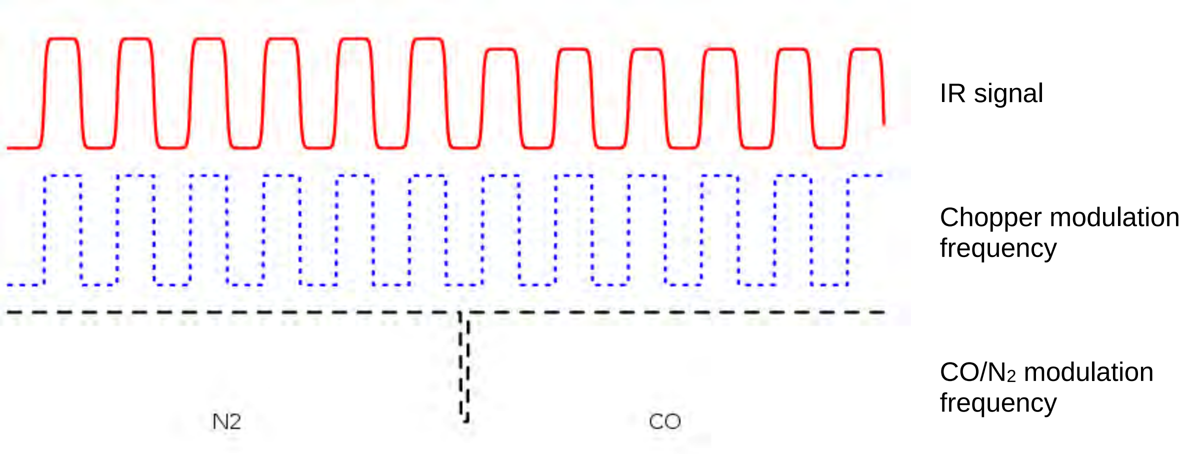


Figure 2–4 – Acquired electric signal diagram

2.3 DESCRIPTION OF SIMPLIFIED CALCULATION

Carry-out the calculations described below in the following order:

- IR signal, chopper modulation signal and CO/N_2 modulation signal are acquired by the measurement board.
- Measurement signal (SigMes) and reference signal (SigRef) are determined by the measurement board. Signal measurement (SigMes) is the IR signal amplitude in the N_2 position, and signal reference (SigRef) is the IR signal amplitude in the CO position.
- SigMes and SigRef refreshes every 10Hz.
- Ratio calculation: $R = \frac{SigMes}{SigRef}$ *(Equation 1)*
- R_n,…, R_{n-3} are the R measurements at t_n,…,t_{n-3} times.
- $Rmoy_n$,…, $Rmoy_{n-3}$ are calculated for each t_n,…,t_{n-3} times by digital filtering of R_n ratio with the following equation :

$$Rmoy_n = \frac{1}{a_0}[(b_0 \times R_n + b_1 \times R_{n-1} + b_2 \times R_{n-2} + b_3 \times R_{n-3}) - (a_1 \times Rmoy_{n-1} + a_2 \times Rmoy_{n-2} + a_3 \times Rmoy_{n-3})]$$ *(Equation 2)*

Where:

a_0,…, a_3 and b_0,…, b_3 are determined by calculation,

- R_{zero} ratio is $Rmoy_n$ saved after a zero-reference
- Absorption calculation : $Abs = \frac{R_{zero} - Rmoy_n}{R_{zero}}$ *(Equation 3)*
- Concentration calculation by the linearization function : $Conc = Pol(Abs)$ *(Equation 4)*
- Pressure correction application : $Conc_{pressure} = Conc \times \frac{P_0}{P}$ *(Equation 5)*
- Dilution correction application : $Conc_{dil} = Conc_{pressure} \times K_{dil}$ *(Equation 6)*
- Unit correction application : $Conc_{unit} = Conc_{dil} \times K_{unit}$ *(Equation 7)*
- Calibration correction application : $Conc_{final} = Conc_{unit} \times K_{span}$ *(Equation 8)*

2.4 PROGRAMMING THE RESPONSE TIME

The automatic response time function may be activated or de-activated in the *« Advanced analyzer configuration »* menu.

The minimum response time may also be modified in this menu.

The response time function changes the a_0,…, a_3 and b_0,…, b_3 coefficients according to the required response time used by the digital filter.

The response time is programmable in seconds from a 20 sec to 240 sec choice list.

The response time can also be programmed in automatic mode. In this case the analyzer auto-selects the most appropriate response.

2.5 ELECTRONIC ARCHITECTURE

Communication between the ARM20 board and the other electronic boards (Measurement board, Interconnection board, Power supply board, Controller board, Pressure sensor board….) follows the schematic shown in Figure 2–5.

The ARM20 board is a rapid calculation and interfacing (communication) board for the “e” series measurement modules. It is installed in all analyzers and offers one Ethernet output (RJ45 socket), and three USB ports (one on the front panel, and two on the rear panel through the Interconnection board). For these analyzers, the ARM20 board is the central element for electronic and metrological operation, and outward communication.

The measurement board performs measurement acquisition and operation parameter acquisitions. All metrological parameters are sent to the ARM20 board through a USB communication protocol.

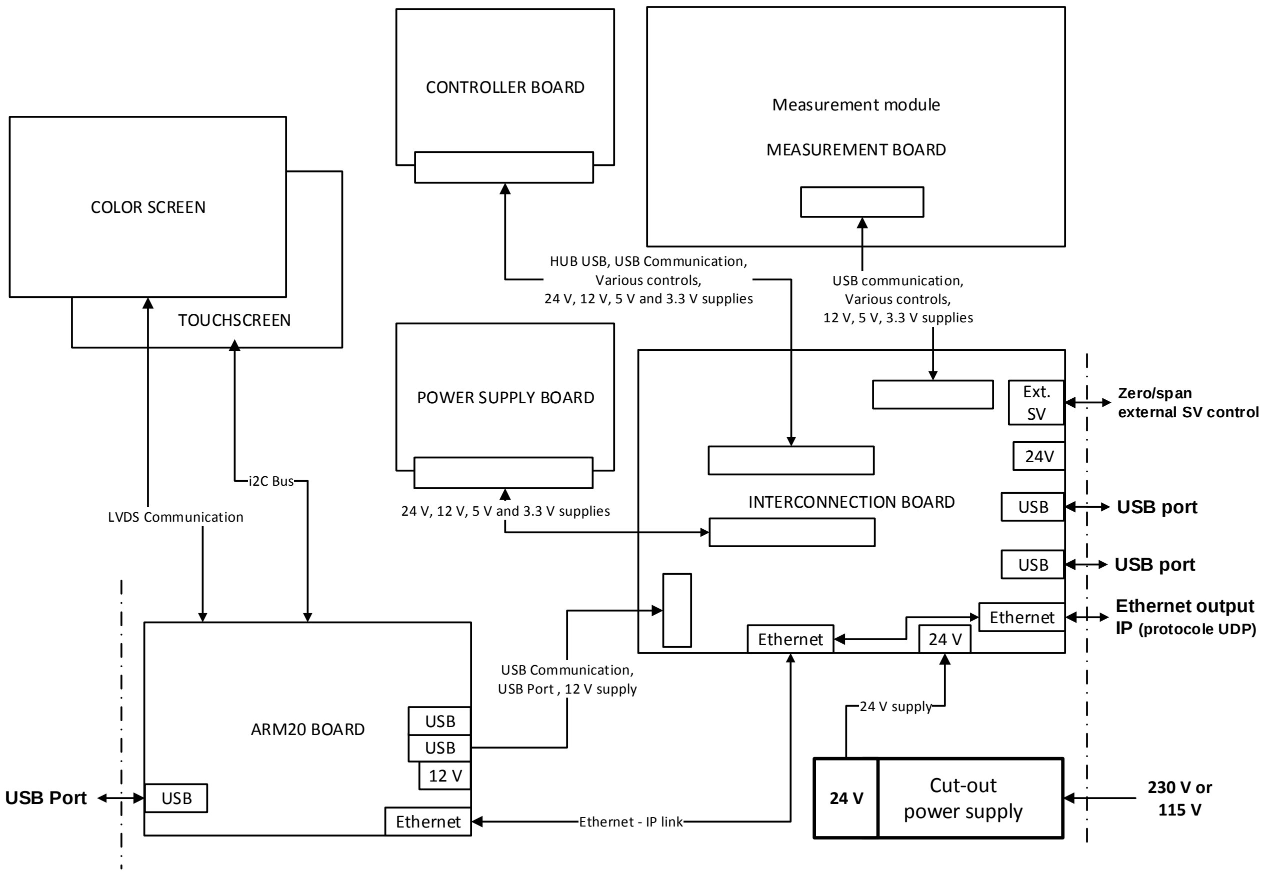
The power supply board provides the analyzer internal voltages from the 24 V cut-out power supply, as follows:

– +24 V filtered and secured,
– +12 V, for LED and ARM20 board supplying,
– +5 V,
– +3.3 V.

The Controller board performs the main following functions:

– It provides (+ 24V) various power control for the internal solenoid valve switchings.
– It allows temperature acquisition and control management of the various internal heating elements.
– It allows pressure signal acquisition from the various pressure sensor boards.
– It integrates one USB hub to ensure communications between the various boards.

The Interconnection board allows connections of all the connectors and sensors together.



SV: Solenoid valve

Figure 2–5 – Electronic architecture

2.6 NETWORK LINK AND USB PORTS

– Network link (Ethernet) :

  One RJ45 connector is interfaced on the analyzer rear panel via the Interconnection board. Network communication (Ethernet) uses UDP protocol.

– USB ports:

  Three USB ports are available in the “e” series electronic architecture.

CHAPTER 3

OPERATING INSTRUCTIONS

3. OPERATING INSTRUCTIONS

3.1. INITIAL START-UP

The analyzer is checked before delivery. Calibration is verified at the factory.

3.1.1. PRELIMINARY OPERATIONS

Refer to Figure 3–1.

Start-up involves the following preliminary operations:

- Visually examine the inside of the instrument to make sure no damage occurred during transport.
- Remove the caps from the gas inlet and outlet (1) (2) on the unit (set aside for future storage).
- Make sure a Teflon filter diaphragm is inside the dust filter, and then connect the 4 mm (I.D.) and 6 mm (O.D.) air sampling tube to the sample inlet (1).
- Connect the Ethernet output (7).
- If necessary, connect accessories via USB ports (8),
- Connect the main power supply cable to a socket 230 V, 50 Hz + ground or 115 V, 60 Hz + ground.
- Connect the pump outlet (2) to the vent.

(1) sample inlet, (2) pump outlet, (3) zero inlet and (4) span inlet, (5) three-contact socket for main power supply, (6) general fuse, (7) Ethernet output, (8) two USB ports, (9) fan, (10) duplicate zero and span solenoid valves for the optional solenoid valve of external calibration, (11) 24 V power supply for ESTEL board option, (12) not used.

Figure 3–1 – Fluid and electrical connections

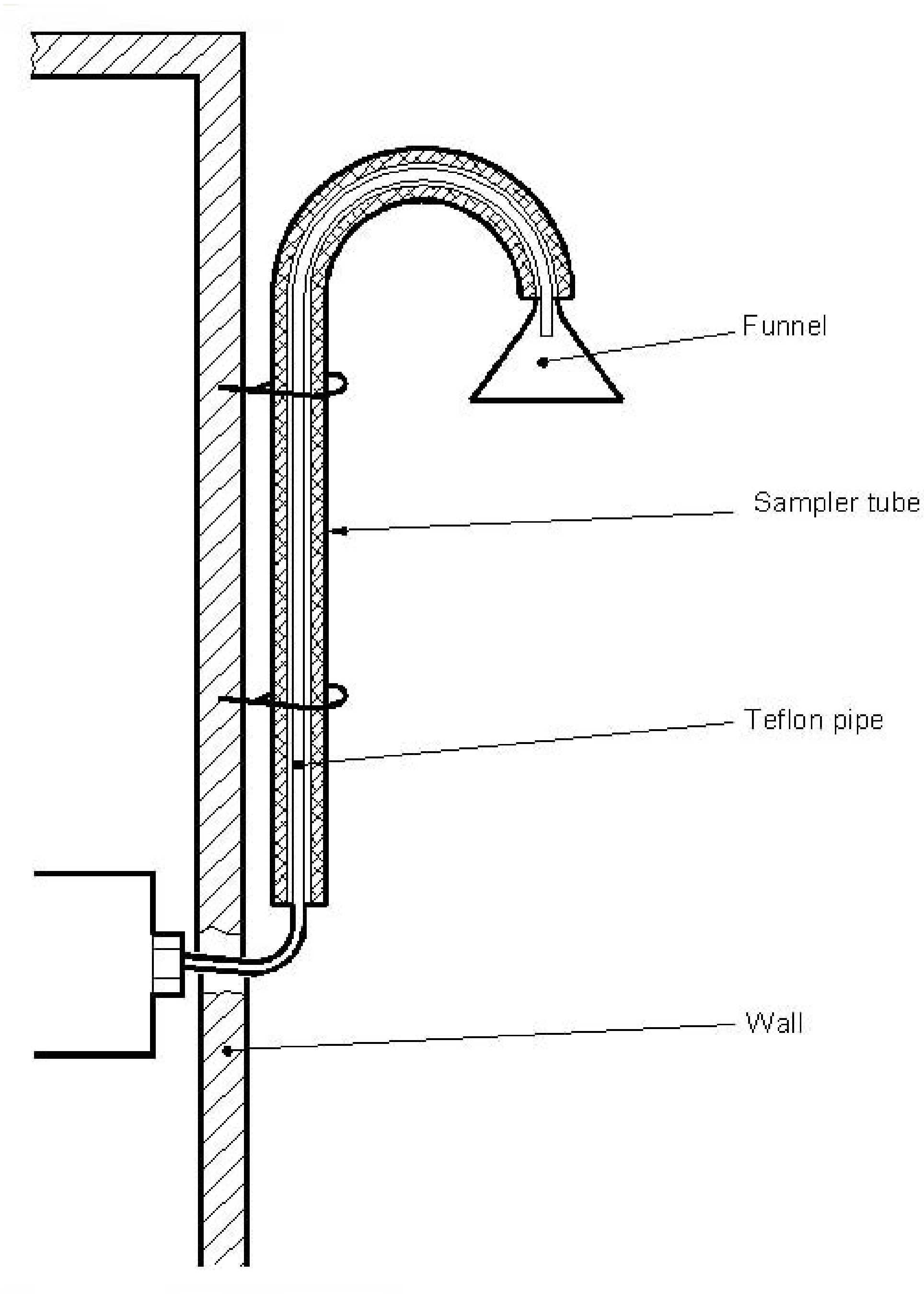


Figure 3–2 – Installation of the sample gas inlet

NOTE : Recommended height for sampling tap: 2.50 m
Maximum recommended length of Teflon sampling pipe: 6 m.

3.1.2. STARTING UP THE UNIT

Starting up the unit consists in carrying out, in the following order, the INSTALLATION / COMMISSIONING procedure described here-below.

1/ Press the ON/OFF push button located on the front panel. The analyzer starts running, it passes into warm-up cycle (duration of which is 1800 seconds maximum). The homepage is displayed: it allows to visualize the warm-up progress period.

The warm-up period is ended when all the metrology parameters are within the operational limits. The warm-up progress icon will disappear and the following homepage is displayed:

This screen is the analyzer standard function homepage. It contains additional pages that are displayed by activating the buttons [button] to [button], present at the top of the screen. These pages allow the measurement channel display, the *« Real-time graph »* of the instantaneous measurement channel values, and the *« Analyzer synoptic »* giving the main parameter values.

By using the touch screen mounted on the analyzer front panel: no password is required to activate the standard functions.

By using a remote PC: a password is required to be input in the pop-up that will appear. Enter the User password given in the « **Warning** » section of the Quick-Start, and validate with [✓].

Button and icon definitions specific to these screens

	Displays the selection buttons of the analyzer fluid inlets: sample inlet, zero inlet, span inlet.
	Warm-up status icon: indicates that analyzer is warming-up.
	Normal operation status icon: indicates that the analyzer operates normally.
CO12e 09:30:02	Information area: indicates the analyzer model and time.
Warm-up	Allows to visualize the warm-up progress status
	Stop button of the current cycle
	Displays the starting buttons of the analyzer cycles: starts calibration cycle, starts zero reference cycle.
	Displays the contextual help
	Displays analyzer information panel.
	Gives access to the advanced analyzer functionalities.

2/ **Access to the advanced analyzer functionalities**

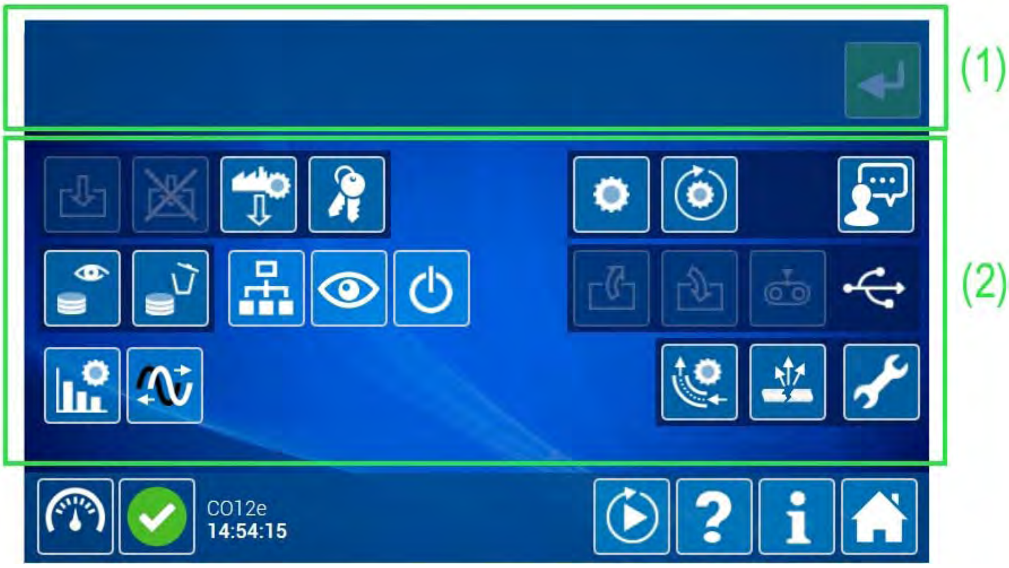
By using the touch screen mounted on the analyzer front panel: touch the button in order to open the User password input pop-up (1). Touch the field (2) to display the QWERTY keyboard (3).

Touch ?123 in order to switch alphanumeric keyboard to numeric keyboard. Enter the User password and validate with : the pop-up and the keyboard closes, and the advanced functionalities homepage opens.

By using a remote PC: do the same with the PC keyboard and mouse.

The button allows to close the pop-up without input validation.

The home page of the advanced analyzer functionalities is presented below:



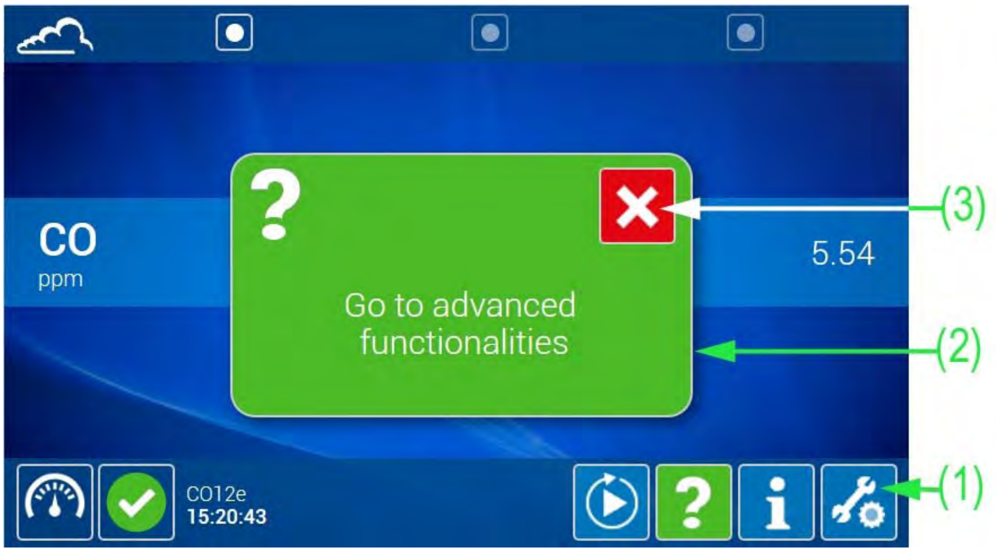
The accessible functions for the User appear in white with a blue background in zone (2). The function access to the functions depends of the password's level that was entered.

Each accessible function is activated by contact, it then changes color to green. The name of the selected function will appear in zone (1), and the button is highlighted . By double clicking on the function's icon or by using the button , the user can access to the corresponding screen.

3/ Contextual help functioning

The contextual help is directly accessible through all the screens. The user activates it by touching / clicking on the button that will become green . Then, the user touches / clicks on the buttons or on a parametric screen part in order to display a pop-up that describes the use of the selected function or button. The pop-up is closed by clicking on .

See the example below:



(1) Activated button (highlighted), (2) pop-up message explaining the function of the activated button, (3) icon to be used in order to close the pop-up.

3.2. PROGRAMMING THE CO12E

3.2.1. SCREEN AND KEYBORAD DESCRIPTION AND USE INSTRUCTIONS

The touch screen mounted on the front panel is alternately used to visualize the control screens and the virtual input screen allowing input and modification of the analyzer parameters. The control button activation is done by touching.

When the analyzer is connected to a remote computer, the parameters are modified using the computer keyboard, and the control buttons are activated by clicking with the mouse.

3.2.1.1. Definition of the control screen areas

The areas of control screens are defined as follow:

(1)	Browsing area proper to the current screen: when the screen has more than one page, activate the button to allow to display the corresponding page.
(2)	Measurement or configuration area. It displays the measurement parameters (gas, value, units...) or the configurable parameters associated with the selected menu.
(3)	Manual control area: inlet fluid selection and manual launching of calibration and zero reference cycles. Information area and advanced functionality access.

<u>Control and information area (3) description</u>

This area is present in all the screens.

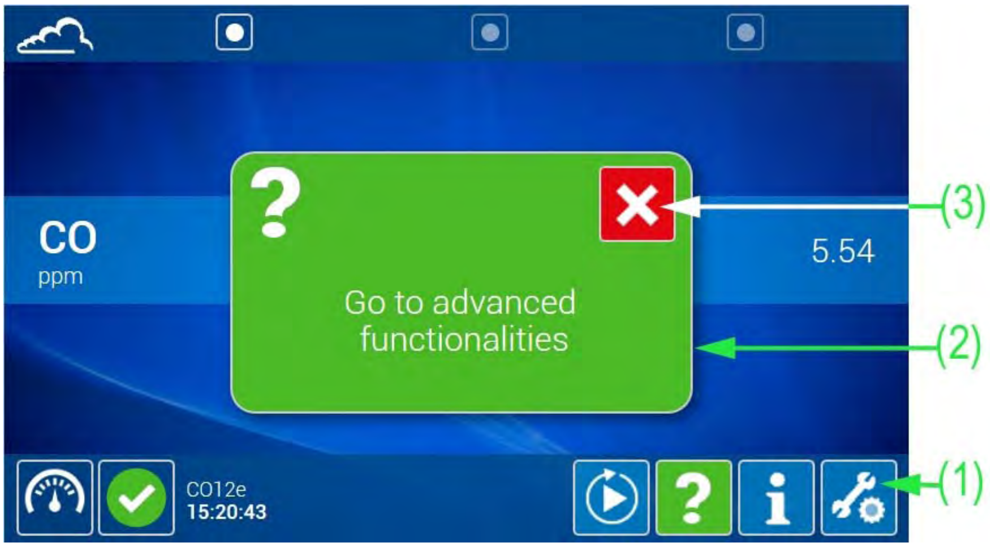
	Activating this button displays the buttons allowing to manually select the fluid inlets of the analyzer: sample inlet, zero inlet, span inlet.
	The icon displayed in this place indicates the currently operating status of the analyzer. The various status icons are: normal operation, warm-up, control, alarm, network disconnected, maintenance, stand-up, USB key connected.
CO12e 09:30:02	Information area indicating model and current time of the analyzer.

	Activating this button displays the buttons allowing to manually start the analyzer cycles: starts calibration cycle, starts zero reference cycle.
	Activating this button displays the contextual help.
	Activating this button displays the analyzer information panel.
	Activating this button gives access to the advanced analyzer functionality home page.

3.2.1.2. Contextual help functioning

The contextual help is directly accessible through all the screens. The user activates it by touching / clicking on the button that will become green . Then, the user touches / clicks on the buttons or on a parametric screen part in order to display a pop-up that describes the use of the selected function or button. The pop-up is closed by clicking on .

See the example below:



(1) Activated button (highlighted), (2) pop-up message explaining the function of the activated button, (3) icon to be used in order to close the pop-up.

3.2.1.3. Virtual keyboard input

The virtual input screen is used to modify the control screen parameters displayed from the front panel touchscreen. This screen is displayed instantly in the lower half-part of the screen when the user touches an input field to be modified. Two touch-button keyboard types are available: numeric and alphanumeric QWERTY. They are displayed depending on the input field nature: numeric keyboard if the field is numeric type, alphanumeric keyboard if the field requires number and letter inputs.

The examples below are showing the keyboard display in the « *General configuration* » screen. The keyboard operation is identical for all screens.

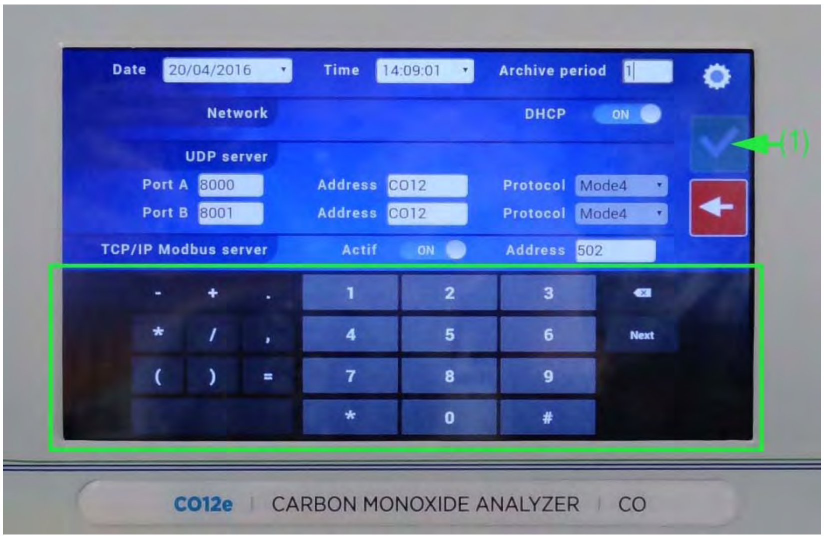
When the user presses down a key, the button (1) at the top right corner is activated and highlighted to . It is used to validate the whole inputs done in the screen, and to close the screen after.

NOTE : Field inputs are indexed.

These keyboard keys work like Android system keys found on tablets and smart-phones.

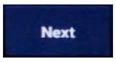
The numeric keyboard:

It is displayed in the area (2) of the screen below:



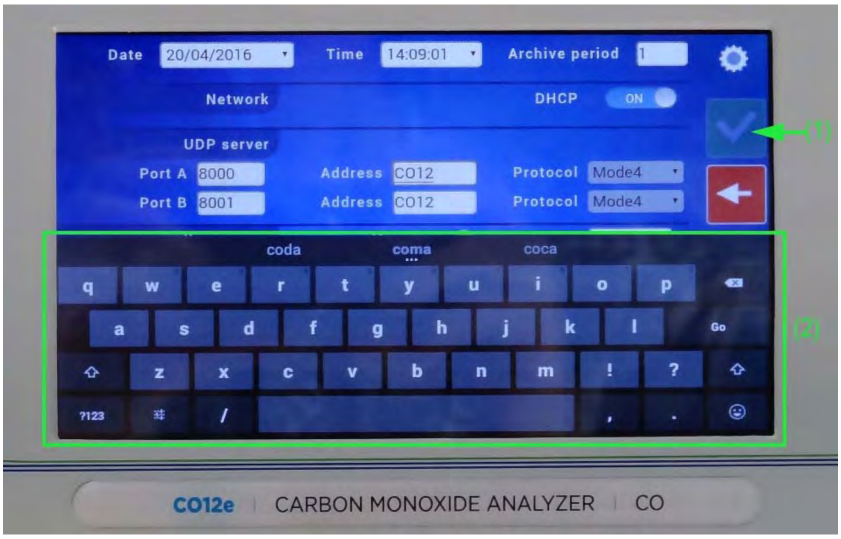
(1) button for input validation, (2) numeric keyboard with touchscreens.

 : clears digits during input.

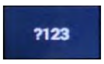


: used to move from an input field to another according to its indexation.

– The alphanumeric keyboard:

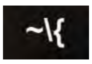


(1) button for input validation, (2) alphanumeric keyboard with touchscreens.

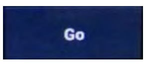


: switches from alphanumeric to numeric keyboard.

: switches from numeric to alphanumeric keyboard.



: switches from numeric to symbol keyboard.



: validates input of the considered field.

3.2.2. OPERATION PARAMETER PROGRAMMING

The standard functionalities cannot be modified. The user can only modify the advanced functionality parameters.

3.2.2.1. Field requiring character input

– Using the front panel touchscreen :

  Touch the input field to be modified: if the field is alphanumeric, the QWERTY keyboard is displayed, if the field is numeric, the numeric keyboard is displayed.

  Input with the touch keys, and validate with . The keyboard closes and the input field is displayed properly filled in the control screen.

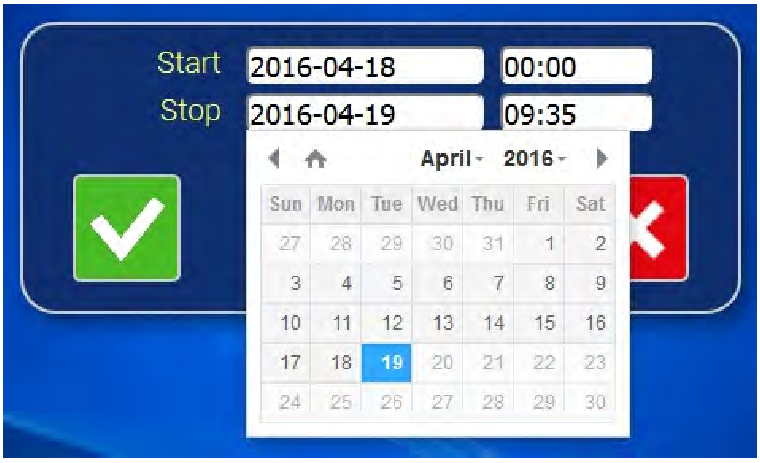
– From a remote PC:

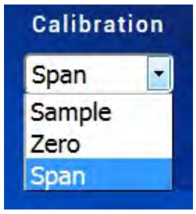
  Use keyboard and mouse of remote PC to input, modify and validate the field characters.

3.2.2.2. Fields requiring parameter selection in a list

Many cases are possible, depending on the input type.

Touch the field to be modified. The parameter or value list to be selected is displayed: the current parameter or value is displayed white in blue background. Touch (or click on with the remote computer mouse) the new parameter or value to be selected. The field is displayed white in blue background. Validate with . The list closes, and this new parameter or this new value replaces the previous.





3.2.2.3. OFF/ON status modification button

To switch OFF to ON, touch (or click on) the white button. The ON field becomes white in blue background. And vice versa.

NOTE : When many modifications are performed in the same screen, the user must ALWAYS validate with the key  to take into account the whole modifications.

3.3. BROWSING ERGONOMY

The CO12e home page is the following:

By default, the home page displays the CO measurement channel.

From the front panel touchscreen, the homepage allows free (i.e. without password) and direct (i.e. the first browsing level) access to the standard functionalities of the analyzer.

Activating the buttons of top screen to allows to drag display sideways to view the « *Real-time graph* » of the instantaneous values of the selected measurement channels, and the « *Analyzer synoptic* » indicating the main operation parameter values.

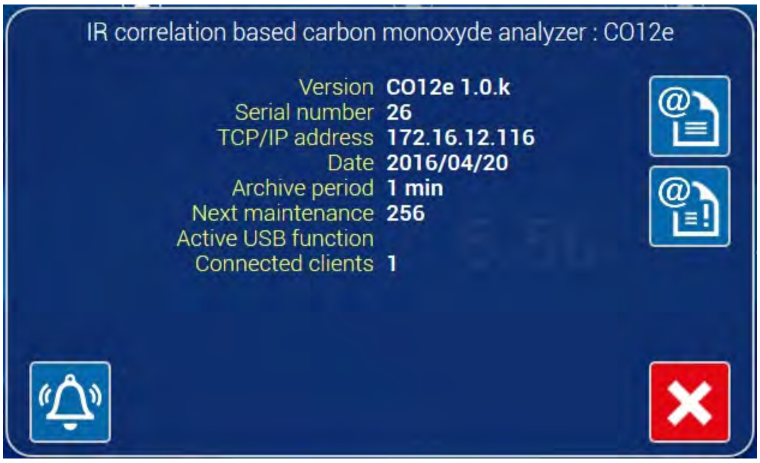
From a remote PC, the page below is displayed first:

The user enter the password in the field (1) and validates with to open the home page.

Standard functionalities are the followings:

	Display of fluid inlet selection buttons.
	Manual selection of sample inlet.
	Manual selection of zero inlet.
	Manual selection of span inlet.
	Display of analyzer status.
CO12e 09:30:02	Indication of analyzer model and time.
	Display of analyzer cycle launching buttons.
	Manual start of calibration cycle.
	Manual start of zero reference cycle.
	Display of contextual help.
	Display of analyzer information panel.
	Access to the advanced analyzer functionalities.
	Access to homepage.

The information panel displays the software version, analyzer serial number, TCP/IP analyzer address, current date programmed in the analyzer, memorization period for data archiving, remaining days up to next maintenance, if YES or NO an USB function is active on the analyzer, the number of connected clients.



Icon and button definition specific to the information panel

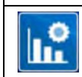
	Means that the analyzer is equipped with a WIFI key for remote connection from a tablet or a smartphone. This icon goes with WIFI TCP/IP identifier and address required for connection.
	Allows to email analyzer status (mux signal values). Available from remote PC only.
	Allows to email recorded events (history). Available from remote PC only.
	Sound signal to locate the corresponding analyzer when not fitted with screen.
	Closes the information panel.

The advanced function access is selectively assigned to password bearers only. There are three possible authorization levels for passwords: user level, advanced level, expert level.

The user-accessible functions are white in blue background. They depend on the hierarchical level of the assigned password.

The access page to the advanced functions is the following:

The analyzer advanced functions are the followings:

	Restore factory settings. It is recommended to backup before executing this operation
	Passwords management
	General configuration (Address, Protocol, Measurement channels...)
	Automatic cycles configuration
	Language selection
	Find and display recorded averages
	Delete all recorded averages (Warning ! this operation can't be cancelled)
	List of connected clients
	Diagnostic functions (alarm, input / output, mux...)
	Set the analyzer in standby mode
	Advanced analyzer configuration
	Set the analyzer phases

	Automatic flow linearization
	Test for leaks
	Set the analyzer in maintenance mode
	Return to standard functionality home page
	Give the USB characteristics (free and total memory) when it is connected to the analyzer.
	Backup of configuration and software on USB when it is connected to the analyzer.
	Restore software and configuration from USB when it is connected to the analyzer
	Record instantaneous measurement on USB when it is connected to the analyzer

3.4. ANALYZER FUNCTION DESCRIPTION

3.4.1. STANDARD FUNCTIONS

3.4.1.1. Analyzer controls

Reminder:

- activates to display , , and access the corresponding controls.
- Activate to display , , and access the corresponding controls.

The analyzer controls are the followings:

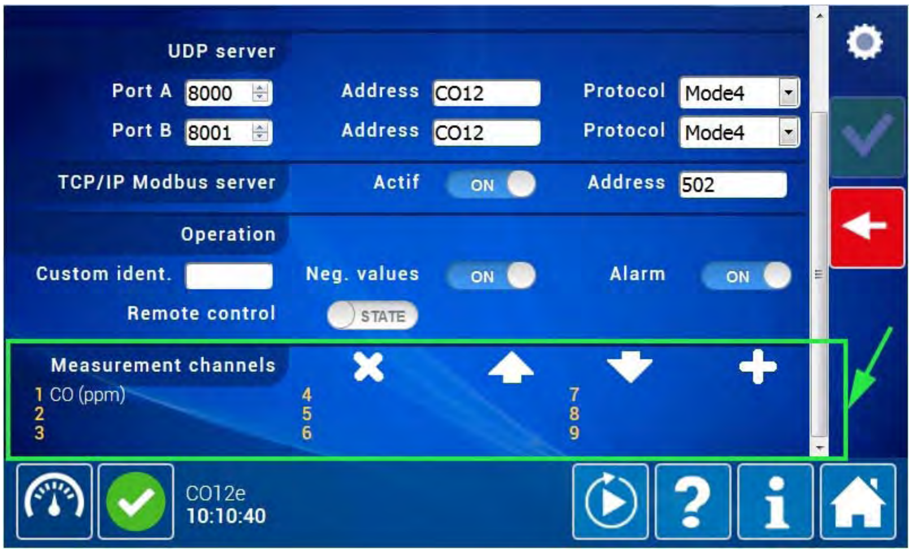
Controls	**Function description**
Selects sample inlet	This function switches the analyzer to the sample gas inlet. The gas is continuously sampled through the dust inlet filter. The unit is selected in the « *Advanced analyzer configuration* » screen.
Selects zero inlet	This function switches the analyzer to the external zero gas inlet. This operation allows stability checking and zero drift to determine the need to launch a zero reference cycle or program its repetition period.
Selects span gas inlet	This function switches the analyzer to the span inlet. The measured span gas value, possibly increased by a programmed offset, is displayed on the screen. This operation allows checking the stability and the span drift to determine the need to launch an auto-span cycle or program its repetition period.
Launches a calibration cycle	This function launches manually an automatic span cycle. The user activates and views cycle progression in the scroll bar Automatic span . At any time, it is possible to abort the current cycle by touching , or finish the current cycle by touching . The current cycle stop results in « K » value modification. During an automatic calibration cycle, the analyzer adjusts its span factor K automatically to equal its reading value (minus the programmed offset) with span gas concentration. The span gas concentrations are programmable in the « *Advanced analyzer configuration* » screen. Adjustment of the cycle duration takes place in the « *Duration* » field of the « *Automatic cycle configuration* » screen. The cycle is finished when the scroll bar is completely grey, Automatic span , it closes automatically.

 Launches a zero reference cycle	This function launches manually an automatic zero correction cycle to adjust the zero drift. The user activates  and visualizes cycle progression in the scroll bar . At any time, it is possible to abort the current cycle by touching , or finish the current cycle by touching . The cycle is finished when the scroll bar is completely grey, , it closes automatically.

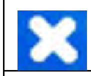
3.4.1.2. Measurement channel display

By default, the homepage displays the compound channel to be measured:

To display additional measurement channels, it is first necessary to select them in the « *Measurement channel* » section of the « *General configuration* » screen shown below (see outlined frame with arrow):



Touch button definitions specific to this section:

	Deletes the selected measurement channel
	Moves upwards the selected measurement channel
	Moves downwards the selected measurement channel
	Adds a measurement channel

To select additional channels, activate  and open the selection pop-up. There are five channel groups: compound, voltage, sensor, calculation, analog input.

Then, to activate  to  in order to display the corresponding group elements, touch/click on the elements to be selected : they become sky-blue highlighted.

Then, activates  to validate this selection and close the pop-up. Do the same for the other channel groups: it is possible to select the whole available channels. The selected measurement channels take place in the numbered fields (see outlined frame with arrow):

When selection is finished, activates  to definitively validate the whole selection, then activates  to display the measurement channels in the homes screen:

Three measurement channels are displayed per page. To display the whole selected channels, the GUI (graphic user interface) adds as many pages as necessary. These additional pages are symbolized by the buttons and displayed at the screen top (see the outlined frame with arrow). The user clicks-on/touches these buttons to display pages successively.

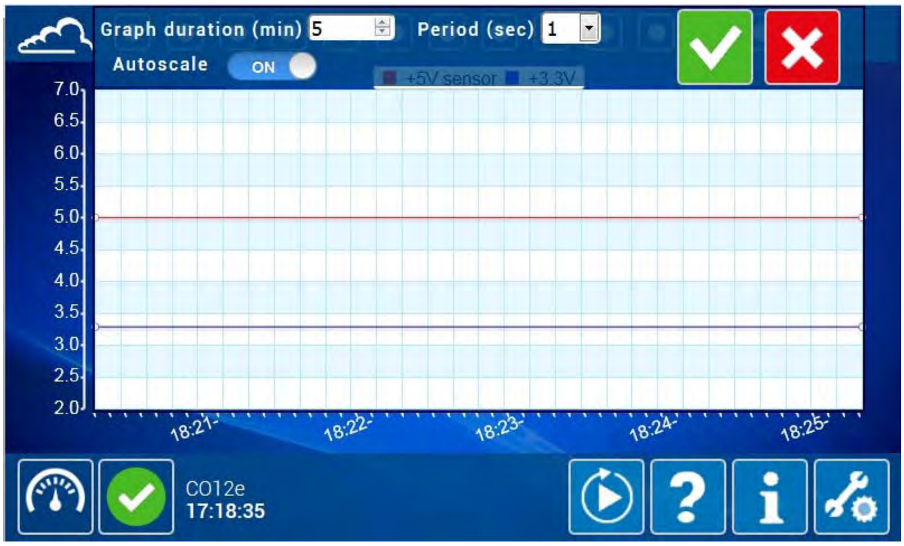
3.4.1.3. Measurement channel curve display

The user views the measurement channel graphs by touching / clicking-on the next-to-last button in the browsing bar at screen top (see outlined frame with arrow). If no channel was previously selected, the following message is displayed:

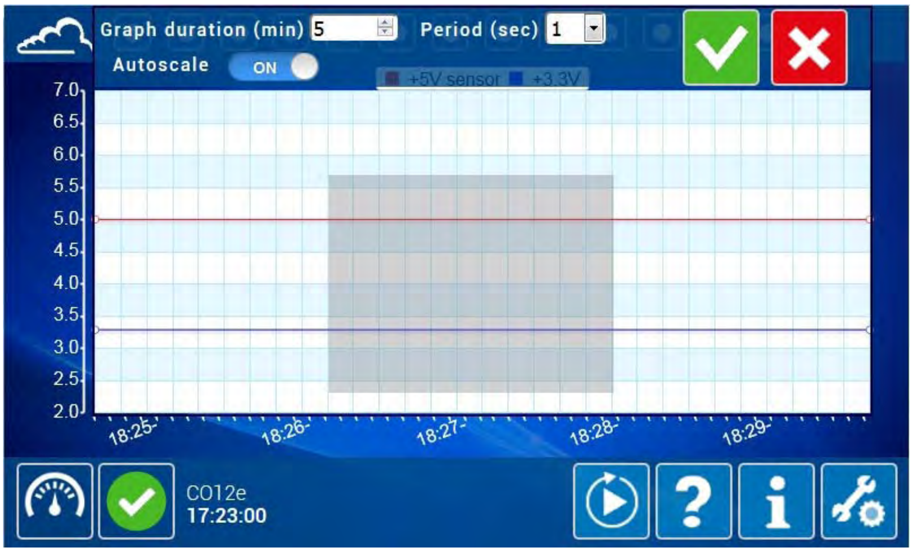
Touch / click-on the channel name to select: they change color and are displayed in green, as shown in the screen below:

Go back to the next-to-last page to display the corresponding curves:

The Y-axis scale setting is automatic and adjusted in real time for current display optimization. Maximum six curves can be displayed simultaneously. By touching / clicking in the graph, the user activates the zoom function with the manual scale, as shown in the screen below:



The user selects the screen zone he wants to zoom:



Then, he activates [✓] to validate: the selected zone is zoomed-in in the screen.

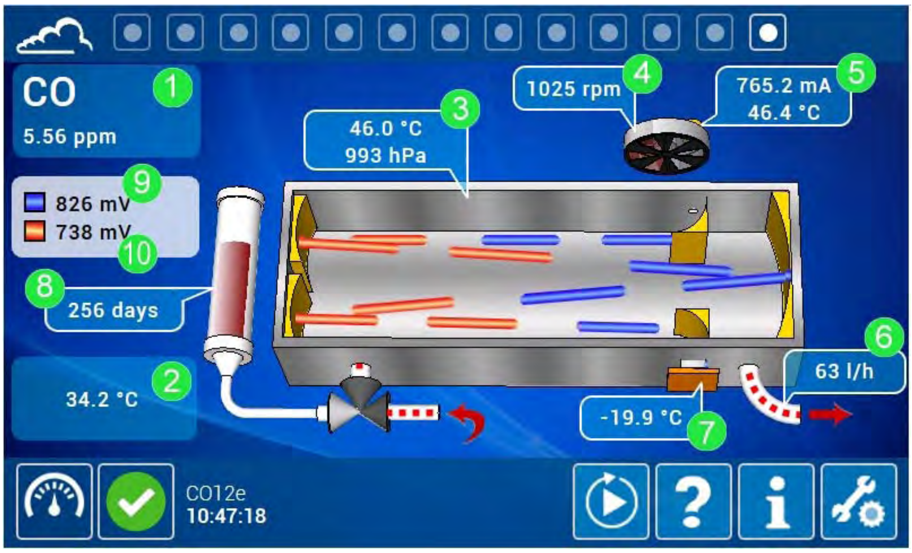
To exit zoom function, the user clicks in the screen two times, then he activates the action with [✓]

This zoom function is available for X-axis and Y-axis.

Moreover, the user can deactivate the auto scale and he can set the desired Y-axis scale.

3.4.1.4. Analyzer synoptic diagram

The user views the synoptic diagram by clicking-on / touching the last button in the browsing bar at screen top (see outlined frame with arrow). This screen displays the entire fluid circuit and the significant operating parameter values.



Screen legends are as follows:

(1): instantaneous measurement of CO concentration

(2): internal temperature of the analyzer

(3): temperature and pressure chamber

(4): motor speed

(5): current and temperature of IR source

(6): sample flow rate (l/h)

(7): detector temperature

(8): zero filter lifespan (in days),

(9): measure signal,

(10): reference signal.

3.4.2. ADVANCED FUNCTIONS

The user accesses the advanced functions homepage by touching / clicking-on .

The advanced functions can only be accessed by authorized users with password. Three different password levels are available to authorize selective access: user level, advanced level, expert level.

The whole advanced functions authorized to users with expert level password are described below.

3.4.2.1. Password management

The « expert » user only can activate this function by touching/double-clicking on to display the password management pop-up.

To modify passwords, the user fill-in the corresponding fields, then touch/click-on to validate modifications and close the window.

Touch/click-on to close the window without validating.

3.4.2.2. General configuration

This screen is accessed by touching/clicking-on .

This screen is used to configure the addresses and protocols necessary for communication and the measurement channels.

DATE and TIME fields: they indicate the current date and hour of the analyzer. They are modifiable with the « expert » level password only.

ARCHIVE PERIOD field: it indicates the analyzer archive period. It is modifiable with the « expert » level password only.

DHCP field: it is used to activate the automatic network configuration.

When ON, it allows to connect the analyzer to a TCP/IP network whose address is generated by a DHCP server.

When OFF, the ADDRESS, MASK and GATEWAY fields are displayed to allow the user to define the TCP / IP address, gateway and mask necessary for connection. This can be done the « expert » level password only.

WIFI/WPA field: it indicates the WPA encryption key of WiFi. It is modifiable with the « expert » level password only (8 to 63 characters, 0-9 and A-F authorized).

UDP SERVER section: it allows configuration of the two available UDP ports, Port A and Port B.

- Port number can be fixed within the range 1000 to 9999.
- Address is used only for Mode4 (four alphanumeric characters) and JBUS (number 0000 to 0255).

They are modifiable with the « expert » level password only

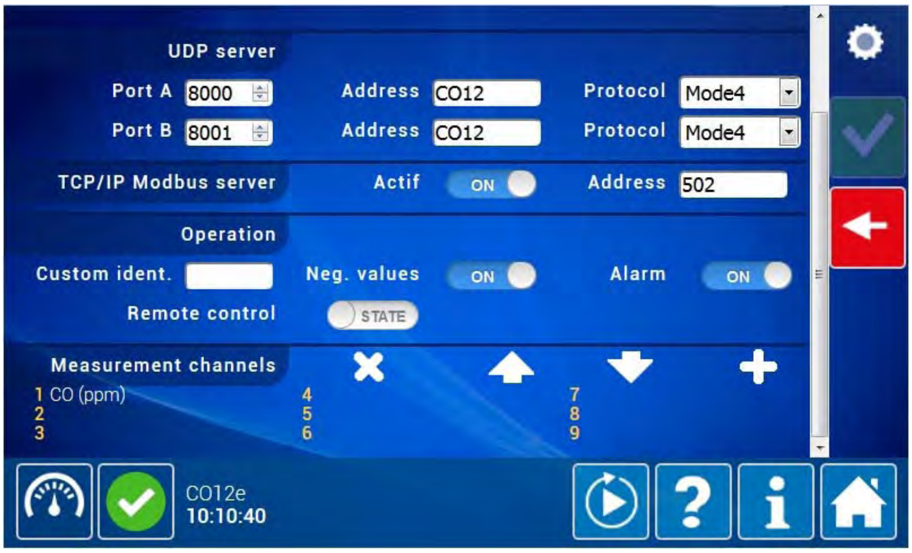
OPERATION section:

– NEG. VALUES field ON/OFF indicates if negative values are authorized or not.

– ALARM field ON/OFF enables or disables the alarm management.

– MEASUREMENT MODE field is displayed when an ozone generator fits the analyzer. It is used to select either the standard mode or the measurement mode with ozone generator.

MEASUREMENT CHANNEL section: it is used to configure the measurement channel display.



3.4.2.3. Automatic cycle configuration

This screen is accessed by touching/clicking-on .

This screen allows configuration of the four periodic cycles of the analyzer: Zero, Span, Zero-Ref., and Calibration. These cycles can be triggered in automatic or manual mode.

INLET field: allows selecting the channel used for the cycle (Zero, Span, Ref-Zero, Calibration).

PROGRAMMED INLET field: when ON, the analyzer uses the programmed inlet when a cycle is launched manually.

REMOTE CONTROL field: allows triggering cycle on a remote-control input (when optional ESTEL/SOREL board(s) is/are available...).

CYCLIC field: enables or disables cycle triggering in automatic mode.

DURATION field: allows fixing purge time.

PURGE DURATION field: it fixes purge time. Purge is applied before or after the cycle depending on the analyzer.

PERIOD field: allows fixing periodicity of automatic triggering.

START HOUR field: allows fixing start hour to trigger cycles automatically. If several cycles are in automatic mode, they will be triggered in the following order: Zero-Ref, Calibration, Zero, and Span.

AT STARTUP field (optional): allows to force a Zero-Ref cycle triggering at analyzer startup (when warming-up cycle is finished).

3.4.2.4. Language selection

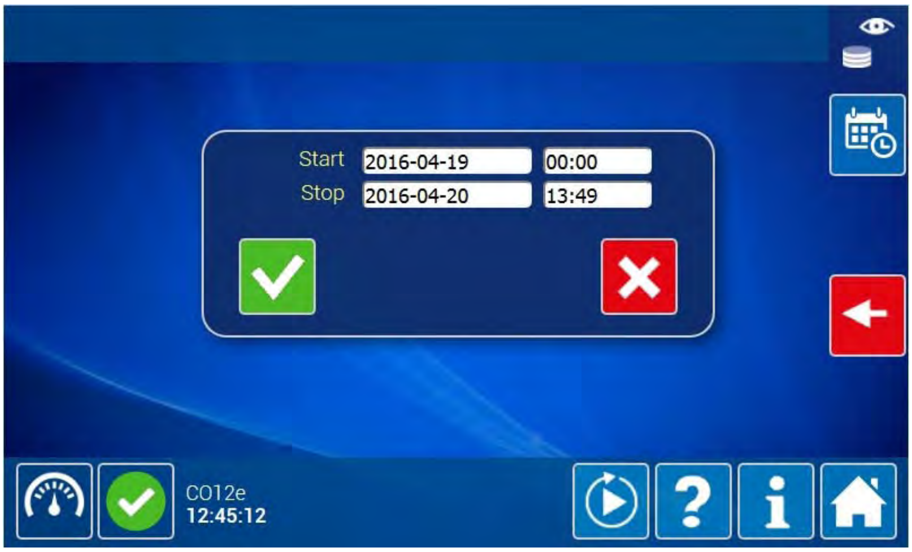
The available languages are English and French.

The user touches/double-clicks on  to display the language selection pop-up. The flag surrounded by a red frame indicates the language in use. The user touches / clicks-on the other flag to select the desired language and close the pop-up.

The message « Language selection » is displayed at screen top when English is selected, and « Choix de la langue » when French is selected.

3.4.2.5. Find and display recorded averages

This screen is accessed by touching/clicking-on . It allows to set the data period the user wants to watch, and to display these data.



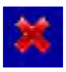
The user touches/clicks-on  to validate the selection, close the pop-up and display the screen to visualize the recorded averages for the period. Touch/click-on  to close the pop-up without validating modifications.

Button definition specific to this screen

 : exports the displayed data to a TXT file.

 : opens the selection popup of dates and times period the user wants to view.

Icon meaning

 : indicates an average stored with an alarm status. Alarm details are displayed by touching this icon.

 : indicates an average stored with a warning status. Warning details are displayed by touching this icon.

 : indicates an average stored with a “calibration” status. Calibration details are displayed by touching this icon (zero, span).

3.4.2.6. Delete all recorded averages

Touching/ double clicking-on this button  delete all the recorded averages.

WARNING : **this action is irreversible.**

3.4.2.7. List of connected clients

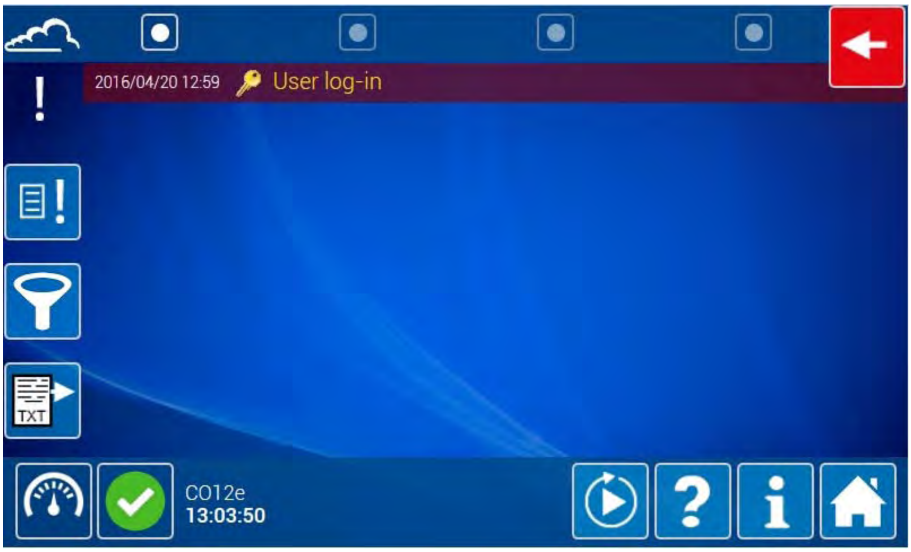
The user touches/double-clicks on  to display the pop-up giving the IP addresses and inactivity duration of the currently connected clients.

Click-on/touch  to close the pop-up.

3.4.2.8. Diagnostic functions

This screen is accessed by touching/clicking-on . It consists of four pages displayed by touching/clicking-on the white points in the screen top browsing bar.

The first page lists the current alarms and significant events on the analyzer and allows access to page 4 for alarm solving.



Button definitions specific to this screen

 Displays or hides all the archived events.

 Displays or hides the simple events. It acts as filter.

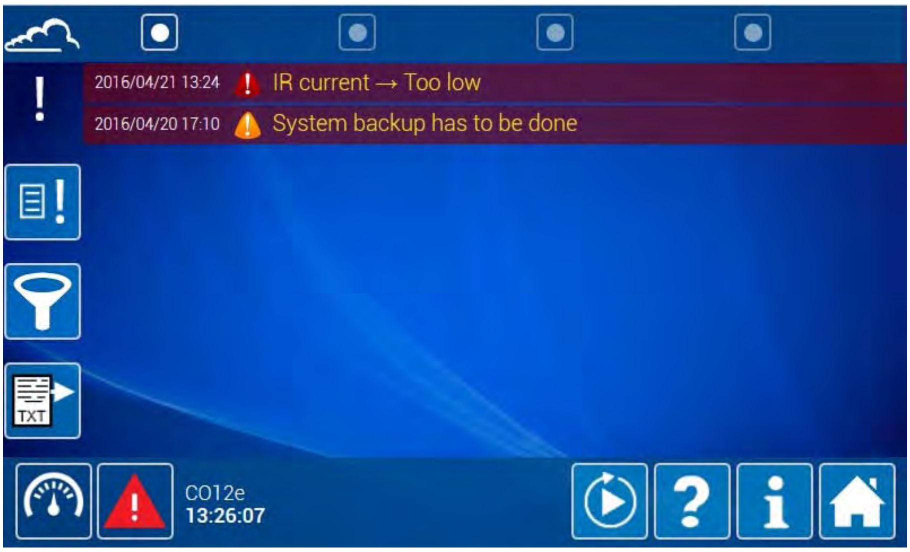
 Exports the history of the recorded events in a TXT file.

The second page displays the analyzer signal values:

The third page displays the control status, the component list and status when detected on analyzer startup:

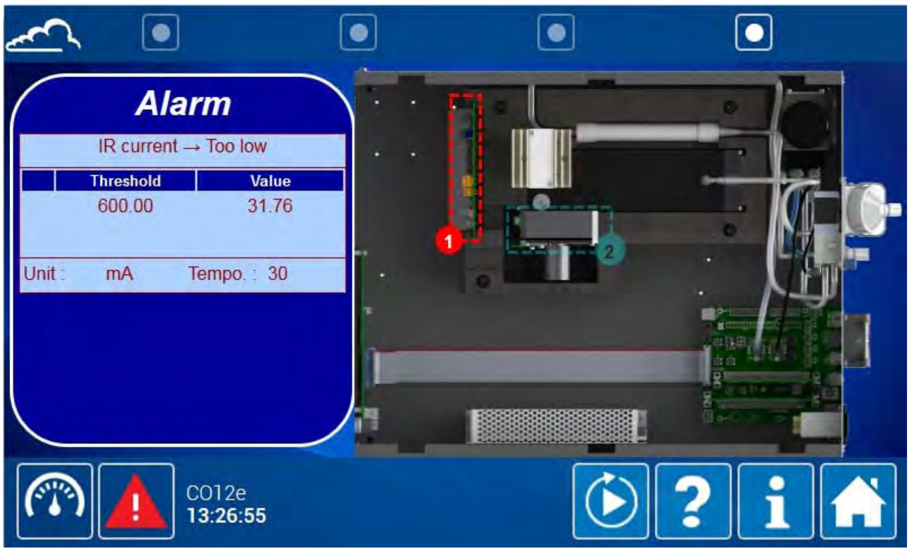
Alarm solving :

When an alarm triggers, the alarm icon is displayed at the bottom right side of the screen. The user touches/clicks-on to access the diagnostic function first page displaying the current alarm and event list, as shown below: fields indicate triggering hour and fault nature. The user touches/clicks-on to access the diagnostic function fourth page.

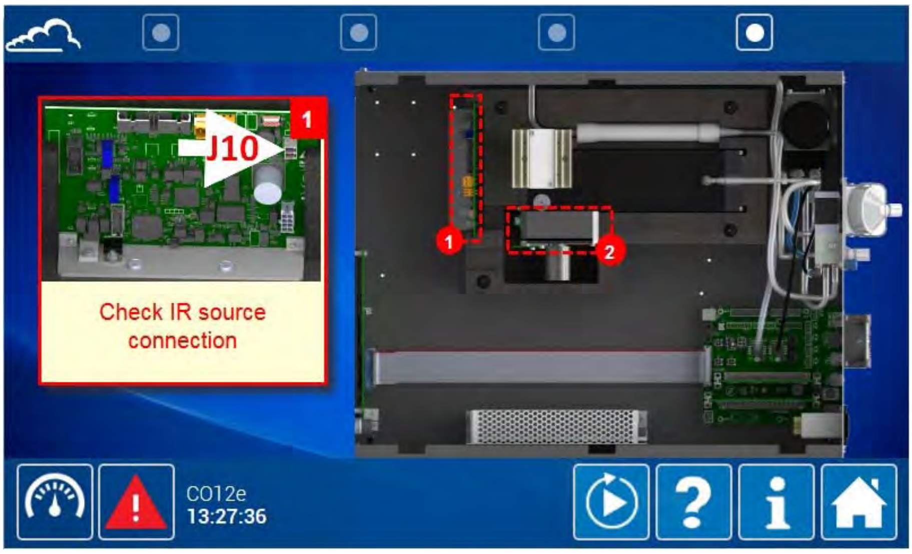


The fourth diagnostic function page displays the alarm threshold exceedance values, and shows the concerned faulty element in the internal analyzer view.

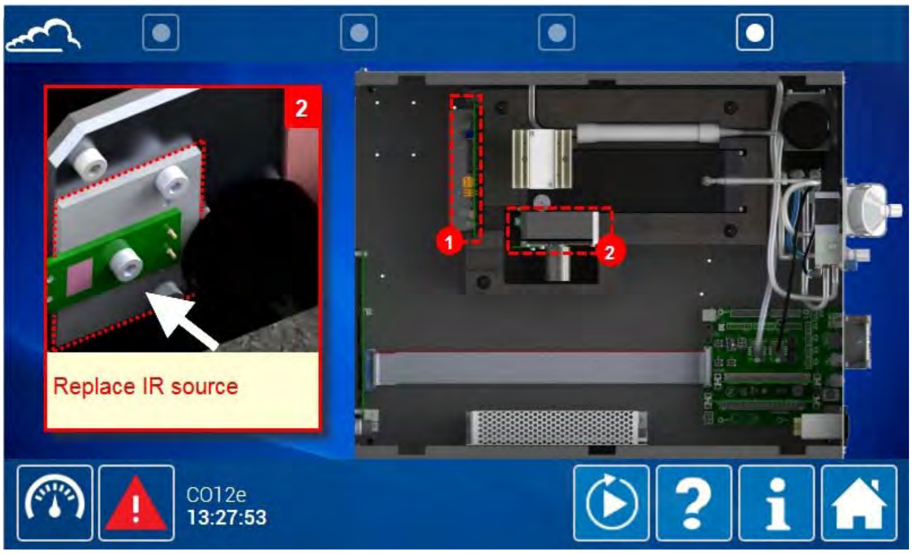
As example, the view below indicates a gas temperature alarm due to a sensor fault on the red-outlined board and focused with 1.



The user touches/clicks-on 1 to display the screen explaining what to do for alarm solving: « Check IR source connection » is written in the red frame of internal view left side, as shown below :



Then, the user touches/clicks-on 2 to display the second screen explaining what to do for alarm solving : « Replace IR source » is written in the red frame of internal view left side, as shown below :



When the alarm is cleared, the analyzer returns to its normal status, and the icon replaces the icon in the bottom left side.

3.4.2.9. Set the analyzer in standby mode

To activate stand-by mode, the user double-clicks on/touches which becomes .

Standby mode is used to stop the pump while all the other controls remain in operation. To reactivate the measurement mode, double-click / touch .

When the analyzer is switched to standby mode, the status icon (in bottom left side of screen) is modified to indicating standby status. However, alarm or control indication is a priority.

Consequently, if the analyzer is switched to standby mode while in alarm or control is active, the alarm icon or control icon will remain displayed and the standby icon will not be displayed.

Under these conditions, to verify if the measurement or standby status is active, the user checks the button is red-outlined or not in the advanced function page.

3.4.2.10. Set the analyzer in maintenance mode

To activate maintenance mode, the user double-clicks on/touches which becomes .

Maintenance mode activation is used to flag that the analyzer is in maintenance. When maintenance mode is activated, the recorded data are tagged with a status mark: "Maintenance" appears next to the concerned data when they are downloaded.

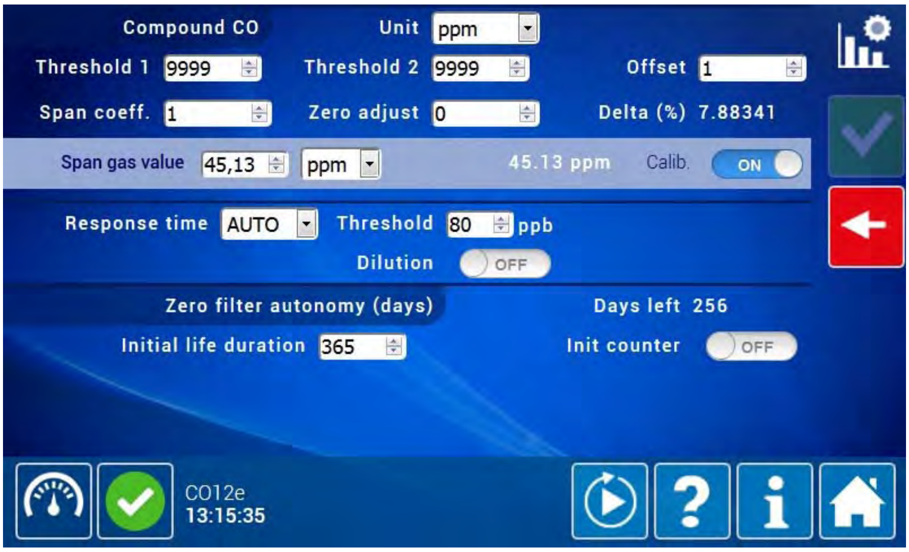
Double-click on/touch to reactivate the measurement mode.

As the analyzer is switched to maintenance mode, the status icon in the left bottom side of the screen changes to indicating maintenance status. However, alarm or control indication is a priority. Consequently, if the analyzer is switched to maintenance mode while in alarm or control is active, the alarm icon or control icon will remain displayed and the maintenance icon will not be displayed.

Under these conditions, to verify if the measurement or maintenance status is active, the user checks the button is red-outlined or not in the advanced function page.

3.4.2.11. Advanced analyzer configuration

This screen is accessed by touching/clicking-on . This screen allows configuration of the metrological parameters.



COMPOUND CO section:

- *« Unit »* field: selects the compound measurement unit.
- *« Threshold 1 »* and *« Threshold 2 »* fields: fixes a limit value to the measurement. If measurement value is out of this limit, an alarm triggers.
- *« Conversion Coef. »* field: displays the coefficient used for unit conversion (for ex. : ppb ➔ µg/Nm^3). This function is only available if unit is µg/m^3, mg/m^3, g/m^3.
- *« Offset »* and *« Span Coef. »* fields: these two values are used to calibrate the measurement with the linearization curve Y = Ax + B. A is the span coefficient, B is the offset. The span coefficient can be modified by the user or by a calibration cycle.
- *« Zero adjust »* field: allows setting manually the compound baseline (zero). As for the *« Span Coef. »,* the analyzer automatically calculates this value when the user launches a Ref-Zero.
- *« Delta (%) »* field: when the span coefficient is modified by a calibration cycle, this value indicates the difference between the new coefficient and the previous coefficient. If this value is greater than 50%, a span alarm is triggered. It is necessary to re-validate manually the span coefficient to disable this alarm. When the analyzer is in alarm, it does not take account the new calculated calibration coefficient, but keeps the previous calibration coefficient.

SPAN GAS VALUE field: span gas cylinder concentration used to perform calibration check. This concentration is the reference value to be reached.

CALIB. ON/OFF field: this field is used when the analyzer can measure many gases. It allows to perform a gas-by-gas calibration with no effect on the other gases. It invalidates or not the auto-calibration for the considered gas.

RESPONSE TIME field: shows response time value. Refer to Chapter 2 of this manual for more details.

DILUTION OFF/ON field: used to activate the dilution function and to set the dilution coefficient.

ZERO FILTER AUTONOMY (days) section: shows the remaining day number before carrying out the next filter maintenance. This value is decreased daily, and an alarm triggers when it reaches 1.

- *« Initial life duration»* field: shows the initial lifetime of the zero filter.
- *« Init. Counter OFF/ON »* field: reset filter autonomy to the programmed value after a filter change.

3.4.2.12. Automatic linearization of the flow

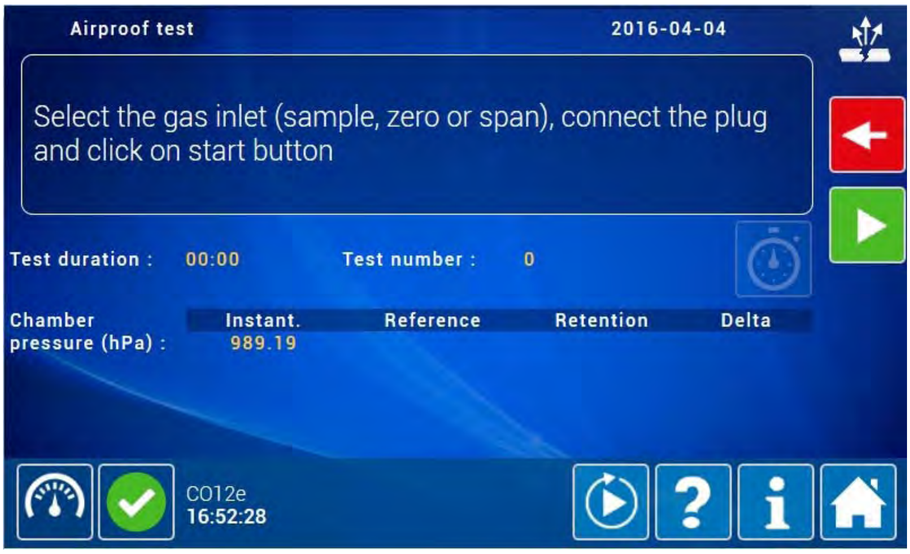
This screen is accessed by touching/clicking-on . It allows to configure the flow rate linearization of the analyzer.

Before linearization launching, the user must connect a flowmeter (0-100 nl/h) to the suitable fluid inlet. Then, he clicks-on/touches the corresponding fluid inlet button , or , or , and he inputs in the « Nominal » field the value read on the flowmeter. Then, he launches linearization by touching/clicking on .

REMARK: the in-factory pump setting is 60% by-default.

3.4.2.13. Airproof test

This screen is accessed by touching/clicking-on  . It explains the procedure to follow for performing the airproof test of the analyzer fluid circuit. The user must follow the instructions detailed in the white-outlined frame.

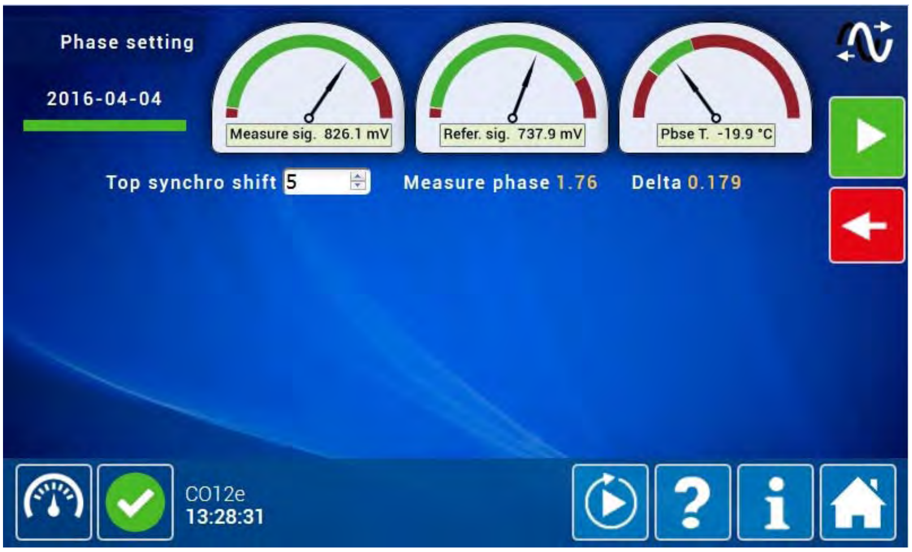


When the user launches the airproof test, the analyzer switches to maintenance mode.

3.4.2.14. Phase setting

This screen is accessed by touching/clicking-on  .

This screen is used to synchronize signals by touching .



By default, the synchro shift is set to 5.

3.5. CALIBRATION

IMPORTANT NOTICE:

Use of the analyzer, as a reference method for EPA reporting, requires periodic multipoint calibration and subsequent zero/span checks as described below. All gases for calibration must be traceable to a National Institute of Standards and Technology (NIST) reference.

3.5.1. OVERVIEW OF CALIBRATION AND CONCEPTS

To ensure the accuracy of performed measurements using the CO12e monitor, the unit must be regularly checked, calibrated and adjusted, following the user quality assurance plan.

– Zero and span check :

  This operation consists in comparing the monitor response, for the used range zero air and span point, to the used gas standards.

  This check is used to measure the monitor drift in time without modifying the adjustment coefficient.

  This check can be performed by using the internal zero air or gas span.

  Periodicity: generally 24 hours in automatic cycle mode.

– 2-point calibration:

  This procedure is used for checking and correcting the monitor response to zero and span points located at approximately 0 % and 80 % respective of the full scale measurement range used.

  Periodicity: monthly, or more frequently if the installation requires it.

– Span (multi-point calibration):

  This involves a complete checkup of the monitor’s linearity performance.

  Periodicity: quarterly, or following out-of-tolerance calibration check results requiring monitor intervention.

Note about gas generation devices:

For pressurized gas devices, it is necessary to provide an excess system to deliver gas at atmospheric pressure to the analyzer inlet. The device materials should be neutral for the gas used. When the device is used in automatic cycle with a cylinder, it is necessary to provide a shutoff solenoid-valve remote-controlled by the analyzer (refer to Figure 3-3).

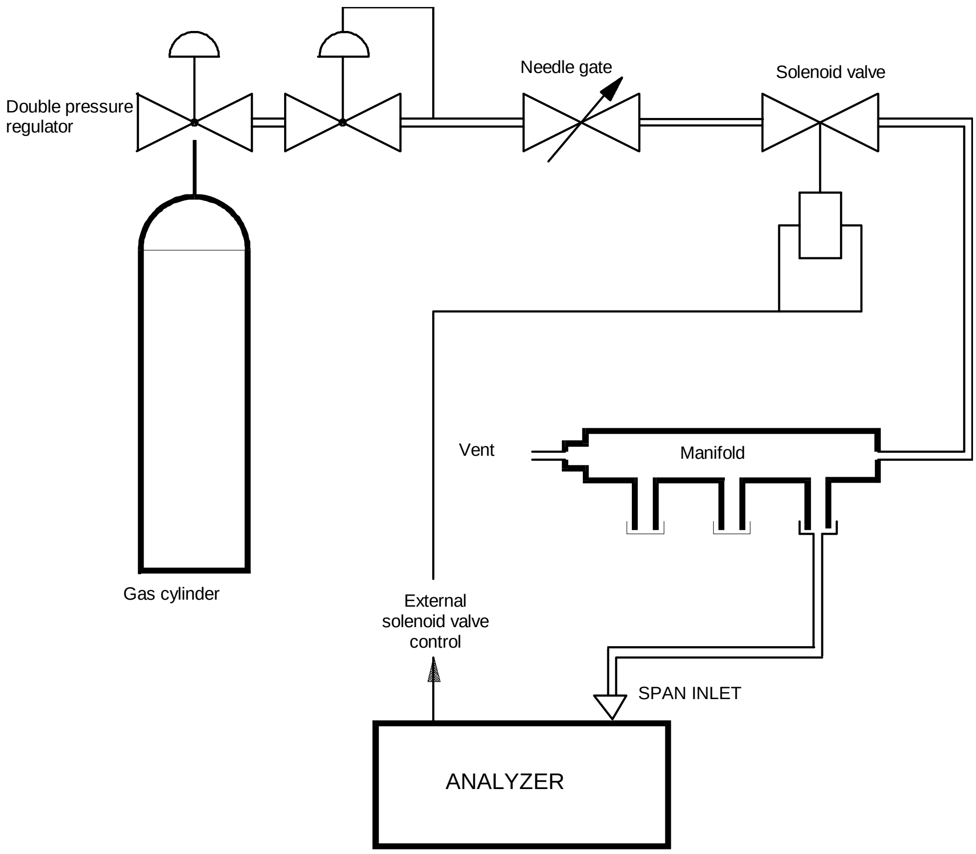


Figure 3-3 – Example of a pressurized gas connection

3.5.1.1. Zero air generation

For check and calibration, zero air generation can be obtained using the following methods:

– Check:

An Internal zero air filter is used for CO measurement.

For optional CO_2 measurement, a 5.0 N_2 cylinder (99.999% ultra-high purity N_2 cylinder, i.e. containing less than 10 ppm of total impurities) is applied to the external zero air inlet port (on rear analyzer panel).

– Calibration:

Cylinder of reconstituted air or zero air generator for CO measurement only (analyzer without CO_2 option).

Cylinder of zero air for optional CO_2 measurement.

Zero air should not contain more than 0.1 ppm of CO and 10 ppm of CO_2 in nitrogen, and be free of contaminants that could be measured by the analyzer.

3.5.1.2. Span gas generation (CO, CO_2)

For check and multipoint calibration, span gas generation can be obtained using the following methods:

– CO check:

Cylinder of CO span gas in air or nitrogen (N_2) (2 % accuracy) with a concentration of approximately 80 % of the full scale of the measurement range used.

– CO multipoint calibration:

Cylinder of CO span gas in nitrogen (N_2) or air, and dilution in zero air to obtain the various required concentrations. It is advised to use a zero air dilution system providing a 100-time higher flow than CO-in-nitrogen cylinder flow. Many certified cylinders at the required concentrations can also be used.

– CO_2 check

Cylinder of CO_2 span gas in air or nitrogen (N_2) (2 % accuracy) with a concentration of approximately 80 % of the full scale of the measurement range used.

– CO_2 multipoint calibration:

Cylinder of CO_2 span gas in nitrogen (N_2) or air, and dilution in zero air to obtain the various required concentrations. It is advised to use a zero air dilution system providing a 100-time higher flow than CO-in-nitrogen cylinder flow. Many certified cylinders at the required concentrations can also be used.

NOTE : The span gas cylinders used should be certified following the user quality assurance plan.

3.5.1.3. Internal solenoid valves

When performing a multipoint calibration the user should connect the zero and span gas sources to the sample inlet port. After this calibration, the zero and span sources should be connected to the corresponding analyzer inlet ports. The CO12e should give identical responses whether the sources are connected to the sample or the zero and span inlets ports of the analyzer. If not, then internal valves should be serviced.

The various gas inlet port can be used for zero and span checks and two-point calibrations.

3.5.2. ZERO AND SPAN POINT CHECK

3.5.2.1. Equipment Required

– Zero air:

Use method described in section 3.5.1.1.

– Span point:

Use method described in section 3.5.1.2.

3.5.2.2. Procedure

– Zero check:

Check that internal zero filter autonomy is higher than 30 days, or connect a zero air free of CO such as a 5.0 N_2 cylinder (99.999% ultra-high purity N_2 cylinder, i.e. containing less than 10 ppm of total impurities).

Use the  key to select zero. Wait for the measurement to stabilize. The Measurement should be within ± 0.1 ppm (taking account the offset if it is programmed). If it is not the case, a zero calibration is necessary.

– Span check:

Use the  key to select span inlet port. Wait for measurement to stabilize. Result will be compared to the concentration generated by the device used, taking account its accuracy as well as a possible programmed offset.

3.5.2.3. Use of Automatic Cycles

To program the cycles, touch  to access the *« Automatic cycle configuration »* screen and refer to screen details in section 3.4.3.2.

– Zero cycle:

Zero air generation device is permanently connected to analyzer zero air inlet port. Recommended duration of Zero check is 180 sec. For optional CO_2 measurement, 5.0 N_2 cylinder (99.999% ultra-high purity N_2 cylinder, i.e. containing less than 10 ppm of total impurities) is connected, it is necessary to control an external solenoid valve through an ESTEL or SOREL board relay (ESTEL board or SOREL board option is recommended).

– Calibration cycle:

Span gas generation device is permanently connected to the analyzer span inlet port and the span inlet is selected for span check. CO concentration must be below the full scale of the measurement range used. Recommended check duration is 300 sec.

3.5.3. TWO-POINT CALIBRATION

3.5.3.1. Equipment Required

– Zero air:

Use method described in section 3.5.1.1.

– Span point:

Use method described in section 3.5.1.2.

3.5.3.2. Procedure

– Zero calibration:

- Use the key to start a zero-reference cycle on zero inlet port (minimum 180 sec). Wait for measurement to stabilize. Measurement should be within ± 0.1 ppm (taking account the offset if it is programmed). If this is not the case, it is necessary to change the internal zero filter load (refer to maintenance sheet in section 4).

– Correction of span point:

- Automatic correction:

  Use the key to start a calibration cycle. Analyzer switches automatically to the programmed inlet port if the optional programmed inlet is set to ON. Otherwise, use the key to select span inlet or the key to select sample inlet before starting a calibration cycle.

  The analyzer automatically modifies its calibration coefficient as a function of the programmed gas concentration. Recommended duration for self-calibration is 300 seconds.

- Manual correction:

  Use the key (span inlet) or the key (sample inlet) to select the appropriate inlet to which gas is connected. Wait for measurement to stabilize. Set the desired K in « *Calibration coef.* » field of « *CONFIGURATION* ⇨ *Metrology configuration* » screen, as follows:

$$K_{new} = K_{former} \times \frac{Span\ gas\ value}{Read\ value_{(without\ offset)}}$$

For details about calculation of span gas values and read values, refer to section 3.4.4.3.

CAUTION: It is advised to note the former K reading before modifying it, since it will be deleted when the new K validation is done.

REMARK: Procedure is the same in case of CO_2 measurement.

3.5.4. MULTI-POINT CALIBRATION

3.5.4.1. Overview

An appropriate device consists of a diluter (MGC101 type), a certified span cylinder (CO or CO_2) (2 % accuracy), and a zero air generator. Certified span cylinder calibration may be associated to reference materials of the National Institute of Standards and Technology (NIST) for calibration in the US EPA measurement field. Refer to Figure 3-4.

Gases will be applied at atmospheric pressure to the analyzer sample gas inlet.

Analyzer calibration requires gas generation of 7 points including zero (example: 0, 15, 30, 45, 60, 75 and 90% of the full scale of the range used). The dilution carrier gas must be the same as for zero measurement.

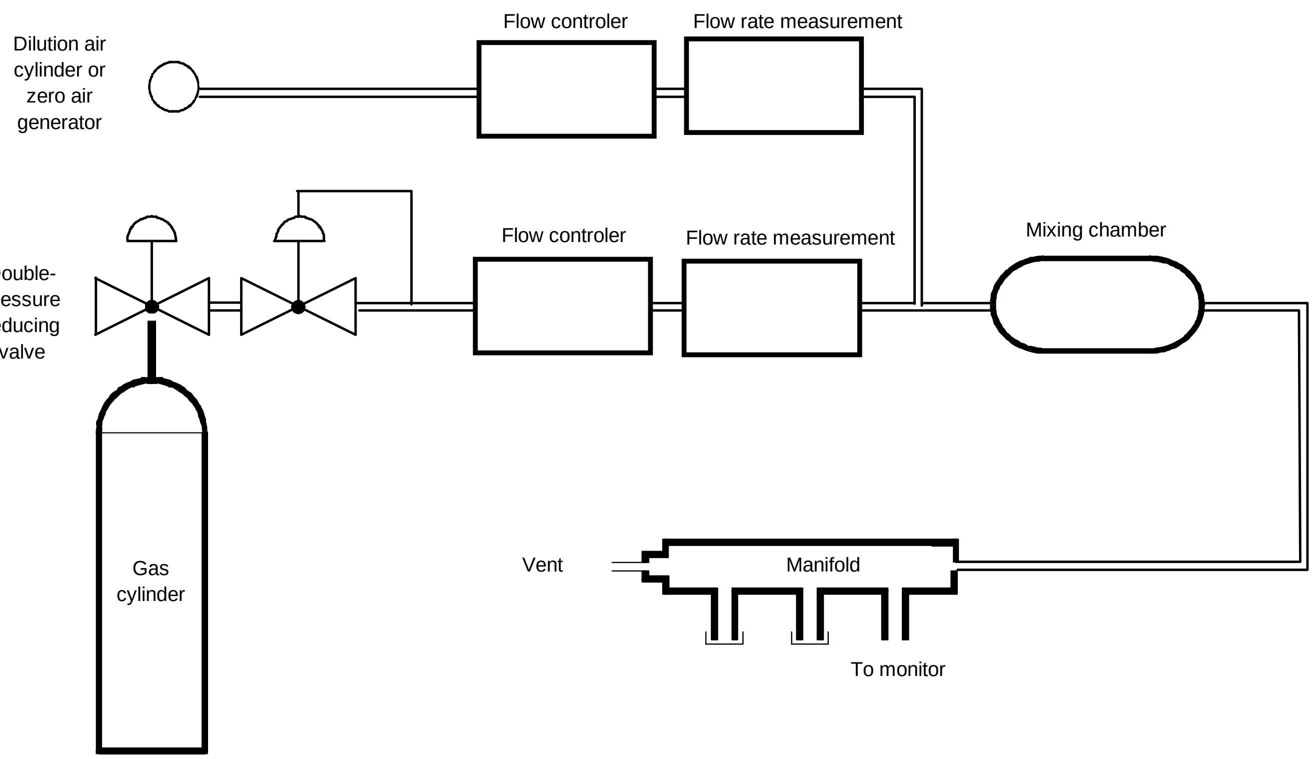


Figure 3-4 – Typical calibration device diagram

3.5.4.2. Equipment Required

– Diluter:
  - Flow controllers: should regulate flow rates to ± 1 %.
  - Flow meters: should allow flow measurement and recording to ± 2 %.
  - Mixing chamber: shape and size should allow homogeneous mixing of span gas and dilution air.

– Manifold:

The manifold includes at least one excess flow outlet and one “analyzer” outlet. This “analyzer” outlet has a sufficient diameter to avoid load losses at the analyzer inlet. The excess flow outlet (at least 20 % of the total flow rate) is designed so the manifold pressure will be close to atmospheric pressure (no overpressure) and ambient air should not cause back pressure.

– Dilution air (zero air):

Zero air generator or cylinder of reconstituted air.

Zero air should not contain more than 0.1 ppm of CO and be free of contaminants that might be measured by the analyzer.

– Span gas (CO):

Certified CO cylinder, concentration 2% in air allowing six-range generation between 15 % and 90 % of the full scale of the range used. Carrier gas may be nitrogen if the system allows a higher dilution ratio than 600:1.

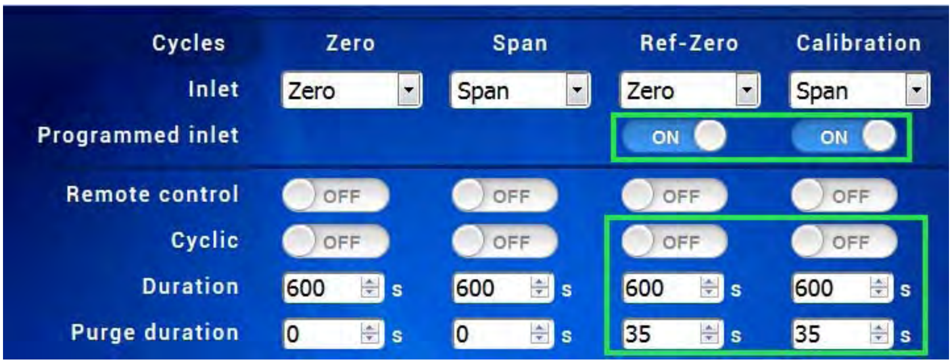
– Span Gas (CO_2) :

Certified CO_2 cylinder, concentration 2% in air allowing six-range generation between 15 % and 90 % of the full scale of the range used. Carrier gas may be nitrogen if the system allows a higher dilution ratio than 600:1.

3.5.4.3. Procedure

– Turn on the analyzer at least 6 hours before performing calibration.

– Touch the key to display *« Automatic cycle configuration»* screen and program analyzer as follows (advised configuration) :



– Touch the key to display *« Advanced analyzer configuration »* screen:

Response time: set Auto

– Connect analyzer sample inlet to manifold dilution system.

– Adjust the dilution system in order to generate a total zero air flow higher than the analyzer sample flow rate by 20%.

– Generate zero air. Wait for measurement to stabilize (recommended duration: 600 sec). Note Z_{CO} value, as a percentage of selected full scale, named ECH (for example: 0.050 for ECH = 50 ⇨ Z_{CO} = 0.1%).

– Follow steps in section 3.4.3.2. (« span point correction » section) to adjust calibration coefficient.

ECH is used to name the analyzer full scale.

– CO measurement : use formula below to calculate generated span value:

$$[CO]_{generated} = \frac{[CO]_{Cylinder} \times F_{CO}}{F_D + F_{CO}} \quad (1)$$

Where:

$[CO]_{Generated}$ is CO concentration of generated gas at manifold outlet,

$[CO]_{Cylinder}$ is CO concentration of certified cylinder,

$[F]_{CO}$ is CO flow in Nl/min,

$[F]_D$ is dilution air flow in Nl/min.

To calculate read value (in ppm) to be taken into account, use following formula:

$$[CO]_{read} = \left(\frac{S_{record} - Z_{CO}}{100}\right) \times ECH \quad (2)$$

Where:

S_{record} is the recorder value, in percentage of recorder full scale,

ECH is the analyzer full scale,

Z_{CO} was measured previously.

– Then generate five CO concentrations within 15 and 90 % of the full scale. For that, vary $[F]_{CO}$ and/or $[F]_D$ flows.

– Plot $[CO]$ read values as a function of $[CO]_{generated}$ values, including zero air point. Check linearity.

– Plot, or calculate using the least squares formula, the calibration line of the analyzer.

$$[CO]_{read} = a \times [CO]_{generated} + b \quad (3)$$

Where:

a: is the linear regression coefficient (slope), and is calculated as follows:

$$a = \frac{n \times \Sigma[CO]_{generated} \times [CO]_{read} - \Sigma[CO]_{generated} \times \Sigma[CO]_{read}}{n \times \Sigma[CO]^2_{generated} - (\Sigma[CO]_{generated})^2} \quad (4)$$

b: is the constant linear regression term (intercept), it is calculated as follows:

$$b = \frac{\Sigma[CO]_{read} - a \times \Sigma[CO]_{generated}}{n} \quad (5)$$

n: is the data number.

– CO_2 measurement : use formula below to calculate generated span value:

$$[CO_2]_{generated} = \frac{[CO_2]_{Cylinder} \times F_{CO_2}}{F_D + F_{CO_2}} \quad (1)$$

Where:

$[CO_2]_{Generated}$	is CO_2 concentration of generated gas at manifold outlet,
$[CO_2]_{Cylinder}$	is CO_2 concentration of certified cylinder,
F_{CO_2}	is CO_2 flow in NI/min,
F_D	is dilution air flow in NI/min.

To calculate read value (in ppm) to be taken into account, use following formula:

$$[CO_2]_{read} = \left(\frac{S_{record} - Z_{CO_2}}{100}\right) \times ECH \quad (2)$$

Where:

S_{record}	is the recorder value, in percentage of recorder full scale,
ECH	is the analyzer full scale,
Z_{CO_2}	was measured previously.

– Then generate five CO_2 concentrations within 15 and 90 % of the full scale. For that, vary $[F]_{CO_2}$ and/or $[F]_D$ flows.

– Plot $[CO_2]$ read values as a function of $[CO]_{generated}$ values, including zero air point. Check linearity.

– Plot, or calculate using the least squares formula, the calibration line of the analyzer.

$$[CO_2]_{read} = a \times [CO_2]_{generated} + b \quad (3)$$

Where:

a: is the linear regression coefficient (slope), and is calculated as follows:

$$a = \frac{n \times \Sigma[CO_2]_{generated} \times [CO_2]_{read} - \Sigma[CO_2]_{generated} \times \Sigma[CO_2]_{read}}{n \times \Sigma[CO_2]^2_{generated} - (\Sigma[CO_2]_{generated})^2} \quad (4)$$

b: is the constant linear regression term (intercept), and it is calculated as follows:

$$b = \frac{\Sigma[CO_2]_{read} - a \times \Sigma[CO_2]_{generated}}{n} \quad (5)$$

n: is the data number.

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CHAPTER 4

PREVENTIVE MAINTENANCE

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4 PREVENTIVE MAINTENANCE

4.1 SAFETY INSTRUCTIONS

The user must follow these safety instructions at all times:

- Always turn off the power supply when performing analyzer maintenance.
- Personnel should be trained in the proper operation of this equipment before attempting to operate it.
- The manufacturer shall not be responsible for any adverse outcomes resulting from the following:
  - Use of the monitor by unqualified service personnel.
  - Use of the monitor under conditions other than those specified in this document.
  - Use of components or accessories not manufactured by Environnement S.A, failure to use recommended parts may reduce the safety features.
  - Use of this equipment in a manner not approved by Environnement S.A, as it can cause harm to the equipment or operating personnel.
  - Inappropriate maintenance of the analyzer.
- A periodic inspection is required.

4.2 MAINTENANCE CALENDAR

By design, the CO12e requires very limited maintenance. However, the unit must be regularly serviced to ensure proper performance over time. The routine maintenance schedule shown below is an example, and this schedule can vary according to operating conditions.

Nature of operations	**Frequency**	**Sheet N°**
Sample inlet dust filter replacement	2 to 4 weeks	4.3.1
Parameter check	15 days	4.3.2
Internal zero filter replacement	6 months	4.3.3
KNF pump maintenance	1 year	4.3.4
Multi passages mirrors replacement	5 years	4.3.5
Source replacement	1 year	4.3.6
Motor replacement	5 years	4.3.7

Annual check

The monitor must undergo a thorough cleaning (measurement cell, restrictors, flow circuit, etc.) in the laboratory at least once a year. All metrological parameters and fitting tightness should be checked at this time.

4.3 MAINTENANCE OPERATION SHEETS

WARNING

- Do not use trichloroethylene or acetone to clean seals and gaskets.

MAINTENANCE SHEET

MONITOR Serial No.:	OPERATION SHEET: 4.3.1	
Scope: Sample inlet dust filter replacement	**PAGE: 1/1**	**Frequency: 2 to 4 weeks according to dust amount**

Date

Proceed in the following order:

– Turn off the analyzer power switch and disconnect the sample inlet.

– Unlock the filter holder cover (1) by pulling the spring (2) upwards.

– Remove the worn filter (3).

– Place the new filter (4) on the filter holder without the separating blue sheet.

– Make sure that the filter correctly covers the filter-holder surface and that it is correctly placed flat on top of it.

– Reposition the filter holder cover, and lock it by lowering the spring (2).

– Connect the sample inlet and power on the analyzer.

(1) filter holder cover, (2) spring, (3) worn filter, (4) new filter

Figure 4–1 – Sample inlet dust filter replacement

Tools and parts required:

- Tweezers
- Sample inlet filter (Teflon filter - porosity 5 µm - ∅ 47 mm) - Ref.: F05-11-842

MAINTENANCE SHEET

MONITOR Serial No.:	**OPERATION SHEET: 4.3.2**	
Scope: Parameter check	**PAGE: 1/1**	**Frequency: 15 days**

Regular follow-up of changes in electrical parameters during maintenance helps to prevent predictable alarms (infrared energy too low, measurement signal, pump clogged or ventilation tube obstructed, etc.). The limit values are shown in the table below.
Compare the voltage values for each multiplexer input (*Diagnostic functions screen)* to the values marked in the test sheet supplied with the device.

Date	MUX channel reading No.								
	1 Source T°C	3 Chamber T°C	4 Detector T°C	5 Chamber pressure	6 Flow	7 IR current	9 Measure signal	11 Ref signal	16 Motor speed
Units	°C	°C	°C	hPa	hPa	mA	mV	mV	turns/min
Lower limit	44 °C	44 °C	-21 °C	800 hPa	5 hPa	600 mA	50 mA	50 mA	1015 turns/min
Upper limit	48 °C	48 °C	-19 °C	1200 hPa	90 hPa	1000 mA	1200 mA	1200 mA	1035 turns/min

<u>Tools required :</u>

- None

MAINTENANCE SHEET

MONITOR Serial No.:	**OPERATION SHEET: 4.3.3**	
Scope: Internal zero filter replacement	**PAGE: 1/1**	**Frequency: 6 months**

Dates

Proceed in the following order:

– Turn off the analyzer and unplug the power cable.

– Remove the cover screw located on the analyzer rear panel. Remove the protective cover.

– Remove the measurement module protective foam cover.

– Disconnect the zero inlet tube (1) and the solenoid valve tube (2).

– Remove the internal zero filter (3) and replace with a new one.

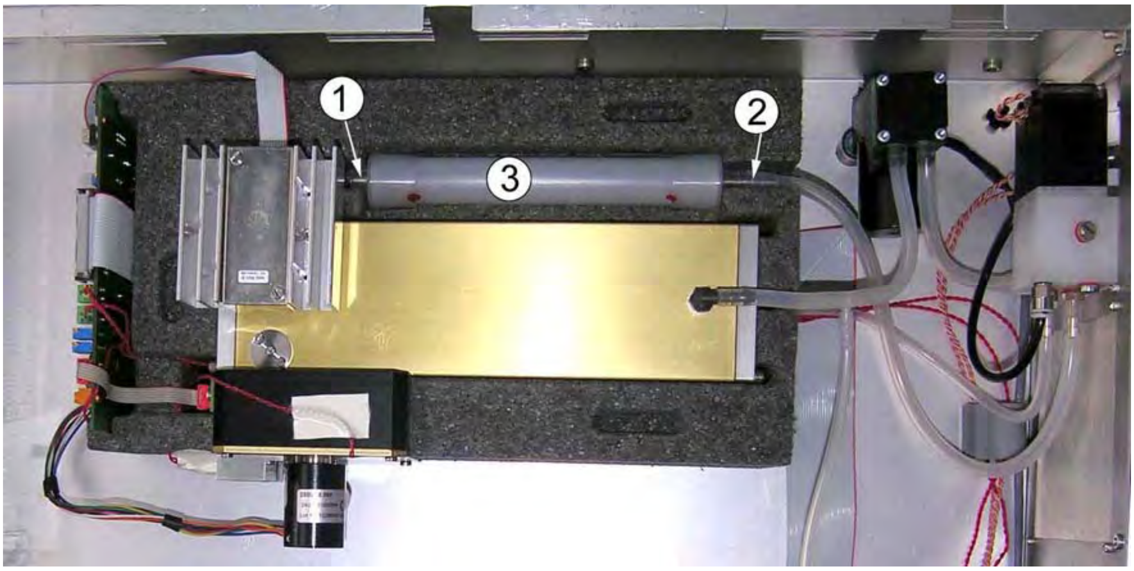
– Reconnect the zero inlet tube (1) and the solenoid valve tube (2).

– Replace the protective foam cover above the measurement module, the protective cover over the analyzer and screw the cover screw located on the rear panel.

– Plug the power cable and power on the analyzer.

– Click-on the alarm icon displayed in the bottom bar of any screen to view active alarms. Then, click-on the internal zero filter alarm and set the internal zero filter countdown to 360.

– Wait at least one hour for the measurement to stabilize, then launch a new zero-reference cycle.



(1) zero inlet tube, (2) solenoid valve tube, (3) internal zero filter

Figure 4–2 – Internal zero filter replacement

Tools required:

- Flat-blade screwdriver, 4 x 100 mm
- Internal zero air filter. Ref.: SAV-K-000229

MAINTENANCE SHEET

MONITOR Serial No.:	OPERATION SHEET: 4.3.4	
Scope: KNF pump maintenance	PAGE: 1/5	Frequency: 1 year

	Date
Before any intervention, unplug the power cable and make sure the pump is turned off. The Diaphragm and Valves are the only pump parts that need replacement. Maintenance operation consists of cleaning and/or replacing them. **Preliminary operation:** – Turn off the analyzer and unplug the power cable. – Unscrew the cover screw located on the analyzer rear panel. Remove the protective cover. – Disconnect the pump from its electrical connection. Unscrew the fluid inlet and the fluid outlet of the pump. – Unscrew and remove the three screws to release the pump from its holder, and perform maintenance outside the analyzer.	
Tools and parts required • Two flat screwdrivers, 1 x 5.5 mm and 0.4 x 2.5 mm • Hexagon socket head wrench n°3 • KNF pump maintenance kit. Ref.: V02-0199 • Cross-tip screwdriver, 4.5 x 75 mm	

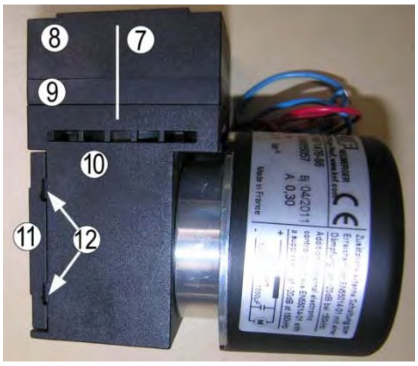
MAINTENANCE SHEET

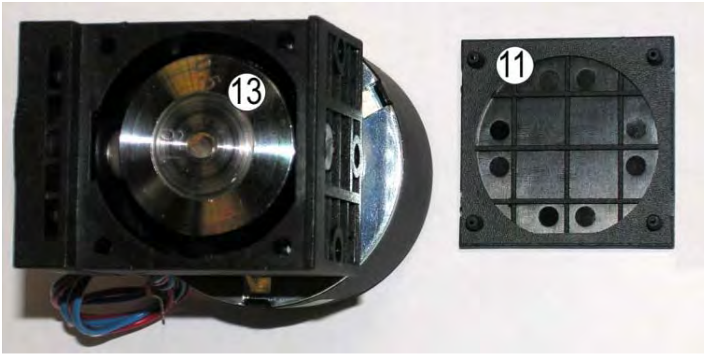
MONITOR Serial No.:	OPERATION SHEET: 4.3.4	
Scope: KNF pump maintenance	PAGE: 2/5	Frequency: 1 year

Dismantling the pump head | Date

– Draw a line with a pen (7) to mark the cover (8), the cylinder head (9), and the pump body (10). This will avoid incorrect part positioning when the pump is reassembled. Remove the cover (11) by delicately turning a screwdriver blade in the slots (12) in order to access the eccentric (13).

– Unscrew the pump head screws (14) to remove the cover (8) and the cylinder head (9) from the pump body (10) in order to release the diaphragm (15), the valves (16), and the O-rings.





(7) pen mark, (8) cover, (9) cylinder head, (10) body pump, (11) eccentric cover, (12) slots, (13) eccentric, (14) screws, (15) diaphragm, (16) valves.

Figure 4–3 – KNF pump head dismantling

Tools and parts required

- Two flat screwdrivers, 1 x 5.5 mm and 0.4 x 2.5 mm
- Hexagon socket head wrench, n°3
- KNF pump maintenance kit. Ref.: V02-0199
- Cross-tip screwdriver, 4.5 x 75 mm

MAINTENANCE SHEET

MONITOR Serial No.:	OPERATION SHEET: 4.3.4	
Scope: KNF pump maintenance	PAGE: 3/5	Frequency: 1 year

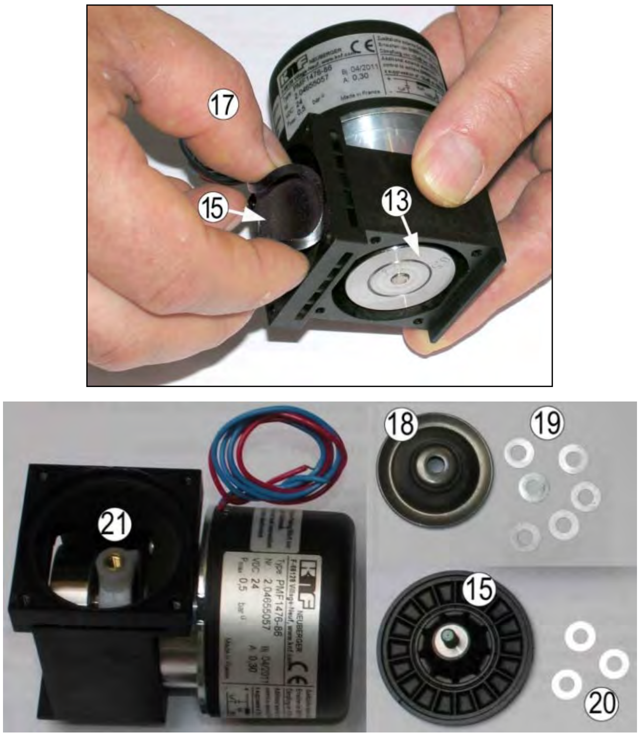
Diaphragm replacement — Date

– Turn the eccentric wheel (13) to position the diaphragm (15) to the upper position, so the diaphragm can be easily grasped by its circumference (17), to unscrew turn counter clockwise.

– The diaphragm is placed on a cupel (18). Remove the washers (19) located between the diaphragm and the cupel, and the washers (20) located between the cupel and the threading hole (21). **Note carefully the washer number at each location because it is critical to install the same washer number at the same location during reassembly.**

– To change the diaphragm (15), put the washers (19) between the diaphragm and the cupel (18) back in place, and install the diaphragm on the cupel. Replace the washers (20) on the external cupel side so they are correctly in place between the cupel and the threading hole (21) upon reassembly.

– Completely rescrew the assembly (diaphragm + cupel + washers) in the threading hole (21).



(13) eccentric, (15) diaphragm, (17) the user grasps the diaphragm by its circumference, (18) cupel, (19) washers, (20) washers, (21) threading hole.

Figure 4–4 – Diaphragm replacement

Tools and parts required

- Two flat screwdrivers, 1 x 5.5 mm and 0.4 x 2.5 mm
- Hexagon socket head wrench, n°3
- KNF pump maintenance kit. Ref.: V02-0199
- Cross-tip screwdriver, 4.5 x 75 mm

MAINTENANCE SHEET

MONITOR Serial No.:	OPERATION SHEET: 4.3.4	
Scope: KNF pump maintenance	PAGE: 4/5	Frequency: 1 year

Date

Valves (22) and O-rings (23) replacement:

The valves are located in the cylinder head. Replace the valves (22) and the O-rings (23), taking care to correctly **fit together the O-rings in their housings.**

(22) valves, (23) O-rings

Figure 4–5 – Valves and O-rings replacement

Tools and parts required

- Two flat screwdrivers, 1 x 5.5 mm and 0.4 x 2.5 mm
- Hexagon socket head wrench, n°3
- KNF pump maintenance kit. Ref.: V02-0199
- Cross-tip screwdriver, 4.5 x 75 mm

MAINTENANCE SHEET

MONITOR Serial No.:	OPERATION SHEET: 4.3.4	
Scope: KNF pump maintenance	PAGE: 5/5	Frequency: 1 year

Date

Pump reassembly

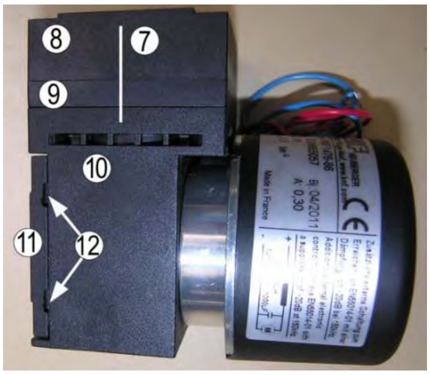
Reassembly is carried out in the reverse order from dismantling.

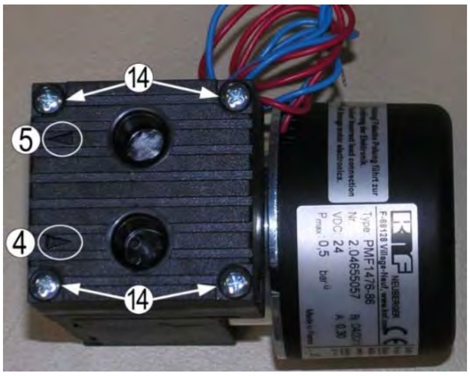
– Reassemble the cover (8) and the cylinder head (9) on the pump body (10) according to the line drawn to mark the various parts (7). Put the four screws of the pump head (14) in place and then screw them clockwise.

– Replace the eccentric cover (11).

– Reassemble the pump in its holder inside the analyzer and replace the screws. Reconnect the electric connector, the fluid inlet line, and the fluid outlet line.

– Replace the analyzer cover, replace the screw, and power on the analyzer.





(4) fluid inlet, (5) fluid outlet, (7) pen mark, (8) cover, (9) cylinder head, (10) body pump, (11) eccentric cover, (12) slots, (14) pump head screws.

Figure 4–6 – Pump reassembly

Tools and parts required

- Two flat screwdrivers, 1 x 5.5 mm and 0.4 x 2.5 mm
- Hexagon socket head wrench, n°3
- KNF pump maintenance kit. Ref.: V02-0199
- Cross-tip screwdriver, 4.5 x 75 mm

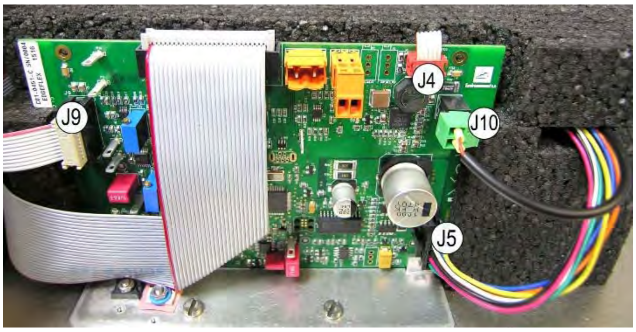
MAINTENANCE SHEET

MONITOR Serial No.:	OPERATION SHEET: 4.3.5	
Scope: Multi passage mirror replacement	PAGE: 1/4	Frequency: 5 years

Proceed in the following order:

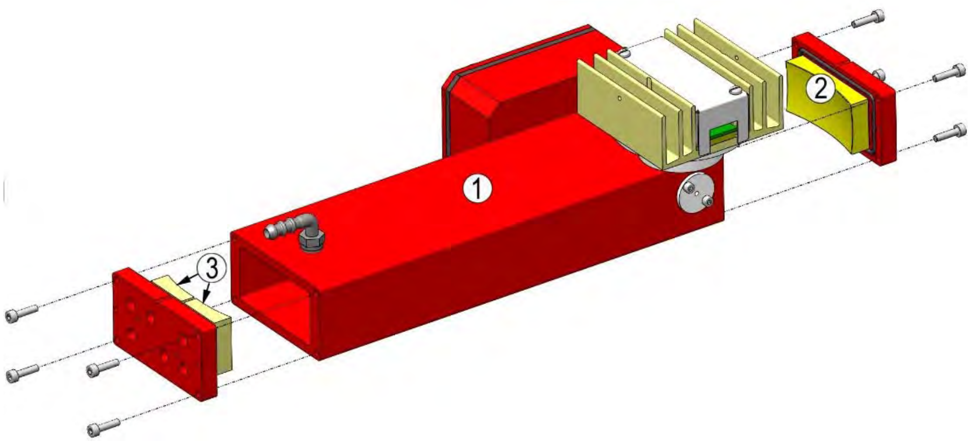
Date

- Turn off the analyzer and unplug the power cable.
- Unscrew the cover screw located on the analyzer rear panel. Remove the protective cover.
- Unplug the electrical connectors from the measurement board J4, J5, J9, J10 (refer to Figure 4–7 to identify connection type).
- Remove the measurement module protective foam cover from its housing.
- Two mirrors are inserted at both ends of the measurement chamber. Before dismantling, refer to Figure 4–8 to identify single mirror and double mirror location.



(J4) « Chopper » modulation and CO/N_2 modulation, (J5) Correlation wheel motor, (J9) IR detector, (J10) IR source.

Figure 4–7 – Measurement board connectors



(1) measurement chamber body, (2) single mirror, (3) double mirror.

Figure 4–8 – Measurement chamber exploded view

Tools required

- Flat-blade screwdriver, 4 x 100 mm
- Allen wrench N°2.5 (hexagonal wrench N°2.5)
- Mirror kit. Ref.: SAV-K-000230

MAINTENANCE SHEET

MONITOR Serial No.:	OPERATION SHEET: 4.3.5	
Scope: Multi passage mirror replacement	**PAGE: 2/4**	**Frequency: 5 years**

Date

Single mirror replacement

– Use an Allen wrench n°2.5 and unscrew completely to remove the two screws (4) aligned in the same diagonal. Then, turn the two screws (5) aligned in the other diagonal three times to loosen.

– Insert the two screws (4) in the holes (6) and screw until they stop. Then, screw a quarter-turn more to separate the mirror from the chamber.

– Unscrew completely screws (5) and (6) and remove the mirror.

– Dismantle mirror (2) from kit and put in place on the chamber, with the mark (7) located above as shown in Figure 4–10.

– Insert both screws (4) and (5) in the same holes as before dismantling, and screw in alignment with the diagonal.

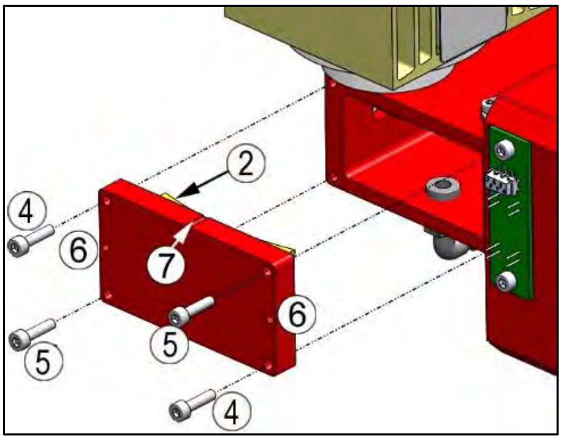


Figure 4–9 – Single mirror replacement

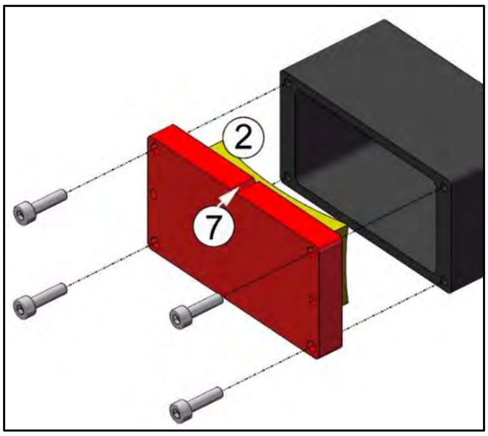


Figure 4–10 – Single mirror kit dismantling

(2) Single mirror, (4) and (5) screws, (6) holes to insert screws, (7) index slot.

Tools required

- Flat-blade screwdriver, 4 x 100 mm
- Allen wrench N°2.5 (hexagonal wrench N°2.5)
- Mirror kit. Ref.: SAV-K-000230

MAINTENANCE SHEET

MONITOR Serial No.:	OPERATION SHEET: 4.3.5	
Scope: Multi passage mirror replacement	PAGE: 3/4	Frequency: 5 years

Double mirror replacement

Date

– Use an Allen wrench n°3 and unscrew completely to remove the two screws (8) aligned in the same diagonal. Then, turn the two screws (9) aligned in the other diagonal three times to loosen.

– Insert the two screws (8) in the holes (10) and screw to stop. Then, still screw a quarter-turn to separate mirror from chamber.

– Unscrew completely screws (9) and (10) and remove the mirror.

– Dismantle mirror (3) from kit and put in place on the chamber, with the mark (11) located above as shown in Figure 4–12.

– Insert both screws (8) and (9) in the same holes as before dismantling, and screw in alignment with the diagonal.

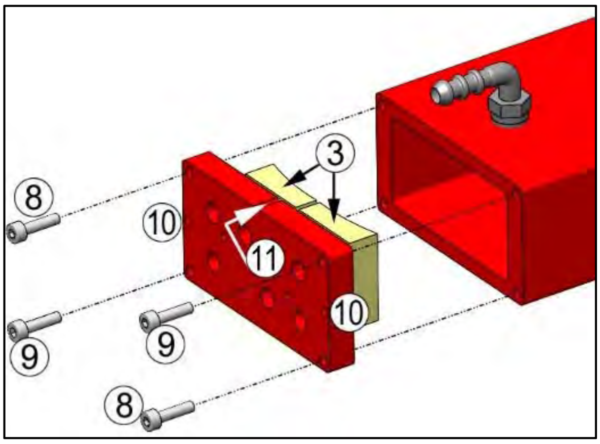


Figure 4–11 – Double mirror replacement

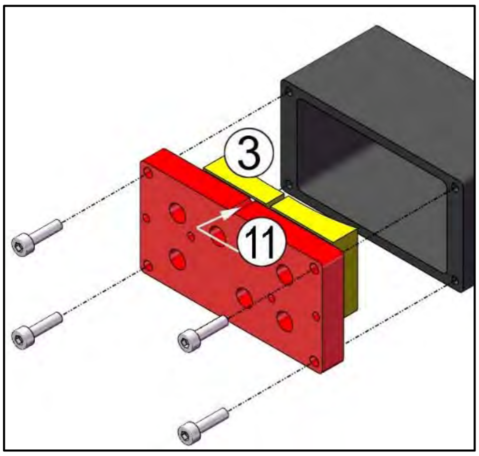


Figure 4–12 – Double mirror kit dismantling

(3) Double mirror, (8) and (9) screws, (10) holes to insert screws, (11) index slot.

Tools required

- Flat-blade screwdriver, 4 x 100 mm
- Allen wrench N°2.5 (hexagonal wrench N°2.5)
- Mirror kit. Ref.: SAV-K-000230

MAINTENANCE SHEET

MONITOR Serial No.:	OPERATION SHEET: 4.3.5	
Scope: Multi passage mirror replacement	PAGE: 4/4	Frequency: 5 years

Measurement chamber reassembly

Date

– Replace the measurement module in its housing, and plug proper electrical connectors to J4, J5, J9 and J10 on the measurement board (refer to Figure 4–7).

– Replace the protective foam cover above the measurement module, the protective cover over the analyzer and screw the cover screw located on the rear panel.

– Plug the power cable and power on the analyzer.

Tools required

- Flat-blade screwdriver, 4 x 100 mm
- Allen wrench N°2.5 (hexagonal wrench N°2.5)
- Mirror kit. Ref.: SAV-K-000230

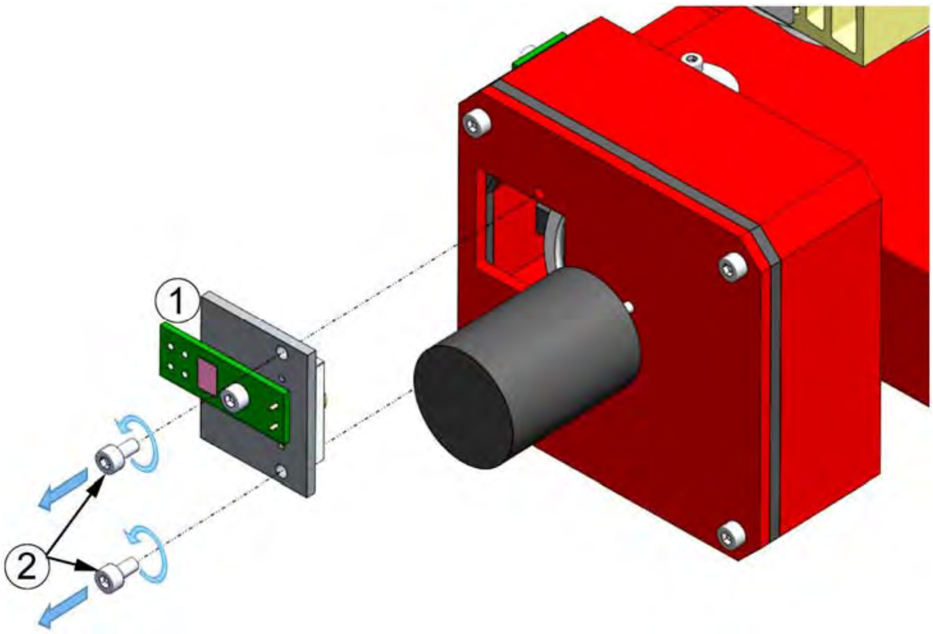
MAINTENANCE SHEET

MONITOR Serial No.:	OPERATION SHEET: 4.3.6	
Scope: Source replacement	PAGE: 1/1	Frequency: 1 year

Proceed in the following order:

Date

- Turn off the analyzer and unplug the power cable.
- Unscrew the cover screw located on the analyzer rear panel. Remove the protective cover.
- Unplug the electrical IR source connector from the measurement board J10.
- Unscrew the two IR source (1) screws (2) and remove it.
- Change the IR source, rescrew the screws (2) and plug the electric connector to the measurement board J10.
- Replace the protective cover over the analyzer and screw the cover screw located on the rear panel.
- Reconnect the power cable and power on the analyzer.
- Wait for warm-up end and launch a zero reference cycle.



(1) IR source, (2) IR source screws.

Figure 4–13 – IR source replacement

Tools required

- Flat-blade screwdriver, 4 x 100 mm
- Allen wrench N°2.5 (hexagonal wrench N°2.5)
- IR source kit. Ref.: SAV-K-000231

MAINTENANCE SHEET

MONITOR Serial No.:	**OPERATION SHEET: 4.3.7**	
Scope: Motor Replacement	**PAGE: 1/2**	**Frequency: 5 years**

	Date
<u>Proceed in the following order:</u> – Turn off the analyzer and unplug the power cable. – Unscrew the cover screw located on the analyzer rear panel. Remove the protective cover. – Remove the measurement module protective foam cover, and remove from its housing. – Unplug the electrical IR source connector from measurement board J10 and the electrical optical fork connector from measurement board J4. – Use an Allen wrench N° 2.5 and unscrew the two screws (1) of the optical fork board (2) to remove. – Unscrew the four correlation box screws (3) and remove the assembly consisting of motor (4)/ source (5)/ plate (6)/ spacer (7)/ correlation wheel (8) assembly. – Use an Allen wrench N° 1.3 and unscrew the two headless screws (9) to remove the correlation wheel (8). – Use an Allen wrench N° 2 and unscrew the four motor screws (10) to remove it. – Replace the motor with a new one. – Reassemble in reverse order. – Plug the electrical IR source connector to J10 and the electrical optical fork connector to J4 on the measurement board. – Replace the protective cover over the analyzer and screw the cover screw located on the rear panel. – Reconnect the power cable and power on the analyzer. – Wait for warm-up end and launch a zero reference cycle.	

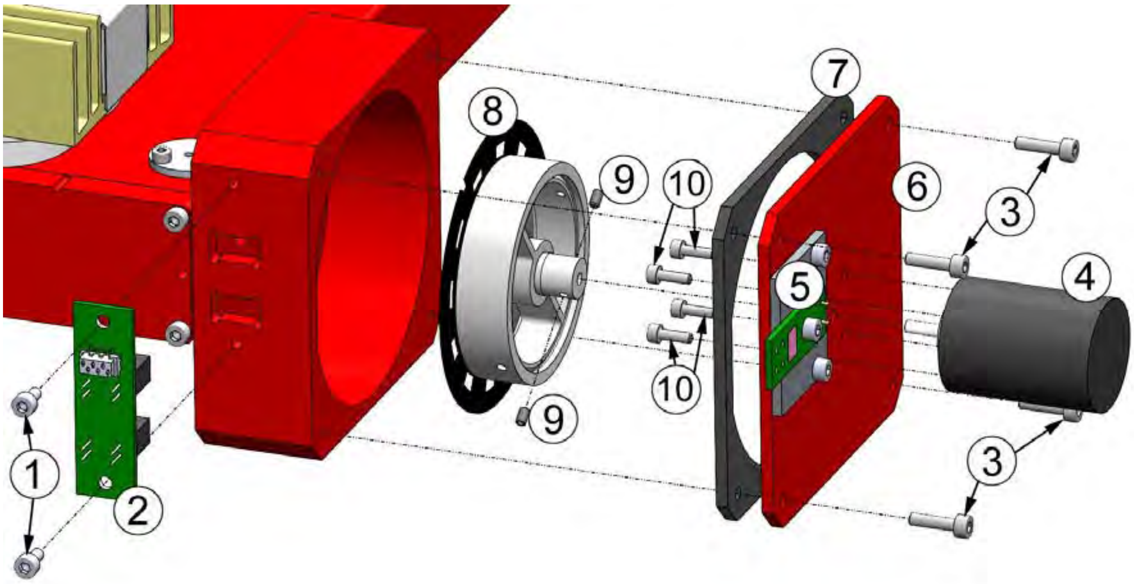
<u>Tools required</u>

- Flat-blade screwdriver, 4 x 100 mm
- Allen wrenches N°1.3, 2, 2.5
- Motor assembly. Ref.: V01-0018

MAINTENANCE SHEET

MONITOR Serial No.:	OPERATION SHEET: 4.3.7	
Scope: -Motor replacement	PAGE: 2/2	Frequency: 5 years

Date



(1) optical fork board screws, (2) optical fork board, (3) correlation box screws, (4) motor, (5) IR source, (6) plate, (7) spacer, (8) correlation wheel, (9) correlation wheel headless screws, (10) motor screws

Figure 4–14 – Motor replacement

Tools required

- Flat-blade screwdriver, 4 x 100 mm
- Allen wrenches N°1.3, 2, 2.5
- Motor assembly. Ref.: V01-0018-A

4.4 KITS AND SPARE PARTS SET FOR CO12e MAINTENANCE

Maintenance kit for 1 year - Ref.: CO12e-K

Line Nb	Designation	Reference	Qty
1	Internal Zero Air Filter	SAV-K-000229	1
2	Teflon filter (porosity 5µm - ∅ 47 mm)	F05-11-842	25
3	Kit for KNF pump	V02-0199	1
4	IR Source Kit	SAV-K-000231	1

CHAPTER 5

CORRECTIVE MAINTENANCE

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5. CORRECTIVE MAINTENANCE

Analyzer corrective maintenance must be carried out only by qualified people using the information provided in this document.

The monitor automatically and continuously self-tests its main components. When any malfunction is detected: the alarm icon ⚠ is displayed and blinks on the home page and in the menu bar of all software screens, next to the date and analyzer name.

It is necessary to touch the alarm icon to directly access the « *DIAGNOSTIC ⇨ Current alarms* » screen and check the malfunction origin.

Table 5–1 summarizes the main faults indicated by the unit with their corresponding possible corrective actions.

Table 5–1 – List of faults and corrective actions

Alarm message (Min./Max. values)	Possible cause(s)	Possible corrective action(s)
DAC out of range Min. value: 0 point Max. value: 4095 points	– Current measurements exceed the set DAC range. – Measurement offset is too high or too low. – Calibration factor is incorrect.	– Set a DAC range complying with the current measurements. – Check and change offset setting. – Check and correct calibration factor setting.
Out of Range Min. value: 0 ppm Max. value: 300 ppm	– CO concentration exceeds the analyzer specification range. – Zero-reference cycle is not performed correctly (example: span gas is used instead of zero).	– Decrease CO concentration by dilution. – Check zero filter and zero-reference cycle setting. Then, perform a new zero-reference cycle.
Zero filter outdated Min. value: Max. value: <10 days	– Internal zero filter has reached its lifetime. – Lifetime countdown of internal zero filter is incorrect.	– Replace internal zero filter and reset lifetime countdown to 360 days. – Reset lifetime countdown to 360 days.
Calibration Fault Min. value: |ΔK/K| >50% Max. value: N.A.	– Calibration cycle was not performed with span gas. – Calibration cycle duration is too short. – Previous calibration is not performed correctly.	– Check span gas cylinder connection to the analyzer span gas inlet. – In the *« Metrology configuration »* screen, check setting of *« Span gas value »* fields indicating span gas concentration connected to the analyzer span gas inlet port. Then, validate former calibration coefficient value. Finally, perform a new calibration cycle if necessary. – In the *« Automatic cycle configuration »* screen, check calibration cycle duration: recommended duration is 300 sec. Change if necessary. – Calculate calibration coefficient using formula: $K_{new}= K_{former} (1+\Delta K/K)$ and correct in *« Metrology configuration »* screen. Then, the analyzer exits alarm mode. Finally, launch a new calibration cycle if necessary.

Alarm message (Min./Max. values)	Possible cause(s)	Possible corrective action(s)
No chamber pressure Min. value: not present Max. value: present	– Chamber pressure sensor cable is disconnected.	– Connect chamber pressure sensor cable.
Chamber pressure Min. value: 300 hPa Max. value: 1200 hPa	– If chamber pressure is abnormally low: • Either sample, zero or span inlet ports are closed, • Or dust filter is clogged or dirty. • Or solenoid valve block is clogged or dirty. • Or chamber pressure sensor is faulty. – If chamber pressure is abnormally high: • Either gas flow of the analyzer inlet ports is too high, and the excess vent is not connected. • Or pressure sensor is faulty.	• Open sample, zero or span inlet analyzer ports. • Check dust filter and replace if necessary, • Check if the sampling line is dirty or kinked. • Check solenoid valve block status: clean with dry, oil-free, compressed air or replace if cleaning is not possible. • Replace chamber pressure sensor. • Check if the excess vent is connected. • Replace pressure sensor.
Flow Fault Min. value: 5 l/h Max. value: 90 l/h	– Pump cable is disconnected. – Pump inlet port is disconnected. – Interconnection board pump command is inactive. – Pressure sensor’s inlet ports of pump and chamber are disconnected. – Restrictor is clogged or dirty.	– Connect pump cable to interconnection board. – Connect restrictor outlet to pump inlet. – Check that the interconnection board pump command is active and the controller board operates correctly. – Check connections of pump and chamber pressure sensors. – Check restrictor and clean if necessary.

Alarm message (Min./Max. values)	Possible cause(s)	Possible corrective action(s)
No cham. Temp Min. value: N.A. Max. value: N.A.	– Chamber temperature sensor cable is disconnected.	– Connect chamber temperature sensor cable.
Cham. T open Min. value: N.A. Max. value: > 70°C	– Chamber temperature sensor is connected but connection is faulty (as an open circuit).	– Replace temperature sensor: analyzer exits alarm mode after 60 sec.
Cham. T shortcut Min. value: < 5°C Max. value: N.A.	– The chamber temperature sensor is connected, but connection is faulty (as a closed circuit).	– Replace chamber temperature sensor: analyzer exits alarm mode after 60 sec.
Chamber temperature Min. value: 44°C Max. value: 48°C	– Controller board configuration is faulty.	– Replace controller board with a calibrated controller board.
No source Temp. Min. value: absent Max. value: N.A.	– IR source temperature cable is disconnected.	– Connect IR source temperature sensor cable.
Source. T open Min. value: N.A. Max. value: > 70°C	– IR source temperature sensor cable is connected but connection is faulty (as an open circuit).	– Replace IR source temperature sensor: the analyzer exits alarm mode after 60 sec.
Source. T shortcut Min. value: < 5°C Max. value: N.A.	– IR source temperature sensor cable is connected, but connection is faulty (as a closed circuit).	– Replace IR source temperature sensor: the analyzer exits alarm mode after 60 sec.
Source temperature Min. value: 44°C Max. value: 48°C	– Controller board configuration is faulty.	– Replace controller board with a calibrated controller board.
No internal Temp Min. value: absent Max. value: absent	– Internal temperature sensor cable is not connected.	– Connect internal temperature sensor cable.

Alarm message (Min./Max. values)	Possible cause(s)	Possible corrective action(s)
Internal temperature Min. value: 5°C Max. value: 50°C	– Ambient temperature is not within the recommended range.	– Install the analyzer in a 5-45°C thermo-controlled room.
IR source fault Min. value: 600 mA Max. value: 1000 mA	– IR source cable is disconnected. – IR source is faulty. – IR source power supply is faulty.	– Reconnect IR source cable. – Replace IR source. – Replace measurement board.
Peltier fault Min. value: 50 mA Max. value: 1200 mA	– Detector is missing. – Detector temperature is close to ambient temperature: Peltier element is faulty. – Peltier element is overheating because of incorrect temperature setting. – Peltier element is overheating for any other cause than incorrect temperature setting.	– Connect detector. – Check or replace detector. – In « DIAGNOSTIC » menu, check that the temperature detector is set to -20°C. – Using external temperature probes, check that the chamber temperature is under 50°C.
Motor fault Min. value: 1015 rpm Max. value: 1035 rpm	– Motor is disconnected. – Motor cannot reach the set speed. – Motor is blocked. – Electronic components for motor control are out of service.	– Turn off the analyzer and reconnect the motor. Then, turn on the analyzer. – Check motor speed: • If motor speed is higher than 1050 rpm, motor speed setting is faulty: ask ENVSA for a configuration file update. • Otherwise motor is faulty and need to be replaced. – Make sure wheel is not blocked inside correlation box. – Replace measurement board.

Alarm message (Min./Max. values)	Possible cause(s)	Possible corrective action(s)
Fork fault Min. value: 3500 Hz Max. value: 4500 Hz	– Fork board photodiode is faulty. – Fork board ribbon is faulty.	– Replace fork board. – Check fork board ribbon connectors.
Top synchro fault Min. value: 1 top/turn Max. value: 1 top/turn	– Fork board is not correctly mounted. – Fork board ribbon is faulty. – The fork board is faulty.	– Check fork board and fix it. – Check connections and replace the ribbon if necessary. – Replace the fork board.
IR signal fault Min. value: 100 mV Max. value: 4000 mV	– Gain setting is out of signal range limits. – IR source is not mounted correctly or IR source window is damaged. – Chamber mirrors are missing or misaligned. – Detector is faulty. – Measurement board is faulty.	– Adjust detector preampli gain, or adjust measurement board signal gain. – Check IR source mounting or replace IR source. – Check that the mirrors are correctly fixed and tightened. – Replace detector. – Replace measurement board.
Meas. Signal Min. value: 50 mV Max. value: 1200 mV	– IR signal frequency and phase are incorrect.	– Check chopper modulation signal. – Perform frequency/phase calibration as recommended.
Ref. Signal Min. value: 50 mV Max. value: 1200 mV	– IR signal frequency and phase are incorrect.	– Check chopper modulation signal.
NO Controller board Min. value: absent Max. value: N.A.	– Controller board is unplugged. – Controller board is not compliant with the analyzer or firmware is missing. – Controller board is faulty	– Disconnect mains cable and turn off the analyzer. Reconnect the controller board ribbon. – Update controller board. – Replace controller board.

Alarm message (Min./Max. values)	Possible cause(s)	Possible corrective action(s)
NO Measure board Min. value: absent Max. value: N.A.	– Measurement board is disconnected. – Measurement board is not compliant with the analyzer or firmware is missing. – Measure board is faulty.	– Turn off the analyzer and disconnect power supply cable. Reconnect measurement board ribbon. – Update measurement board. – Replace Measure board.
Supply fault Min. value: N.A. Max. value: N.A.	– Supply board is faulty. – Measurement board microcontroller is faulty. – Abnormal power consumption is detected. – 24 V power supply is not stable.	– Replace supply board. – Replace measurement board. – Check that all devices as solenoid valves, laminar heating, motor, or other external devices are connected to 24 V external relay output. – Replace power supply.
5 V sensor fault Min. value: 4.75 V Max. value: 5.25 V	– Power supply board is faulty. – 5 V sensors are faulty.	– Replace power supply board. – Check all pressure and temperature sensors.

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Table 5–2 – Interconnection board configuration and LEDs description

Jumpers	Connections
J1	Controller board (with ribbon cable)
J2	Power supply board
J3	ARM20 board (with ribbon cable)
J4	24 V general power supply from 230 V/24 V supply box
J5	Pump pressure sensor board
J6	Zero SV
J8	Span SV
J9	Chamber pressure sensor board
J10	Rack fan
J15	24 V Estel board power supply, 2e series rear panel
J19	SV zero/span and SV measurement power supply, rear panel
J20	CO chamber pump
J22	Additional CO chamber wheel motor (not used)
J23	External TCP/IP LAN
J24	Internal TCP/IP
J27	CO measurement board
J28	External USB1
J29	Internal temperature
J30	External USB2
J31	Internal USB3

LED N°	Identification	LED turned on	LED turned off
LED1	Span SV	Active	Disabled
LED3	Rack fan	Rotating	Stopped
LED4	Zero SV	Active	Disabled
LED13	+ 24 V	Present	Not present

SV: solenoid valve

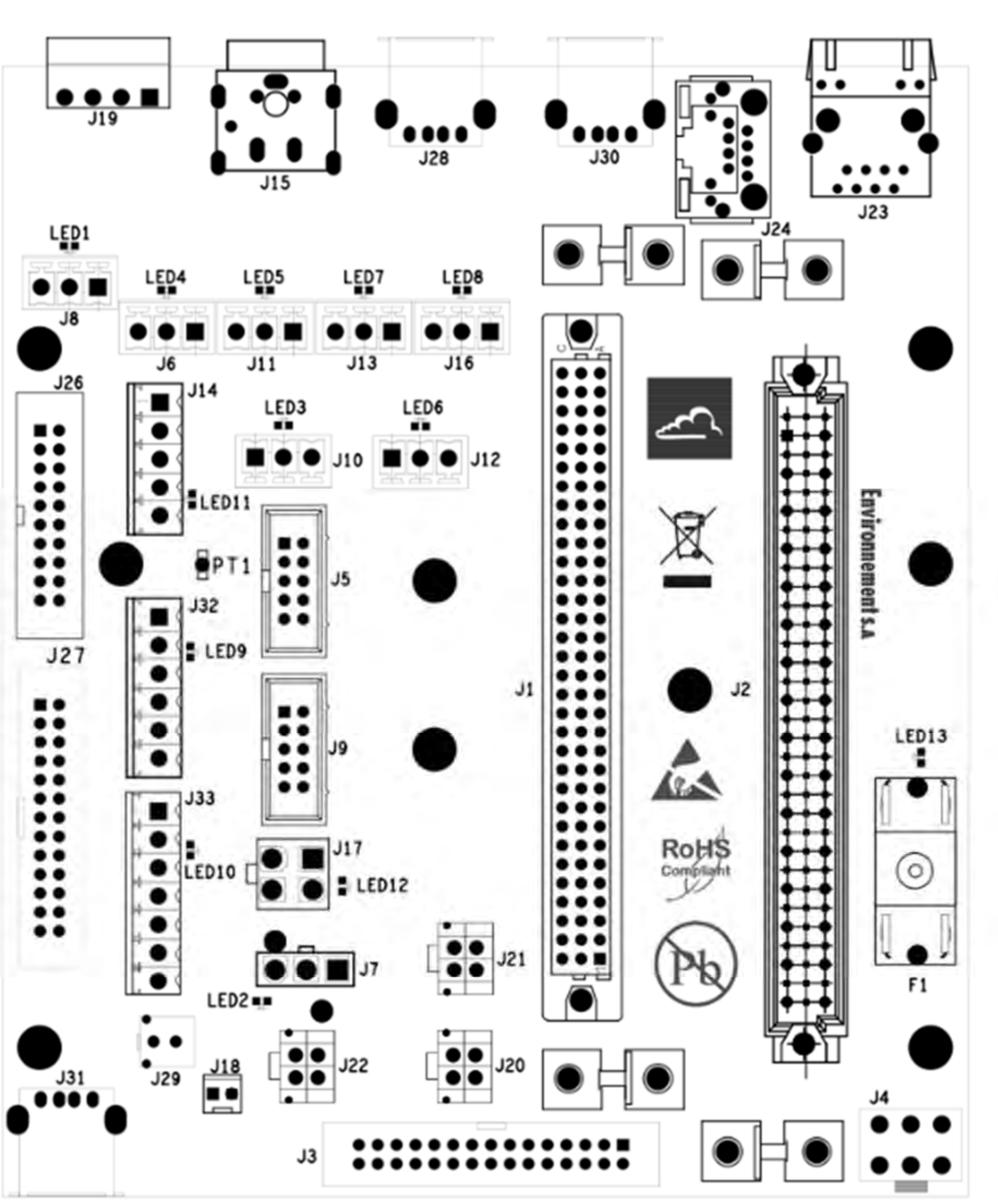

Figure 5–1 – Interconnection board diagram

Table 5–3 – Controller board connections and LEDs description

Jumpers	Connections
J1	INTERCONNECTION board
J3	Programming

LED N°	Identification	Color	Turned on	Turned off	Blinking
LED1	Activity indicator	Orange	Active	Disabled	– Fast, loading mode. – Slow, (1 Hz) normal mode
LED3	USB on Channel 1	Green	Detected	Not detected	N.A.
LED6	USB on Channel 2	Green	Detected	Not detected	N.A.
LED10	USB on Channel 3	Green	Detected	Not detected	N.A.
LED12	USB on Channel 4	Green	Detected	Not detected	N.A.

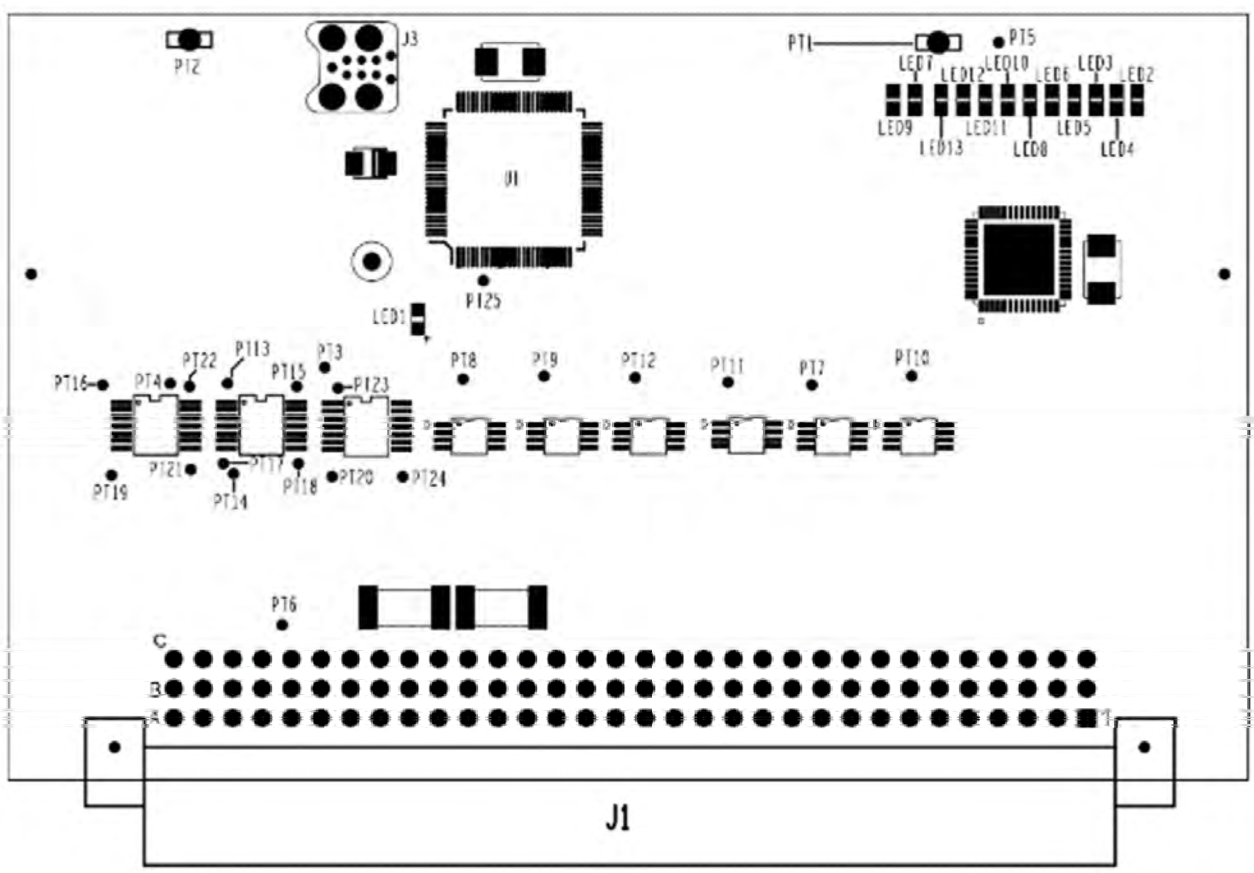

Figure 5–2 – Controller board diagram

Table 5–4 – Power supply board connections and LEDs description

Jumpers	Connections
J1	INTERCONNECTION board

LED N°	Identification	Color	Turned on	Turned off
LED1	+24 V indicator	Orange	Present	Not present
LED2	+5 V indicator	Orange	Present	Not present
LED3	+12 V indicator	Orange	Present	Not present
LED4	+3.3 V indicator	Blue	Present	Not present

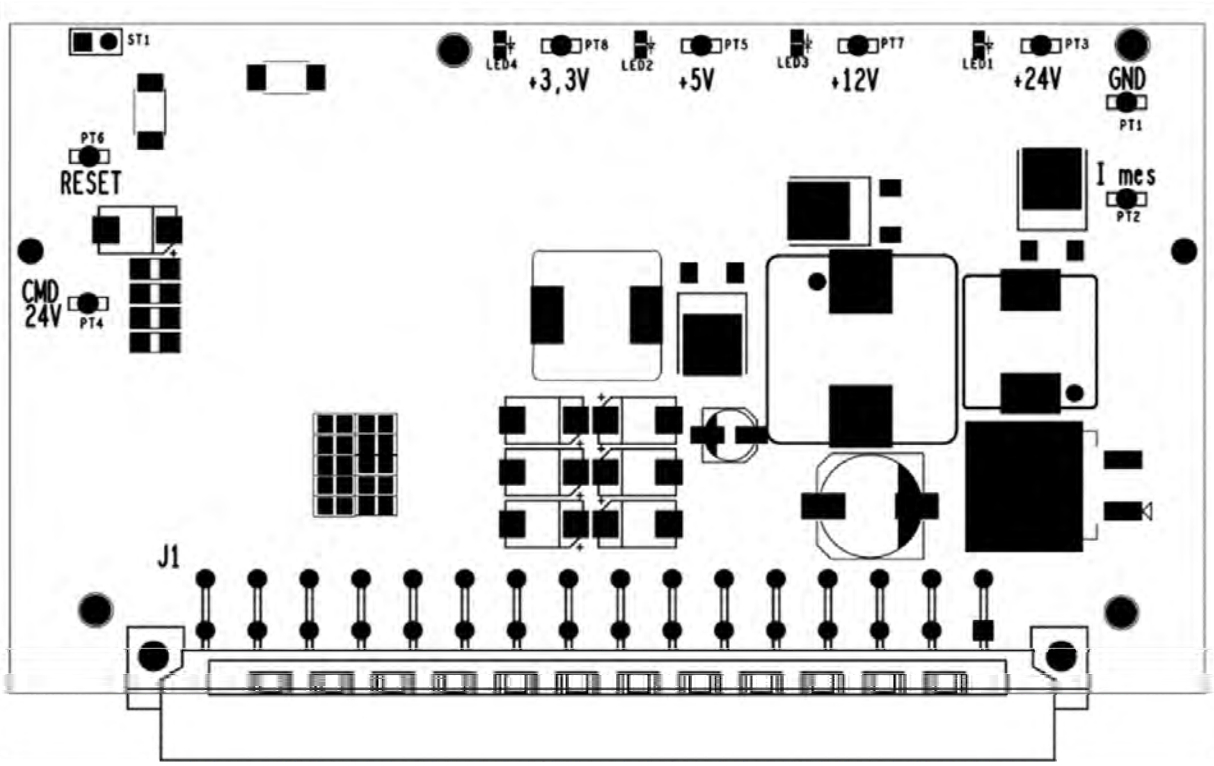

Figure 5–3 – Power supply board diagram

Table 5–5 – Test points, LEDs description and connections for the CO measurement board

Jumpers	Connections
J1	Ribbon cable towards the Interconnection board
J2	Heating of CO measurement chamber
J3	T° sensor of CO measurement chamber
J4	« Chopper » modulation and CO/N_2 modulation
J5	Correlation wheel motor
J9	IR detector
J10	IR source
J11	CPLD programming
J13	Microcontroller programming

Jumpers	Test points/Signal type
PT1	GND
PT2	analog GND
PT3	-12 V
PT4	+12 V
PT5	3.3 V
PT6	5 V
PT7	4 V
PT8	1.8 V
PT12	Analog synchro top
PT13	Analog modulation chopper
PT18	0-4 V clamped IR signal
PT19	Signal IR clamp
PT20	(-12 V / 12 V) not-clamped IR signal
PT21	Acquisition clock
PT22	VOC PLL
PT23	Logic synchro top
PT24	Logic modulation chopper
PT25	Motor power

LED N°	Identification	Color	Turned on	Turned off	Blinking
LED1	CO measurement chamber Heating indicator	Red	100%	Not in use	– Regulating
LED2	Chopper modulation Indicator ~~of~~	Green	Detected	Not detected	N.A.
LED3	"CO/ N2" synchronization passage indicator	Green	Detected	Not detected	N.A.
LED4	USB indicator	Green	Active	Inactive	N.A.
LED5	Board activity indicator	Orange	N.A.	No activity	– Fast, loading mode – Slow (1Hz), normal mode
LED6	IR source regulation indicator	Green	OK	Problem	N.A.

Potentiometer	Nature of adjustment
P1	Adjusts the temperature IR detector set point
P5	Adjusts the IR signal gain

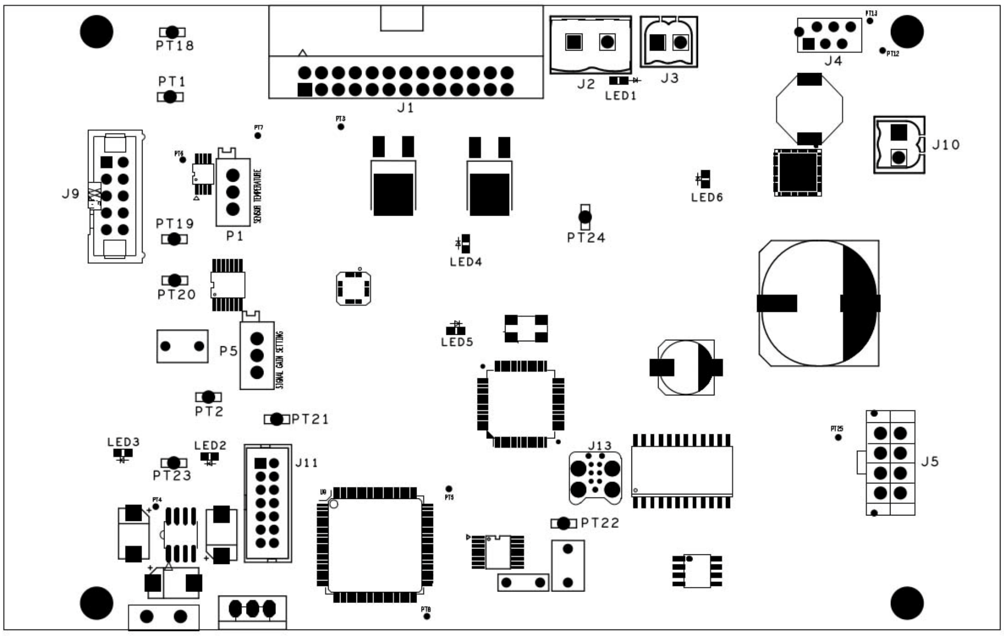

Figure 5–4 – CO measurement board diagram

Table 5–6 – ARM20 board description

Identification	Functions
J1	LCD screen
J2	Interconnection board link
J6	Touchscreen
J9	Push button link
SW1	Recovery ARM20
SW2	Reset
SW3	Power button

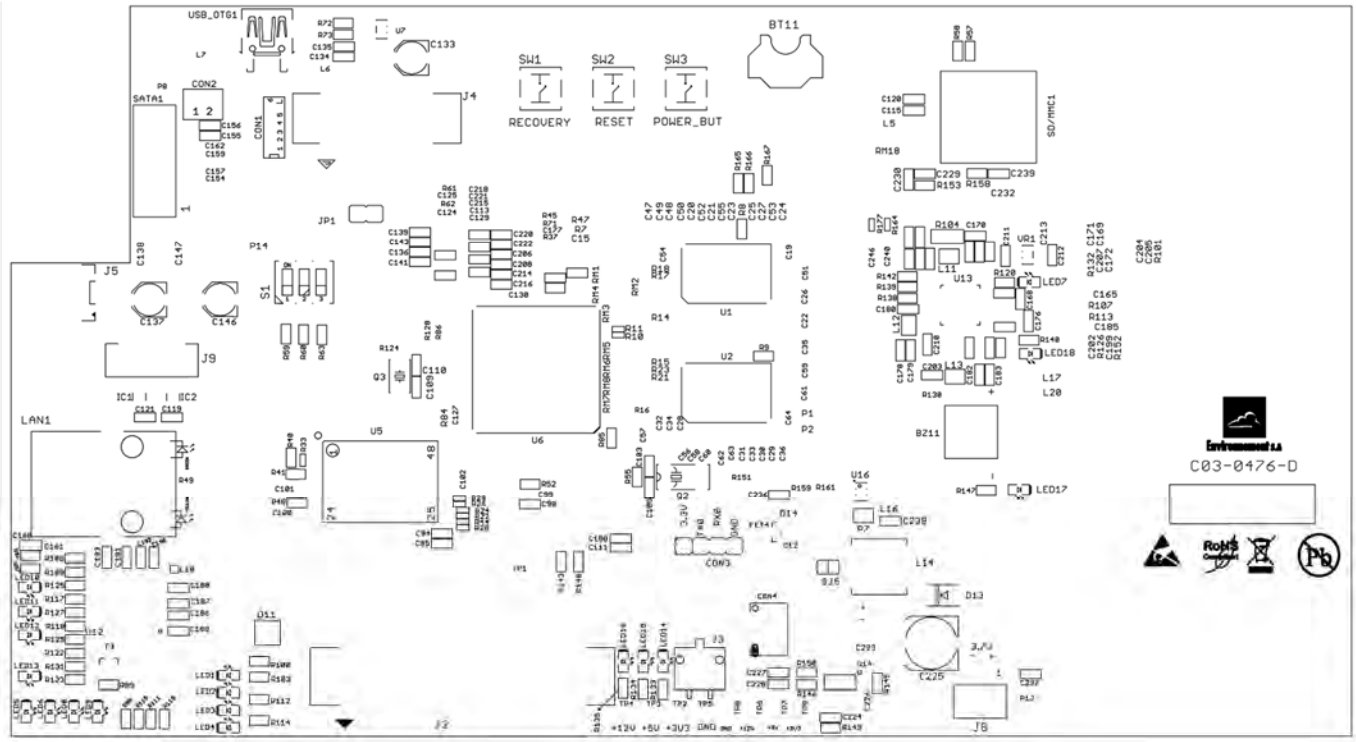

Figure 5–5 – ARM20 board

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