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Report on the performance test for the APOA-380 ambient air measuring system manufactured by Horiba Europe GmbH for the component ozone

TÜV Report: EuL/21262682/C
Cologne, 07 February 2025

www.umwelt-tuv.de

tre-service@de.tuv.com

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TÜV Rheinland Energy & Environment GmbH
D - 51105 Cologne, Am Grauen Stein,
Tel: + 49 (0) 221 806-5200, fax: 0221 806-1349

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Report on the performance test for the APOA-380 ambient air measuring system manufactured by Horiba Europe GmbH for the component ozone

AMS designation: APOA-380

Manufacturer:
Horiba Europe GmbH
Hans-Mess-Strasse 6
61440 Oberursel
Germany

Test period: March 2024 to August 2024

Date of report: 07 February 2025

Report number: EuL/21262682/C

Editor:
Dipl.-Ing. Martin Schneider
Phone: +49 221 806-1614
martin.schneider@de.tuv.com

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Total		263	Pages

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Table of contents

List of tables

List of figures

Blank page

1. Summary and certification proposal

1.1 Summary Overview

On behalf of Horiba Europe GmbH, TÜV Rheinland Energy & Environment GmbH carried out performance testing for the APOA-380 ambient air measuring system for the component ozone. The test was performed in respect of the following standards and requirements:

- VDI Guideline 4202 Part 1: Performance test, declaration of suitability, and certification of point-related measuring systems for gaseous air pollutants, April 2018
- EN 14625: Ambient air - Standard method for the measurement of the concentration of ozone by ultraviolet photometry, December 2012
- EN 14625: Ambient air - Standard method for the measurement of the concentration of ozone by ultraviolet photometry, December 2024

The APOA-380 measuring system measures the ozone component using the ultraviolet photometry method. The measuring principle thus corresponds to the EU reference method according to standard EN 14625. The tests were performed in a laboratory and in a three-month field test in Cologne. The following measuring ranges were tested.

Table 1: Measuring ranges tested

Measured component	Measuring range in [µg/m³] [1]	Measuring range in [ppb] or [nmol/mol]
Ozone	0 – 500	0 – 250

[1] The specifications refer to 20 °C and 101.3 kPa

During performance testing, the AMS met the requirements specified in standard EN 14625 (2012) and VDI 4202, Part 1 (2018).

In December 2024, the revised version of EN 14625 was published in English (date of publication 18 December 2024). The standard is expected to be published in German in spring 2025. During testing of the Horiba APOA-380 measuring system, the future requirements of EN 14625:2024 were also taken into account. Test were also performed regarding test criteria with revised requirements and were analysed on the basis of the requirements of EN 14625:2024.

Specifically, the following criteria apply:

- 8.4.7 Sensitivity coefficient to sample gas pressure
- 8.4.8 Sensitivity coefficient to the sample gas temperature
- 8.4.9 Sensitivity coefficient to the surrounding temperature

The analyses based on the requirements of EN 14625:2024 are presented in Annex 1 of this report. Additionally, the total uncertainty is also shown there with the test results in accordance with EN 14625:2024.

TÜV Rheinland Energy & Environment GmbH therefore recommends the instrument’s approval as a performance-tested measuring system for the continuous monitoring of ozone concentrations.

1.2 Certification proposal

Based on the positive results obtained, the following recommendation on the announcement of the AMS as a certified system is put forward:

AMS designation:

APOA-380 for ozone

Manufacturer:

Horiba Europe GmbH, Oberursel, Germany

Field of application:

For continuous ambient air monitoring of ozone (stationary operation)

Measurement ranges during performance testing:

Component	Certification range	Unit
Ozone	0–500	µg/m³

Software versions:

A7:	P2002638C	1.01
M4:	P2002642B	1.00
Analyzer:	P2002584C	1.02
FPGA:	P2002759A	1.01

Restrictions:

None

Notes:

1. The measuring system also fulfils the requirements of EN 14625:2024
2. This report on the performance test is available online at www.qal1.de.

Test Report:

TÜV Rheinland Energy & Environment GmbH, Cologne
Report no.: EuL/21262682/C dated 07 February 2025

1.3 Summary report on test results

Performance criterion	Requirement	Test result	Satis-fied	Page
7 Performance criteria				
7.3 General requirements				
7.3.1 Measured value display	The measuring system shall have an operative measured value display as part of the instrument.	The measuring system has an operative measured value display at the front of the instrument.	yes	32
7.3.2 Calibration inlet	The measuring system may have a test gas inlet separate from the sample gas inlet.	The measuring system has a test gas inlet separate from the sample gas inlet at the instrument back.	yes	33
7.3.3 Easy maintenance	It should be possible to perform the necessary maintenance works on the AMS without major overheads, preferably from outside.	Maintenance work can be carried out externally with standard tools and reasonable effort.	yes	34
7.3.4 Functional check	Special instruments for this purpose are to be considered as belonging to the equipment, to be used in the corresponding sub-tests and to be evaluated.	The tested measuring system does not have internal devices for operating the functional check.	not applicable	35
7.3.5 Set-up times and warm-up times	The instruction manual shall include specifications in this regard.	Set-up times and warm-up times have been determined.	yes	36
7.3.6 Instrument design	The instruction manual shall include specifications in this regard.	Specifications made in the instruction manual concerning instrument design are complete and correct.	yes	37
7.3.7 Unintended adjustment	Shall secure measuring system against that.	The measuring system is secured against unintended and unauthorised adjustment of instrument parameters by way of a password.	yes	38
7.3.8 Data output	The output signals shall be provided digitally and/or as analogue signals.	The measured signals are available both analogue (4 – 20 mA, 0 – 1/5/10 V) and digitally (via TCP/IP, RS 232, USB).	yes	39
7.3.9 Digital interface	The digital interface shall allow the transmission of output signals, status signals, and others. Access to the measuring system shall be secured against unauthorised use.	The digital transmission of measured values functions correctly and is password-protected against unauthorised access.	yes	40

Performance criterion	Requirement	Test result	Satisfied	Page
7.3.10 Data transmission protocol	Shall meet the requirements stipulated in Table 1 of VDI Guideline 4202 Part 1.	The measuring system has a Bayern-Hessen transmission protocol installed as standard. Measured and status signals are transmitted correctly. The configuration is listed in the manual (see operating manual supplements AP-380 series EU version) in chapter 5 from page 7 onwards.	yes	41
7.3.11 Measuring range	The upper limit of measurement shall be greater or equal to the upper limit of the certification range.	A measuring range of 0 – 250 ppb (500 µg/m³) is set as standard for ozone. Supplementary measuring ranges up to 0 – 10 ppm are possible. The measuring system's upper limit of measurement exceeds the upper limit of the certification range in each case.	yes	42
7.3.12 Negative output signals	Shall not be suppressed (live zero).	The measuring system also provides negative output signals.	yes	43
7.3.13 Failure in the mains voltage	Uncontrolled emission of operation and calibration gas shall be avoided; instrument parameters shall be secured by buffering against loss; when mains voltage returns, the instrument shall automatically reach the operation mode and start the measurement.	On return of mains voltage, the instrument returns to normal operating mode and automatically resumes measuring. The duration of the warm-up phase depends on the duration of the power failure..	yes	44
7.3.14 Operating states	Must be able to be monitored by status signals that can be transmitted telemetrically.	The measuring system provides various ports to ensure comprehensive monitoring and control via an external computer.	yes	45
7.3.15 Switch-over	Switch-over between measurement and functional check and/or calibration shall be possible telemetrically.	As a rule, all necessary work for functional checks can be monitored and controlled directly on the instrument or by telemetric remote control.	yes	46
7.3.16 Instrument software	Shall be displayed when switched on. Changes affecting instrument functions shall be communicated to the test laboratory.	The instrument's software version is displayed. Software changes are communicated to the test laboratory.	yes	47

Performance criterion	**Requirement**	**Test result**	**Satis-fied**	**Page**
7.4 Requirements on performance characteristics for testing in the laboratory				
7.4.1 General requirements	The manufacturer's specifications in the instruction manual shall not contradict the results of the performance test.	Tests were performed based on the performance criteria and requirements of VDI 4202, Part 1 (2018), EN 14625 (2012) and EN 14625 (2024).	yes	48
7.4.2 Test requirements	Has to comply with the requirements set out in VDI standard 4202-1:2018.	Tests were performed based on the performance criteria and requirements of VDI 4202, Part 1 (2018), EN 14625 (2012) and EN 14625 (2024).	yes	49
Section 8.4 provides a summary of the evaluation of performance characteristics determined in the laboratory.				
7.5 Requirements on performance characteristics for testing in the field				
7.5.1 General requirements	Has to comply with the requirements set out in VDI standard 4202-1:2018.	Tests were performed based on the performance criteria and requirements of VDI 4202, Part 1 (2018), EN 14625 (2012) and EN 14625 (2024).	yes	64
7.5.2 Location for the field test	The monitoring station for the field test is to be chosen according to the requirements of the 39th BImSchV such that the expected concentrations of the measured components correspond to the designated task. The equipment of the monitoring station shall allow the implementation of the field test and shall fulfil all requirements considered to be necessary during measurement planning.	The field test location was selected in compliance with the 39th BImSchV. Details on the location of the measuring station are given in chapter 4.3.	yes	65
7.5.3 Test requirements	The measuring systems shall be installed in the monitoring station and, after connecting to the existing or separate sampling system, activated properly. The adjustments of the measuring system shall meet the specifications of the manufacturer. All adjustments are to be documented in the test report.	During the field test, the measuring system was operated and serviced according to the manufacturer's instructions.	yes	66
Section 8.5 provides a summary of the evaluation of performance characteristics determined in the field.				

Performance criterion	**Requirement**	**Test result**	**Satis-fied**	**Page**
8.4 Procedures for determination of the performance characteristics during the laboratory test according to EN 14625				
8.4.3 Response time	Rise and fall response time ≤ 180 s each. Difference between rise and fall response time ≤ 10 s.	The values determined remained considerably below the maximum permissible response time of 180 s at all times. The maximum determined response time for system 1 was 13 s. For system 2 it was 13 s.	yes	73
8.4.4 Short-term drift	The short-term drift at zero must be ≤ 2.0 nmol/mol/12 h. The short-term drift at span level must be ≤ 6.0 nmol/mol/12 h.	For instrument 1 the value for the short-term drift at zero point was 0.19 nmol/mol/. For instrument 2 it was 0.18 nmol/mol/. Short-term drift at reference point was 0.18 nmol/mol for instrument 1 and 0.31 nmol/mol/12 h for instrument 2.	yes	77
8.4.5 Repeatability standard deviation	The performance criteria are as follows: Repeatability standard deviation at zero shall not exceed 1.0 nmol/mol. At a sample gas concentration at the span point it shall not exceed 3.0 nmol/mol.	For instrument 1 the value for the repeatability standard deviation at zero point was 0.03 nmol/mol. For instrument 2 it was 0.08 nmol/mol. Repeatability standard deviation at reference point was 1.25 nmol/mol for instrument 1 and 1.24 nmol/mol for instrument 2.	yes	81
8.4.6 Lack-of-fit of linearity of the calibration function	The deviation from the linearity of the calibration function at zero shall not exceed 5.0 nmol/mol. At concentrations above zero, it shall not exceed 4% of the measured value.	The deviation from the linear regression line for instrument 1 is -0.31 nmol/mol at zero point and no more than 1.41% of the nominal value for concentrations above zero. The deviation from the linear regression line for instrument 2 is 0.03 nmol/mol at zero point and no more than 1.44% of the nominal value for concentrations above zero.	yes	84
8.4.7 Sensitivity coefficient to sample gas pressure	The sensitivity coefficient to sample gas pressure shall be ≤ 2.0 nmol/mol/kPa.	For instrument 1, the sensitivity coefficient to sample gas pressure was 0.09 nmol/mol/kPa. For instrument 2, the sensitivity coefficient to sample gas pressure was 0.05 nmol/mol/kPa.	yes	89

Performance criterion	Requirement	Test result	Satis-fied	Page
8.4.8 Sensitivity coefficient to sample gas temperature	The sensitivity coefficient to the sample gas temperature shall be ≤ 1.0 nmol/mol/K.	For instrument 1, the sensitivity coefficient to sample gas temperature was 0.04 nmol/mol/K. For instrument 2, the sensitivity coefficient to sample gas temperature was 0.05 nmol/mol/K.	yes	91
8.4.9 Sensitivity coefficient to the surrounding temperature	The sensitivity coefficient to the surrounding temperature shall be ≤ 1.0 nmol/mol/K.	The sensitivity coefficient to the surrounding temperature bst did not exceed the performance criterion specified at 1.0 nmol/mol/K. For the purpose of the uncertainty calculation, the largest value bst is used for both instruments. This was 0.229 nmol/mol/K for instrument 1 and 0.174 nmol/mol/K for instrument 2.	yes	93
8.4.10 Sensitivity coefficient to electrical voltage	The sensitivity coefficient to electrical voltage shall not exceed 0.30 nmol/mol/V.	At no test item did the sensitivity coefficient to electrical voltage bv exceed the value of 0.3 nmol/mol/V specified in standard EN 14625. For the purpose of the uncertainty calculation, the largest bv is used for both instruments. For instrument 1, this is 0.05 nmol/mol/V and for instrument 2 it is 0.05 nmol/mol/V.	yes	96
8.4.11 Interferents	Interferents at zero and at concentration $c_{t.}$ The maximum permissible deviation for the interfering component H_2O is ≤ 10.0 nmol/mol and for toluene and m-xylene, ≤ 5.0 nmol/mol each.	This results in a value for the cross-sensitivity at zero of 0.31 nmol/mol for instrument 1 and 0.10 nmol/mol for instrument 2 for H2O, -0.42 nmol/mol for instrument 1 and -0.47 nmol/mol for instrument 2 for toluene and 0.05 nmol/mol for instrument 1 and -0.16 nmol/mol for instrument 2 for m-xylene. This results in a value for the cross-sensitivity at the limit value ct of -1.82 nmol/mol for instrument 1 and -2.60 nmol/mol for instrument 2 for H2O, -1.61 nmol/mol for instrument 1 and -1.98 nmol/mol for instrument 2 for toluene and 0.78 nmol/mol for instrument 1 and 0.31 nmol/mol for instrument 2 for m-xylene.	yes	98
8.4.12 Averaging test	The averaging effect shall not exceed 7% of the measured value.	The performance criterion specified by standard EN 14625 is fully satisfied.	yes	101

Performance criterion	Requirement	Test result	Satis-fied	Page
8.4.13 Difference sample/calibration port	The difference between the sample and calibration ports shall not exceed 1%.	The performance criterion of EN 14625 was fully met with a maximum deviation of 0.25 % and -0.14 % respectively.	yes	104
8.4.14 Residence time in the analyser	The residence time in the analyser shall not exceed 3.0 s.	Residence time in the analyser was 1.2 s.	yes	106
8.5 Determination of the performance characteristics during the field test according to EN 14625				
8.5.4 Long-term drift	The long-term drift at zero point shall not exceed ≤ 5.0 nmol/mol. Long-term drift at span level shall not exceed 5% of the certification range.	Maximum long-term drift at zero point $D_{l,z}$ was at -1.27 nmol/mol for instrument 1 and -0.36 nmol/mol for instrument 2. Maximum long-term drift at reference point $D_{l,s}$ was at -1.56% for instrument 1 and -2.09% for instrument 2.	yes	107
8.5.6 Inspection interval	The period of unattended operation of the AMS shall be at least 2 weeks.	The necessary maintenance tasks determine the period of unattended operation. In essence, these include contamination checks, plausibility checks and checks of potential status/error warnings. The particle filter has to be changed depending on the dust load at the measuring point. A check of the zero and span point must be carried out at least every 14 days in accordance with EN 14625.	yes	112
8.5.5 Reproducibility standard deviation for ozone under field conditions	Reproducibility standard deviation under field conditions shall not exceed 5% of the mean value over a period of three months.	The reproducibility standard deviation for ozone under field conditions was 4.13 % related to the mean value over the duration of the field test of 3 months. Thus, the requirements of EN 14625 are satisfied.	yes	110
8.5.7 Period of availability of the analyser	Availability of the analyser shall be at least 90%.	The availability was at 100%. Thus, the requirement of EN 14625 is satisfied.	yes	113

2. Task definition

2.1 Nature of the test

On behalf of the company Horiba Europe GmbH, TÜV Rheinland Energy & Environment GmbH carried out performance testing for the APOA-380 ambient air measuring system. The test was carried out as a complete performance test.

2.2 Objectives

The AMS is designed to determine ozone concentrations in ambient air in the following concentration ranges:

Component	Certification range	Unit
Ozone	0 - 500	µg/m³

The APOA-380 measuring system measures the ozone component using the ultraviolet photometry method.

The task was to carry out performance testing in line with the applicable standards and taking into consideration the latest developments in the field.
The test was performed on the basis of the following standards:

- VDI Guideline 4202 Part 1: Automated measuring systems for air quality monitoring – Performance test, declaration of suitability, and certification of point-related measuring systems for gaseous air pollutants, April 2018
- EN 14625: Ambient air - Standard method for the measurement of the concentration of ozone by ultraviolet photometry, December 2012
- EN 14625: Ambient air - Standard method for the measurement of the concentration of ozone by ultraviolet photometry, December 2024

3. Description of the AMS tested

3.1 Measuring principle

The APOA-380 ambient air measuring system is a continuous ozone analyser. The measuring principle is based on ultraviolet absorption. It was designed for the continuous measurement of ozone in ambient air.

Figure 1: The APOA-380 analyser

The measuring principle is based on the determination of light absorption through the gas being measured in the characteristic wavelength range for the gas, which for the ozone component is in the UV range at a wavelength of 254 nm. The evaluation is done by measuring the absorption based on the dependence between the gas concentration and the amount of absorbed light according to Beer-Lambert's law:

Beer-Lambert Law:

$$I = I_0 * e^{-\alpha L c}$$

at standard temperature and pressure (STP)

I_o is light intensity without absorption
I is intensity with absorption
L is the absorption path or distance that the light travels during absorption
c is the concentration of the absorbing gas, in this case CO
α is the absorption coefficient (this provides information about the degree of absorption)
To solve this equation for c, it must be rearranged as follows:

$$c = \ln\left(\frac{I_0}{I}\right) * \left(\frac{1}{\alpha L}\right) \text{ at STP}$$

Since both the ambient temperature and pressure influence the density of the sample gas and thus the number of ozone molecules present in the absorption tube, this changes the amount of light absorbed.

To determine this effect, the equation was extended by the following addition:

$$c = \ln\left(\frac{I_0}{I}\right) * \left(\frac{1}{\alpha L}\right) * \left(\frac{T}{273K} * \frac{29{,}92 inHg}{p}\right)$$

T = sample gas temperature in Kelvin
p = sample pressure in inches of mercury

3.2 AMS scope and set-up

The APOA-380 ozone analyser determines the concentration of ozone (O_3) in a sample drawn into the instrument. In the APOA-380, the intensity of ultraviolet light is measured after it has passed through a measuring chamber. The light is absorbed in proportion to the amount of ozone present. Every four seconds, a shuttle valve switches between a gas flow with ozone and a reference gas flow that has been purged of ozone. These measured values are calculated together with the sample gas pressure and temperature to provide a stable ozone measurement value.

The photometer in the APOA-380 analyser uses a high-power mercury vapour lamp to generate a UV light beam. This beam passes through a cell, which is non-reactive with O_3 and permeable to UV radiation at 254 nm, and then enters the absorption tube filled with sample gas. As ozone absorbs UV radiation efficiently, the absorption path for a measurable drop in UV intensity is long enough (approx. 42 cm) so that the light beam only has to pass through the absorption tube once. The UV light passes through a similar cell at the other end of the absorption tube and is detected by a vacuum diode. This diode only detects beams at or near a wavelength of 254 nm. The accuracy of the detector is high enough so that no additional optical filter for UV light is required. The detector reacts to the UV light and emits a voltage that is directly proportional to the light intensity. The voltage is digitised and sent to the CPU of the device to be used for calculating the O_3 concentration in the absorption tube.

Table 2 lists a number of important instrument characteristics of the APOA-380.

Table 2: APOA-380 instrument characteristics (manufacturer's specifications)

Measured range:	Maximum 0 – 10 ppm (selectable)
Units:	ppb / ppm / µg/m³ / mg/m³
Measured compounds:	Ozone
Sample flow rate	Approx. 0.6 litre/min (during the test)
Outputs:	• Ethernet TCP/IP • Modbus • Serial interface, RS232 • 0 – 1/5/10 Volt analogue • 4 – 20 mA analogue • USB
Input voltage:	100 V to 240 V, 50 Hz or 60 Hz
Power:	80 W; 140 W max.
Dimensions (l x w x h) / weight:	568 x 430 x 221 mm / ~ 15 kg

3.3 AMS adjustment

The measuring system was commissioned according to manufacturer instructions. No internal zero adjustment cycle was activated during performance testing.

The APOA-380 analyser firmware processes sample concentration data via a programmed adaptive filter. During operation, the firmware can automatically switch between two different temporal filter lengths depending on the respective conditions. When measuring stable concentrations, the firmware calculates an average of the last measurements by default. This ensures stable readings. If the filter detects rapid changes in concentration, it reduces the averaging time to allow the analyser to respond more quickly. The adaptive filter is always active and can neither be adjusted nor deactivated by the user.

3.4 Software versions

The APOA-380 analyser works with different boards and processors. The system display shows 5 different software versions.

“FPGA“ and “Analyzer“: These two versions are installed on the instrument-specific measuring module.

“A7“ and “M7“: These two versions are installed on the analyser CPU board. The analyser CPU board is identical for all instruments in the APxx-380 series.

"I/O#1": this software is only relevant for the optionally available analogue signal board. Analogue data output is not mandatory for air quality monitoring systems on the basis of the standards specified here. The ‘I/O#1’ software is not stated in the announcement text.

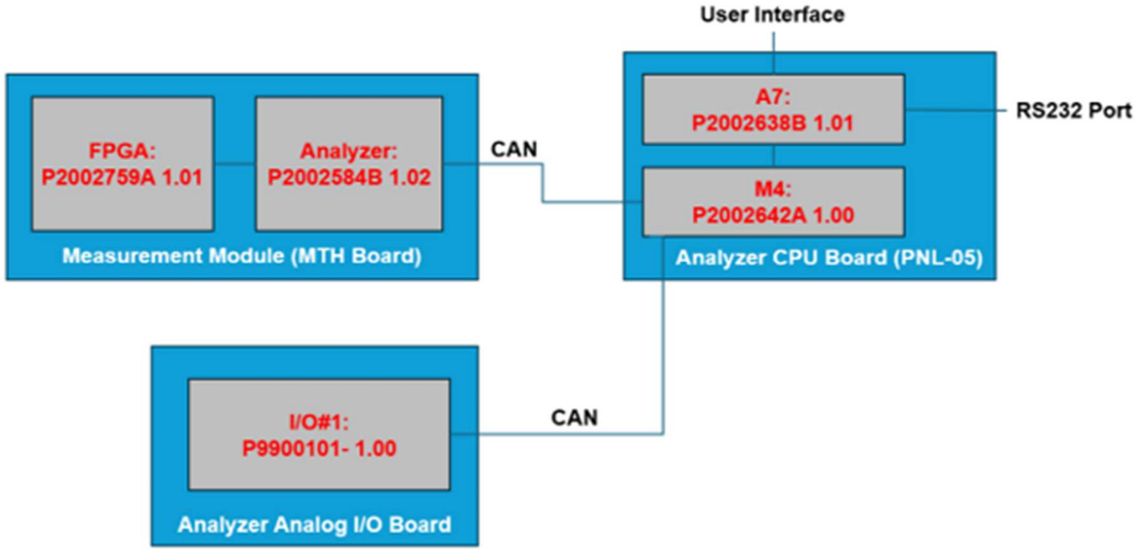


Figure 2: Software overview

The following software updates were introduced after the test work was completed.

A7:	P2002638B	1.01 →	A7:	P2002638C	1.01
M4:	P2002642A	1.00 →	M4:	P2002642B	1.00
Analyzer:	P2002584B	1.02 →	Analyzer:	P2002584C	1.02
FPGA:	P2002759A	1.01 →	unchanged		

The software updates are a series of minor bug fixes and cosmetic improvements. The software changes were submitted to the test laboratory and categorised as type 0 changes based on EN 15267. The announcement text of this report refers directly to the current software versions.

4. Test programme

4.1 General remarks

Two identical APOA-380 instruments with the following serial numbers were submitted to performance testing:

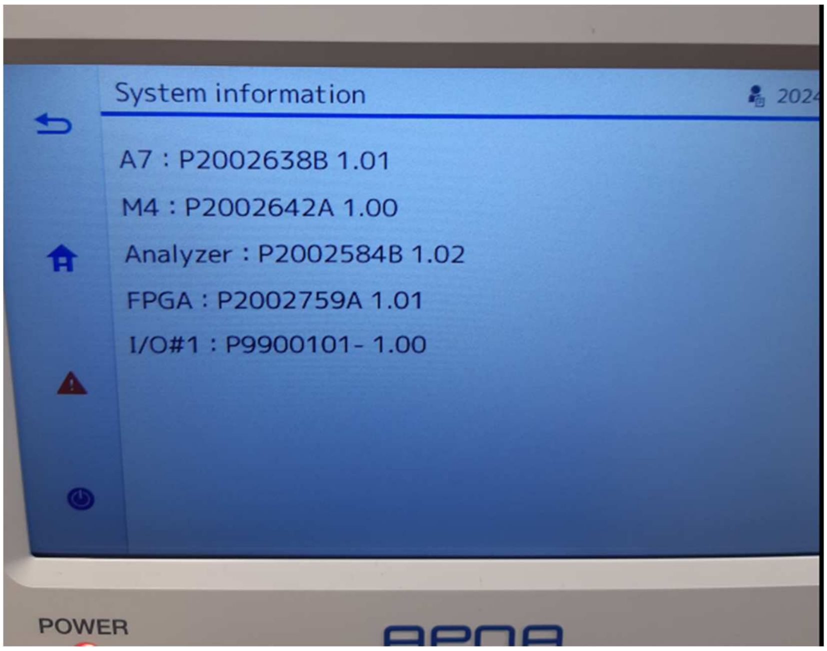
System 1:	SN XEHXE7RR and
System 2:	SN WJX5WPV9

The test was carried out with the following software versions:

A7:	P2002638B	1.01
M4:	P2002642A	1.00
Analyzer:	P2002584B	1.02
FPGA:	P2002759A	1.01

The test comprised a laboratory test to determine the performance characteristics as well as a field test over a period of several months.

In this report, the heading for each performance criterion cites the requirements according to the relevant standards ([1, 2, 3]) including its chapter number and wording.



A7 : P2002638B 1.01

M4 : P2002642A 1.00

Analyzer : P2002584B 1.02

FPGA : P2002759A 1.01

I/O#1 : P9900101- 1.00

Figure 3: Software version of the APOA-380 test instruments

A software update was introduced after the test work was completed. Details on the software update are shown in chapter 3.4.

4.2 Laboratory test

The laboratory test was performed with two identical APOA-380 systems with the serial numbers SN: XEHXE7RR and SN: WJX5WPV9. Standards [1] and [2] specify the following test programme for the laboratory test:

- Description of instrument functions
- General requirements
- Calibration line fit
- Short-term drift
- Repeatability standard deviation
- Sensitivity to sample gas pressure
- Sensitivity to sample gas temperature
- Sensitivity to surrounding temperature
- Sensitivity to supply voltage
- Cross-sensitivities
- Averaging effect
- Response time
- Difference sample/calibration inlet

Measured values were recorded using an external data logger.

Chapters 6 and 7 summarize the results of the laboratory tests.

4.3 Field test

The field test according to EN 14625 and VDI 4202-1 was carried out with two identical APOA-380 measuring systems from 29.04.2024 to 02.08.2024. The instruments used were identical to those used for laboratory testing. The serial numbers were:

System 1:	SN XEHXE7RR
System 2:	SN WJX5WPV9

The following test programme was determined for the field test:

- Long-term drift
- Period of unattended operation
- Availability
- Reproducibility standard deviation under field conditions

Measured values were recorded using an external data logger.

Chapters 6 and 7 summarize the results of the field tests.

To carry out the field test, the measuring systems were installed in a measuring station near Cologne. The measuring station is located in the direct vicinity of a busy, six-lane national motorway. The distance from the measuring station to the nearest roadway is approx. 5.0 m.

Figure 4: Measuring station for conducting the field test

The measuring systems were installed in the station, which was air-conditioned to 20 °C, in a 19" rack and connected to a sampling system. Both systems were installed with a sample gas line of 2.5 m through a T-piece at the same connection of the sampling system. This ensured that both systems carried out a representative measurement of the same sample air volume. The sampling head is located on the front side of the measuring station at a total height of approx. 3.00 m.

Figure 5: APOA-380 in the measuring station during the field test

5. Reference Measurement Method

5.1 Method of measurement

Test gases used for adjustment purposes during the test

An ozone generator from Environics was used to generate the test concentrations for ozone.

To check the ozone concentrations generated, the ozone generator used was calibrated at the National EU Reference Laboratory for Air Quality (Federal Environment Agency in Langen). Calibration was performed using a primary NIST standard reference photometer. The measuring principle is UV photometry according to ISO 13964 "Determination of ozone in ambient air".

Zero gas:	Synthetic air
Ozone generator:	Manufactured by Environics
Type:	6103
Serial number:	SN: 7018
Last inspection on / by:	16.02.2024 / UBA Langen Calibration certificate No. 006-2024

6. Test results in accordance with VDI 4202, Part 1 (2018)

6.1 7.3 General requirements

6.1 7.3.1 Measured value display

The measuring system shall have an operative measured value display as part of the instrument.

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 measuring system has an operative measured value display at the front of the instrument.

6.5 Assessment

The measuring system has an operative measured value display at the front of the instrument.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Figure 6 shows the tested AMS with integrated measured value display.

Figure 6: APOA-380 system with integrated measured value display

6.1 7.3.2 Calibration inlet

The measuring system may have a test gas inlet separate from the sample gas inlet.

6.2 Equipment

No additional equipment is required.

6.3 Testing

It was tested whether the instrument includes a test gas inlet separate from the sample gas inlet.

6.4 Evaluation

The measuring system has a test gas inlet separate from the sample gas inlet at the instrument back.

6.5 Assessment

The measuring system has a test gas inlet separate from the sample gas inlet at the instrument back.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Chapter 7.1 8.4.13 Difference sample/calibration port explains the functionality of the separate sample gas inlet.

6.1 7.3.3 Easy maintenance

Necessary maintenance of the measuring systems should be possible without large effort, if possible from outside.

6.2 Equipment

No additional equipment is required.

6.3 Testing

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

6.4 Evaluation

The user is advised to perform the following maintenance activities:

1. Checking the operational status
   The operational status may be monitored and checked by visual inspections of the instrument's display or via an external PC connected to the AMS.
2. Checking the particle filter at the sample gas inlet. The frequency at which the particle filter needs to be replaced depends on the dust concentrations in ambient air.

6.5 Assessment

Maintenance work can be carried out externally with standard tools and reasonable effort.

Criterion satisfied? yes

6.6 Detailed presentation of test results

The work on the instruments was carried out during the test based on the work and work procedures described in the manual in chapter 7. Complying with the procedures described in the manual, no difficulties were identified. All maintenance activities were possible without any difficulties using standard tools.

6.1 7.3.4 Functional check

If the operation or the functional check of the measuring system require particular instruments, they shall be considered as part of the measuring system and be applied in the corresponding sub-tests and included in the assessment.
The performance of test gas generators, which are part of the measuring system, shall be checked by comparing it to the requirements for test gases used for continuous quality assurance. They have to provide a status signal indicating that they are ready for operation. It must be possible to control them directly or remotely.

6.2 Equipment

Operating manual.

6.3 Testing

The tested measuring system does not have internal devices for operating the functional check. The current operating status of the measuring system is continuously monitored and any issues will be flagged via a series of different error messages.

The functional check of the instruments was performed using external test gases.

6.4 Evaluation

The tested measuring system does not have internal devices for operating the functional check. The current operating status is continuously monitored and any issues will be flagged via a series of different error messages.

External monitoring of the zero and span point using test gases is possible.

6.5 Assessment

The tested measuring system does not have internal devices for operating the functional check.

Criterion satisfied? not applicable

6.6 Detailed presentation of test results

Not applicable.

6.1 7.3.5 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

Operating manual and additional clock.

6.3 Testing

The measuring systems were set up following the manufacturer's instructions. Set-up times and warm-up times were recorded separately.

Necessary constructional measures prior to the installation such as the installation of a sampling system in the analysis room were not taken into account.

6.4 Evaluation

The set-up time is of course dependent on the conditions at the installation site as well as the availability of the power supply at the installation site. Since the APOA-380 is a compact analyser, the set-up time is mainly determined by the following tasks:

- Connecting the AMS to supply voltage;
- Connecting the tubing (sampling, discharged air).

Commissioning and changing positions in the laboratory on various occasions (installation in/removal from the climatic chamber) as well as the installation at the field test location resulted in a set-up time of ~0.5 h. The manufacturer specifies the set-up time as one hour in the manual (see operating manual for the AP-380 series EU version) in chapter 2 on page 4.

When switched on from a completely cold state, the unit required approx. 180 minutes for the system to complete the warm-up phase and enter measurement mode. The determined warm-up time is in accordance with the information in the manual. The manual specifies the warm-up phase as approx. 3 hours (see operating manual AP-380 series EU version, chapter 2 on page 4)

The measuring system has to be installed at a location where it is protected from weather conditions, e.g. in an air-conditioned measurement container.

6.5 Assessment

Set-up times and warm-up times have been determined.

It is possible to operate the measuring system at different locations with limited effort. The set-up time is approx. one hour and the warm-up time is up to 3 hours, depending on the required stabilisation time.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 7.3.6 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
Preventing condensation within the analyser.

6.2 Equipment

Operating manual, a measuring system for recording energy consumption and scales.

6.3 Testing

The instrument design of the measuring systems handed over for testing was compared to the description provided in the manual. The energy consumption specified was verified over 24 h during normal operation in the field test.

6.4 Evaluation

The measuring system is intended for horizontal mounting (e.g. on a table or in a rack) sheltered from weather conditions. The temperature at the site of installation must be between 0 °C and 40 °C.

The dimensions and weight of the measuring system correspond to the information provided in the operating manual.

The power requirement of the measuring system is specified by the manufacturer as 80 W. During start-up (warm-up) a short-term consumption of 140 W was recorded. During normal operation, energy consumption is 80 W.

6.5 Assessment

Specifications made in the instruction manual concerning instrument design are complete and correct.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 7.3.7 Unintended adjustment

It shall be possible to secure the adjustment of the measuring system against illicit or unintended adjustment during operation. Alternatively, the operating manual shall specifically note that the measuring system may only be installed in a secured area.

6.2 Equipment

The test of this criterion did not require any further equipment.

6.3 Testing

The measuring system can be operated via a display at its front with a touch panel or via a PC connected to the measuring system directly or via a network.

The system has an internal function (password protection) against unintentional or unauthorised adjustment. It is only possible to change parameters or adjust the measuring system after entering the password.

6.4 Evaluation

On entering the correct password, it is possible to change instrument parameters affecting measurement characteristics via the control panel and via an external computer.

6.5 Assessment

The measuring system is secured against unintended and unauthorised adjustment of instrument parameters by way of a password.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 7.3.8 Data output

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

6.2 Equipment

Analogue Yokogawa data logger, PC.

6.3 Testing

The measuring system provides the following transmission routes: Modbus, RS232, USB, digital outputs, TCP/IP network. Moreover, the measuring system also provides an option to output analogue signals (V or mA).

6.4 Evaluation

Measured signals are displayed on the back of the instrument as follows.

Analogue:	4 – 20 mA or 0 – 1/5/10 V,	Selectable concentration range
Digital:	RS232, USB, digital inputs and outputs, TCP/IP network	

6.5 Assessment

The measured signals are available both analogue (4 – 20 mA, 0 – 1/5/10 V) and digitally (via TCP/IP, RS 232, USB).

The use of additional measuring and peripheral devices is possible via the respective connection ports on the instruments.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 7.3.9 Digital interface

The digital interface shall allow the transmission of output signals, status signals, and information like instrument type, measurement range, and measured component and unit. The digital interface shall be described fully in respective standards and guidelines.
Access to the measuring system via digital interfaces, e.g. for data transmission, shall be secured against unauthorised access, e.g. by a password.

6.2 Equipment

PC.

6.3 Testing

The measuring system has various digital transmission paths. It is also possible to output data via analogue signals.

6.4 Evaluation

Digital measured signals are provided as follows:

TCP/IP, Modbus, RS232 or USB

Digital output signals were checked. All relevant pieces of information such as measured signals, status signals, measured component, measuring range, unit and instrument information can be transmitted digitally. Access to system parameters is password-protected.

6.5 Assessment

The digital transmission of measured values functions correctly and is password-protected against unauthorised access.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 7.3.10 Data transmission protocol

The measuring system shall contain at minimum one data transmission protocol for the digital transmission of the output signal.
Every data transmission protocol provided by the manufacturer for the measuring system shall allow the correct transmission of the data and detect errors in the transmission. The data transmission protocol including the used commands is to be documented in the instruction manual. The data transmission protocol shall allow to transmit at minimum the following data:
Identification of the measuring system
Identification of measured components
Unit
Output signal with time signature (date and time)
Operation and error status
Operating commands for remote control of the measuring systems

All data are to be transmitted as clear text (ASCII characters).

6.2 Equipment

A PC.

6.3 Testing

The measuring system has an installed Modbus Bavaria/Hesse transmission protocol as standard. Other data transfer protocols are available in consultation with the manufacturer.

6.4 Evaluation

The measuring system has a Modbus Bavaria/Hesse transmission protocol installed as standard. Other data transfer protocols are available in consultation with the manufacturer. Measured and status signals are transmitted correctly.

6.5 Assessment

The measuring system has a Bayern-Hessen transmission protocol installed as standard. Measured and status signals are transmitted correctly. The configuration is listed in the manual (see operating manual supplements AP-380 series EU version) in chapter 5 from page 7 onwards.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 7.3.11 Measuring range

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

6.2 Equipment

The test of this criterion did not require any further equipment.

6.3 Testing

It was checked whether the upper limit of the measuring range for the measuring system is greater than or equal to the upper limit of the certification range.

6.4 Evaluation

In theory, it is possible to set the measuring system to measuring ranges of up to 0–10 ppm.

Possible measuring range:	10 ppm
Upper limit of the certification range for ozone:	500 µg/m³ (250 ppb or nmol/mol)

6.5 Assessment

A measuring range of 0 – 250 ppb (500 µg/m³) is set as standard for ozone. Supplementary measuring ranges up to 0 – 10 ppm are possible.

The measuring system’s upper limit of measurement exceeds the upper limit of the certification range in each case.

Criterion satisfied? yes

6.6 Detailed presentation of test results

VDI Guideline 4202, Part 1 and standard EN 14625 define the following minimum requirements for the certification ranges of continuous air quality monitoring systems for ozone.

Table 3: Certification ranges VDI 4202-1 and EN 14625

Measured component	CR lower limit	CR upper limit	Limit value (alarm threshold)	Evaluation period
	in µg/m³	in µg/m³	in µg/m³	
Ozone	0	500	240	1 h

6.1 7.3.12 Negative output signals

Negative output signals or measured values may not be suppressed (live zero).

6.2 Equipment

The test of this criterion did not require any further equipment.

6.3 Testing

It was tested in the laboratory as well as in the field whether the measuring system can also output negative measured values.

6.4 Evaluation

The AMS displays negative values.

6.5 Assessment

The measuring system also provides negative output signals.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 7.3.13 Failure in the mains voltage

In case of malfunction of the measuring system or failure in the mains voltage uncontrolled emission of operation and calibration gas shall be avoided. The measurement 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 required for this performance criterion.

6.3 Testing

A simulated failure in the mains voltage served to test whether the instrument remained fully functional and reached operation mode on return of the mains voltage.

6.4 Evaluation

As the measuring system requires neither operating nor calibration gases for operation, uncontrolled gas leakage is not possible.

Once the measuring system resumes operation after a power failure it is in warm-up mode until it reaches an appropriate operating temperature again. How long it will take up to fully warm up again will depend on the ambient conditions and the temperature of the system when switching it back on again. After completion of the warm-up phase, the measuring system will switch back automatically into the mode which had been active before the failure in mains voltage. An operational status signal is displayed during the warm-up phase.

6.5 Assessment

On return of mains voltage, the instrument returns to normal operating mode and automatically resumes measuring. The duration of the warm-up phase depends on the duration of the power failure.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 7.3.14 Operating states

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

6.2 Equipment

Computer for data acquisition.

6.3 Testing

The measuring system has various interfaces such as RS232, LAN/WLAN or USB and analogue inputs and outputs. For example, the LAN/WLAN interface can be used to establish a simple connection between the analyser and an external PC. This enables telemetric data transmission, configuration settings can be made and the analyser display can be shown on the PC. In this mode it is possible to access and operate all the information and features from the analyser display via the computer.

6.4 Evaluation

The measuring system allows for comprehensive monitoring and control via various connectors.

6.5 Assessment

The measuring system provides various ports to ensure comprehensive monitoring and control via an external computer.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 7.3.15 Switch-over

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

6.2 Equipment

Not required for this performance criterion.

6.3 Testing

It is possible to monitor and control the AMS on the instrument itself or telemetrically.

6.4 Evaluation

All operating procedures which do not require on-site practical handling may be performed both by the operator on the instrument itself or telemetrically.

6.5 Assessment

As a rule, all necessary work for functional checks can be monitored and controlled directly on the instrument or by telemetric remote control.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 7.3.16 Instrument software

The measuring system shall be able to display the version of the instrument software.

6.2 Equipment

Not required for this performance criterion.

6.3 Testing

It was tested whether the software version can be displayed on the instrument. The AMS manufacturer was informed of the obligation to communicate any changes to the instrument software to the test laboratory.

6.4 Evaluation

The current software version is displayed when switching on the instrument. It can also be viewed at any time in the "System Setting" menu.

The software versions installed during the test and the current valid software versions are listed in chapter 3.4.

6.5 Assessment

The instrument’s software version is displayed. Software changes are communicated to the test laboratory.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Figure 3 shows the software version displayed by the measuring system.

6.1 7.4 Requirements on performance characteristics in the laboratory testing

6.1 7.4.1 General requirements

The performance characteristics which shall be determined during testing in the laboratory and their related performance criteria for measured components according to the 39th BImSchV are given in Table A1 of VDI 4202-1.
The certification range for other components is to be defined. Performance criteria are to be defined by drawing from Table A1 of standard VDI 4202-1 (2018). These definitions shall be cleared with the relevant body before testing.
The determination of the performance characteristics shall be done according to the procedures described in section 8.4.

6.2 Equipment

Not required for this performance criterion.

6.3 Testing

Tests were performed based on the performance criteria and requirements of VDI 4202, Part 1 (2018), EN 14625 (2012) and EN 14625 (2024).

6.4 Evaluation

Not applicable.

6.5 Assessment

Tests were performed based on the performance criteria and requirements of VDI 4202, Part 1 (2018), EN 14625 (2012) and EN 14625 (2024).

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 7.4.2 Test requirements

Before operating the measuring system, the instruction manual of the manufacturer shall be followed particularly with regard to the set-up of equipment and the quality and quantity of the consumable supplies necessary.

The measuring system shall be allowed to warm up for the duration specified by the manufacturer before undertaking any tests. If the warm-up time is not specified, a minimum of 4 h applies.

If auto-scale or self-correction functions are arbitrary, these functions shall be turned off during the laboratory test.

If auto-scale or self-correction functions are not arbitrary but treated as "normal operating conditions", times and values of the self-correction shall be available for the test laboratory. The values of the auto-zero and auto-drift corrections are subject to the same restrictions as given in the performance characteristics.

Before applying test gases to the measuring system, the test gas system shall have been operated for a sufficiently long time in order to stabilize the concentrations applied to the measuring system. The measuring system shall be tested using an implemented particle filter.

Most measuring systems are able to display the output signal as running average of an adjustable period. Some measuring systems adjust the integration time as a function of the frequency of the fluctuations of the concentration of the measured component automatically. These options are typically used for equalisation of the output data. It does not have to be proved that the selected value for the averaging period or the use of an active filter affects the result of testing the averaging period and the response time.

The adjustments of the measuring system shall meet the specifications of the manufacturer. All settings have to be recorded in the test report.

For the determination of the various performance characteristics, suitable zero and test gases shall be used.

Parameters: During the test for each individual performance characteristic, the values of the following parameters shall be stable within the specified range given in Table 3 of standard VDI 4202-1.

Test gas: For the determination of the various performance characteristics, test gases traceable to national or international standards shall be used.

6.2 Equipment

Not required for this performance criterion.

6.3 Testing

Tests were performed based on the performance criteria and requirements of VDI 4202, Part 1 (2018), EN 14625 (2012) and EN 14625 (2024).

6.4 Evaluation

The warm-up time described in the manual was observed.

Neither auto-scale nor self-correction functions were activated during the laboratory test.

The tests were carried out with the particle filters supplied with the system.

Test gases used comply with the requirements of VDI 4202-1.

6.5 Assessment

Tests were performed based on the performance criteria and requirements of VDI 4202, Part 1 (2018), EN 14625 (2012) and EN 14625 (2024).

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 7.4.3 Response time and memory effect

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

Determination and evaluation of the response time corresponds exactly to determining the response time in accordance with standard EN 14625 (2012). Please therefore refer to 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.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.4.4 Short-term drift

The short-term drift at zero point shall not exceed 2.0 nmol/mol.
The short-term drift at span point shall not exceed 6.0 nmol/mol.

6.2 Equipment

Not applicable.

6.3 Testing

Determination and evaluation of the short-term drift corresponds exactly to determining the short term drift in accordance with standard EN 14625 (2012). Please therefore refer to 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.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.4.5 Repeatability standard deviation

The repeatability standard deviation at zero point shall be ≤ 1.0 nmol/mol of the upper limit of the certification range.
The repeatability standard deviation at reference point shall not exceed 3.0 nmol/mol.

6.2 Equipment

Not applicable.

6.3 Testing

Performing and evaluating the repeatability standard deviation at zero point corresponds exactly to determining the repeatability standard deviation in accordance with standard EN 14625 (2012). Please therefore refer to 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.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.4.6 Linearity

The analytical function describing the relationship between the measured values and the desired values shall be linear.
The deviation from the linearity of the calibration function at zero shall not exceed 5 nmol/mol. At concentrations above zero, it shall not exceed 4% of the measured value.

6.2 Equipment

Not applicable.

6.3 Testing

Performing and evaluating the linearity corresponds exactly to determining the lack-of-fit in accordance with standard EN 14625 (2012). Please therefore refer to chapter

6.4 Evaluation

See chapter 7.1 8.4.6 Lack-of-fit of linearity of the calibration function.

6.5 Assessment

See chapter 7.1 8.4.6 Lack-of-fit of linearity of the calibration function.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.4.7 Sensitivity coefficient to sample gas pressure

The sensitivity coefficient of sample gas pressure at reference point shall not exceed 2.0 (nmol/mol)/kPA.

6.2 Equipment

Not applicable.

6.3 Testing

Performing and evaluating the sensitivity coefficient to sample gas pressure corresponds exactly to determining the sensitivity coefficient to sample gas pressure in accordance with standard EN 14625 (2012). Please therefore refer to chapter 7.1 8.4.7 Sensitivity coefficient to sample gas pressure.

6.4 Evaluation

See chapter 7.1 8.4.7 Sensitivity coefficient to sample gas pressure.

6.5 Assessment

See chapter 7.1 8.4.7 Sensitivity coefficient to sample gas pressure.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.4.8 Sensitivity coefficient to sample gas temperature

The sensitivity coefficient to sample gas temperature shall not exceed 1.0 (nmol/mol)/kPA.

6.2 Equipment

Not applicable.

6.3 Testing

Performing and evaluating the sensitivity coefficient to sample gas temperature corresponds exactly to determining the sensitivity coefficient to the sample gas temperature in accordance with standard EN 14625 (2012). Please therefore refer to chapter 7.1 8.4.8 Sensitivity coefficient to sample gas temperature.

6.4 Evaluation

See chapter 7.1 8.4.8 Sensitivity coefficient to sample gas temperature.

6.5 Assessment

See chapter 7.1 8.4.8 Sensitivity coefficient to sample gas temperature.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.4.9 Sensitivity coefficient to the surrounding temperature

The sensitivity coefficient of surrounding temperature shall not exceed 1.0 (nmol/mol)/kPA.

6.2 Equipment

Not applicable.

6.3 Testing

Performing and evaluating the sensitivity coefficient to the surrounding temperature corresponds exactly to determining the sensitivity coefficient to the surrounding temperature in accordance with standard EN 14625 (2012). Please therefore refer to chapter 7.1 8.4.9 Sensitivity coefficient to the surrounding temperature.

6.4 Evaluation

See chapter 7.1 8.4.9 Sensitivity coefficient to the surrounding temperature.

6.5 Assessment

See chapter 7.1 8.4.9 Sensitivity coefficient to the surrounding temperature.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.4.10 Sensitivity coefficient to electrical voltage

The sensitivity coefficient to electrical voltage shall not exceed 0.3 (nmol/mol)/V.

6.2 Equipment

Not applicable.

6.3 Testing

Performing and evaluating the sensitivity coefficient to electrical voltage corresponds exactly to determining the sensitivity coefficient to electrical voltage in accordance with standard EN 14625 (2012). Please therefore refer to chapter 7.1 8.4.10 Sensitivity coefficient to electrical voltage.

6.4 Evaluation

See chapter 7.1 8.4.10 Sensitivity coefficient to electrical voltage.

6.5 Assessment

See chapter 7.1 8.4.10 Sensitivity coefficient to electrical voltage.
Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.4.11 Cross-sensitivity

The change in the measured value caused by interfering components in the sample gas shall not exceed the requirements of Table A of VDI 4202, Part 1 (April 2018), at zero and span 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 the certification range shall be used as reference point.

6.2 Equipment

Not applicable.

6.3 Testing

Performing and evaluating cross sensitivity corresponds exactly to determining interferents in accordance with standard EN 14625 (2012). Please therefore refer to 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

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.4.12 Averaging effect

The measuring system shall enable hourly averages.

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

6.2 Equipment

Not applicable.

6.3 Testing

Performing and evaluating the averaging effect corresponds exactly to determining the averaging test in accordance with standard EN 14625 (2012).
However, according to VDI 4202-1 (2018), a concentration between zero and 200 nmol/mol ozone should be used to determine the averaging effect. According to EN 14625 (2012), the test of the averaging effect should be carried out between zero and the concentration c_t (1h limit = 120 nmol/mol). For reasons of clarity and for better comparability with previously approved systems, this test was carried out in accordance with the concentration specifications in EN 14625. Furthermore, the value used is closer to the ozone concentrations usually measured in Central Europe. The reader is therefore referred to chapter 7.1 8.4.12 Averaging test.

6.4 Evaluation

See chapter 6.1 7.4.12 Averaging effect.

6.5 Assessment

See chapter 6.1 7.4.12 Averaging effect.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.4.13 Difference between sample and calibration port

If a measuring system, standardly or optionally, possesses a test gas inlet separated from the sample gas inlet, this configuration shall be tested.
The difference between the measured values obtained by feeding gas at the sample gas and test gas inlet shall not exceed 1 %.

6.2 Equipment

Not applicable.

6.3 Testing

Determination and evaluation of the difference between sample and calibration port corresponds exactly to determining the difference sample/calibration port in accordance with standard EN 14625 (2012). Please therefore refer to 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.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.4.14 Converter efficiency

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

6.2 Equipment

Not applicable.

6.3 Testing

The tested measuring system does not use a converter.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable as the measuring system does not use a converter.

Criterion satisfied? Not applicable

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.4.15 Residence time in the analyser

If the residence time has influence on the output signal, like for NO_X and ozone measuring systems, it is necessary to calculate the residence time from the volume flow and the volume of the gas lines and other relevant components of the measuring system and the particle filter casing.

In the case of NO_X and O_3 measurements, the residence time shall not exceed 3 s.

6.2 Equipment

Not applicable.

6.3 Testing

Performing and evaluating the averaging effect corresponds exactly to determining the averaging test in accordance with standard EN 14625 (2012). Please therefore refer to chapter 7.1 8.4.14 Residence time in the analyser.

6.4 Evaluation

See chapter 7.1 8.4.14 Residence time in the analyser.

6.5 Assessment

See chapter 7.1 8.4.14

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.5 Requirements on performance characteristics for testing in the field

6.1 7.5.1 General requirements

The performance characteristics which shall be determined during testing in the field and their related performance criteria for measured components according to 39. BImSchV are given in Table A1 of VDI 4202-1 (2018).
The certification range for other components is to be defined. Performance criteria are to be defined by drawing from Table A1 of VDI 4202-1 (2018) These definitions shall be cleared with the relevant body before testing.
The determination of the performance characteristics shall be done according to the procedures de-scribed in Section 8.5 of VDI 4202-1 (2018).

6.2 Equipment

Not required for this performance criterion.

6.3 Testing

Tests were performed based on the performance criteria and requirements of VDI 4202, Part 1 (2018), EN 14625 (2012) and EN 14625 (2024).

6.4 Evaluation

Not applicable.

6.5 Assessment

Tests were performed based on the performance criteria and requirements of VDI 4202, Part 1 (2018), EN 14625 (2012) and EN 14625 (2024).

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 7.5.2 Location for the field test

The monitoring station for the field test is to be chosen according to the requirements of 39th BImSchV such that the expected concentrations of the measured components to be measured correspond to the designated task. The equipment of the monitoring station shall allow the implementation of the field test and shall fulfil all requirements considered to be necessary during measurement planning.

6.2 Equipment

Not required for this performance criterion.

6.3 Testing

The field test location was selected in compliance with the 39th BImSchV.

6.4 Evaluation

The field test location was selected in compliance with the 39th BImSchV. Details on the location of the measuring station are given in chapter 4.3.

6.5 Assessment

The field test location was selected in compliance with the 39th BImSchV. Details on the location of the measuring station are given in chapter 4.3.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 7.5.3 Test requirements

The measuring systems shall be installed in the monitoring station and, after connecting to the existing or separate sampling system, activated properly.
The adjustments of the measuring system shall meet the specifications of the manufacturer. All settings have to be recorded in the test report.
The measuring systems shall be maintained during the field test, following the manufacturer’s specifications, and shall be checked with suitable test gases regularly.
If the instrument has an auto-scaling or self-correction function and it is regarded as a “normal operating condition”, it shall be operational during the field test. The magnitude of the self-correction has to be available to the testing laboratory. The values of the auto-zero and auto-drift corrections for the inspection interval (long-term drift) are subject to the same restrictions as given in the performance characteristics.

6.2 Equipment

Not required for this performance criterion.

6.3 Testing

For the purpose of field testing, the measuring system was mounted in a measuring station and connected to the existing sampling system. The measuring system was then commissioned following the manufacturer’s instructions in the manual.

Neither self-correction nor auto-zero functions were activated during the field test.

6.4 Evaluation

During the field test, the measuring system was operated and serviced according to the manufacturer’s instructions. Neither self-correction nor auto-zero functions were activated.

6.5 Assessment

During the field test, the measuring system was operated and serviced according to the manufacturer’s instructions.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 7.5.4 Long-term drift

The long-term drift at zero point shall not exceed 5.0 nmol/mol.
The long-term drift at reference point shall not exceed 5 % of the upper limit of the certification range.

6.2 Equipment

Not applicable.

6.3 Testing

Determination and evaluation of the long-term drift corresponds exactly to determining the long term drift in accordance with standard EN 14625 (2012). Please therefore refer to 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.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.5.5 Reproducibility standard deviation under field conditions

The standard deviation from paired measurements under field conditions shall be determined with two identical measuring systems by paired measurements in the field test.
The standard deviation under field conditions shall not exceed 5% of the mean value over a period of three months.

6.2 Equipment

Not applicable.

6.3 Testing

Performing and evaluating the standard deviation from paired measurements corresponds exactly to determining the reproducibility standard deviation in accordance with standard EN 14625 (2012). Please therefore refer to chapter 7.1 8.5.5 Reproducibility standard deviation for ozone under field conditions.

6.4 Evaluation

See chapter 7.1 8.5.5 Reproducibility standard deviation for ozone under field conditions.

6.5 Assessment

See chapter 7.1 8.5.5 Reproducibility standard deviation for ozone under field conditions.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.5.6 Inspection interval

The inspection interval of the measuring system shall be determined during the field test and specified. The maintenance interval should be three months, if possible, but at least two weeks.

6.2 Equipment

Not required for this performance criterion.

6.3 Testing

Performing and evaluating the inspection interval corresponds exactly to determining the period of unattended operation in accordance with standard EN 14625 (2012). Please therefore refer to chapter 7.1 8.5.6 Inspection interval .

6.4 Evaluation

See chapter 7.1 8.5.6 Inspection interval .

6.5 Assessment

See chapter 7.1 8.5.6 Inspection interval.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.5.7 Availability

The availability of the measuring system shall be determined during the field test and shall be at least 95%.

6.2 Equipment

Not applicable.

6.3 Testing

Determination and evaluation of the availability corresponds exactly to determining the period of availability of the analyser in accordance with standard EN 14625 (2012). Please therefore refer to chapter 7.1 8.5.7 Period of availability of the analyser.

6.4 Evaluation

See chapter 7.1 8.5.7 Period of availability of the analyser.

6.5 Assessment

See chapter 7.1 8.5.7 Period of availability of the analyser.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.5.8 Converter efficiency

At the end of the field test, the converter efficiency shall be at least 95 %.

6.2 Equipment

Not applicable.

6.3 Testing

The tested measuring system does not use a converter.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable as the measuring system does not use a converter.
Criterion satisfied? not applicable

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.6 Type approval and calculation of the measurement uncertainty

The type approval of the measuring system requires the following:

1) The value of each individual performance characteristic tested in the laboratory shall fulfil the criterion stated in Table A1 of VDI 4202-1 (2018).

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 Table C1 of VDI 4202-1 (2018). This criterion is the maximum uncertainty of individual measurements for continuous measurements at the 1-hour limit value. The relevant specific performance characteristics and the calculation procedure are given in Annex F of standard VDI 4202-1 (2018).

3) The value of each individual performance characteristic tested in the laboratory shall fulfil the criterion stated in Table A1 of VDI 4202-1 (2018).

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 shall fulfil the criterion as stated in Table C1 of VDI 4202-1 (2018). This criterion is the maximum uncertainty of individual measurements for continuous measurements at the 1-hour limit value. The relevant specific performance characteristics and the calculation procedure are given in Annex F of standard VDI 4202-1 (2018).

6.2 Equipment

Not applicable.

6.3 Testing

The uncertainty calculation was performed in line with standard EN 14625 (2012) and is presented in 7.1 8.6 Calculation of the total uncertainty, standard EN 14625 (2012) according to Annex E of EN 14625 (2012)

6.4 Evaluation

The uncertainty calculation was performed in line with standard EN 14625 (2012) and is presented in 7.1 8.6 Calculation of the total uncertainty, standard EN 14625 (2012) according to Annex E of EN 14625 (2012)

6.5 Assessment

The uncertainty calculation was performed in line with standard EN 14625 (2012) and is presented in 7.1 8.6 Calculation of the total uncertainty, standard EN 14625 (2012) according to Annex E of EN 14625 (2012)

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

7. Test results in accordance with standard EN 14625 (2012)

7.1 8.4.3 Response time

Rise and fall response time ≤ 180 s each. Difference between rise and fall response time ≤ 10 s.

7.2 Testing

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

The change from zero gas to span gas and vice versa needs to be made almost instantaneously, with the use of a suitable valve. The valve outlet must be mounted directly at the inlet of the meter and both zero and span gas must be supplied with the same excess, which is discharged by means of a T-piece. The gas flows of zero and span gas must be selected in such a way that the dead time in the valve and in the T-piece is negligible compared to the dead time of the meter. 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 fort the dead time (rise) as shown in Figure 7. When the reading shows 98% of the applied concentration, 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 shows 2% of the applied concentration, the whole cycle as shown in Figure 7 is complete.

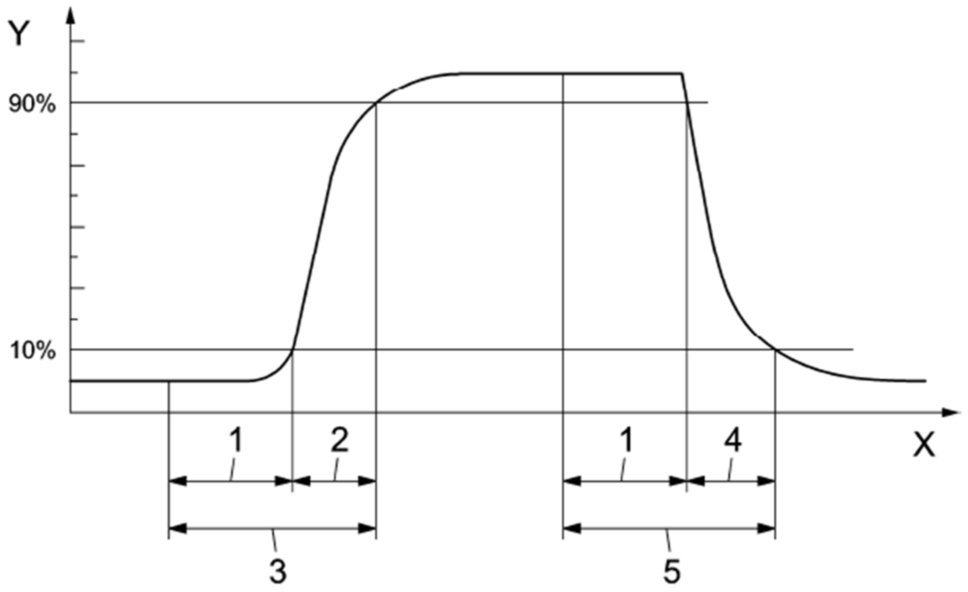
The elapsed time (response time) between the start of the step change and reaching 90% of the analyser final stable reading of the applied concentration shall be measured. The whole cycle shall be repeated four times. The average of the four response times (rise) and the average of the four response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

The difference in response times shall be calculated according to: Where:

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

Where 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 indicated above.



Key

Y analyser response
X time
1 lag time
2 rise time
3 response time (rise)
4 fall time
5 response time (fall)

Figure 7: Diagram illustrating the response time

7.3 Testing

The test was performed in line with the requirements of EN 14625 mentioned previously. An external data logger was used to record data.

7.4 Evaluation

Table 4: Response times of the APOA-380 measuring system for ozone

	requirement	device 1		device 2	
average rise t_r [s]	≤ 180 s	12.5	✓	13	✓
average fall t_f [s]	≤ 180 s	13	✓	12.5	✓
difference t_d [s]	≤ 10 s	-0.5	✓	0.5	✓

For ozone, system 1, the maximum t_r was 12.5 s, the maximum t_f was 13 s and t_d -0.5 s.
For ozone, system 2, the maximum t_r was 13 s, the maximum t_f was 12.5 s and t_d 0.5 s.

7.5 Assessment

The values determined remained considerably below the maximum permissible response time of 180 s at all times. The maximum determined response time for system 1 was 13 s. For system 2 it was 13 s.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 5: Individual results of the response time for ozone

2024-03-12		device 1					
	80%		rise			fall	
measuring range	200.00	0.0 0.00	0.9 180.00	1.0 200.00	1.0 200.00	0.1 20.00	0.0 0.00
cycle 1	t = 0	15:30:00	15:30:13	15:30:30	15:36:00	15:36:14	15:36:30
	delta t		00:00:13			00:00:14	
	delta t [s]		13			14	
cycle 2	t = 0	15:42:00	15:42:12	15:42:30	15:48:00	15:48:12	15:48:30
	delta t		00:00:12			00:00:12	
	delta t [s]		12			12	
cycle 3	t = 0	15:54:00	15:54:12	15:54:30	16:00:00	16:00:12	16:00:30
	delta t		00:00:12			00:00:12	
	delta t [s]		12			12	
cycle 4	t = 0	16:06:00	16:06:13	16:06:30	16:12:00	16:12:14	16:12:30
	delta t		00:00:13			00:00:14	
	delta t [s]		13			14	

2024-03-12		device 2					
	80%		rise			fall	
measuring range	200.00	0.0 0.00	0.9 180.00	1.0 200.00	1.0 200.00	0.1 20.00	0.0 0.00
cycle 1	t = 0	15:30:00	15:30:14	15:30:30	15:36:00	15:36:14	15:36:30
	delta t		00:00:14			00:00:14	
	delta t [s]		14			14	
cycle 2	t = 0	15:42:00	15:42:12	15:42:30	15:48:00	15:48:12	15:48:30
	delta t		00:00:12			00:00:12	
	delta t [s]		12			12	
cycle 3	t = 0	15:54:00	15:54:13	15:54:30	16:00:00	16:00:12	16:00:30
	delta t		00:00:13			00:00:12	
	delta t [s]		13			12	
cycle 4	t = 0	16:06:00	16:06:13	16:06:30	16:12:00	16:12:12	16:12:30
	delta t		00:00:13			00:00:12	
	delta t [s]		13			12	

7.1 8.4.4 Short-term drift

Short-term drift at zero shall not exceed 2.0 nmol/mol/12 h.
The short-term drift at reference level shall not exceed 6.0 nmol/mol/12 h.

7.2 Testing

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). Wait the time equivalent to one independent reading and then record 20 individual measurements, 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. After a period of 12 h, zero and span gas is fed to the analyser. Wait the time equivalent to one independent reading and then record 20 individual measurements, 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-hour 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 measurements at zero at the end of the drift period;

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

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

Where:

$D_{S,S}$ is the 12-hour drift at span;

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

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

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

7.3 Testing

The test was performed in line with the requirements of EN 14625 mentioned previously. Pursuant to EN 14625, the test shall be performed at a concentration level of 70% to 80% of the certification range for ozone.

7.4 Evaluation

Table 6 shows the measured values determined for the short-term drift.

Table 6: Results for the short-term drift

	requirements	device 1		device 2	
averange at zero at the beginning [nmol/mol]	-	0.21		0.52	
averange at zero at the end (12h) [nmol/mol]	-	0.40		0.70	
averange at span at the beginning [nmol/mol]	-	191.17		191.43	
averange at span at the end (12h) [nmol/mol]	-	191.54		191.92	
12-hour drift at zero $D_{s,z}$ [nmol/mol]	≤ 2,0	0.19	✓	0.18	✓
12-hour drift at span $D_{s,s}$ [nmol/mol]	≤ 6,0	0.18	✓	0.31	✓

7.5 Assessment

For instrument 1 the value for the short-term drift at zero point was 0.19 nmol/mol/. For instrument 2 it was 0.18 nmol/mol/.

Short-term drift at reference point was 0.18 nmol/mol for instrument 1 and 0.31 nmol/mol/12 h for instrument 2.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 7 and Table 8 present the individual test results.

Table 7: Individual results for short-term drift. 1st test gas application

at beginning		
zero level		
2024-03-25	device 1	device 2
time	[nmol/mol]	[nmol/mol]
18:00:00	0.2	0.5
18:01:00	0.2	0.6
18:02:00	0.2	0.5
18:03:00	0.3	0.5
18:04:00	0.3	0.5
18:05:00	0.2	0.6
18:06:00	0.2	0.6
18:07:00	0.3	0.5
18:08:00	0.2	0.5
18:09:00	0.2	0.5
18:10:00	0.2	0.6
18:11:00	0.2	0.6
18:12:00	0.3	0.5
18:13:00	0.2	0.5
18:14:00	0.2	0.5
18:15:00	0.2	0.5
18:16:00	0.2	0.5
18:17:00	0.3	0.6
18:18:00	0.3	0.5
18:19:00	0.3	0.5
average	**0.2**	**0.5**

at beginning		
span level		
2024-03-25	device 1	device 2
time	[nmol/mol]	[nmol/mol]
18:35:00	191.3	190.9
18:36:00	193.9	193.3
18:37:00	193.8	193.8
18:38:00	191.6	191.9
18:39:00	190.8	191.3
18:40:00	190.3	190.8
18:41:00	191.3	191.7
18:42:00	190.6	190.9
18:43:00	191.3	191.6
18:44:00	191.3	191.4
18:45:00	190.6	190.6
18:46:00	190.5	190.6
18:47:00	190.2	190.5
18:48:00	189.7	190.5
18:49:00	191.4	191.7
18:50:00	192.2	192.3
18:51:00	190.3	190.9
18:52:00	190.2	190.8
18:53:00	191.1	191.4
18:54:00	191.4	191.7
average	**191.2**	**191.4**

Table 8: Individual results for short-term drift. 2nd test gas application

after 12h		
zero level		
2024-03-26	device 1	device 2
time	[nmol/mol]	[nmol/mol]
06:00:00	0.3	0.6
06:01:00	0.3	0.6
06:02:00	0.3	0.6
06:03:00	0.5	0.8
06:04:00	0.5	0.8
06:05:00	0.5	0.8
06:06:00	0.5	0.8
06:07:00	0.3	0.8
06:08:00	0.3	0.8
06:09:00	0.3	0.8
06:10:00	0.3	0.6
06:11:00	0.3	0.6
06:12:00	0.3	0.6
06:13:00	0.5	0.6
06:14:00	0.5	0.6
06:15:00	0.5	0.6
06:16:00	0.5	0.6
06:17:00	0.5	0.6
06:18:00	0.5	0.8
06:19:00	0.5	0.8
average	**0.4**	**0.7**

after 12h		
span level		
2024-03-26	device 1	device 2
time	[nmol/mol]	[nmol/mol]
06:35:00	190.2	190.2
06:36:00	190.9	190.8
06:37:00	191.4	191.1
06:38:00	192.7	192.5
06:39:00	192.0	191.1
06:40:00	192.8	193.1
06:41:00	192.2	192.5
06:42:00	191.9	192.3
06:43:00	191.6	192.2
06:44:00	190.9	191.6
06:45:00	190.9	191.3
06:46:00	191.1	191.6
06:47:00	190.8	191.6
06:48:00	191.1	192.0
06:49:00	191.1	191.7
06:50:00	190.9	191.9
06:51:00	191.4	192.2
06:52:00	193.1	193.6
06:53:00	192.5	193.1
06:54:00	191.3	192.2
average	**191.5**	**191.9**

7.1 8.4.5 Repeatability standard deviation

The performance criteria are as follows: Repeatability standard deviation at zero shall not exceed 1.0 nmol/mol. At a sample gas concentration at the reference point it shall not exceed 3 nmol/mol.

7.2 Test procedure

After waiting the time equivalent of one independent reading, 20 individual measurements both at zero concentration and at a test gas concentration (c_t), similar to the 1-hour alarm threshold, shall be performed.

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

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

Where:

s_r the repeatability standard deviation;

x_i the ith measurement;

$\overline{x}$ 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 indicated above, both at zero and at the test gas concentration c_t (1-hour alarm threshold).

The detection limit of the measuring system is calculated from the repeatability standard deviation and the slope of the calibration function determined in accordance with Chapter 8.4.6 according to the following equation:

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

Where:

$l_{\det}$ is the lower detection limit of the measuring system, in nmol/mol;

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

B is the slope of the calibration function according to Annex A based on the data from 8.4.6.

7.3 Testing

The test was performed in line with the requirements of EN 14625 mentioned previously. In compliance with the standard, the test has to be performed with the ozone component. The test should be carried out in accordance with EN 14625 at a concentration level of approx. 120 nmol/mol ozone.

7.4 Evaluation

Table 9 presents the results for the repeatability standard deviation.

Table 9: Repeatability standard deviation at zero and span point

	requirement	device 1		device 2	
repeatability standard deviation $s_{r,z}$ at zero [nmol/mol]	≤ 1,0	0.03	✓	0.08	✓
repeatability standard deviation $s_{r,ct}$ at c_t [nmol/mol]	≤ 3,0	1.25	✓	1.24	✓
detection limit [nmol/mol]		0.12		0.25	

7.5 Assessment

For instrument 1 the value for the repeatability standard deviation at zero point was 0.03 nmol/mol. For instrument 2 it was 0.08 nmol/mol. Repeatability standard deviation at reference point was 1.25 nmol/mol for instrument 1 and 1.24 nmol/mol for instrument 2.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 10 lists the results of individual measurements.

Table 10: Individual results for repeatability standard deviation

2024-03-13	zero level	
	device 1	device 2
time	[nmol/mol]	[nmol/mol]
14:22:00	-0.2	0.3
14:23:00	-0.2	0.3
14:24:00	-0.2	0.3
14:25:00	-0.2	0.2
14:26:00	-0.2	0.2
14:27:00	-0.2	0.2
14:28:00	-0.2	0.2
14:29:00	-0.2	0.2
14:30:00	-0.2	0.2
14:31:00	-0.2	0.3
14:32:00	-0.2	0.3
14:33:00	-0.2	0.3
14:34:00	-0.2	0.3
14:35:00	-0.2	0.2
14:36:00	-0.2	0.2
14:37:00	-0.3	0.2
14:38:00	-0.2	0.2
14:39:00	-0.2	0.2
14:40:00	-0.2	0.2
14:41:00	-0.2	0.2
average	-0.2	0.2

2024-03-13	ct level	
	device 1	device 2
time	[nmol/mol]	[nmol/mol]
15:09:00	118.4	121.9
15:10:00	117.7	122.0
15:11:00	118.3	121.9
15:12:00	121.9	121.3
15:13:00	121.9	120.8
15:14:00	120.5	120.5
15:15:00	119.8	120.5
15:16:00	119.5	120.6
15:17:00	119.2	122.0
15:18:00	119.5	122.3
15:19:00	119.4	122.0
15:20:00	118.4	122.0
15:21:00	117.8	121.4
15:22:00	117.7	120.6
15:23:00	117.7	120.9
15:24:00	118.0	124.7
15:25:00	119.1	124.8
15:26:00	119.7	123.3
15:27:00	119.4	122.7
15:28:00	119.4	122.2
average	119.2	121.9

7.1 8.4.6 Lack-of-fit of linearity of the calibration function

The deviation from the linearity of the calibration function at zero shall not exceed 5 nmol/mol. At concentrations above zero, it shall not exceed 4% of the measured value.

7.2 Test procedure

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 four response times shall be taken into account before the next measurement is performed.

The regression function and the deviations are calculated in accordance with Annex A of standard EN 14625. The deviations from the linear regression function shall comply with the performance criterion specified above.

Establishment of the regression line:

A linear regression function in the form of $Y_i = A + B * X_i$ is made 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) times the number of repetitions (at least five) at a particular concentration level.

The coefficient a is obtained from:

$$a = \sum Y_i / n$$

Where:

- a is the average value of the Y-values;
- Y_i is the individual Y-value;
- N is the number of measuring 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 $(= \sum x_i / n)$
- X_i is the individual x-value.

The function $Y_i = a + B (X_i - X_z)$ is converted via the calculation of A into $Y_i = A + B * X_i$

$A = a – B * X_z$

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

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

Each residual 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

The test was performed in line with the requirements of EN 14625 mentioned previously.

7.4 Evaluation

The following linear regressions were established:
Figure 8 and Figure 9 summarise the results of the group averages for ozone.

Table 11: Deviation from the analytical function for ozone

	requirements	device 1		device 2	
largest value of the relative residuals r_{max} [%]	≤ 4,0	1.41	✓	1.44	✓
residual at zero r_z [nmol/mol]	≤ 5,0	-0.31	✓	0.03	✓

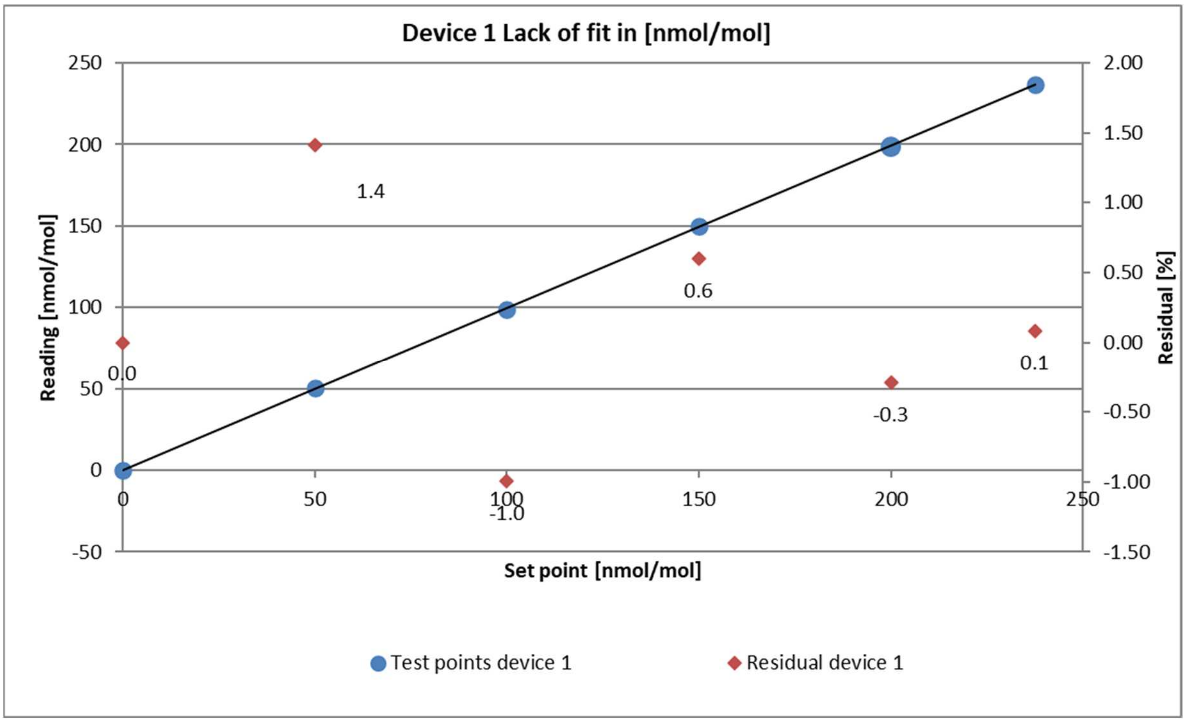


Figure 8: Lack-of-fit results obtained from the group averages for system 1

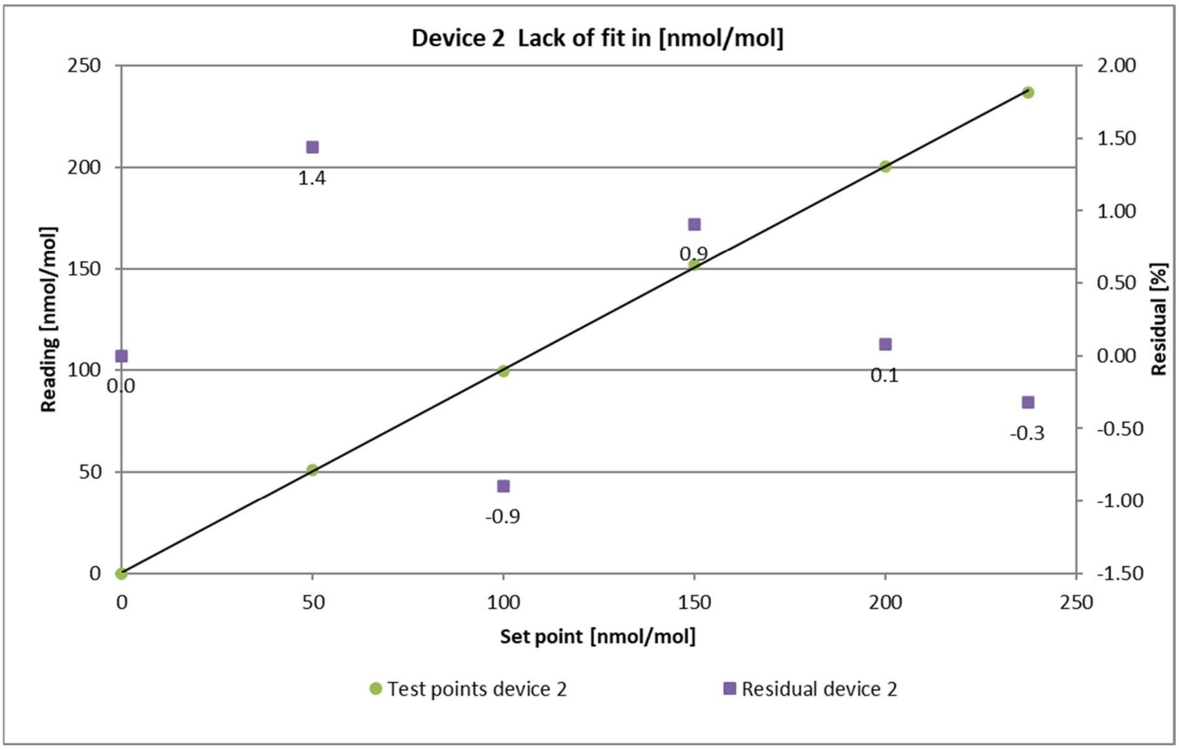


Figure 9: Lack-of-fit results obtained from the group averages for system 2

7.5 Assessment

The deviation from the linear regression line for instrument 1 is -0.31 nmol/mol at zero point and no more than 1.41% of the nominal value for concentrations above zero. The deviation from the linear regression line for instrument 2 is 0.03 nmol/mol at zero point and no more than 1.44% of the nominal value for concentrations above zero.

The residuals from the ideal regression line do not exceed the limit values required by standard EN 14625.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 12 presents the individual test results.

Table 12: Individual results of the lack-of-fit test

2024-03-13		device 1 [nmol/mol]		device 2 [nmol/mol]	
time	level [%]	actual value y_i	set value x_i	actual value y_i	set value x_i
12:44:00	80	197.97	200.00	199.22	200.00
12:45:00	80	199.53	200.00	201.09	200.00
12:46:00	80	200.00	200.00	201.72	200.00
12:47:00	80	197.97	200.00	200.31	200.00
12:48:00	80	197.03	200.00	199.38	200.00
average		198.50		200.34	
$r_{c,rel}$		-0.29		0.08	
12:59:00	40	99.38	100.00	100.16	100.00
13:00:00	40	98.91	100.00	99.69	100.00
13:01:00	40	98.28	100.00	99.38	100.00
13:02:00	40	98.13	100.00	99.22	100.00
13:03:00	40	97.81	100.00	99.06	100.00
average		98.50		99.50	
$r_{c,rel}$		-1.00		-0.90	
13:14:00	0	-0.31	0.00	0.00	0.00
13:15:00	0	-0.31	0.00	0.00	0.00
13:16:00	0	-0.31	0.00	0.00	0.00
13:17:00	0	-0.31	0.00	0.16	0.00
13:18:00	0	-0.31	0.00	0.00	0.00
average		-0.31		0.03	
r_z					
13:29:00	60	150.78	150.00	152.03	150.00
13:30:00	60	150.63	150.00	151.72	150.00
13:31:00	60	150.31	150.00	151.72	150.00
13:32:00	60	150.00	150.00	151.56	150.00
13:33:00	60	149.22	150.00	151.25	150.00
average		150.19		151.66	
$r_{c,rel}$		0.60		0.91	
13:44:00	20	50.31	50.00	51.72	50.00
13:45:00	20	52.97	50.00	51.09	50.00
13:46:00	20	51.41	50.00	51.25	50.00
13:47:00	20	48.59	50.00	51.41	50.00
13:48:00	20	48.75	50.00	50.63	50.00
average		50.41		51.22	
$r_{c,rel}$		1.41		1.44	
13:59:00	95	236.56	237.50	237.19	237.50
14:00:00	95	236.88	237.50	236.88	237.50
14:01:00	95	236.41	237.50	238.75	237.50
14:02:00	95	237.19	237.50	236.88	237.50
14:03:00	95	236.09	237.50	234.53	237.50
average		236.63		236.84	
$r_{c,rel}$		0.08		-0.32	

7.1 8.4.7 Sensitivity coefficient to sample gas pressure

The sensitivity coefficient to sample gas pressure shall be ≤ 2.0 nmol/mol/kPa.

7.2 Test procedures

Measurements are taken at a concentration of about 70% to 80% of the maximum of the certification range of NO 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 measurements, the averages at each pressure are calculated.

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

The sensitivity coefficient to sample gas pressure is calculated as follows.

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

Where:

b_{gp}	is the sample gas pressure sensitivity coefficient;
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 sampling gas pressure P_2;
P_1	is the minimum sampling gas pressure P_1;
P_2	is the maximum sampling gas pressure P_2.
b_{gp}	shall comply with the performance criterion indicated above.

7.3 Testing

The test was performed in line with the requirements of EN 14625 mentioned previously.

Negative pressure was produced by reducing the test gas volume fed by means of blocking the sample gas line. For the positive pressure test, the AMS was connected to a sample gas source. The test gas volume generated was set at a higher rate than the volume sucked in by the analyser. The excess supply was diverted via T-piece. The positive pressure was produced by blocking the bypass line. The test gas pressure was determined with the help of a pressure sensor located in the sample gas path.

Individual measurements were performed at concentrations around 70% to 80% of the maximum certification range and sample gas pressures of 80 kPa and 110 kPa.

7.4 Evaluation

The following sensitivity coefficients to sample gas pressure were determined.

Table 13: Sensitivity coefficient to sample gas pressure

	requirement	device 1		device 2	
sensitivity coeff. sample gas pressure b_{gp} [nmol/mol/kPa]	≤ 2,0	0.09	✓	0.05	✓

7.5 Assessment

For instrument 1, the sensitivity coefficient to sample gas pressure was 0.09 nmol/mol/kPa.
For instrument 2, the sensitivity coefficient to sample gas pressure was 0.05 nmol/mol/kPa.
Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 14: Individual results of the sensitivity to changes in sample gas pressure

			device 1	device 2
time	pressure [kPa]	concentration	[nmol/mol]	[nmol/mol]
15:31:00	80	187.50	189.53	190.31
15:32:00	80	187.50	191.41	192.19
15:33:00	80	187.50	191.72	192.66
average C_{P1}			190.89	191.72
16:06:00	110	187.50	188.28	190.31
16:07:00	110	187.50	187.97	190.31
16:08:00	110	187.50	188.13	190.47
average C_{P2}			188.13	190.36

7.1 8.4.8 Sensitivity coefficient to sample gas temperature

The sensitivity coefficient to sample gas temperature shall be ≤ 1.0 nmol/mol/K.

7.2 Test procedures

Measurements shall be performed at sample gas temperatures of T_1 = 0 °C and T_2 = 30 °C. The sensitivity coefficient to sample gas temperature is determined at a concentration of around 70% to 80% of the maximum certification range. Wait the time equivalent to one independent measurement and record three individual measurements at each temperature.

The sample gas temperature, measured at the inlet of the analyser, shall be held constant for at least 30 minutes.

The sensitivity coefficient to sample gas temperature is calculated as follows:

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

Where:

b_{gt} is the sample gas temperature sensitivity coefficient;

$C_{GT,1}$ 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 indicated above.

7.3 Testing

The test was performed in line with the requirements of EN 14625 mentioned previously.

For the test, the test gas and the dilution gas were placed in the climatic chamber. The test gas mixture was fed through an approx. 50 metre long hose bundle, which was located in a climate chamber. The measuring systems were installed directly upstream of the climatic chamber. The end of the tube-bundle was led out of the climatic chamber and connected to the measuring systems. The feed line outside of the climatic chamber was isolated; a thermometer was used to monitor the temperature of the test gas directly upstream of the measuring system. The temperature of the climatic chamber was adjusted so that the gas temperature directly upstream of the analysers was 0 °C and 30 °C respectively.

7.4 Evaluation

Table 15: Sensitivity coefficient to the sample gas temperature

	requirement	device 1		device 2	
sensitivity coeff. sample gas temperature b_{gt} [nmol/mol/K]	≤ 1,0	0.04	✓	0.05	✓

7.5 Assessment

For instrument 1, the sensitivity coefficient to sample gas temperature was 0.04 nmol/mol/K.
For instrument 2, the sensitivity coefficient to sample gas temperature was 0.05 nmol/mol/K.
Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 16: Individual results of the influence of the sample gas temperature

			device 1	device 2
time	temp [ºC]	concentration	[nmol/mol]	[nmol/mol]
08:45:00	0	187.50	189.84	191.41
08:46:00	0	187.50	189.69	191.25
08:47:00	0	187.50	190.00	191.25
average $C_{GT,1}$			189.84	191.30
14:26:00	30	187.50	188.91	189.69
14:27:00	30	187.50	189.06	189.38
14:28:00	30	187.50	188.28	190.16
average $C_{GT,2}$			188.75	189.74

7.1 8.4.9 Sensitivity coefficient to the surrounding temperature

The sensitivity coefficient to the surrounding temperature shall be ≤ 1.0 µmol/mol/K.

7.2 Test procedures

The sensitivity of the analyser readings to the surrounding temperature shall be determined by performing measurements at the following temperatures within the specifications of the manufacturer:

1) at the minimum temperature T_{min} = 0 °C;
2) at the temperature T_I = 20 °C;
3) at the maximum temperature T_{max} = 30 °C.

For these tests, a climate chamber is necessary.

The sensitivity coefficient to sample gas temperature is determined at zero concentration and a concentration of about 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 shall be recorded.

The sequence of test temperatures is as follows:

T_I, T_{min}, T_I and T_I, T_{max}, T_I

At the first temperature (T_I), 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_I, at T_{min} and again at T_I. This measurement procedure shall be repeated at the temperature sequence of T_I, T_{max} and at T_I.

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

x_T is the average 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 surrounding temperature in the laboratory;

$T_{S,0}$ is the average of the surrounding temperatures at set point.

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

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

7.3 Testing

The test was performed in line with the requirements of EN 14625 mentioned previously.

7.4 Evaluation

The following sensitivity coefficients to the surrounding temperature have been determined.

Table 17: Sensitivity coefficient to the surrounding temperature

	requirements	device 1		device 2	
sensitivity coefficient at 0 ºC for zero level [nmol/mol/K]	≤ 1,0	0.007	✓	0.020	✓
sensitivity coefficient at 30 ºC for zero level [nmol/mol/K]	≤ 1,0	0.031	✓	0.008	✓
sensitivity coefficient at 0 ºC for span level [nmol/mol/K]	≤ 1,0	0.034	✓	0.070	✓
sensitivity coefficient at 30 ºC for span level [nmol/mol/K]	≤ 1,0	0.229	✓	0.174	✓

As is evident from Table 17, the sensitivity coefficient to the surrounding temperature at zero and at span point meets the performance criteria.

7.5 Assessment

The sensitivity coefficient to the surrounding temperature b_{st} did not exceed the performance criterion specified at 1.0 nmol/mol/K. For the purpose of the uncertainty calculation, the largest value b_{st} is used for both instruments. This was 0.229 nmol/mol/K for instrument 1 and 0.174 nmol/mol/K for instrument 2.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 18 presents the individual test results.

Table 18: Individual results of the sensitivity coefficient to the surrounding temperature

	zero level				span level			
			device 1	device 2			device 1	device 2
date	time	temp [ºC]	[nmol/mol]	[nmol/mol]	time	temp [ºC]	[nmol/mol]	[nmol/mol]
08.04.2024	08:25:00	20	0.8	0.6	08:55:00	20	190.2	190.5
08.04.2024	08:26:00	20	0.3	0.8	08:56:00	20	189.8	189.8
08.04.2024	08:27:00	20	0.3	0.8	08:57:00	20	190.0	189.4
average ($X_{1(TS1)}$)			0.5	0.7			190.0	189.9
08.04.2024	18:08:00	0	0.6	0.0	18:22:00	0	190.2	191.3
08.04.2024	18:09:00	0	0.6	0.2	18:23:00	0	190.5	190.8
08.04.2024	18:10:00	0	0.6	0.2	18:24:00	0	190.5	191.1
average($X_{Ts,1}$)		0	0.6	0.1			190.4	191.0
09.04.2024	07:44:00	20	0.5	0.3	07:57:00	20	188.3	188.8
09.04.2024	07:45:00	20	0.5	0.3	07:58:00	20	189.5	189.8
09.04.2024	07:46:00	20	0.6	0.2	07:59:00	20	190.3	189.5
average ($X_{2(TS1)}$) = ($X_{1(TS2)}$)			0.5	0.3			189.4	189.4
09.04.2024	18:08:00	30	0.2	-0.2	18:23:00	30	192.0	191.6
09.04.2024	18:09:00	30	0.2	-0.5	18:24:00	30	191.9	191.3
09.04.2024	18:10:00	30	0.2	-0.2	18:25:00	30	191.6	191.4
average($X_{Ts,2}$)			0.2	-0.3			191.8	191.4
10.04.2024	07:04:00	20	0.0	-0.8	07:19:00	20	190.0	190.5
10.04.2024	07:05:00	20	0.5	-0.6	07:20:00	20	189.1	189.8
10.04.2024	07:06:00	20	0.8	-0.5	07:21:00	20	190.0	189.5
average ($X_{2(TS2)}$)			0.4	-0.6			189.7	189.9

7.1 8.4.10 Sensitivity coefficient to electrical voltage

The sensitivity coefficient to electrical voltage shall not exceed 0.3 nmol/mol/V.

7.2 Test procedures

The sensitivity coefficient to electrical voltage shall be determined at both ends of the voltage range specified by the manufacturer, V_1 and V_2, at zero concentration 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 to electrical voltage in accordance with EN 14625 is calculated as follows:

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

Where:

b_v is the voltage sensitivity coefficient,

C_{V1} is the average concentration reading of the measurements at voltage V_1

C_{V2} is the average concentration reading of the measurements 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 indicated above.

7.3 Testing

For the purpose of determining the sensitivity coefficient to electrical voltage, a transformer was looped into the measuring system's voltage supply. Test gases were applied to the zero and span point at various voltages.

7.4 Evaluation

The following sensitivity coefficients to electrical voltage have been determined.

Table 19: Sensitivity coefficient to electrical voltage

	requirement	device 1		device 2	
sensitivity coeff. of voltage b_v at zero level [nmol/mol/V]	≤ 0,3	0.00	✓	0.00	✓
sensitivity coeff. of voltage b_v at span level [nmol/mol/V]	≤ 0,3	0.05	✓	0.05	✓

7.5 Assessment

At no test item did the sensitivity coefficient to electrical voltage b_v exceed the value of 0.3 nmol/mol/V specified in standard EN 14625. For the purpose of the uncertainty calculation, the largest b_v is used for both instruments. For instrument 1, this is 0.05 nmol/mol/V and for instrument 2 it is 0.05 nmol/mol/V.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 20: Individual results of the sensitivity coefficient to electrical voltage

2024-03-20			device 1	device 2
time	voltage [V]	concentration	[nmol/mol]	[nmol/mol]
11:03:00	207	0.0	-0.63	0.00
11:04:00	207	0.0	-0.63	0.00
11:05:00	207	0.0	-0.47	0.00
average C_{V1} at zero			-0.57	0.00
11:13:00	253	0.0	-0.47	0.16
11:14:00	253	0.0	-0.31	0.00
11:15:00	253	0.0	-0.47	0.00
average C_{V2} at zero			-0.42	0.05
12:38:00	207	187.50	193.59	194.38
12:39:00	207	187.50	192.50	193.13
12:40:00	207	187.50	191.56	192.19
average C_{V1} at Span			192.55	193.23
12:48:00	253	187.50	189.84	190.47
12:49:00	253	187.50	190.16	190.94
12:50:00	253	187.50	190.63	191.41
average C_{V2} at Span			190.21	190.94

7.1 8.4.11 Interferents

Interferents at zero and at the concentration c_t *(at the level of the 1-hour alarm threshold= 120 nmol/mol for ozone). The maximum permissible deviations for the interfering components toluene and m-xylene are ≤ 5.0 nmol/mol each and for* H_2O *it is≤ 10.0 nmol/mol.*

7.2 Test procedures

The analyser response to certain interferents shall be tested. The interferents can give a positive or negative response. The test is performed at zero concentration and a test gas concentration (c_t) similar to the 1-hour alarm threshold (120 nmol/mol for ozone).

The concentration of the mixtures of the test gases with the interferent shall have an expanded uncertainty of ≤ 5% and shall be traceable to nationally accepted standards. The interferents to be tested and their respective concentrations are shown in Table 21. The influence of each interferent shall be determined separately. The concentration of the measurand shall be corrected for the dilution flux due to the addition of the interfering component (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 measurand at concentration c_t and the interferent to be investigated. The influence quantities at zero and concentration c_t are calculated from:

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

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

Where:

$X_{\text{int},z}$ is the influence quantity of the interferent at zero;

x_z is the average of the measurements at zero;

$X_{\text{int},ct}$ is the influence quantity of the interferent at concentration c_t;

x_{ct} is the average of the measurements at concentration c_t;

c_t is the applied concentration at the one-hour limit value.

The influence quantities of the interferents shall comply with the performance criteria indicated above, both at zero and at concentration c_t.

7.3 Testing

The test was performed in line with the requirements of EN 14625 mentioned previously. The instruments were set at zero and concentration c_t (approximately 120 nmol/mol). Zero and test gas with the various interfering components were then applied. The interferents listed in Table 21 were applied in the concentrations indicated.

Table 21: Interferents in accordance with EN 14625

Interferent	Value
H2O	19 mmol/mol
Toluene	0.5 µmol/mol
m-xylene	0.5 µmol/mol

7.4 Evaluation

The following overview presents the influence quantities of each interfering substance. When determining the influence of moisture, the dilution effect which occurs inside the test gas generation system was also taken into account.

Table 22: Influence of the tested interferents (c_t = 120 nmol/mol)

	requirements	**device 1**		**device 2**	
influence quantity interferent H_2O at zero [nmol/mol]	≤ 10.0 nmol/mol	0.31	✓	0.10	✓
influence quantity interferent H_2O at c_t [nmol/mol]	≤ 10.0 nmol/mol	-1.82	✓	-2.60	✓
influence quantity interferent toluol at zero [nmol/mol]	≤ 5,0 nmol/mol	-0.42	✓	-0.47	✓
influence quantity interferent toluol at c_t [nmol/mol]	≤ 5,0 nmol/mol	-1.61	✓	-1.98	✓
influence quantity interferent m-Xylol at zero [nmol/mol]	≤ 5,0 nmol/mol	0.05	✓	-0.16	✓
influence quantity interferent m-Xylol at c_t [nmol/mol]	≤ 5,0 nmol/mol	0.78	✓	0.31	✓

7.5 Assessment

This results in a value for the cross-sensitivity at zero of 0.31 nmol/mol for instrument 1 and 0.10 nmol/mol for instrument 2 for H_2O, -0.42 nmol/mol for instrument 1 and -0.47 nmol/mol for instrument 2 for toluene and 0.05 nmol/mol for instrument 1 and -0.16 nmol/mol for instrument 2 for m-xylene.

This results in a value for the cross-sensitivity at the limit value c_t of -1.82 nmol/mol for instrument 1 and -2.60 nmol/mol for instrument 2 for H_2O, -1.61 nmol/mol for instrument 1 and -1.98 nmol/mol for instrument 2 for toluene and 0.78 nmol/mol for instrument 1 and 0.31 nmol/mol for instrument 2 for m-xylene.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 23 presents the individual test results.

Table 23: Individual results from the interfering substances test

	without interferents			with interferents		
	time	device 1	device 2	time	device 1	device 2
zero gas + H_2O (19 mmol/mol)	13:16:00	0.31	0.47	0.56	0.63	0.63
	13:17:00	0.16	0.47	0.57	0.47	0.63
	13:18:00	0.16	0.63	0.57	0.47	0.63
	average x_z	0.21	0.52	average x_z	0.52	0.63
test gas c_t + H_2O (19 mmol/mol)	14:00:00	122.34	122.03	0.60	119.84	118.28
	14:01:00	121.09	121.72	0.61	119.53	119.84
	14:02:00	121.41	121.25	0.61	120.00	119.06
	average x_{ct}	121.61	121.67	average x_{ct}	119.79	119.06
zero gas + Toluol (0,5 µmol/mol)	11:22:00	0.94	0.16	0.48	0.47	-0.47
	11:23:00	0.78	0.00	0.48	0.31	-0.47
	11:24:00	0.78	-0.16	0.48	0.47	-0.47
	average x_z	0.83	0.00	average x_z	0.42	-0.47
test gas c_t + Toluol (0,5 µmol/mol)	12:48:00	123.13	123.59	0.54	120.78	120.94
	12:49:00	121.56	122.19	0.54	120.31	120.47
	12:50:00	121.72	122.03	0.54	120.47	120.47
	average x_{ct}	122.14	122.60	average x_{ct}	120.52	120.63
zero gas + m-Xylol (0,5 µmol/mol)	11:47:00	0.78	0.00	0.50	0.78	-0.31
	11:48:00	0.63	-0.16	0.50	0.78	-0.31
	11:49:00	0.63	-0.31	0.50	0.63	-0.31
	average x_z	0.68	-0.16	average x_z	0.73	-0.31
test gas c_t + m-Xylol (0,5 µmol/mol)	12:22:00	120.31	120.16	0.52	121.56	121.09
	12:23:00	120.31	120.31	0.52	121.88	121.09
	12:24:00	121.41	121.41	0.52	120.94	120.63
	average x_{ct}	120.68	120.63	average x_{ct}	121.46	120.94

7.1 8.4.12 Averaging test

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

7.2 Test conditions

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 constant ozone concentration between zero and the concentration c_t

The time span (t_c) of the constant ozone concentrations must be at least equal to that required to achieve four independent display values (which is equal to at least sixteen response times). The time period (t_v) of the varying ozone concentration shall be at least equal to a period to obtain four independent readings. The time period (t_{O3}) for the ozone concentration shall be 45 s followed by a period (t_{zero}) of 45 s of zero concentration. Further:

c_t is the test gas concentration;

t_v is the total number of t_{O3} and t_{zero} pairs, (at least 3 such pairs.)

The change from t_{O3} 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 under test.

The averaging effect (E_{av}) is calculated according to:

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

Where:

E_{av} is the averaging effect (%);

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

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

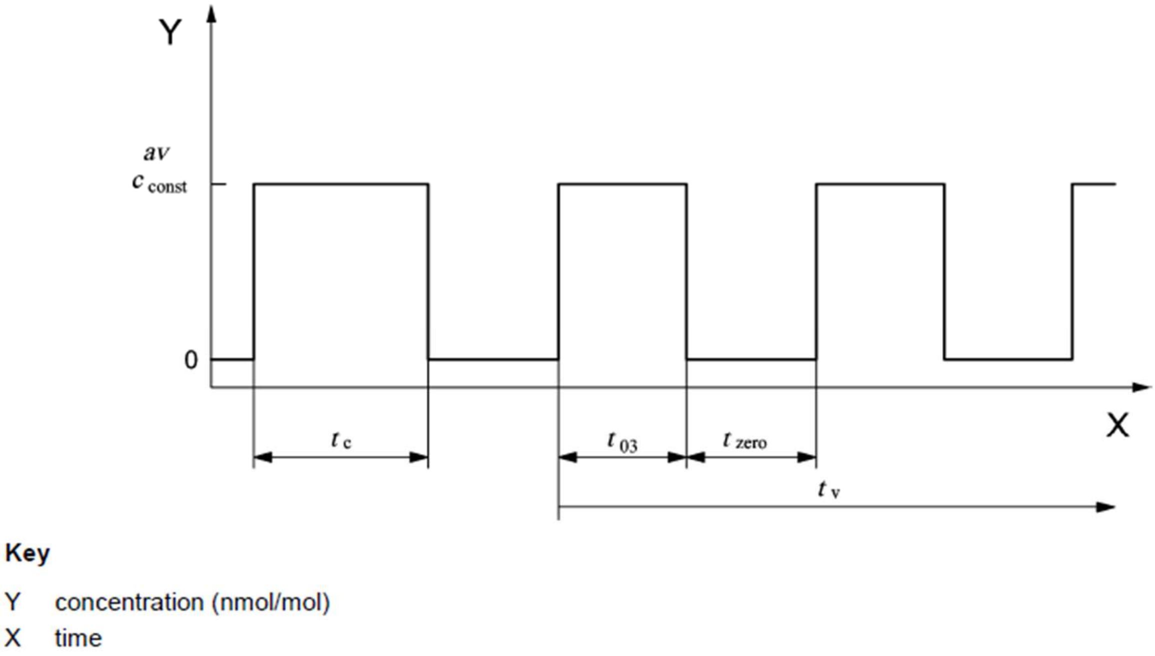


Figure 10: Test of the averaging effect (t_{O3} = t_{zero} = 45 s.)

7.3 Testing

The averaging test was performed in compliance with the requirements specified in EN 14625. As this is a direct-measuring ozone measuring system, this test was carried out with an ozone concentration that changed abruptly between zero and the concentration ct (120 nmol/mol). First, the average was calculated at a constant test gas concentration. Then, a three-way valve served to switch between zero and test gas every 45 s. During that period of alternating test gas application the average was calculated again.

7.4 Evaluation

The following averages were determined during the test.

Table 24: Results of the averaging test

	requirement	device 1		device 2	
averaging effect E_{av} [%]	≤ 7%	0.8	✓	-1.0	✓

This results in the following averaging effects:

System 1: 0.8%

System 2: -1.0 %

7.5 Assessment

The performance criterion specified by standard EN 14625 is fully satisfied.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 25 presents the individual results of the averaging test.

Table 25: Results of the averaging test

2024-03-18		device 1	device 2
	time	[nmol/mol]	[nmol/mol]
average constant concentration $C_{av,c}$	12:11:00	120.3	121.8
	till		
	12:30:00		
average variable concentration $C_{av,c}$	12:31:00	59.6	62.0
	till		
	12:50:00		

2024-03-18		device 1	device 2
	time	[nmol/mol]	[nmol/mol]
average constant concentration $C_{av,c}$	12:59:00	119.6	120.6
	till		
	13:18:00		
average variable concentration $C_{av,c}$	13:19:00	57.7	58.9
	till		
	13:38:00		

2024-03-18		device 1	device 2
	time	[nmol/mol]	[nmol/mol]
average constant concentration $C_{av,c}$	13:46:00	120.9	122.3
	till		
	14:05:00		
average variable concentration $C_{av,c}$	14:06:00	61.6	63.3
	till		
	14:25:00		

7.1 8.4.13 Difference sample/calibration port

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

7.2 Test procedures

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:

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

Where:

Δx_{SC} is the difference sample/calibration port;

x_{sam} is the average of the measured concentration using the sample port;

x_{cal} is the average of the measured concentration using the calibration port;

c_t is the concentration of the test gas;

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

7.3 Testing

The test was performed in compliance with the requirements specified in EN 14625. During the test, the gas path was switched between sample gas and span gas inlet using a three-way valve.

7.4 Evaluation

During the test, the following differences between sample and calibration port were determined:

Table 26: Results of determining the difference between sample/calibration port

	requirement	device 1		device 2	
difference sample/calibration port Δx_{cs} [%]	≤ 1%	0.25	✓	-0.14	✓

7.5 Assessment

The performance criterion of EN 14625 was fully met with a maximum deviation of 0.25 % and -0.14 % respectively.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 27 presents the individual values.

Table 27: Individual results for testing the difference between sample and calibration port

		device 1	device 2
2024-03-20	time	[nmol/mol]	[nmol/mol]
calibration port	08:08:00	189.5	190.9
	08:09:00	189.8	190.9
	08:10:00	191.6	191.9
sample port	08:18:00	190.2	191.7
	08:19:00	189.7	191.4
	08:20:00	189.7	191.4

7.1 8.4.14 Residence time in the analyser

The residence time in the analyser shall be ≤ 3.0 s.

7.2 Test procedures

The residence time inside the analyser shall be calculated on the basis of the flow and the volumes of the tubing and other relevant components inside the analyser.

7.3 Testing

The gas volume of the APOA-380 measuring system is approximately 12.0 ml from the sample inlet to the measuring cell. The nominal sample gas flow is at 0.6 l/min. This results in a residence time in the analyser of 1.2 s.

7.4 Evaluation

Not applicable.

7.5 Assessment

Residence time in the analyser was 1.2 s.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Not applicable.

7.1 8.5.4 Long-term drift

The long-term drift at zero point shall not exceed ≤ 5.0 nmol/mol.
Long-term drift at span level shall not exceed 5% of the certification range.

7.2 Test procedures

After each two-week zero and span gas test, the drift of the measuring instruments under test shall be calculated at zero and span level in accordance with the procedures specified in this section. 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 were performed at zero and span level following the calibration (after waiting the time equivalent to a single independent reading).

The long-term drift is calculated as follows:

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

Where:

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

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

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

$D_{L,Z}$ shall comply with the performance criterion indicated 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_t;

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

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

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

7.3 Testing

For the purpose of this test, test gas was applied every other week. Table 28 and Table 29 report the measured values for bi-weekly test gas applications.

7.4 Evaluation

Table 28: Results for the long-term drift at zero point

		requierment	Device 1		Device 2	
average start $Cz_{,1}$ at zero [nmol/mol]	29.04.2024	≤ 5,0	--	✓	--	✓
long term drift $D_{L,Z}$ at zero [nmol/mol]	13.05.2024	≤ 5,0	-1.27	✓	-0.33	✓
long term drift $D_{L,Z}$ at zero [nmol/mol]	27.05.2024	≤ 5,0	-1.08	✓	-0.36	✓
long term drift $D_{L,Z}$ at zero [nmol/mol]	10.06.2024	≤ 5,0	-0.61	✓	0.04	✓
long term drift $D_{L,Z}$ at zero [nmol/mol]	24.06.2024	≤ 5,0	-1.15	✓	0.14	✓
long term drift $D_{L,Z}$ at zero [nmol/mol]	08.07.2024	≤ 5,0	-0.99	✓	-0.33	✓
long term drift $D_{L,Z}$ at zero [nmol/mol]	22.07.2024	≤ 5,0	-0.99	✓	-0.30	✓
long term drift $D_{L,Z}$ at zero [nmol/mol]	02.08.2024	≤ 5,0	-1.11	✓	-0.33	✓

Table 29: Results for the long-term drift at span point

		requierment	Device 2 1		Device 2	
average start $Cs_{,1}$ at span [nmol/mol]	29.04.2024	≤ 5 %	--	✓	--	✓
long term drift $D_{L,S}$ at span [nmol/mol]	13.05.2024	≤ 5 %	0.61	✓	0.59	✓
long term drift $D_{L,S}$ at span [nmol/mol]	27.05.2024	≤ 5 %	1.00	✓	1.26	✓
long term drift $D_{L,S}$ at span [nmol/mol]	10.06.2024	≤ 5 %	-1.11	✓	-1.28	✓
long term drift $D_{L,S}$ at span [nmol/mol]	24.06.2024	≤ 5 %	-1.56	✓	-2.09	✓
long term drift $D_{L,S}$ at span [nmol/mol]	08.07.2024	≤ 5 %	-1.15	✓	-0.22	✓
long term drift $D_{L,S}$ at span [nmol/mol]	22.07.2024	≤ 5 %	-1.07	✓	-0.45	✓
long term drift $D_{L,S}$ at span [nmol/mol]	02.08.2024	≤ 5 %	-0.86	✓	1.55	✓

7.5 Assessment

Maximum long-term drift at zero point $D_{l,z}$ was at -1.27 nmol/mol for instrument 1 and -0.36 nmol/mol for instrument 2. Maximum long-term drift at reference point $D_{l,s}$ was at -1.56% for instrument 1 and -2.09% for instrument 2.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 30 presents the individual values obtained for the determination of the long-term drift.

Table 30: Individual results for the drift tests

Zero Concentration			
		Device 1	Device 2
Date	Time	[nmol/mol]	[nmol/mol]
29.04.2024	10:20:00	0.31	0.16
	10:21:00	0.47	0.94
	10:22:00	0.63	1.09
	Mittel	0.47	0.73
	10:24:00	0.78	1.25
	10:25:00	0.94	1.25
	10:26:00	1.09	1.25
	Mittel	0.94	1.25
	10:28:00	0.31	0.94
	10:29:00	0.47	0.94
	10:30:00	0.47	0.78
	Mittel	0.42	0.89
	10:32:00	0.31	0.78
	10:33:00	0.31	0.94
	10:34:00	0.47	0.94
	Mittel	0.36	0.89
	10:36:00	0.47	0.78
	10:37:00	0.47	0.63
	10:38:00	0.31	0.78
		0.42	0.73
Average field start $c_{z,0}$		**0.52**	**0.90**
13.05.2024	09:17:00	-1.25	0.31
	09:18:00	-0.94	0.47
	09:19:00	-0.63	0.63
	09:20:00	-0.63	0.63
	09:21:00	-0.31	0.78
	aver. $c_{z,1}$	**-0.75**	**0.56**
27.05.2024	09:24:00	-0.94	0.31
	09:25:00	-0.78	0.47
	09:26:00	-0.47	0.63
	09:27:00	-0.31	0.63
	09:28:00	-0.31	0.63
	aver. $c_{z,1}$	**-0.56**	**0.53**
10.06.2024	09:30:00	-0.47	0.78
	09:31:00	-0.31	0.94
	09:32:00	0.00	0.94
	09:33:00	0.16	0.94
	09:34:00	0.16	1.09
	aver. $c_{z,1}$	**-0.09**	**0.94**
24.06.2024	09:19:00	-0.63	1.41
	09:20:00	-0.63	1.41
	09:21:00	-0.47	1.41
	09:22:00	-0.63	0.78
	09:23:00	-0.78	0.16
	aver. $c_{z,1}$	**-0.62**	**1.03**
08.07.2024	09:16:00	-0.63	0.16
	09:17:00	-0.78	0.63
	09:18:00	-0.63	0.78
	09:19:00	-0.31	0.47
	09:20:00	0.00	0.78
	aver. $c_{z,1}$	**-0.47**	**0.56**
22.07.2024	09:31:00	-1.09	0.31
	09:32:00	-0.63	0.47
	09:33:00	-0.31	0.63
	09:34:00	-0.16	0.63
	09:35:00	-0.16	0.94
	aver. $c_{z,1}$	**-0.47**	**0.59**
02.08.2024	07:51:00	-0.47	0.16
	07:52:00	-0.63	0.47
	07:53:00	-0.63	0.63
	07:54:00	-0.78	0.78
	07:55:00	-0.47	0.78
	aver. $c_{z,1}$	**-0.59**	**0.56**

C_t-Concentration			
		Device 1	Device 2
Date	Time	[nmol/mol]	[nmol/mol]
29.04.2024	11:02:00	179.06	179.38
	11:03:00	178.59	179.06
	11:04:00	180.47	180.47
	Mittel	179.38	179.64
	11:06:00	180.16	180.63
	11:07:00	179.69	179.84
	11:08:00	180.16	179.53
	Mittel	180.00	180.00
	11:10:00	181.56	179.22
	11:11:00	181.56	179.22
	11:12:00	179.06	179.38
	Mittel	180.73	179.27
	11:14:00	180.47	180.47
	11:15:00	180.47	180.78
	11:16:00	180.16	180.63
	Mittel	180.36	180.63
	11:18:00	180.16	179.53
	11:19:00	180.94	179.06
	11:20:00	181.56	179.22
		180.89	179.27
Average field start $c_{s,0}$		**180.27**	**179.76**
13.05.2024	09:29:00	180.78	180.94
	09:30:00	180.47	181.09
	09:31:00	180.78	180.94
	09:32:00	180.00	180.16
	09:33:00	178.44	179.38
	aver. $c_{s,1}$	**180.09**	**180.50**
27.05.2024	09:35:00	181.41	181.88
	09:36:00	180.78	181.56
	09:37:00	180.16	181.56
	09:38:00	180.94	182.03
	09:39:00	181.72	181.41
	aver. $c_{s,1}$	**181.00**	**181.69**
10.06.2024	09:44:00	177.81	177.66
	09:45:00	177.34	177.81
	09:46:00	177.66	177.81
	09:47:00	177.81	177.66
	09:48:00	177.81	176.72
	aver. $c_{s,1}$	**177.69**	**177.53**
24.06.2024	09:35:00	176.56	176.09
	09:36:00	176.41	176.09
	09:37:00	176.25	176.25
	09:38:00	176.25	176.41
	09:39:00	176.41	176.25
	aver. $c_{s,1}$	**176.38**	**176.22**
08.07.2024	09:27:00	177.19	179.38
	09:28:00	177.34	178.75
	09:29:00	177.34	179.38
	09:30:00	177.19	178.75
	09:31:00	177.19	178.91
	aver. $c_{s,1}$	**177.25**	**179.03**
22.07.2024	09:43:00	177.50	178.59
	09:44:00	177.50	178.91
	09:45:00	177.50	178.59
	09:46:00	177.34	178.44
	09:47:00	177.03	178.75
	aver. $c_{s,1}$	**177.38**	**178.66**
02.08.2024	08:03:00	177.50	181.88
	08:04:00	177.66	182.66
	08:05:00	177.97	182.34
	08:06:00	177.19	182.50
	08:07:00	177.81	181.88
	aver. $c_{s,1}$	**177.63**	**182.25**

7.1 8.5.5 Reproducibility standard deviation for ozone under field conditions

Reproducibility standard deviation under field conditions shall not exceed 5% of the mean value over a period of three months.

7.2 Test procedures

The reproducibility standard deviation under field conditions is calculated from the measured hourly averaged data during the three-month period.

The difference $\Delta x_{f,i}$ for each (ith) parallel measurement is calculated from:

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

Where:

$\Delta x_{f,i}$ is the ith difference in a parallel measurement;

$x_{f,1,i}$ is the ith measurement result of analyser 1;

$x_{f,2,i}$ is the ith measurement result of analyser 2;

The reproducibility standard deviation under field conditions is calculated according to:

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

Where:

$s_{r,f}$ is the reproducibility standard deviation under field conditions (%);

n is the number of parallel measurements;

c_f is the average concentration of ozone measured during the field test;

The reproducibility standard deviation under field conditions, $s_{r,f}$, shall comply with the performance criterion indicated above.

7.3 Testing

The reproducibility standard deviation under field conditions was calculated from the hourly averages over the field test period according to the equation stated above.

7.4 Evaluation

Table 31: Reproducibility standard deviation based on complete field test data

reproducibility standard deviation in field		
no. of measurments (1h- average)	[n]	2283
average of both analyzers (3 month)	[nmol/mol]	27.39
standard deviation from paired measurements	[nmol/mol]	1.131
reproducibility standard deviation in field $S_{r,f}$	**[%]**	**4.13**
requirement	≤ 5,0 %	✓

The reproducibility standard deviation under field conditions is at 4.13% of the average.

7.5 Assessment

The reproducibility standard deviation for ozone under field conditions was 4.13 % related to the mean value over the duration of the field test of 3 months. Thus, the requirements of EN 14625 are satisfied.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Figure 11 provides an illustration of the reproducibility standard deviation under field conditions.

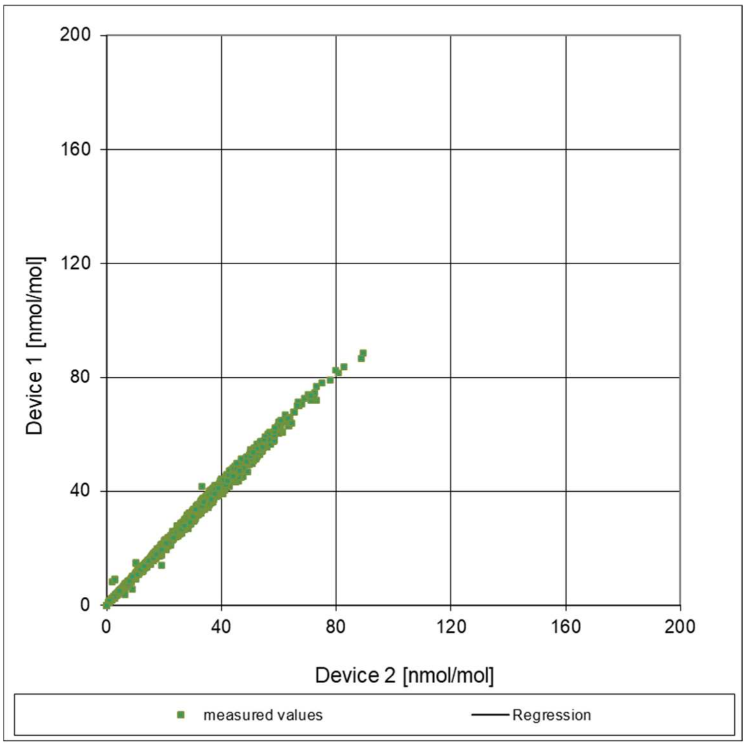


Figure 11: Reproducibility standard deviation under field conditions

7.1 8.5.6 Inspection interval

The period of unattended operation of the AMS shall be at least 2 weeks.

7.2 Equipment

Not required for this performance criterion.

7.3 Testing

With regard to this minimum requirement, the maintenance tasks required in a specific period and the length of that period for the correct functioning of the measuring system were identified. Furthermore, in determining the maintenance interval, the drift determined for zero and span point in accordance with 7.1 8.5.4 Long-term drift have been taken into consideration.

7.4 Evaluation

Over the entire period of the field test, no unacceptable drift was observed. The maintenance interval is thus determined by the necessary maintenance works.

During the three month field test period, maintenance is generally limited to contamination and plausibility checks and potential status/error messages. Naturally, the frequency of filter replacement will depend on the ambient dust concentration at the site of installation. Chapter 5 of the manual and chapter 8 of this report provide information about tasks to be performed in the maintenance interval.

7.5 Assessment

The necessary maintenance tasks determine the period of unattended operation. In essence, these include contamination checks, plausibility checks and checks of potential status/error warnings. The particle filter has to be changed depending on the dust load at the measuring point. A check of the zero and span point must be carried out at least every 14 days in accordance with EN 14625.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Not applicable in this instance.

7.1 8.5.7 Period of availability of the analyser

Availability of the analyser shall be at least 90%.

7.2 Test procedures

The correct operation of the analysers shall be checked at least every fourteen days. It is recommended that this check is performed every day during the first fourteen days. These checks consist 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 calculated as:

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

Where:

A_a is the availability of the analyser (%);

t_u is the total time period with validated measuring data;

t_t is the time period of the field test minus the time for calibration, conditioning and maintenance, t_u and t_t shall be expressed in the same units.

The availability shall comply with the performance criterion indicated above.

7.3 Testing

Using the equation given above, the availability was calculated from the total period of the field test and the outage times which occurred during this period.

Evaluation

Outage times which occurred during the field test are listed in Table 32.

Table 32: Availability of the APOA-380 measuring system

		System 1	System 2
Operation time	h	2277	2277
Outage time	h	0	0
Maintenance time	h	8	8
Actual operating time:	h	2269	2269
Actual operating time incl. maintenance times:	h	2277	2277
Availability	%	100	100

Maintenance times were caused by daily test gas feeding for the purpose of determining the drift behaviour and the maintenance interval and by times needed for replacing the Teflon filter built into the sample gas path.

7.5 Assessment

The availability was at 100%. Thus, the requirement of EN 14625 is satisfied.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Not applicable.

7.1 8.6 Calculation of the total uncertainty, standard EN 14625 (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 standard EN 14625.

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 individual measurements for continuous measurements at the 1-hour limit value. The relevant specific performance characteristics and the calculation procedure are given in Annex E of standard EN 14625.

3) The value of each of the individual performance characteristics tested in the field shall fulfil the criterion stated in Table E.1 of EN 14625.

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 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 individual measurements for continuous measurements at the 1-hour limit value. The relevant specific performance characteristics and the calculation procedure are given in Annex E of standard EN 14625.

7.2 Equipment

Calculation of the total uncertainty in accordance with standard EN 14625 (2012), Annex E

7.3 Testing

At the end of the performance test, the total uncertainties were calculated from the values obtained during the test.

7.4 Evaluation

Regarding 1) The value of each performance characteristic tested in the laboratory tests fulfils the criterion stated in Table E.1 of EN 14625.

Regarding 2) The expanded uncertainty calculated from the standard uncertainties due to the values of the specific performance characteristics obtained in the laboratory tests fulfils the criterion as stated.

Regarding 3) The value of each performance characteristic tested in the field tests fulfils the criterion stated in Table E.1 of EN 14625.

Regarding 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 as stated.

7.5 Assessment

The requirement regarding the expanded uncertainty of the measuring system is complied with.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 33 summarises the results for items 1 and 3.

Table 34 and Table 36 contain the results regarding item 2.

Table 35 and Table 37 contain the results regarding item 4.

Table 33: Relevant performance characteristics and criteria according to EN 14625

Performance characteristic	**Performance criterion**	**Test result**	**Satisfied**	**Page**
8.4.5 Repeatability standard deviation at zero	≤ 1.0 nmol/mol	S_r System 1: 0.03 nmol/mol S_r System 2: 0.08 nmol/mol	yes	81
8.4.5 Repeatability standard deviation at concentration level c_t	≤ 3.0 nmol/mol	S_r system 1: 1.25 nmol/mol S_r System 2: 1.24 nmol/mol	yes	81
8.4.6 Lack-of-fit (deviation from the linear regression)	Largest deviation from the linear regression function > 0, ≤ 4.0% of the reading Residual at zero: ≤ 5 nmol/mol	$X_{l,z}$ System 1: ZP -0.31 nmol/mol X_l System 1: RP 1.41% $X_{l,z}$ System 2: ZP 0.03 nmol/mol X_l System 2: RP 1.44%	yes	84
8.4.7 Sensitivity coefficient of sample gas pressure	≤ 2.0 nmol/mol/kPa	b_{gp} System 1: 0.09 nmol/mol/kPa b_{gp} System 2: 0.05 nmol/mol/kPa	yes	89
8.4.8 Sensitivity coefficient of sample gas temperature	≤ 1.0 nmol/mol/K	b_{gt} System 1: 0.04 nmol/mol/K b_{gt} System 2: 0.05 nmol/mol/K	yes	91
8.4.9 Sensitivity coefficient of surrounding temperature	≤ 1.0 nmol/mol/K	b_{st} System 1: 0.229 nmol/mol/K b_{st} System 2: 0.174 nmol/mol/K	yes	93
8.4.10 Sensitivity coefficient of electrical voltage	≤ 0.3 nmol/mol/V	b_v System 1: RP 0.05 nmol/mol/V b_v System 2: RP 0.05 nmol/mol/V	yes	96
8.4.11 Interferent at zero and at concentration level c_t	H_2O ≤ 10.0 nmol/mol Toluene ≤ 5.0 nmol/mol m-xylene ≤ 5.0 nmol/mol	H_2O System 1: ZP 0.31 nmol/mol / RP -1.82 nmol/mol System 2: ZP 0.10 nmol/mol / RP -2.60 nmol/mol Toluene System 1: ZP -0.42 nmol/mol / RP -1.61 nmol/mol System 2: ZP -0.47 nmol/mol / RP -1.98 nmol/mol m-xylene System 1: ZP 0.05 nmol/mol / RP 0.78 nmol/mol System 2: ZP -0.16 nmol/mol / RP 0.31 nmol/mol	yes	98

Performance characteristic	Performance criterion	Test result	Satisfied	Page
8.4.12 Averaging effect	≤ 7.0% of the measured value	E_{av} System 1: 0.8% E_{av} System 2: -1.0%	yes	101
8.4.13 Difference sample/calibration port	≤ 1.0%	Δ_{SC} System 1: 0.25% Δ_{SC} System 2: -0.14%	yes	104
8.4.3 Response time (rise)	≤ 180 s	t_r System 1: 12.5 s t_r System 2: 13 s	yes	73
8.4.3 Response time (fall)	≤ 180 s	t_f System 1: 13 s t_f System 2: 12.5 s	yes	73
8.4.3 Difference between the rise and fall response time	≤ 10 s	t_d System 1: -0.5 s t_d System 2: 0.5 s	yes	73
8.4.14 Residence time	≤ 3.0 s	System 1: 1.2 s System 2: 1.2 s	yes	106
8.5.7 Availability of the analyser	> 90%	A_a System 1: 100% A_a Analyser 2: 100%	yes	113
8.5.5 Reproducibility standard deviation under field conditions	≤ 5.0% of the average over a period of 3 months	$S_{r,f}$ System 1: 4.13% $S_{r,f}$ System 2: 4.13%	yes	110
8.5.4 Long-term drift at zero point	≤ 5.0 nmol/mol	$C_{,z}$ System 1: -1.27 nmol/mol $C_{,z}$ System 2: -0.36 nmol/mol	yes	107
8.5.4 Long-term drift at span level	≤ 5.0% of the upper limit of the certification range	$C_{,s}$ Analyser 1: max. -1.56% $C_{,s}$ Analyser 2: max. -2.09%	yes	107
8.4.4 Short-term drift at zero	≤ 2.0 nmol/mol over 12 h	$D_{s,z}$ System 1: 0.19 nmol/mol $D_{s,z}$ System 2: 0.18 nmol/mol	yes	77
8.4.4 Short-term drift at span level	≤ 6.0 nmol/mol over 12 h	$D_{s,s}$ System 1: 0.18 nmol/mol $D_{s,s}$ System 2: 0.31 nmol/mol	yes	77

Table 34: Expanded uncertainty. Laboratory test for system 1

Measuring device:	APOA 380	Serial-No.:	XEHXE7RR	
Measured component:	O3	1h-alert threshold:	120	nmol/mol

No.	Performance characteristic	Performance criterion		Result	Partial uncertainty		Square of partial uncertainty	
1	Repeatability standard deviation at zero	≤	1.0 nmol/mol	0.030	$u_{r,z}$	0.00	0.0000	
2	Repeatability standard deviation at 1h-alert threshold	≤	3.0 nmol/mol	1.250	$u_{r,lh}$	0.15	0.0230	
3	"lack of fit" at 1h-alert threshold	≤	4.0% of measured value	1.410	$u_{l,lh}$	0.98	0.9543	
4	Sensitivity coefficient of sample gas pressure at 1h-alert threshold	≤	2.0 nmol/mol/kPa	0.090	u_{gp}	0.98	0.9693	
5	Sensitivity coefficient of sample gas temperature at 1h-alert threshold	≤	1.0 nmol/mol/K	0.040	u_{gt}	0.44	0.1915	
6	Sensitivity coefficient of surrounding temperature at 1h-alert threshold	≤	1.0 nmol/mol/K	0.229	u_{st}	2.51	6.2755	
7	Sensitivity coefficient of electrical voltage at 1h-alert threshold	≤	0.30 nmol/mol/V	0.050	u_V	0.84	0.7034	
8a	Interferent H_20 with 19 mmol/mol	≤	10 nmol/mol (Zero)	0.310	u_{H2O}	-1.36	1.8443	
		≤	10 nmol/mol (Span)	-1.820				
8b	Interferent Toluene with 0,5 µmol/mol	≤	5.0 nmol/mol (Zero)	-0.420	$u_{int,pos}$ or $u_{int,\ neg}$	0.93	0.8640	
		≤	5.0 nmol/mol (Span)	-1.610				
8c	Interferent Xylene with 0,5 µmol/mol	≤	5.0 nmol/mol (Zero)	0.050				
		≤	5.0 nmol/mol (Span)	0.780				
9	Averaging effect	≤	7.0% of measured value	0.800	u_{av}	0.55	0.3072	
18	Difference sample/calibration port	≤	1.0%	0.250	$u_{\Delta sc}$	0.30	0.0900	
21	Uncertainty of test gas	≤	3.0%	2.000	u_{cg}	1.20	1.4400	
					Combined standard uncertainty	u_c	3.6963	nmol/mol
					Expanded uncertainty	U	7.3925	nmol/mol
					Relative expanded uncertainty	W	6.16	%
					Maximum allowed expanded uncertainty	W_{req}	15	%

Table 35: Expanded uncertainty. Laboratory and field test for system 1

Measuring device:	APOA 380	Serial-No.:	XEHXE7RR	
Measured component:	O3	1h-alert threshold:	120	nmol/mol

No.	Performance characteristic	Performance criterion		Result	Partial uncertainty		Square of partial uncertainty	
1	Repeatability standard deviation at zero	≤	1.0 nmol/mol	0.030	$u_{r,z}$	0.00	0.0000	
2	Repeatability standard deviation at 1h-alert threshold	≤	3.0 nmol/mol	1.250	$u_{r,lh}$	not considered, as ur,lh = 0,15 < ur,f	-	
3	"lack of fit" at 1h-alert threshold	≤	4.0% of measured value	1.410	$u_{l,lh}$	0.98	0.9543	
4	Sensitivity coefficient of sample gas pressure at 1h-alert threshold	≤	2.0 nmol/mol/kPa	0.090	u_{gp}	0.98	0.9693	
5	Sensitivity coefficient of sample gas temperature at 1h-alert threshold	≤	1.0 nmol/mol/K	0.040	u_{gt}	0.44	0.1915	
6	Sensitivity coefficient of surrounding temperature at 1h-alert threshold	≤	1.0 nmol/mol/K	0.229	u_{st}	2.51	6.2755	
7	Sensitivity coefficient of electrical voltage at 1h-alert threshold	≤	0.30 nmol/mol/V	0.050	u_V	0.84	0.7034	
8a	Interferent H_20 with 19 mmol/mol	≤	10 nmol/mol (Zero)	0.310	u_{H2O}	-1.36	1.8443	
		≤	10 nmol/mol (Span)	-1.820				
8b	Interferent Toluene with 0,5 µmol/mol	≤	5.0 nmol/mol (Zero)	-0.420	$u_{int,pos}$ or $u_{int,\ neg}$	0.93	0.8640	
		≤	5.0 nmol/mol (Span)	-1.610				
8c	Interferent Xylene with 0,5 µmol/mol	≤	5.0 nmol/mol (Zero)	0.050				
		≤	5.0 nmol/mol (Span)	0.780				
9	Averaging effect	≤	7.0% of measured value	0.800	u_{av}	0.55	0.3072	
10	Reproducibility standard deviation under field conditions	≤	5.0% of average over 3 months	4.130	$u_{r,f}$	4.96	24.5619	
11	Long term drift at zero level	≤	5.0 nmol/mol	-1.270	$u_{d,l,z}$	-0.73	0.5376	
12	Long term drift at span level	≤	5.0% of max. of certification range	-1.560	$u_{d,l,lh}$	-1.08	1.1681	
18	Difference sample/calibration port	≤	1.0%	0.250	$u_{\Delta sc}$	0.30	0.0900	
21	Uncertainty of test gas	≤	3.0%	2.000	u_{cg}	1.20	1.4400	
					Combined standard uncertainty	u_c	6.3172	nmol/mol
					Expanded uncertainty	U	12.6344	nmol/mol
					Relative expanded uncertainty	W	10.53	%
					Maximum allowed expanded uncertainty	W_{req}	15	%

Table 36: Expanded uncertainty. Laboratory test for system 2

Measuring device:	APOA 380				Serial-No.:		WJX5WPV9	
Measured component:	O3				1h-alert threshold:		120	nmol/mol
No.	**Performance characteristic**	**Performance criterion**		**Result**	**Partial uncertainty**		**Square of partial uncertainty**	
1	Repeatability standard deviation at zero	≤	1.0 nmol/mol	0.080	$u_{r,Z}$	0.01	0.0001	
2	Repeatability standard deviation at 1h-alert threshold	≤	3.0 nmol/mol	1.240	$u_{r,lv}$	0.15	0.0218	
3	"lack of fit" at 1h-alert threshold	≤	4.0% of measured value	1.440	$u_{l,lv}$	1.00	0.9953	
4	Sensitivity coefficient of sample gas pressure at 1h-alert threshold	≤	2.0 nmol/mol/kPa	0.050	u_{gp}	0.55	0.2992	
5	Sensitivity coefficient of sample gas temperature at 1h-alert threshold	≤	1.0 nmol/mol/K	0.050	u_{gt}	0.55	0.2992	
6	Sensitivity coefficient of surrounding temperature at 1h-alert threshold	≤	1.0 nmol/mol/K	0.174	u_{st}	1.90	3.6231	
7	Sensitivity coefficient of electrical voltage at 1h-alert threshold	≤	0.30 nmol/mol/V	0.050	u_V	0.84	0.7034	
8a	Interferent H_20 with 19 mmol/mol	≤	10 nmol/mol (Zero)	0.100	u_{H2O}	-1.94	3.7639	
		≤	10 nmol/mol (Span)	-2.600				
8b	Interferent Toluene with 0,5 µmol/mol	≤	5.0 nmol/mol (Zero)	-0.470	$u_{int,pos}$ or $u_{int,\ neg}$	1.14	1.3068	
		≤	5.0 nmol/mol (Span)	-1.980				
8c	Interferent Xylene with 0,5 µmol/mol	≤	5.0 nmol/mol (Zero)	-0.160				
		≤	5.0 nmol/mol (Span)	0.310				
9	Averaging effect	≤	7.0% of measured value	-1.000	u_{av}	-0.69	0.4800	
18	Difference sample/calibration port	≤	1.0%	-0.140	u_{Dsc}	-0.17	0.0282	
21	Uncertainty of test gas	≤	3.0%	2.000	ucg	1.20	1.4400	
				Combined standard uncertainty	u_c		3.6001	nmol/mol
				Expanded uncertainty	U		7.2003	nmol/mol
				Relative expanded uncertainty	W		6.00	%
				Maximum allowed expanded uncertainty	W_{req}		15	%

Table 37: Expanded uncertainty. Laboratory and field test for system 2

Measuring device:	APOA 380				Serial-No.:		WJX5WPV9	
Measured component:	O3				1h-alert threshold:		120	nmol/mol
No.	**Performance characteristic**	**Performance criterion**		**Result**	**Partial uncertainty**		**Square of partial uncertainty**	
1	Repeatability standard deviation at zero	≤	1.0 nmol/mol	0.080	$u_{r,z}$	0.01	0.0001	
2	Repeatability standard deviation at 1h-alert threshold	≤	3.0 nmol/mol	1.240	$u_{r,lh}$	not considered, as ur,lh = 0,14 < ur,f	-	
3	"lack of fit" at 1h-alert threshold	≤	4.0% of measured value	1.440	$u_{l,lh}$	1.00	0.9953	
4	Sensitivity coefficient of sample gas pressure at 1h-alert threshold	≤	2.0 nmol/mol/kPa	0.050	u_{gp}	0.55	0.2992	
5	Sensitivity coefficient of sample gas temperature at 1h-alert threshold	≤	1.0 nmol/mol/K	0.050	u_{gt}	0.55	0.2992	
6	Sensitivity coefficient of surrounding temperature at 1h-alert threshold	≤	1.0 nmol/mol/K	0.174	u_{st}	1.90	3.6231	
7	Sensitivity coefficient of electrical voltage at 1h-alert threshold	≤	0.30 nmol/mol/V	0.050	u_V	0.84	0.7034	
8a	Interferent H_20 with 19 mmol/mol	≤	10 nmol/mol (Zero)	0.100	u_{H2O}	-1.94	3.7639	
		≤	10 nmol/mol (Span)	-2.600				
8b	Interferent Toluene with 0,5 µmol/mol	≤	5.0 nmol/mol (Zero)	-0.470	$u_{int,pos}$ or $u_{int,\ neg}$	1.14	1.3068	
		≤	5.0 nmol/mol (Span)	-1.980				
8c	Interferent Xylene with 0,5 µmol/mol	≤	5.0 nmol/mol (Zero)	-0.160				
		≤	5.0 nmol/mol (Span)	0.310				
9	Averaging effect	≤	7.0% of measured value	-1.000	u_{av}	-0.69	0.4800	
10	Reproducibility standard deviation under field conditions	≤	5.0% of average over 3 months	4.130	$u_{r,f}$	4.96	24.5619	
11	Long term drift at zero level	≤	5.0 nmol/mol	-0.360	$u_{d,l,z}$	-0.21	0.0432	
12	Long term drift at span level	≤	5.0% of max. of certification range	-2.090	$u_{d,l,lh}$	-1.45	2.0967	
18	Difference sample/calibration port	≤	1.0%	-0.140	$u_{\Delta sc}$	-0.17	0.0282	
21	Uncertainty of test gas	≤	3.0%	2.000	u_{cg}	1.20	1.4400	
				Combined standard uncertainty	u_c		6.2961	nmol/mol
				Expanded uncertainty	U		12.5922	nmol/mol
				Relative expanded uncertainty	W		10.49	%
				Maximum allowed expanded uncertainty	W_{req}		15	%

8. Recommendations for use in practice

Work in the maintenance interval

The tested measuring systems require regular performance of the following tasks:

- Regular visual inspections/telemetric inspections
- System status checks
- System display checks for error messages
- Replacement of the internal particle filter at the sample gas inlet depending on the conditions at the measuring location
- Zero and reference checks using suitable test gas every two weeks in accordance with standard EN 14625

Other than that, the manufacturer’s instructions in chapter 7 in the user manual are to be followed.

Environmental Protection/Air Pollution Control

Dipl.-Ing. Martin Schneider

Dr. Peter Wilbring

Cologne, 07 February 2025
EuL/21262682/C

9. Bibliography

[1] VDI 4202 part 1: Performance test, declaration of suitability, and certification of point-related measuring systems for gaseous air pollutants, April 2018

[2] European standard EN 14625: Ambient air - Standard method for the measurement of the concentration of ozone by ultraviolet photometry, December 2012

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

[4] Directive 2024/2881 of the European Parliament and of the Council of 23 October 2024 on ambient air quality and cleaner air for Europe

[5] EN 14625: Ambient air - Standard method for the measurement of the concentration of ozone by ultraviolet photometry, December 2024

10. Annexes

Annex 1	**Evaluation according to EN 14625:2024**
Annex 2	**Certificate of Accreditation to EN ISO/IEC 17025**
Annex 3	**Weather data during field testing**
Annex 4	**Manual**

Annex 1:

Evaluation on the basis of EN 14625:2024

Performance testing detailed in this report was carried out and evaluated on the basis of VDI 4202-1 (April 2018) and EN 14625 (November 2012). The revised version of the EN 14625 standard was published in English at the end of 2024 (date of publication 18 December 2024). The standard is expected to be published in German in spring 2025. The changes to the testing requirements that were made in the revised standard were known at the start of the test process.

During the testing of the Horiba APOA-380 measuring system, the revised requirements of EN 14625:2024 were also taken into account. Tests with revised requirements were also carried out and evaluated on the basis of the requirements of EN 14625:2024. Specifically, the following criteria apply:

- 8.4.7 Sensitivity coefficient to sample gas pressure
- 8.4.8 Sensitivity coefficient to the sample gas temperature
- 8.4.9 Sensitivity coefficient to the surrounding temperature

The individual test criteria are listed below with the respective test results. Changes to the test requirements are marked in blue. Additionally, the total uncertainty is also shown with the test results in accordance with EN 14625:2024.

10 8.4.7 Sensitivity coefficient to sample gas pressure (EN 14625:2024)

The sensitivity coefficient to sample gas pressure shall be ≤ 2.0 nmol/mol/kPa.

7.2 Test procedures

Measurements are taken at a concentration of about 70% to 80% of the maximum of the certification range at an absolute pressure of about **90 kPa** ± 0.2 kPa and about 110 ± 0.2 kPa. At each pressure after waiting the time equivalent to one independent reading, three individual measurements are recorded. From these measurements, the averages at each pressure are calculated.

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

Instrument manufacturers shall describe in detail how pressure correction is implemented in their instrument, and the exact locations of the pressure sensors used for these calculations.

- Option 1: If the pressure compensation hardware is completely contained within the sample tubing and measurement cell, the instruments will be tested in the lab by varying the sample inlet pressure in the range from 90 kPa to 110 kPa. If an instrument has multiple flow paths (e.g. the O_3 flow path for chemiluminescent NOx analysers or baseline cross-flow systems) the inlet pressure for those particular paths shall be varied identically and concurrently with the pressure in the main sample flow path.

- Option 2: If manipulation of the inlet pressure of the sample flow paths or the additional flow paths is technically not possible or if the pressure compensation is based on other pressure sensors outside of the impacted flow paths, the instruments shall be tested at a suitable pressure test stand. An example is described in Annex H. The instruments are tested in the laboratory by varying the sample inlet pressure in the range from 90 kPa to 110 kPa.

The sensitivity coefficient to sample gas pressure is calculated as follows.

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

Where:

b_{gp}	is the sample gas pressure sensitivity coefficient;
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 sampling gas pressure P_2;
P_1	is the minimum sampling gas pressure P_1;
P_2	is the maximum sampling gas pressure P_2.

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

In compliance with the standard, the test has to be performed with the ozone component. Pursuant to EN 14625, the test shall be performed at a concentration level of 70% to 80% of the certification range for ozone.

7.3 Testing

The test was carried out in accordance with the aforementioned test specifications of EN 14625:2024. The measuring system works with a closed gas path.

The ambient pressure (and therefore also the sample gas pressure in the analyser) is measured in the APOA-380 by a pressure sensor installed on the board. This had to be pressurised in the same ratio as the sample gas when carrying out this test.

A negative pressure could be generated in each case by reducing the volume of test gas supplied by restricting the sample gas line. For the positive pressure test, the AMS was connected to a sample gas source. The test gas volume generated was set at a higher rate than the volume sucked in by the analyser. The excess supply was diverted via a T-piece. The positive pressure was produced by blocking the bypass line. The test gas pressure was determined with the help of a pressure sensor located in the sample gas path.

Individual measurements were performed at concentrations around 70% to 80% of the maximum certification range and sample gas pressures of **90 kPa** and 110 kPa.

7.4 Evaluation

The following sensitivity coefficients to sample gas pressure were determined:

Table 38: Sensitivity coefficient to sample gas pressure, EN 14625:2024

	requirement	device 1		device 2	
sensitivity coeff. sample gas pressure b_{gp} [nmol/mol/kPa]	≤ 2,0	0.12	✓	0.14	✓

7.5 Assessment

According to EN 14625:2024, the sensitivity coefficient to sample gas pressure for ozone was 0.12 nmol/mol/kPa for instrument 1 and 0.14 nmol/mol/kPa for instrument 2.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 39: Individual results of the sensitivity to sample gas pressure, EN 14625:2024

2024-04-03			device 1	device 2
time	pressure [kPa]	concentration	[nmol/mol]	[nmol/mol]
15:50:00	90	187.50	190.47	193.13
15:51:00	90	187.50	190.63	193.13
15:52:00	90	187.50	190.63	193.28
average C_{P1}			190.57	193.18
16:06:00	110	187.50	188.28	190.31
16:07:00	110	187.50	187.97	190.31
16:08:00	110	187.50	188.13	190.47
average C_{P2}			188.13	190.36

10 8.4.8 Sensitivity coefficient to the sample gas temperature (EN 14625:2024)

The sensitivity coefficient to the sample gas temperature shall be ≤ 1.0 nmol/mol/K.

7.2 Test procedures

Measurements shall be performed at sample gas temperatures of **T_1 = 5 °C and T_2 = 40 °C** . The sensitivity coefficient to sample gas temperature is determined at a concentration of around 70% to 80% of the maximum certification range. Wait the time equivalent to one independent measurement and record three individual measurements at each temperature.

The sample gas temperature, measured at the inlet of the analyser, shall be held constant for at least 30 minutes.

The sensitivity coefficient to sample gas temperature is calculated as follows:

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

Where:

b_{gt}	is the sample gas temperature sensitivity coefficient;
$C_{GT,1}$	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 indicated above.

In compliance with the standard, the test has to be performed with the ozone component. Pursuant to EN 14625:2024, the test shall be performed at a concentration level of 70% to 80% of the certification range of ozone.

7.3 Testing

The test was carried out in accordance with the aforementioned test specifications of EN 14625:2024.

For the test, the test gas and the dilution gas were placed in the climatic chamber. The test gas mixture was fed through an approx. 50 metre long hose bundle, which was located in a climate chamber. The measuring systems were installed directly upstream of the climatic chamber. The end of the tube-bundle was led out of the climatic chamber and connected to the measuring systems. The feed line outside of the climatic chamber was isolated; a thermometer was used to monitor the temperature of the test gas directly upstream of the measuring system. The temperature of the climatic chamber was adjusted so that the gas temperature directly upstream of the analysers was 5 °C and 40 °C respectively.

7.4 Evaluation

Table 40: Sensitivity coefficient to the sample gas temperature, EN 14625:2024

	requirement	device 1		device 2	
sensitivity coeff. sample gas temperature b_{gt} [nmol/mol/K]	≤ 1,0	0.07	✓	0.05	✓

7.5 Assessment

The sensitivity coefficient to the sample gas temperature was 0.07 nmol/mol/K for instrument 1 and 0.05 nmol/mol/K for instrument 2.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 41: Individual results of the influence of the sample gas temperature, EN 14625:2024

2024-04-12			device 1	device 2
time	temp [ºC]	concentration	[nmol/mol]	[nmol/mol]
07:32:00	5	190.00	189.53	192.19
07:33:00	5	190.00	191.41	192.19
07:34:00	5	190.00	191.72	192.66
average $C_{GT,1}$			190.89	192.34
13:12:00	40	190.00	188.75	190.78
13:13:00	40	190.00	188.28	190.31
13:14:00	40	190.00	188.59	190.31
average $C_{GT,2}$			188.54	190.47

10 8.4.9 Sensitivity coefficient to the surrounding temperature (EN 14625:2024)

The sensitivity coefficient to the surrounding temperature shall be ≤ 1.0 nmol/mol/K.

7.2 Test procedures

The sensitivity of the analyser readings to the surrounding temperature shall be determined by performing measurements at the following temperatures (or within the specifications of the manufacturer):

1) at the minimum temperature T_{min} = 5 °C;
2) at the temperature T_l = 20 °C;
3) at the maximum temperature T_{max} = 40 °C.

For these tests, a climate chamber is necessary.

In compliance with the standard, the test has to be performed with the component NO. Pursuant to EN 14625:2024, the test shall be performed at a concentration level of 70% to 80% of the certification range of ozone.

At each temperature setting after waiting the time equivalent to one independent measurement, three individual measurements at zero and at span 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, at T_{min} and again at T_l. This measurement procedure shall be repeated at the temperature sequence of T_l, T_{max} and at 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 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 surrounding temperature sensitivity coefficient;

x_T is the average 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 surrounding temperature in the laboratory;

$T_{S,0}$ is the average of the surrounding temperatures at set point.

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

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

7.3 Testing

The test was carried out in accordance with the aforementioned test specifications of EN 14625:2024.

7.4 Evaluation

The following sensitivity coefficients to the surrounding temperature have been determined:

Table 42: Sensitivity coefficients to the surrounding temperature, EN 14625:2024

	requirements	device 1		device 2	
sensitivity coefficient at 5 ºC for zero level [nmol/mol/K]	≤ 1,0	0.016	✓	0.009	✓
sensitivity coefficient at 40 ºC for zero level [nmol/mol/K]	≤ 1,0	0.000	✓	0.027	✓
sensitivity coefficient at 5 ºC for span level [nmol/mol/K]	≤ 1,0	0.073	✓	0.122	✓
sensitivity coefficient at 40 ºC for span level [nmol/mol/K]	≤ 1,0	0.112	✓	0.085	✓

As is evident from Table 42, the sensitivity coefficient to the surrounding temperature at zero and at span point meets the performance criteria.

7.5 Assessment

The sensitivity coefficient to the surrounding temperature b_{st} did not exceed the performance criterion specified at 1.0 nmol/mol/K. For the purpose of the uncertainty calculation, the largest value b_{st} is used for both instruments. For ozone, this would be 0.112 nmol/mol/K for instrument 1 and 0.122 nmol/mol/K for instrument 2.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 43 presents the individual test results.

Table 43: Individual results of the sensitivity coefficients to the surrounding temperature, EN 14625:2024

	zero level				span level			
			device 1	device 2			device 1	device 2
date	time	temp [ºC]	[nmol/mol]	[nmol/mol]	time	temp [ºC]	[nmol/mol]	[nmol/mol]
2024-04-08	08:25:00	20	0.8	0.6	08:55:00	20	190.2	190.5
2024-04-08	08:26:00	20	0.3	0.8	08:56:00	20	189.8	189.8
2024-04-08	08:27:00	20	0.3	0.8	08:57:00	20	190.0	189.4
average ($X_{1(TS1)}$)			0.5	0.7			190.0	189.9
2024-04-08	15:21:00	5	0.2	0.5	15:35:00	5	191.1	190.8
2024-04-08	15:22:00	5	0.3	0.5	15:36:00	5	190.2	191.1
2024-04-08	15:23:00	5	0.3	0.2	15:37:00	5	191.1	192.5
average($X_{Ts,1}$)		0	0.3	0.4			190.8	191.5
2024-04-09	07:44:00	20	0.5	0.3	07:57:00	20	188.3	188.8
2024-04-09	07:45:00	20	0.5	0.3	07:58:00	20	189.5	189.8
2024-04-09	07:46:00	20	0.6	0.2	07:59:00	20	190.3	189.5
average ($X_{2(TS1)}$) = ($X_{1(TS2)}$)			0.5	0.3			189.4	189.4
2024-04-09	14:27:00	40	0.3	-0.9	14:42:00	40	191.7	190.8
2024-04-09	14:28:00	40	0.5	-0.8	14:43:00	40	191.6	191.6
2024-04-09	14:29:00	40	0.6	-0.5	14:44:00	40	192.0	191.7
average($X_{Ts,2}$)			0.5	-0.7			191.8	191.4
2024-04-10	07:04:00	20	0.0	-0.8	07:19:00	20	190.0	190.5
2024-04-10	07:05:00	20	0.5	-0.6	07:20:00	20	189.1	189.8
2024-04-10	07:06:00	20	0.8	-0.5	07:21:00	20	190.0	189.5
average ($X_{2(TS2)}$)			0.4	-0.6			189.7	189.9

10 Total uncertainty in accordance with Annex E of EN 14625 (2025)

Table 44: Expanded uncertainty. Laboratory test for system 1. EN 14625:2024

Measuring device:	APOA 380				Serial-No.:		XEHXE7RR	
Measured component:	O3				1h-alert threshold:		120	nmol/mol
No.	**Performance characteristic**	**Performance criterion**		**Result**	**Partial uncertainty**		**Square of partial uncertainty**	
1	Repeatability standard deviation at zero	≤	1.0 nmol/mol	0.030	$u_{r,z}$	0.00	0.0000	
2	Repeatability standard deviation at 1h-alert threshold	≤	3.0 nmol/mol	1.250	$u_{r,lh}$	0.15	0.0230	
3	"lack of fit" at 1h-alert threshold	≤	4.0% of measured value	1.410	$u_{l,lh}$	0.98	0.9543	
4	Sensitivity coefficient of sample gas pressure at 1h-alert threshold	≤	2.0 nmol/mol/kPa	0.120	u_{gp}	0.88	0.7659	
5	Sensitivity coefficient of sample gas temperature at 1h-alert threshold	≤	1.0 nmol/mol/K	0.070	u_{gt}	0.89	0.7981	
6	Sensitivity coefficient of surrounding temperature at 1h-alert threshold	≤	1.0 nmol/mol/K	0.112	u_{st}	1.43	2.0432	
7	Sensitivity coefficient of electrical voltage at 1h-alert threshold	≤	0.30 nmol/mol/V	0.050	u_V	0.84	0.7034	
8a	Interferent H_20 with 19 mmol/mol	≤	10 nmol/mol (Zero)	0.310	u_{H2O}	-1.36	1.8443	
		≤	10 nmol/mol (Span)	-1.820				
8b	Interferent Toluene with 0,5 µmol/mol	≤	5.0 nmol/mol (Zero)	-0.420	$u_{int,pos}$ or $u_{int, neg}$	0.93	0.8640	
		≤	5.0 nmol/mol (Span)	-1.610				
8c	Interferent Xylene with 0,5 µmol/mol	≤	5.0 nmol/mol (Zero)	0.050				
		≤	5.0 nmol/mol (Span)	0.780				
9	Averaging effect	≤	7.0% of measured value	0.800	u_{av}	0.55	0.3072	
18	Difference sample/calibration port	≤	1.0%	0.250	$u_{\Delta sc}$	0.30	0.0900	
21	Uncertainty of test gas	≤	3.0%	2.000	u_{cg}	1.20	1.4400	
				Combined standard uncertainty	u_c		3.1358	nmol/mol
				Expanded uncertainty	U		6.2716	nmol/mol
				Relative expanded uncertainty	W		5.23	%
				Maximum allowed expanded uncertainty	W_{req}		15	%

Table 45: Expanded uncertainty. Laboratory and field test for system 1. EN 14625:2024

Measuring device:	APOA 380				Serial-No.:		XEHXE7RR	
Measured component:	O3				1h-alert threshold:		120	nmol/mol
No.	**Performance characteristic**	**Performance criterion**		**Result**	**Partial uncertainty**		**Square of partial uncertainty**	
1	Repeatability standard deviation at zero	≤	1.0 nmol/mol	0.030	$u_{r,z}$	0.00	0.0000	
2	Repeatability standard deviation at 1h-alert threshold	≤	3.0 nmol/mol	1.250	$u_{r,lh}$	not considered, as ur,lh = 0,15 < ur,f	-	
3	"lack of fit" at 1h-alert threshold	≤	4.0% of measured value	1.410	$u_{l,lh}$	0.98	0.9543	
4	Sensitivity coefficient of sample gas pressure at 1h-alert threshold	≤	2.0 nmol/mol/kPa	0.120	u_{gp}	0.88	0.7659	
5	Sensitivity coefficient of sample gas temperature at 1h-alert threshold	≤	1.0 nmol/mol/K	0.070	u_{gt}	0.89	0.7981	
6	Sensitivity coefficient of surrounding temperature at 1h-alert threshold	≤	1.0 nmol/mol/K	0.112	u_{st}	1.43	2.0432	
7	Sensitivity coefficient of electrical voltage at 1h-alert threshold	≤	0.30 nmol/mol/V	0.050	u_V	0.84	0.7034	
8a	Interferent H_20 with 19 mmol/mol	≤	10 nmol/mol (Zero)	0.310	u_{H2O}	-1.36	1.8443	
		≤	10 nmol/mol (Span)	-1.820				
8b	Interferent Toluene with 0,5 µmol/mol	≤	5.0 nmol/mol (Zero)	-0.420	$u_{int,pos}$ or $u_{int, neg}$	0.93	0.8640	
		≤	5.0 nmol/mol (Span)	-1.610				
8c	Interferent Xylene with 0,5 µmol/mol	≤	5.0 nmol/mol (Zero)	0.050				
		≤	5.0 nmol/mol (Span)	0.780				
9	Averaging effect	≤	7.0% of measured value	0.800	u_{av}	0.55	0.3072	
10	Reproducibility standard deviation under field conditions	≤	5.0% of average over 3 months	4.130	$u_{r,f}$	4.96	24.5619	
11	Long term drift at zero level	≤	5.0 nmol/mol	-1.270	$u_{d,l,z}$	-0.73	0.5376	
12	Long term drift at span level	≤	5.0% of max. of certification range	-1.560	$u_{d,l,lh}$	-1.08	1.1681	
18	Difference sample/calibration port	≤	1.0%	0.250	$u_{\Delta sc}$	0.30	0.0900	
21	Uncertainty of test gas	≤	3.0%	2.000	u_{cg}	1.20	1.4400	
				Combined standard uncertainty	u_c		6.0065	nmol/mol
				Expanded uncertainty	U		12.0130	nmol/mol
				Relative expanded uncertainty	W		10.01	%
				Maximum allowed expanded uncertainty	W_{req}		15	%

Table 46: Expanded uncertainty. Laboratory test for system 2. EN 14625:2024

Measuring device: APOA 380 Serial-No.: WJX5WPV9
Measured component: O3 1h-alert threshold: 120 nmol/mol

No.	Performance characteristic	Performance criterion		Result	Partial uncertainty		Square of partial uncertainty
1	Repeatability standard deviation at zero	≤	1.0 nmol/mol	0.080	$u_{r,Z}$	0.01	0.0001
2	Repeatability standard deviation at 1h-alert threshold	≤	3.0 nmol/mol	1.240	$u_{r,lv}$	0.15	0.0218
3	"lack of fit" at 1h-alert threshold	≤	4.0% of measured value	1.440	$u_{l,lv}$	1.00	0.9953
4	Sensitivity coefficient of sample gas pressure at 1h-alert threshold	≤	2.0 nmol/mol/kPa	0.140	u_{gp}	1.02	1.0424
5	Sensitivity coefficient of sample gas temperature at 1h-alert threshold	≤	1.0 nmol/mol/K	0.050	u_{gt}	0.64	0.4072
6	Sensitivity coefficient of surrounding temperature at 1h-alert threshold	≤	1.0 nmol/mol/K	0.122	u_{st}	1.56	2.4243
7	Sensitivity coefficient of electrical voltage at 1h-alert threshold	≤	0.30 nmol/mol/V	0.050	u_V	0.84	0.7034
8a	Interferent H_20 with 19 mmol/mol	≤	10 nmol/mol (Zero)	0.100	u_{H2O}	-1.94	3.7639
		≤	10 nmol/mol (Span)	-2.600			
8b	Interferent Toluene with 0,5 µmol/mol	≤	5.0 nmol/mol (Zero)	-0.470	$u_{int,pos}$ or $u_{int, neg}$	1.14	1.3068
		≤	5.0 nmol/mol (Span)	-1.980			
8c	Interferent Xylene with 0,5 µmol/mol	≤	5.0 nmol/mol (Zero)	-0.160			
		≤	5.0 nmol/mol (Span)	0.310			
9	Averaging effect	≤	7.0% of measured value	-1.000	u_{av}	-0.69	0.4800
18	Difference sample/calibration port	≤	1.0%	-0.140	u_{Dsc}	-0.17	0.0282
21	Uncertainty of test gas	≤	3.0%	2.000	ucg	1.20	1.4400

Combined standard uncertainty	u_c	3.5515	nmol/mol
Expanded uncertainty	U	7.1031	nmol/mol
Relative expanded uncertainty	W	5.92	%
Maximum allowed expanded uncertainty	W_{req}	15	%

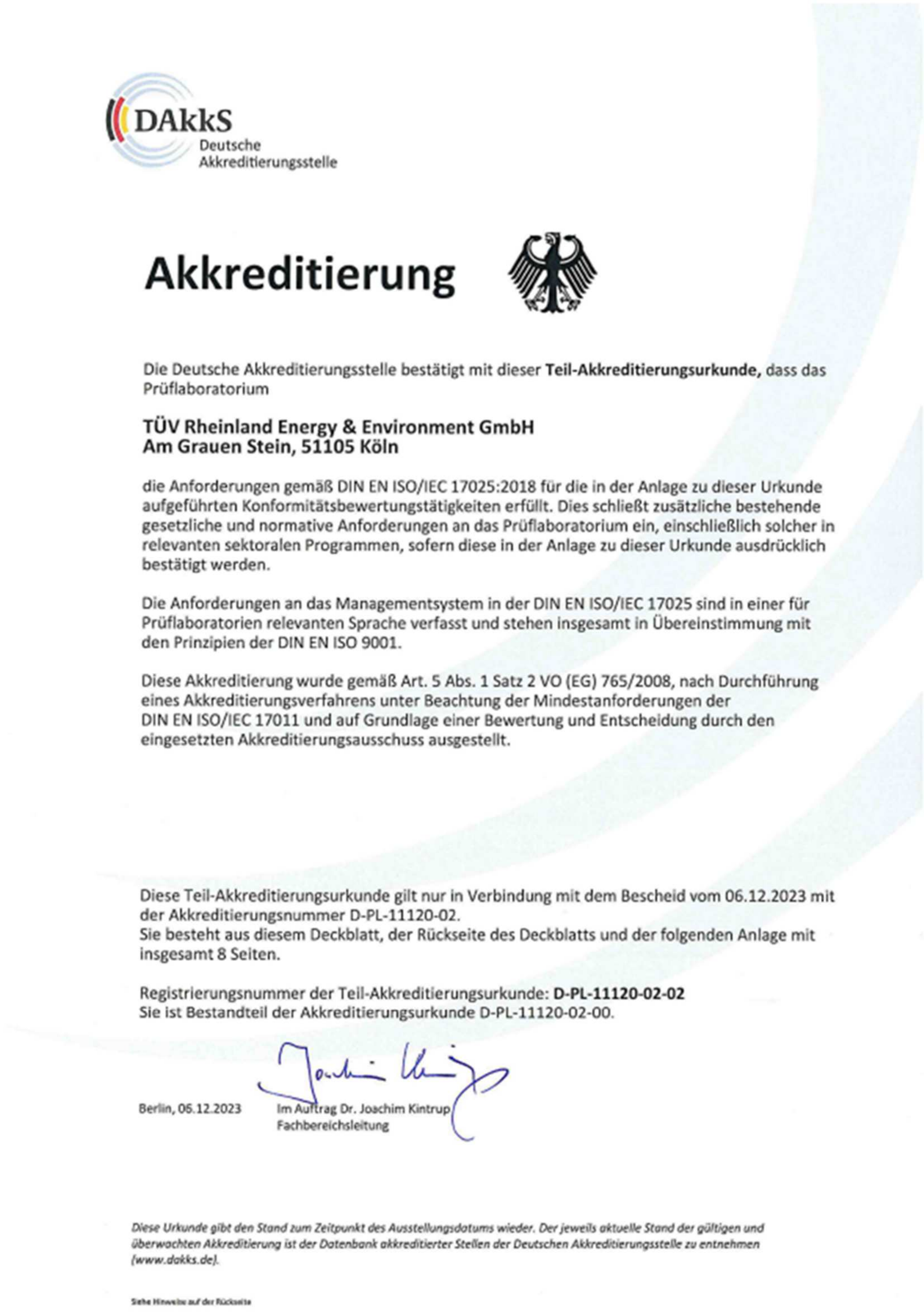
Table 47: Expanded uncertainty. Laboratory and field test for system 2. EN 14625:2024

Measuring device: APOA 380 Serial-No.: WJX5WPV9
Measured component: O3 1h-alert threshold: 120 nmol/mol

No.	Performance characteristic	Performance criterion		Result	Partial uncertainty		Square of partial uncertainty
1	Repeatability standard deviation at zero	≤	1.0 nmol/mol	0.080	$u_{r,z}$	0.01	0.0001
2	Repeatability standard deviation at 1h-alert threshold	≤	3.0 nmol/mol	1.240	$u_{r,lh}$	not considered, as ur,lh = 0,14 < ur,f	-
3	"lack of fit" at 1h-alert threshold	≤	4.0% of measured value	1.440	$u_{l,lh}$	1.00	0.9953
4	Sensitivity coefficient of sample gas pressure at 1h-alert threshold	≤	2.0 nmol/mol/kPa	0.140	u_{gp}	1.02	1.0424
5	Sensitivity coefficient of sample gas temperature at 1h-alert threshold	≤	1.0 nmol/mol/K	0.050	u_{gt}	0.64	0.4072
6	Sensitivity coefficient of surrounding temperature at 1h-alert threshold	≤	1.0 nmol/mol/K	0.122	u_{st}	1.56	2.4243
7	Sensitivity coefficient of electrical voltage at 1h-alert threshold	≤	0.30 nmol/mol/V	0.050	u_V	0.84	0.7034
8a	Interferent H_20 with 19 mmol/mol	≤	10 nmol/mol (Zero)	0.100	u_{H2O}	-1.94	3.7639
		≤	10 nmol/mol (Span)	-2.600			
8b	Interferent Toluene with 0,5 µmol/mol	≤	5.0 nmol/mol (Zero)	-0.470	$u_{int,pos}$ or $u_{int, neg}$	1.14	1.3068
		≤	5.0 nmol/mol (Span)	-1.980			
8c	Interferent Xylene with 0,5 µmol/mol	≤	5.0 nmol/mol (Zero)	-0.160			
		≤	5.0 nmol/mol (Span)	0.310			
9	Averaging effect	≤	7.0% of measured value	-1.000	u_{av}	-0.69	0.4800
10	Reproducibility standard deviation under field conditions	≤	5.0% of average over 3 months	4.130	$u_{r,f}$	4.96	24.5619
11	Long term drift at zero level	≤	5.0 nmol/mol	-0.360	$u_{d,l,z}$	-0.21	0.0432
12	Long term drift at span level	≤	5.0% of max. of certification range	-2.090	$u_{d,l,lh}$	-1.45	2.0967
18	Difference sample/calibration port	≤	1.0%	-0.140	$u_{\Delta sc}$	-0.17	0.0282
21	Uncertainty of test gas	≤	3.0%	2.000	u_{cg}	1.20	1.4400

Combined standard uncertainty	u_c	6.2685	nmol/mol
Expanded uncertainty	U	12.5369	nmol/mol
Relative expanded uncertainty	W	10.45	%
Maximum allowed expanded uncertainty	W_{req}	15	%

Annex 2:



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Akkreditierung

Die Deutsche Akkreditierungsstelle bestätigt mit dieser **Teil-Akkreditierungsurkunde,** dass das Prüflaboratorium

TÜV Rheinland Energy & Environment GmbH
Am Grauen Stein, 51105 Köln

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Berlin, 06.12.2023

Im Auftrag Dr. Joachim Kintrup
Fachbereichsleitung

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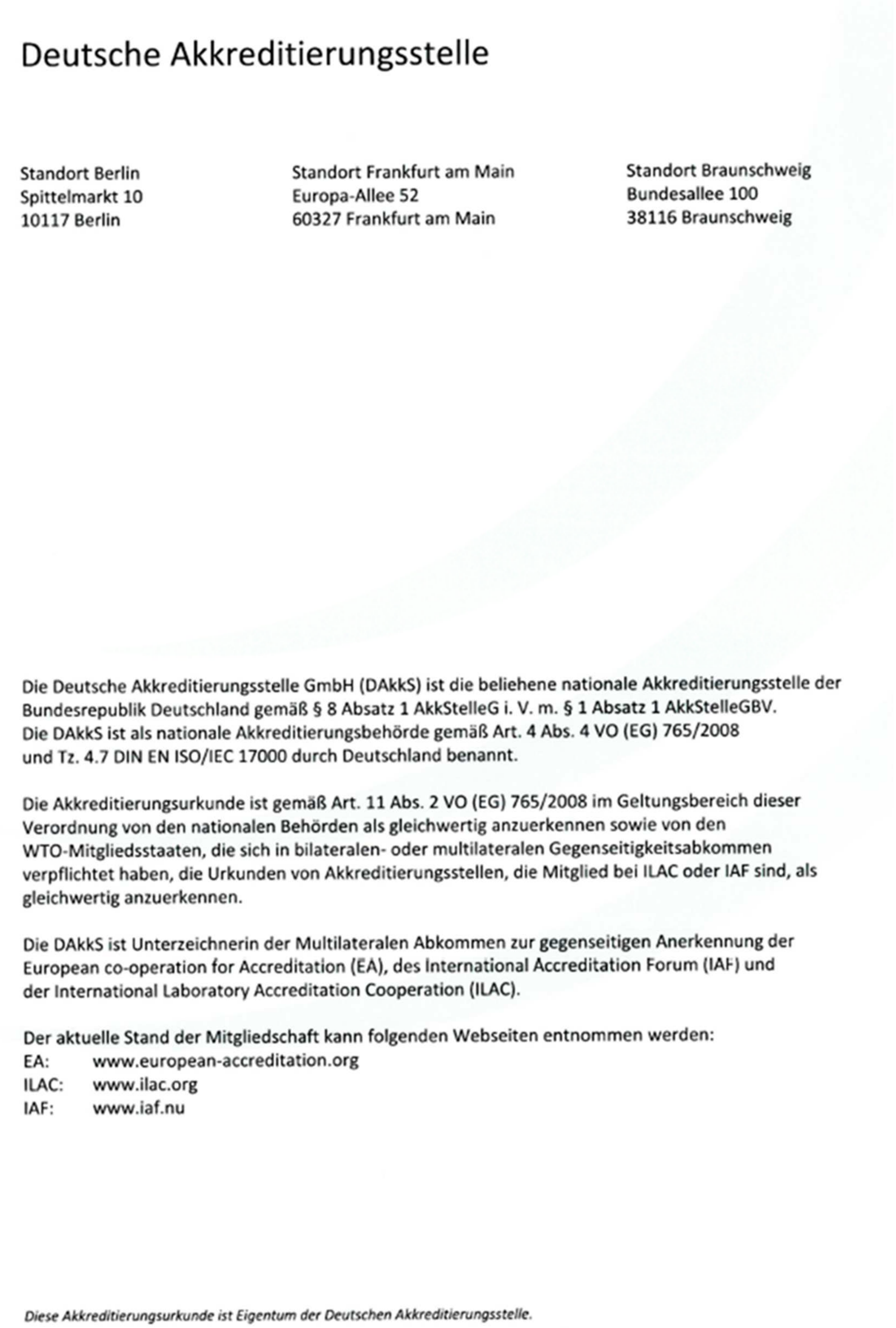
Figure 12: Certificate of accreditation according to EN ISO/IEC 17025



Deutsche Akkreditierungsstelle

Standort Berlin
Spittelmarkt 10
10117 Berlin

Standort Frankfurt am Main
Europa-Allee 52
60327 Frankfurt am Main

Standort Braunschweig
Bundesallee 100
38116 Braunschweig

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Figure 12: Certificate of accreditation according to EN ISO/IEC 17025 - page 2

Annex 3:

Table 48: Weather data (daily averages), April/May 2024

April / May 2024	Date	Avg. Air temperature [°C]	Rel. Humidity [%]	Air pressure [hPa]
29	29.04.2024	14.8	66.4	1012.7
30	30.04.2024	17.9	66.2	1008.5
1	01.05.2024	19.5	69.6	999.0
2	02.05.2024	17.8	75.4	992.5
3	03.05.2024	12.9	81.2	1003.4
4	04.05.2024	12.4	79.2	1006.8
5	05.05.2024	13.8	75.1	1002.5
6	06.05.2024	13.6	91.3	1001.1
7	07.05.2024	14.1	89.0	1010.2
8	08.05.2024	13.8	82.8	1018.5
9	09.05.2024	15.2	72.0	1019.3
10	10.05.2024	16.7	67.1	1016.0
11	11.05.2024	17.8	65.9	1013.8
12	12.05.2024	19.8	60.9	1009.3
13	13.05.2024	19.6	68.1	1004.4
14	14.05.2024	20.8	63.0	999.3
15	15.05.2024	17.2	80.7	999.3
16	16.05.2024	16.7	86.0	998.3
17	17.05.2024	15.5	88.3	999.4
18	18.05.2024	15.6	88.4	1002.6
19	19.05.2024	15.6	82.6	1003.8
20	20.05.2024	16.9	75.8	1003.8
21	21.05.2024	15.6	86.3	1000.4
22	22.05.2024	16.8	77.6	1002.4
23	23.05.2024	16.8	70.7	1008.3
24	24.05.2024	14.3	92.1	1010.4
25	25.05.2024	16.3	79.0	1010.1
26	26.05.2024	17.2	76.9	1009.1
27	27.05.2024	15.8	80.1	1010.1
28	28.05.2024	14.9	73.6	1011.2
29	29.05.2024	16.5	81.7	1004.2
30	30.05.2024	15.6	82.4	999.7
31	31.05.2024	15.8	78.4	1004.1

Table 49: Weather data (daily averages), June 2024

July 2024	Date	Avg. Air temperature [°C]	Rel. Humidity [%]	Air pressure [hPa]
1	01.06.2024	16.2	87.1	1009.0
2	02.06.2024	15.0	83.3	1014.2
3	03.06.2024	13.8	74.7	1013.4
4	04.06.2024	16.9	70.3	1007.3
5	05.06.2024	15.4	79.6	1005.9
6	06.06.2024	15.3	64.4	1009.9
7	07.06.2024	16.5	61.6	1011.4
8	08.06.2024	17.3	61.4	1006.0
9	09.06.2024	16.1	59.4	1004.1
10	10.06.2024	12.7	72.0	1001.4
11	11.06.2024	13.6	64.6	1008.5
12	12.06.2024	12.4	70.0	1012.5
13	13.06.2024	14.8	60.2	1010.5
14	14.06.2024	16.7	71.5	1001.9
15	15.06.2024	16.8	63.6	998.9
16	16.06.2024	16.2	73.2	1001.5
17	17.06.2024	16.9	89.5	1005.1
18	18.06.2024	18.2	88.2	1006.2
19	19.06.2024	17.1	82.7	1010.2
20	20.06.2024	17.6	82.1	1011.6
21	21.06.2024	19.1	83.3	1005.7
22	22.06.2024	16.9	77.0	1007.3
23	23.06.2024	19.9	69.6	1012.3
24	24.06.2024	21.1	67.6	1012.7
25	25.06.2024	22.6	64.7	1008.3
26	26.06.2024	24.0	62.2	1004.3
27	27.06.2024	25.4	63.1	1002.8
28	28.06.2024	21.3	59.4	1008.9
29	29.06.2024	20.5	62.6	1006.7
30	30.06.2024	18.0	86.1	1002.5

Table 50: Weather data (daily averages), July / August 2024

July / August 2024	Date	Avg. Air temperature [°C]	Rel. Humidity [%]	Air pressure [hPa]
1	01.07.2024	16.8	76.7	1008.4
2	02.07.2024	15.3	85.6	1008.2
3	03.07.2024	14.3	81.0	1004.9
4	04.07.2024	17.0	73.2	1002.1
5	05.07.2024	17.0	69.6	1004.5
6	06.07.2024	19.1	67.0	998.4
7	07.07.2024	17.2	56.0	1007.2
8	08.07.2024	18.7	64.1	1010.4
9	09.07.2024	23.8	63.3	1007.8
10	10.07.2024	21.7	82.1	1008.8
11	12.07.2024	21.1	69.5	1010.5
12	12.07.2024	16.9	83.1	1004.7
13	13.07.2024	16.2	72.5	1006.8
14	14.07.2024	18.8	67.1	1006.8
15	15.07.2024	20.9	69.2	1004.9
16	16.07.2024	19.7	76.4	1005.7
17	17.07.2024	20.4	69.0	1013.6
18	18.07.2024	21.8	67.5	1015.6
19	19.07.2024	22.8	66.8	1012.6
20	20.07.2024	24.4	69.0	1004.2
21	21.07.2024	22.8	77.8	1002.2
22	22.07.2024	21.7	68.7	1010.2
23	23.07.2024	20.5	73.2	1011.2
24	24.07.2024	19.4	71.8	1014.0
25	25.07.2024	20.7	64.1	1008.8
26	26.07.2024	21.4	76.5	1005.5
27	27.07.2024	19.1	93.1	1007.9
28	28.07.2024	19.4	73.8	1017.5
29	29.07.2024	20.8	67.4	1016.8
30	30.07.2024	23.9	63.0	1010.8
31	31.07.2024	22.2	76.5	1008.5
1	01.08.2024	21.3	90.1	1005.7

Annex 4:

Manual