TÜV RHEINLAND ENERGY GMBH

Performance test report for the nCLD AL^2 ambient air measuring system manufactured by ECO PHYSICS AG for the components NO, NO_2 and NO_x

TÜV-Report: 936/21250441/A
Cologne, 30 July 2021

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D-PL-11120-02-00

Performance test report for the nCLD AL^2 ambient air measuring system manufactured by ECO PHYSICS AG for the components NO, NO$_2$ and NO$_x$

AMS designation: nCLD AL^2

Manufacturer:

ECO PHYSICS AG
Bubikonerstrasse 45
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Test period: October 2020 to July 2021

Date of report: 30 July 2021

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1. Summary and certification proposal

1.1 Summary Overview

On behalf of ECO PHYSICS AG, TÜV Rheinland Energy GmbH carried out the performance test for the nCLD AL^2 measuring system for the components NO, NO_2 and NO_x. The test was carried out in compliance with the following norms / standards and requirements:

- VDI Guideline 4202 part 1: Performance test, declaration of suitability, and certification of point-related measuring systems for gaseous air pollutants of April 2018
- EN 14211: Ambient air – Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence, of November 2012

The nCLD AL^2 measuring system measures the components NO, NO_2 and NO_x using the chemiluminescence method. This measuring principle conforms to the EU reference method. The tests were carried out in the laboratory of TÜV Rheinland Energy GmbH and during a three-month field test near Cologne.

ECO PHYSICS AG distributes the tested measuring system under two different designations. The models nCLD AL^2 and nCLD 855Y are metrologically identical.

The nCLD AL^2 model underwent a complete performance test with two test specimens. This model is also only available in the tested version. The nCLD 855Y model is almost identical in construction to the nCLD AL^2. The difference is in the side cladding of the housing. The nCLD 855Y has built-in side rails.

During performance testing, a model of the type nCLD 855Y (SN 0140) passed all test criteria. The measurement performance of this model is identical to the results of the two nCLD AL^2 analysers. As an example, the evaluation of the repeatability standard deviation at the zero and span point as well as the evaluation of the sensitivity coefficient of the ambient temperature are presented in Annex 4.

The measuring ranges are indicated below:

Table 1: Measuring ranges tested

Measured component	Measuring range in [µg/m³] [1]	Measuring range in [ppb] or [nmol/mol]
NO	0 - 1200	0 - 962
NO_2	0 - 500	0 - 261

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

During performance testing, the AMS met the requirements specified in standard EN 14211 (2012) and VDI 4202, part 1 (2018).

TÜV Rheinland Energy GmbH therefore recommends the instrument's approval as a performance-tested measuring system for continuous monitoring of air quality affected by nitrogen oxides.

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:

nCLD AL^2 for NO, NO_2 und NO_x

Manufacturer:

ECO PHYSICS AG, Dürnten, Switzerland

Field of application:

For the continuous measurement of ambient air concentrations of nitrogen oxides in stationary use.

Measuring ranges during performance testing:

Component	Certification range	Unit
Nitrogen monoxide	0 - 1200	µg/m³
Nitrogen dioxide	0 - 500	µg/m³

Software version:

Version: 1.7.0.0

Restrictions:

None

Note:

1. This report on the performance test is available online at www.qal1.de.
2. The performance test also includes the nCLD 855Y version.

Test Report:

TÜV Rheinland Energy GmbH, Cologne
Report no.: 936/21250441/A dated 30 July 2021

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	34
7.3.2 Calibration inlet	The measuring system may have a test gas inlet separate from the sample gas inlet.	The nCLD AL2 measuring system does not have a test gas inlet separate from the sample gas inlet. Zero and test gases are fed to the measuring system via the test gas inlet.	not applicable	35
7.3.3 Easy maintenance	It should be possible to carry out maintenance work externally without any great effort.	Maintenance takes reasonable effort and is possible with standard tools from the outside.	yes	36
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	37
7.3.5 Set-up times and warm-up times	The instruction manual shall include specifications in this regard.	The set-up and warm-up times are specified in the operating instructions. The manufacturer's specifications are accurate.	yes	38
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	39
7.3.7 Unintended adjustment	Shall have means of security to this effect.	The measuring system is secured against unintended and unauthorised adjustment of instrument parameters by way of a password.	yes	40
7.3.8 Data output	The output signals shall be provided digitally and/or as analogue signals.	Measured signals are available in analogue 4-20 mA or 0-10 V and digital (via RS232, Bluetooth, LAN/WLAN or USB).	yes	41
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 measured value transmission functions correctly and is protected against unauthorised access by password protection.	yes	42

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 so-called EP data transmission protocol as standard. This protocol is pre-programmed by default. Measured and status signals are transmitted correctly. The commands used are shown in the system manual in chapter 8.	yes	43
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 – 500 µg/m³ for NO_2 and 1200 µg/m³ for NO is set as standard. Supplementary measuring ranges up to 0 – 50 ppm are possible. The measuring system's upper limit of measurement exceeds the upper limit of the certification range in each case.	yes	44
7.3.12 Negative output signals	Shall not be suppressed (live zero).	The measuring system also provides negative output signals.	yes	45
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.	yes	46
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	47
7.3.15 Switch-over	Switch-over between measurement and functional check and/or calibration shall be possible telemetrically.	In principle, it is possible to monitor all tasks necessary for a functional check on the instrument itself or telemetrically.	yes	48
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	49

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 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 shown in Table A1 of VDI 4202-1. The performance parameters for the laboratory test shall be determined according to the procedures described in section 8.4 of VDI 4202-1.	The test was carried out using the performance criteria and requirements of VDI 4202 Part 1 (2018) and EN 14211 (2012).	yes	50
7.4.2 Test requirements	Has to comply with the requirements set out in VDI standard 4202-1:2018.	The test was carried out using the performance criteria and requirements of VDI 4202 Part 1 (2018) and EN 14211 (2012).	yes	51
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.	The test was carried out using the performance criteria and requirements of VDI 4202 Part 1 (2018) and EN 14211 (2012).	yes	69
7.5.2 Location of 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	70
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	71
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 14211				
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 unit 1 was 2 sec for NO and 2 sec for NO_2. For unit 2 it was 2 sec for NO and 2 sec for NO_2.	yes	82
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 -0.04 nmol/mol/12 h, for instrument 2 it was -0.03 nmol/mol/12 h. Short-term drift at span point was 1.66 nmol/mol/12 h for instrument 1 and -0.97 nmol/mol/12 h for instrument 2.	yes	87
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 0.00 nmol/mol, for instrument 2 it was 0.01 nmol/mol. Repeatability standard deviation at reference point was 0.45 nmol/mol for instrument 1 and 0.95 nmol/mol for instrument 2.	yes	91
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 was -0.06 nmol/mol at zero point and no more than 0.55% of the nominal value for concentrations above zero. The deviation from the linear regression line for instrument 2 is 0.00 nmol/mol at zero point and no more than 1.01% of the target value for concentrations above zero.	yes	94
8.4.7 Sensitivity coefficient to sample gas pressure	The sensitivity coefficient to sample gas pressure shall be ≤ 8.0 nmol/mol/kPa.	For instrument 1, the sensitivity coefficient to sample gas pressure was 0.08 nmol/mol/kPa. For instrument 2, the sensitivity coefficient to sample gas pressure was 0.06 nmol/mol/kPa.	yes	99

Performance criterion	Requirement	Test result	Satis-fied	Page
8.4.8 Sensitivity coefficient to sample gas temperature	The sensitivity coefficient to sample gas temperature shall be ≤ 3.0 µmol/mol/K.	For instrument 1, the sensitivity coefficient to sample gas temperature was 0.03 nmol/mol/K. For instrument 2, the sensitivity coefficient to sample gas temperature was 0.01 nmol/mol/K.	yes	101
8.4.9 Sensitivity coefficient to surrounding temperature	The sensitivity coefficient to the surrounding temperature shall be ≤ 3.0 µmol/mol/K.	The sensitivity coefficient to the surrounding temperature b_{st} did not exceed the performance criterion specified at 3.0 nmol/mol/K. For the purpose of the uncertainty calculation, the largest value b_{st} is used for both instruments. This would be 0.269 nmol/mol/K for instrument 1 and 0.128 nmol/mol/K for instrument 2.	yes	103
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 b_v exceed the value of 0.3 nmol/mol/V specified in standard EN 14211. For the purpose of the uncertainty calculation, the largest b_v is used for both instruments. For instrument 1, this is 0.00 nmol/mol/V and for instrument 2 it is 0.00 nmol/mol/V.	yes	106
8.4.11 Interferents	Interfering components at zero and at the NO concentration c_t (500 ± 50 nmol/mol). Deviations for interferents H_2O, CO_2 and NH_3 shall not exceed 5.0 nmol/mol.	This resulted in a value for the cross-sensitivity at zero for NO of 0.00 nmol/mol for unit 1 and -0.34 nmol/mol for unit 2 for H_2O, 0.71 nmol/mol for unit 1 and 0.44 nmol/mol for unit 2 for CO_2 and 0.34 nmol/mol for unit 1 and -0.09 nmol/mol for unit 2 for NH_3. For the cross-sensitivity at the limit value c_t, the values for NO were 0.85 nmol/mol for unit 1 and -1.17 nmol/mol for unit 2 for H2O, -0.23 nmol/mol for unit 1 and -0.48 nmol/mol for unit 2 for CO_2 and 0.51 nmol/mol for unit 1 and 1.45 nmol/mol for NH_3.	yes	108
8.4.12 Averaging test	The averaging effect shall not exceed 7% of the measured value.	The performance criterion of EN 14211 for the averaging test was fully complied with at -1.8 % and -1.6 % respectively.	yes	111

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%.	This test criterion does not apply. The measuring system is not equipped with a test gas inlet separate from the sample gas inlet. Test gases have to be fed via the sample inlet.	Not applicable	114
8.4.14 Converter efficiency	The converter efficiency shall be at least 98%.	The performance criterion of EN 14211 was fully met with a converter efficiency of at least 99.2 %.	yes	115
8.4.15 Residence time in the analyser	The residence time in the analyser shall not exceed 3.0 s.	Residence time in the analyser was 1.8 s.	yes	115
8.5 Determination of the performance characteristics during the field test according to EN 14211				
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 0.27 nmol/mol for instrument 1 and 0.96 nmol/mol for instrument 2. Maximum long-term drift at reference point $D_{l,s}$ was at 1.29% for instrument 1 and 1.30% for instrument 2.	yes	118
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 at the test gas inlet must be changed depending on the dust load at the measurement location. EN 14211 requires checking of zero and span points at least once every two weeks.	yes	126
8.5.5 Reproducibility standard deviation for NO2 under field conditions	Reproducibility standard deviation under field conditions shall not exceed 5% of the mean value over a period of three months.	The comparative standard deviation for NO_2 under field conditions was 4.21 % related to the mean value over the duration of the field test of 3 months. Thus, the requirements of EN 14211 are satisfied.	yes	122
8.5.7 Period of availability of the analyser	Availability of the analyser shall be at least 90%.	The availability is at 100%. Thus, the requirement of EN 14211 is satisfied.	yes	127

2. Task definition

2.1 Nature of the test

On behalf of the company ECO PHYSICS AG, TÜV Rheinland Energy GmbH carried out a performance test for the nCLD AL^2 measuring system. The test was carried out as a complete performance test.

2.2 Objectives

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

Component	Certification range	Unit
Nitrogen monoxide	0 – 1,200	µg/m³
Nitrogen dioxide	0 – 500	µg/m³

The nCLD AL^2 measuring system measures the components NO, NO_2 and NO_x using the chemiluminescence method.

The performance test was carried out on the basis of the current standards / guidelines for performance testing, taking into account the latest developments.
The test was carried out in compliance with the following standards / norms:

- 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 14211: Ambient air – Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence, of November 2012

3. Description of the AMS tested

3.1 Measuring principle

The nCLD AL^2 ambient air measuring system is a continuous nitrogen oxide analyser. The instrument uses the chemiluminescence method as a measuring principle. It was designed for the continuous measurement of NO, NO_2 and NO_x in ambient air.

Figure 1: View of the nCLD AL^2 analyser

The measuring principle of the nCLD AL^2 is based on the fact that nitrogen oxide (NO) and ozone (O_3) react with each other to produce a characteristic luminescence with an intensity linearly proportional to the NO concentration. Infrared light emission results when NO_2 molecules decay to lower energy states. Specifically:

$$NO + O_3 \rightarrow NO_2 + O_2 + hv$$

In order to measure NO_2 in the sample air, it must be converted to NO before measurement. For this reduction to take place, the gas flows through a converter in which a temperature of 350 °C is maintained. NO is measured directly without a converter. The dual-channel principle allows the simultaneous measurement of NO and NO_x, and thus the temporally correct NO_2 measurement with optimum precision.

The ambient air sample is drawn into the nCLD AL^2 through the “sample” bulkhead. The sample flows through a capillary, and then to the mode solenoid valve. The solenoid valve routes the sample either straight to the reaction chamber (NO mode) or through the NO_2-to-NO converter and then to the reaction chamber (NO_x mode). The pressure in the reaction chamber is measured to deduce the sample flow. Pressure deviations outside of the acceptable range are reported as a fault.

Dry air enters the nCLD AL^2 through the permeation dryer, flows through a flow switch and then through a corona discharge ozone generator. The ozonator generates the ozone needed for the chemiluminescent reaction. At the reaction chamber, the ozone reacts with the NO in the sample to produce excited NO_2 molecules. A photomultiplier tube (PMT) housed in a thermoelectric cooler detects the luminescence generated during this reaction. From the reaction chamber, the exhaust air travels through the ozone (O_3) converter to the pump, and is released through the vent.

The NO and NO_x concentrations calculated in the NO and NO_x modes are stored in memory. The difference between the concentrations is used to calculate the NO_2 concentration.

The nCLD AL^2 outputs NO, NO_2, and NO_x concentrations on the front panel display and the analogue outputs. The data is also available over the serial or Ethernet connection.

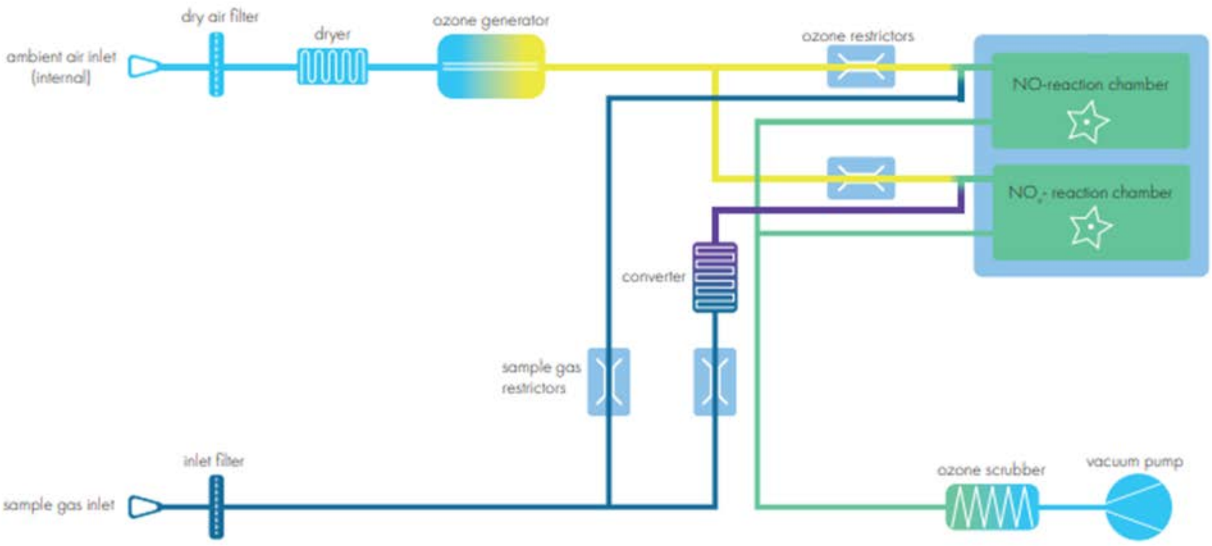


Figure 2: Flow diagram nCLD AL^2

3.2 AMS scope and set-up

The nCLD AL^2 nitrogen oxide analyser uses the chemiluminescent method for the continuous measurement of NO, NO_2 and NO_x in ambient air.

The test gas flows through a measuring orifice to the two measuring chambers. For NO this is by direct means and for NO_x is initially via the NO_2 converter.

Ambient air enters the analyser through an inlet filter and permeation dryer and is passed to the corona discharge ozone generator.

From the reaction chamber, the exhaust air flows through the ozone scrubber to the pump and is discharged through the vent.

The determined measured data is stored in the system and output via the various signal outputs.

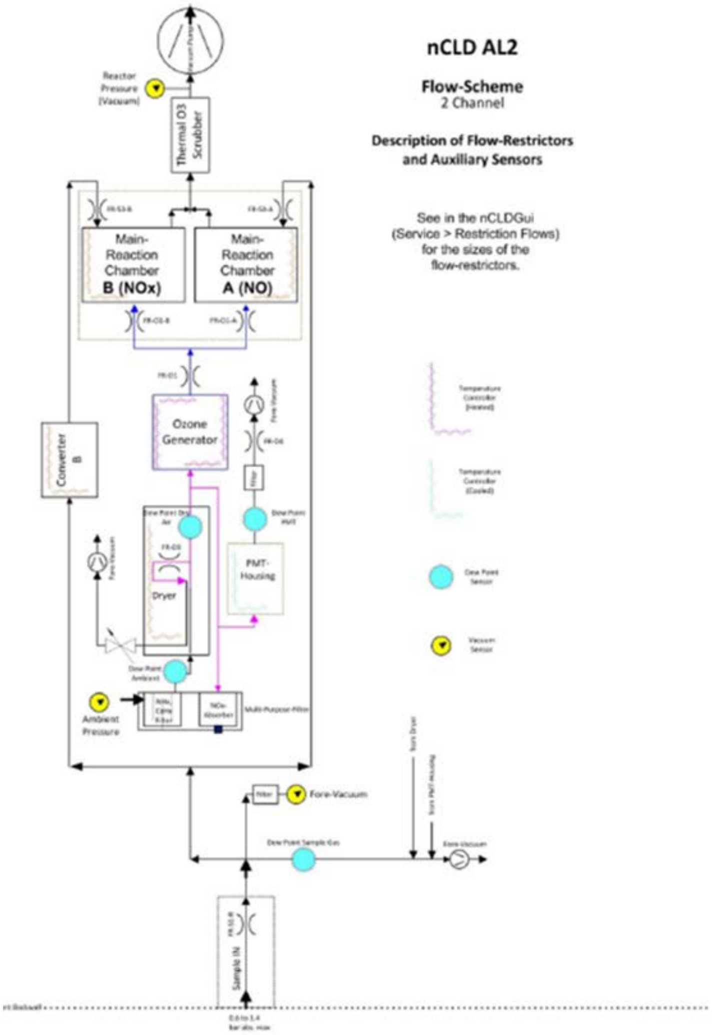


Figure 3: Flow diagram nCLD AL^2

Figure 4: Overview of the nCLD AL^2

1. Switched-mode power supply and main processor board with USB interfaces
2. Gas inlet
3. Air dryer
5. Hot Box (includes converter and ozone scrubber)
8. Vacuum pump
9. Detector unit (PMT housing with reaction chambers)
10. Ozone generator
12. Combi-filter
13. Start pressure switch with two-colour LED
14. High-resolution colour screen with touch-sensitive surface (GUI touchscreen)

The system components include:

- Converter: The NO_2/NO converter consists of a heated and thermally insulated steel block in which the actual converter cartridge is located. This can be easily replaced if necessary. As converter material, the cartridge contains, depending on the option, a certain metallic, catalytically active material with a large specific surface area, which results in a high efficiency and a long service life of the converter. In the nCLD AL^2, the converter type Y is used, a molybdenum converter heated to 350 °C.
- Ozone generator: The integrated ozone generator works according to the principle of the so-called "silent electrical discharge". Dry air is passed through an alternating electric field, whereby an ionisation reaction creates ozone from the atmospheric oxygen. The ozone reacts with the NO in the ambient air sample to produce the electronically excited NO_2 molecules.
- Permeation dryer: The permeation dryer provides a continuous stream of dry air to the ozonator.
- Switched-mode power supply and main processor board: The common electronics contain the core computational and power routing hardware. It also includes the USB ports, the Ethernet port and the I/O ports. All electronics operate from a universal VDC supply. The main processor board is also located here.
- Detector unit: This contains the PMT housings as well as the detectors.

Table 2 lists a number of important instrument characteristics of the nCLD AL^2.

Table 2: Technical data nCLD AL^2 (manufacturer's data)

Measured range:	Maximum 0 – 50 ppm (freely programmable)
Units:	ppb or µg/m³
Measured compounds:	NO, NO_2 and NO_x
Sample flow rate	~1.0 l/min (during the test)
Outputs:	• USB port (rear) • Bluetooth • LAN / WLAN • RS232 • Flash memory • Analogue (0-10V, 4-20 mA) through external box
Input voltage:	100 to 240 V, 50 Hz to 60 Hz
Power:	140 W; 350 W max.
Dimensions (l x w x h) / weight:	540 x 450 x 133 mm / ~ 23 kg

3.3 AMS adjustment

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

No specific averaging times can be set in the analyser. It is possible to activate an averaging filter (slow, medium, fast, off). During performance testing, this filter was activated in the "slow" setting.

During the test, the converter type "Y" (own designation ECO PHYSICS AG) provided as standard for the nCLD AL^2 was used. This is a molybdenum converter heated to 350 °C.

3.4 Version nCLD 855 Y

ECO PHYSICS AG distributes the tested measuring system under two different designations. The nCLD AL^2 and nCLD 855Y models operate identically in terms of measurement technology.

The nCLD AL^2 model underwent a complete performance test with two test specimens. This model is also only available in the tested version. The nCLD 855Y model is almost identical in construction to the nCLD AL^2. The difference is in the side cladding of the housing. The nCLD 855Y has built-in side rails. Furthermore, it is possible to integrate additional modules into the nCLD 855Y which enable or facilitate the determination of the ambient air under special conditions. The additional modules were not part of this performance test.

The available options for da nCLD 855Y are:

- Calibration gas valve options: It is possible to integrate one or more gas inlets with controlled solenoid valves. This enables the automatic remote-controlled feeding of zero and test gases during operation. (Page 32 in the manual.)
- Heated inlet: It is possible to heat the area of the sample gas inlet up to the first orifice. This is to improve the measuring response under climatically hot, humid conditions. (Page 33 in the manual.)

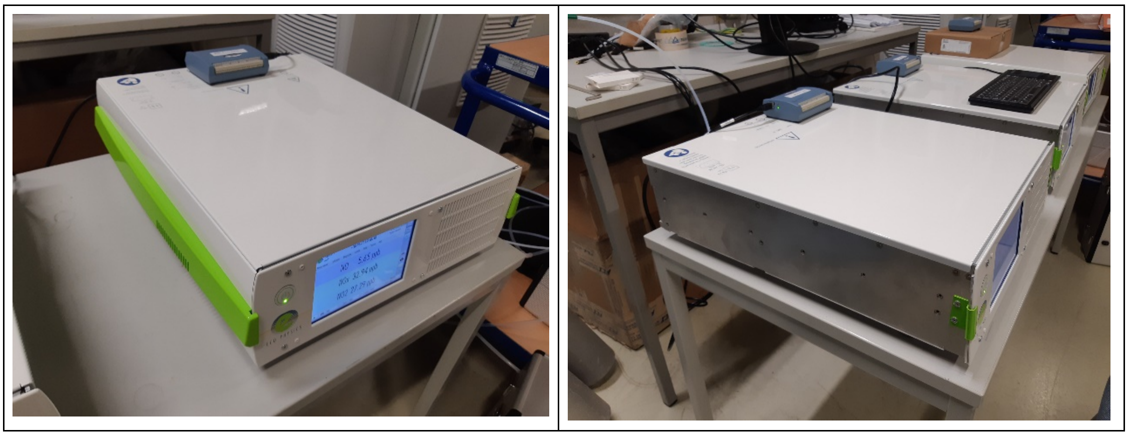


Figure 5: Left: the nCLD 855 Y. Right: the nCLD AL^2

During performance testing, a model of the type nCLD 855Y (SN 0140) passed all test criteria. The measurement characteristics of this model are equivalent to the results of the two nCLD AL^2 analysers. As an example, the evaluation of the repeatability standard deviation at the zero and span point as well as the evaluation of the sensitivity coefficient of the ambient temperature are given in Annex 3.

Both versions use the same software version.

Figure 6: nCLD 855 Y in the field measuring station

4. Test programme

4.1 General remarks

Two identical nCLD AL^2 instruments with the following serial numbers were submitted to performance testing:

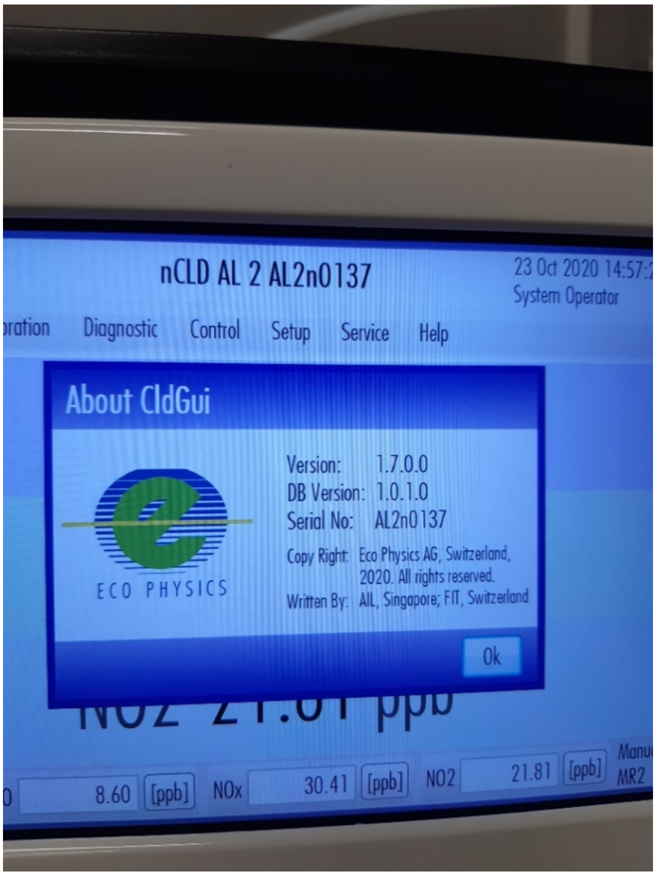
Instrument 1:	SN 0137 and
Instrument 2:	SN 0138

In addition, an analyser of the type nCLD 855Y with the number SN 0140 underwent the performance test.

The tests were performed with software version: 1.7.0.0

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.



Version: 1.7.0.0
DB Version: 1.0.1.0
Serial No: AL2n0137
Copy Right: Eco Physics AG, Switzerland, 2020. All rights reserved.
Written By: AIL, Singapore; FIT, Switzerland

8.60 [ppb] NOx 30.41 [ppb] NO2 21.81 [ppb]

Figure 7: Software version of the nCLD AL^2 tested instruments

4.2 Laboratory test

The laboratory test was carried out with two identical systems of the type nCLD AL^2 with the serial numbers SN: 0137 and SN: 0138. In addition, an analyser of the type nCLD 855Y with the number SN 0140 underwent the laboratory test.

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
- Converter efficiency

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 was carried out with 2 identical measuring systems of the type nCLD AL^2 from 12 April 2021 to 19 July 2021. The instruments used were identical to those used for laboratory testing. The serial numbers were:

Instrument 1:	SN 0137
Instrument 2:	SN 0138

In addition, an analyser of the type nCLD 855Y with the number SN 0140 underwent the field test.

The following test programme was determined for the field test:

- Long-term drift
- Maintenance interval
- Availability
- Reproducibility standard deviation under field conditions
- Converter efficiency (VDI 4202-1:2018)

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 8: 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 1.0 m through a T-piece at the same connection of the sampling system. This ensured that both systems performed 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 9: nCLD AL² 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

Certified nitrogen monoxide and nitrogen dioxide test gases were used for the purpose of testing. The specified test gases were used during the entire test and, where necessary, were diluted with the help of a (Hovacal) mass flow controller.

Test gas bottle (S/N 64616) was traced back by the national EU reference laboratory for ambient air quality (Federal Environment Agency in Langen). Quality assurance of test gases used was based on the traceable test gas in the TRE laboratory.

Zero gas:	**synthetic air**
Test gas NO:	**224.1 ppb in N_2**
Number of test gas cylinder:	16782 (Bottles SN: 64616)
Manufacturer / manufacturing date:	Linde / 07.04.2020
Stability guarantee / certified:	12 months
Checking of the certificate by / on:	UBA Langen / 17.06.2020 Calibration certificate No. 021-2020
Measurement uncertainty as per calibration certificate:	+/- 4.5 nmol/mol
Test gas NO:	**2080 ppb in N_2**
Number of test gas cylinder:	16811
Manufacturer / manufacturing date:	Nippon Gases / 11.03.2020
Stability guarantee / certified:	24 months
Certificate checked by:	Own laboratory
Rel. uncertainty according to certificate:	5%
***Test gas NO_2:**	**4.6 ppm in synth. air**
Number of test gas cylinder:	16806
Manufacturer / manufacturing date:	Nippon Gases / 07.02.2020
Stability guarantee / certified:	12 months
Certificate checked by:	Own laboratory
Rel. uncertainty according to certificate:	5%

Test gases marked with "*" were used exclusively for individual test points before the expiry of the stability guarantee.

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 10 shows a test specimen with integrated measured value display.

Figure 10: nCLD AL^2 test specimen with 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

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

6.4 Evaluation

The nCLD AL^2 measuring system has only one test gas inlet. Zero and test gases are also fed to the measuring system via this inlet.

6.5 Assessment

The nCLD AL^2 measuring system does not have a test gas inlet separate from the sample gas inlet. Zero and test gases are fed to the measuring system via the test gas inlet.

Criterion satisfied? Not applicable

6.6 Detailed presentation of test results

Not applicable.

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. Quarterly replacement of the combi-filter and the dust filter on the front and rear panel.

6.5 Assessment

Maintenance takes reasonable effort and is possible with standard tools from the outside.

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 9. 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 nCLD AL^2 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 ~30 minutes. Information on the set-up time can be found in the manual in chapter 4.1.1.

When switched on from a completely cold state, the unit required approx. 45 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. In the manual, the warm-up phase is given as up to 50 minutes (chapter 5.1).

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

The set-up and warm-up times are specified in the operating instructions. The manufacturer's specifications are accurate.

It is possible to operate the measuring system at different locations with limited effort. The set-up time is approx. 0.5 hours and the warm-up time approx. 0.75 hours.

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 and a measuring system for recording energy consumption (Gossen Metrawatt) 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 30 °C.

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

The energy requirement of the measuring system is specified by the manufacturer as a maximum of 400 watts. During start-up (warm-up) a short-term consumption of 250 W was recorded. During normal operation, energy consumption is 140 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 instrument provides an internal feature (password protection) to secure it against illicit or unintended 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 – 10 V, concentration range selectable
Digital:	RS232, Bluetooth, LAN/WLAN or USB

6.5 Assessment

Measured signals are available in analogue 4-20 mA or 0-10 V and digital (via RS232, Bluetooth, LAN/WLAN or USB).

The instrument provides additional interfaces (e.g. analogue outputs) for connecting additional measuring or other peripheral 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 provides the following transmission routes: RS232, Bluetooth, LAN/WLAN or USB. Moreover, the measuring system also provides an option to output analogue signals (V or mA).

6.4 Evaluation

Digital measured signals are provided as follows:

RS232, Bluetooth, LAN/WLAN 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.

Digital data retrieval always requires entry of the correct password.

6.5 Assessment

The digital measured value transmission functions correctly and is protected against unauthorised access by password protection.

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

Operating manual, PC

6.3 Testing

The measuring system has a so-called EP data transmission protocol as standard. This protocol is pre-programmed by default. Other data transmission protocols are available in consultation with the manufacturer.

6.4 Evaluation

The measuring system has a so-called EP data transmission protocol as standard. Measured and status signals are transmitted correctly.

6.5 Assessment

The measuring system has a so-called EP data transmission protocol as standard. This protocol is pre-programmed by default. Measured and status signals are transmitted correctly.
The commands used are shown in the system manual in chapter 8.

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

We compared the upper limit of measurement to the upper limit of the certification range to verify whether the former was larger or equal to the latter.

6.4 Evaluation

In theory, it is possible to set the measuring system to measuring ranges of up to 0 – 20 ppm.

Possible measuring range:	50 ppm
Upper limit of the certification range for NO:	1200 µg/m³ (962 ppb or nmol/mol)
Upper limit of the certification range for NO_2:	500 µg/m³ (261 ppb or nmol/mol)

6.5 Assessment

A measuring range of 0 – 500 µg/m³ for NO_2 and 1200 µg/m³ for NO is set as standard. Supplementary measuring ranges up to 0 – 50 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

Standard VDI 4202, part 1 as well as the standard EN 14211 contain the following minimum requirements for the certification ranges of continuous ambient air quality measuring instruments for nitrogen oxides:

Table 3: Certification ranges VDI 4202-1 and EN 14211

Measured component	CR lower limit	CR upper limit	Limit value	Evaluation period
	in µg/m³	in µg/m³	in µg/m³	
Nitrogen dioxide	0	500	200	1 h
Nitrogen monoxide	0	1 200	631.3 *)	1 h

* No limit value is defined for NO. Standard EN 14211 recommends using a value of 500 ± 50 nmol/mol instead.

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

Since the measuring systems do not rely on operation and calibration gases, uncontrolled emission of gases 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. The warm-up phase is indicated by a status message.

6.5 Assessment

On return of mains voltage, the instrument returns to normal operating mode and automatically resumes measuring.

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, Bluetooth, 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

The measuring system can be monitored and controlled by the operator at the unit or by the telemetric remote control.

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

In principle, it is possible to monitor all tasks necessary for a functional check on the instrument itself or telemetrically.

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 via the menu item "About".

Testing was performed with software version 1.7.0.0.

In addition, a DB version: 1.0.1.0 is also specified in the above menu. This is the version of the internal memory database. In measurement mode, the measurement data as well as all internal unit parameters are stored internally every second. On the display unit, this data can be shown in various ways in tabular and graphic form. The database and its version is independent and has no relation to the measurement functions of the analyser.

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 7 on page 29 shows the system software version in the display of the measuring instrument.

6.1 7.4 Requirements on performance characteristics for testing in the laboratory

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

The test was carried out using the performance criteria and requirements of VDI 4202 Part 1 (2018) and EN 14211 (2012).

6.4 Evaluation

Not applicable.

6.5 Assessment

The test was carried out using the performance criteria and requirements of VDI 4202 Part 1 (2018) and EN 14211 (2012).

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 adjustments are to be documented 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

The test was carried out using the performance criteria and requirements of VDI 4202 Part 1 (2018) and EN 14211 (2012).

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 system for test gas application ran smoothly; tests were performed with the internal upstream particle filters.

No specific averaging times can be set in the analyser. It is possible to activate an averaging filter (slow, medium, fast, off). During performance testing, this filter was activated in the "slow" setting.

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

6.5 Assessment

The test was carried out using the performance criteria and requirements of VDI 4202 Part 1 (2018) and EN 14211 (2012).

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 14211 (2012). The reader is therefore referred 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 14211 (2012). The reader is therefore referred 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 14211 (2012). The reader is therefore referred 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 14211 (2012). The reader is therefore referred to chapter 7.1 8.4.6 Lack-of-fit of linearity of the calibration function.

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 8.0 (nmol/mol)/kPA.

6.2 Equipment

Not applicable.

6.3 Testing

Performing and evaluating the sensitivity coefficient of sample gas pressure corresponds exactly to determining the sensitivity coefficient to sample gas pressure in accordance with standard EN 14211 (2012). The reader is therefore referred 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 of sample gas temperature shall not exceed 3.0 (nmol/mol)/kPA.

6.2 Equipment

Not applicable.

6.3 Testing

Performing and evaluating the sensitivity coefficient of sample gas temperature corresponds exactly to determining the sensitivity coefficient to sample gas temperature in accordance with standard EN 14211 (2012). The reader is therefore referred 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 surrounding temperature

The sensitivity coefficient of surrounding temperature shall not exceed 3.0 (nmol/mol)/kPA.

6.2 Equipment

Not applicable.

6.3 Testing

Performing and evaluating the sensitivity coefficient of surrounding temperature corresponds exactly to determining the sensitivity coefficient to the surrounding temperature in accordance with standard EN 14211 (2012). The reader is therefore referred to chapter 7.1 8.4.9 Sensitivity coefficient to surrounding temperature.

6.4 Evaluation

See chapter 7.1 8.4.9 Sensitivity coefficient to surrounding temperature

6.5 Assessment

See chapter 7.1 8.4.9 Sensitivity coefficient to 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 of electrical voltage corresponds exactly to determining the sensitivity coefficient to electrical voltage in accordance with standard EN 14211 (2012). The reader is therefore referred 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 14211 (2012). The reader is therefore referred 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

Test gases, mixing station

6.3 Testing

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 concentration of NO_2 at a concentration $c_{t,NO2}$ which is about twice the hourly limit value; and
- a stepwise varied concentration of NO between zero and 600 nmol/mol (concentration $c_{t,NO}$).

The time span (t_c) of the constant NO concentrations shall be at least equal to the time span necessary to obtain four independent display values (corresponding to at least 16 response times). The time interval (t_v) of the changed NO concentration shall be at least equal to the time interval (t_{NO}) required to obtain four independent display values. The NO concentration must be 45 s followed by the time period (t_{zero}) of 45 s for zero concentration. Further:

c_t is the test gas concentration;

t_v is a time period including a whole number of t_{NO} and t_{zero} pairs, and contains a minimum of 3 such pairs.

The change from t_{NO} 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 for NO (X_{av}) is:

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

Where:

E_{av}	is the averaging effect (%);
C_{const}^{av}	is the average of the at least four independent measurements during the variable concentration period;
C_{var}^{av}	is the average of the at least four independent measurements during the variable concentration period;

The following applies differently for NO_x measuring instruments

The averaging effect shall be determined for the measured components NO_2 and NO. Here, the averaging effect for NO is calculated according to the formula mentioned on page 62 based on EN 14211. The determination of the averaging effect for NO_2 is calculated according to the following formula from VDI 4202-1 (2018):

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

Where:

E_{av}	is the averaging effect (%);
C_{const}^{av}	is the average of the at least four independent measurements during the variable concentration period;
C_{var}^{av}	is the average of the at least four independent measurements during the variable concentration period;

The averaging test was carried out according to the specifications of EN 14211 and VDI 4202-1. With the help of a mass flow controller we applied a step change of the NO concentration between zero and 600 nmol/mol and, at the same time, a constant NO_2 concentration $c_{t,NO2}$ of roughly twice the hourly limit value. 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.

6.4 Evaluation

The following averages were determined during the test:

Table 4: Results of the averaging test for NO

	requirement	device 1		device 2	
averaging effect E_{av} [%]	≤ 7%	-1,8	✓	-1,6	✓

This results in the following averaging effects for NO:

System 1 (12): -1.8 %

System 2 (14): -1.6 %

Table 5: Results of the averaging test for NO_2

	requirement	device 1		device 2	
averaging effect E_{av} [%]	≤ 7%	-1,3	✓	-1,2	✓

This results in the following averaging effects for NO_2:

System 1 (12): -1.3 %

System 2 (14): -1.2 %

6.5 Assessment

The performance requirement of VDI4202-1 as well as EN 14211 is fully complied with.

Criterion satisfied? yes

6.6 Detailed presentation of test results

In Table 6 and Table 7 the individual results of the averaging effect test are shown.

Table 6: Results of the averaging test for NO

		device 1	device 2
	time	[nmol/mol]	[nmol/mol]
average constant concentration $C_{av,c}$	12:07:00	594,2	593,6
	till		
	12:26:00		
average variable concentration $C_{av,c}$	12:27:00	302,5	301,3
	till		
	12:46:00		

		device 1	device 2
	time	[nmol/mol]	[nmol/mol]
average constant concentration $C_{av,c}$	12:58:00	592,6	592,6
	till		
	13:17:00		
average variable concentration $C_{av,c}$	13:18:00	300,6	301,6
	till		
	13:37:00		

		device 1	device 2
	time	[nmol/mol]	[nmol/mol]
average constant concentration $C_{av,c}$	13:48:00	591,6	592,6
	till		
	14:07:00		
average variable concentration $C_{av,c}$	14:08:00	302,4	300,4
	till		
	14:27:00		

Table 7: Results of the averaging test for NO_2

		device 1	device 2
	time	[nmol/mol]	[nmol/mol]
average constant concentration $C_{av,c}$	12:07:00	216,9	217,8
	till		
	12:26:00		
average variable concentration $C_{av,c}$	12:27:00	221,8	222,2
	till		
	12:46:00		

		device 1	device 2
	time	[nmol/mol]	[nmol/mol]
average constant concentration $C_{av,c}$	12:58:00	221,3	221,4
	till		
	13:17:00		
average variable concentration $C_{av,c}$	13:18:00	224,3	224,5
	till		
	13:37:00		

		device 1	device 2
	time	[nmol/mol]	[nmol/mol]
average constant concentration $C_{av,c}$	13:48:00	224,2	224,4
	till		
	14:07:00		
average variable concentration $C_{av,c}$	14:08:00	224,6	224,7
	till		
	14:27:00		

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

The measuring system is not equipped with a test gas inlet separate from the sample gas inlet. Test gases have to be fed via the sample inlet.

6.4 Evaluation

This test criterion does not apply.

6.5 Assessment

This test criterion does not apply. The measuring system is not equipped with a test gas inlet separate from the sample gas inlet. Test gases have to be fed via the sample inlet.

Criterion satisfied? Not applicable

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

Determination and evaluation of the converter efficiency in the laboratory corresponds exactly to determining the converter efficiency in accordance with standard EN 14211 (2012). The reader is therefore referred to chapter 7.1 8.4.14 Converter efficiency.

6.4 Evaluation

See chapter 7.1 8.4.14 Converter efficiency

6.5 Assessment

See chapter 7.1 8.4.14 Converter efficiency

Criterion satisfied? yes

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 14211 (2012). This is why we 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 39th 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

The test was carried out using the performance criteria and requirements of VDI 4202 Part 1 (2018) and EN 14211 (2012).

6.4 Evaluation

Not applicable.

6.5 Assessment

The test was carried out using the performance criteria and requirements of VDI 4202 Part 1 (2018) and EN 14211 (2012).

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 7.5.2 Location of 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 adjustments are to be documented 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 measuring system contains auto-scale or self-correction functions and they are treated as "normal operating conditions", these functions shall be turned on during the field test. Values of the self-correction shall be available to the test 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 14211 (2012). The reader is therefore referred to chapter 7.1 8.5.4 Long-term drift.

VDI 4202-1 (2018) Additionally applies to NO$_x$ measuring instruments:

For measuring instruments with two detectors, the drifts of the NO and NO$_x$ channels may be different when testing the long-term drift with NO. This can be determined by observing the long-term drift on both channels. If the drifts are significantly different, an additional component is to be added to the uncertainty.

The nCLD AL^2 measuring system works with two detectors.

6.4 Evaluation

See chapter 7.1 8.5.4 Long-term drift.

The evaluation of the long-term drift of the NO$_x$ measurement channels with NO.

6.5 Assessment

See chapter 7.1 8.5.4 Long-term drift. The long-term drift of the NO$_x$ measuring channels when NO is added does not differ significantly from the drift of the NO measuring channels.

Criterion satisfied? yes

6.6 Detailed presentation of test results

The individual values of the determination of the long-term drift are shown in Table 8 to Table 10.

Table 8: Results of the long-term drift of the NO$_x$ channel at zero point

		requierment	Device 1		Device 2	
average start Cz$_{,1}$ at zero [nmol/mol]	12.04.2021	≤ 5,0	--	✓	--	✓
long term drift D$_{L,Z}$ at zero [nmol/mol]	26.04.2021	≤ 5,0	0.00	✓	0.00	✓
long term drift D$_{L,Z}$ at zero [nmol/mol]	10.05.2021	≤ 5,0	0.08	✓	0.19	✓
long term drift D$_{L,Z}$ at zero [nmol/mol]	25.05.2021	≤ 5,0	0.00	✓	0.00	✓
long term drift D$_{L,Z}$ at zero [nmol/mol]	07.06.2021	≤ 5,0	0.00	✓	0.31	✓
long term drift D$_{L,Z}$ at zero [nmol/mol]	21.06.2021	≤ 5,0	0.12	✓	0.06	✓
long term drift D$_{L,Z}$ at zero [nmol/mol]	05.07.2021	≤ 5,0	0.00	✓	0.00	✓
long term drift D$_{L,Z}$ at zero [nmol/mol]	19.07.2021	≤ 5,0	0.00	✓	0.00	✓

Table 9: Results of the long-term drift of the NO_x channel at span point

		requierment	Device 2 1		Device 2	
average start $Cs_{,1}$ at span [nmol/mol]	12.04.2021	≤ 5 %	--	✓	--	✓
long term drift $D_{L,S}$ at span [nmol/mol]	26.04.2021	≤ 5 %	1.06	✓	-0.67	✓
long term drift $D_{L,S}$ at span [nmol/mol]	10.05.2021	≤ 5 %	1.42	✓	0.42	✓
long term drift $D_{L,S}$ at span [nmol/mol]	25.05.2021	≤ 5 %	0.71	✓	0.74	✓
long term drift $D_{L,S}$ at span [nmol/mol]	07.06.2021	≤ 5 %	0.96	✓	0.76	✓
long term drift $D_{L,S}$ at span [nmol/mol]	21.06.2021	≤ 5 %	0.55	✓	0.71	✓
long term drift $D_{L,S}$ at span [nmol/mol]	05.07.2021	≤ 5 %	1.83	✓	0.93	✓
long term drift $D_{L,S}$ at span [nmol/mol]	19.07.2021	≤ 5 %	1.04	✓	1.06	✓

Table 10: Individual values from the drift tests of the NO_x channel

Zero Concentration			
		Device 1	Device 2
Date	Time	[nmol/mol]	[nmol/mol]
12.04.2021	10:31:00	0.00	0.00
	10:32:00	0.00	0.00
	10:33:00	0.00	0.00
	average	0.00	0.00
	10:34:00	0.00	0.00
	10:35:00	0.00	0.00
	10:36:00	0.00	0.00
	average	0.00	0.00
	10:37:00	0.00	0.00
	10:38:00	0.00	0.00
	10:39:00	0.00	0.00
	average	0.00	0.00
	10:40:00	0.00	0.00
	10:41:00	0.00	0.00
	10:42:00	0.00	0.00
	average	0.00	0.00
	10:43:00	0.00	0.00
	10:44:00	0.00	0.00
	10:45:00	0.00	0.00
	average	0.00	0.00
Average field start $c_{z,0}$		**0.00**	**0.00**
26.04.2021	09:12:00	0.00	0.00
	09:13:00	0.00	0.00
	09:14:00	0.00	0.00
	09:15:00	0.00	0.00
	09:16:00	0.00	0.00
	aver. $c_{z,1}$	**0.00**	**0.00**
10.05.2021	11:29:00	0.13	0.16
	11:30:00	0.29	0.77
	11:31:00	0.00	0.00
	11:32:00	0.00	0.00
	11:33:00	0.00	0.00
	aver. $c_{z,1}$	**0.08**	**0.19**
25.05.2021	09:51:00	0.00	0.00
	09:52:00	0.00	0.00
	09:53:00	0.00	0.00
	09:54:00	0.00	0.00
	09:55:00	0.00	0.00
	aver. $c_{z,1}$	**0.00**	**0.00**
07.06.2021	11:58:00	0.00	0.96
	11:59:00	0.00	0.38
	12:00:00	0.00	0.00
	12:01:00	0.00	0.00
	12:02:00	0.00	0.19
	aver. $c_{z,1}$	**0.00**	**0.31**
21.06.2021	09:49:00	0.19	0.19
	09:50:00	0.38	0.10
	09:51:00	0.00	0.00
	09:52:00	0.00	0.00
	09:53:00	0.00	0.00
	aver. $c_{z,1}$	**0.12**	**0.06**
05.07.2021	09:05:00	0.00	0.00
	09:06:00	0.00	0.00
	09:07:00	0.00	0.00
	09:08:00	0.00	0.00
	09:09:00	0.00	0.00
	aver. $c_{z,1}$	**0.00**	**0.00**
19.07.2021	08:47:00	0.00	0.00
	08:48:00	0.00	0.00
	08:49:00	0.00	0.00
	08:50:00	0.00	0.00
	08:51:00	0.00	0.00
	aver. $c_{z,1}$	**0.00**	**0.00**

C_t-Concentration			
		Device 1	Device 2
Date	Time	[nmol/mol]	[nmol/mol]
12.04.2021	11:03:00	719.58	720.54
	11:04:00	719.58	720.54
	11:05:00	719.58	720.54
	average	719.58	720.54
	11:06:00	719.58	720.54
	11:07:00	719.58	720.54
	11:08:00	719.58	720.54
	average	719.58	720.54
	11:09:00	719.58	720.54
	11:10:00	719.58	720.54
	11:11:00	719.58	720.54
	average	719.58	720.54
	11:12:00	719.58	720.54
	11:13:00	719.58	720.54
	11:14:00	719.58	720.54
	average	719.58	720.54
	11:15:00	719.58	720.54
	11:16:00	719.58	720.54
	11:17:00	719.58	720.54
	average	719.58	720.54
Average field start $c_{s,0}$		**719.58**	**720.54**
26.04.2021	09:20:00	727.27	715.73
	09:21:00	727.27	715.73
	09:22:00	727.27	715.73
	09:23:00	727.27	715.73
	09:24:00	727.27	715.73
	aver. $c_{s,1}$	**727.27**	**715.73**
10.05.2021	11:36:00	731.99	724.96
	11:37:00	732.47	725.64
	11:38:00	729.20	724.10
	11:39:00	728.23	722.75
	11:40:00	728.23	721.50
	aver. $c_{s,1}$	**730.02**	**723.79**
25.05.2021	10:02:00	722.37	730.93
	10:03:00	723.71	722.65
	10:04:00	725.35	725.16
	10:05:00	725.93	725.35
	10:06:00	726.31	725.35
	aver. $c_{s,1}$	**724.73**	**725.89**
07.06.2021	12:09:00	727.27	726.69
	12:10:00	726.41	726.31
	12:11:00	726.31	726.31
	12:12:00	726.31	726.31
	12:13:00	726.31	726.31
	aver. $c_{s,1}$	**726.52**	**726.39**
21.06.2021	10:00:00	723.71	724.39
	10:01:00	724.96	726.02
	10:02:00	722.85	726.21
	10:03:00	723.42	726.12
	10:04:00	723.42	725.93
	aver. $c_{s,1}$	**723.67**	**725.73**
05.07.2021	09:16:00	733.14	727.27
	09:17:00	733.04	727.27
	09:18:00	733.04	727.27
	09:19:00	733.04	727.27
	09:20:00	732.56	727.27
	aver. $c_{s,1}$	**732.97**	**727.27**
19.07.2021	08:56:00	726.41	727.37
	08:57:00	728.43	728.62
	08:58:00	726.50	728.52
	08:59:00	726.50	728.43
	09:00:00	727.75	728.43
	aver. $c_{s,1}$	**727.12**	**728.27**

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 14211 (2012). The reader is therefore referred to chapter 7.1 8.5.5 Reproducibility standard deviation for NO_2 under field conditions.

6.4 Evaluation

See chapter 7.1 8.5.5 Reproducibility standard deviation for NO_2 under field conditions

6.5 Assessment

See chapter 7.1 8.5.5 Reproducibility standard deviation for NO_2 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 14211 (2012). The reader is therefore referred 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 14211 (2012). This is why we 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

Test specimens, ozone generator, NO test gas

6.3 Testing

VDI 4202-1:2018 additionally requires the converter efficiency to be tested at the end of the field test. The procedure was analogous to the testing of the conversion efficiency in the laboratory according to EN 14211 (2012).

The converter efficiency is determined by measurements with calculated amounts of NO_2. This can be achieved by means of gas-phase titration of NO to NO_2 with ozone.

The test shall be performed at two concentration levels: at about 50% and about 95% of the maximum of the certification range of NO_2.

The NO_x measuring system shall be calibrated applying an NO concentration of about 70% to 80% of the maximum certification range for NO to the NO and NO_x channels. Both channels need to be adjusted to display the same value. The values shall be recorded.

A known NO concentration at 50% of the NO certification range is applied to the measuring system until a stable signal is obtained. This stable period shall be at least as long as four response times. Four individual readings each are performed at the NO and the NO_x channel. Then, NO is brought to react with O_3 to produce NO_2. This mixture containing a constant NO_x concentration is applied to the measuring system until the output signal has stabilised. This stable period shall be at least four response times of the measuring system under test; the NO concentration after gas-phase titration shall be between 10% and 20% of the original NO concentration. Then, four individual readings each are performed at the NO and the NO_x channel. Then, the O_3 supply is cut and only NO is applied to the measuring system until the output signal has stabilised again. This stable period shall be at least as long as four response times of the measuring system. After that the average of the four individual measurements at the NO and the NO_x channel is calculated.

The converter efficiency is calculated as follows:

$$E_{conv} = \left(1 - \frac{(NO_x)_i - (NO_x)_f}{(NO)_i - (NO)_f}\right) \times 100\%$$

Where:

E_{conv} is the converter efficiency in %;

$(NO_x)_i$ is the average of the four individual measurements at the NO_x channel at the initial NO_x concentration;

$(NO_x)_f$ is the average of the four individual measurements at the NO_x channel at the resulting NO_x concentration after applying O_3;

$(NO)_i$ is the average of the four individual measurements at the NO channel at the initial NO concentration;

$(NO)_f$ is the average of the four individual measurements at the NO channel at the resulting NO concentration after applying O_3;

The lowest value of the two converter efficiencies shall be reported.

6.4 Evaluation

During the test, the following converter efficiencies were determined for the two nCLD AL^2 measuring systems. The lowest value of the two NO$_2$ concentration is reported below.

	requirement	device 1		device 2	
converter efficiency E_c [%]	≥ 98%	99.4	✓	98.4	✓

6.5 Assessment

The performance criterion specified by standard VDI 4202-1 (2018) is fully satisfied. The converter efficiency at the end of the field test was 99.4 % for unit 1 and 98.4 % for unit 2.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 11 presents the individual values.

Table 11: Individual results for the converter efficiency

				device 1		device 2	
	time	O_3 [nmol/mol]	NO_2 [nmol/mol]	NO [nmol/mol]	NO_x [nmol/mol]	NO [nmol/mol]	NO_x [nmol/mol]
	14:08:00	start					
O_3=0, NO=50%	06:51:00	0.0	0.0	484.8	483.9	486.8	487.7
	06:52:00	0.0	0.0	484.8	483.9	486.8	487.7
	06:53:00	0.0	0.0	484.8	483.9	486.8	487.7
	06:54:00	0.0	0.0	484.8	483.9	486.8	487.7
average		0.0	0.0	484.8	483.9	486.8	487.7
NO_2= 50% 130.75	07:10:00	130.0	132.0	355.0	483.0	356.9	487.2
	07:11:00	130.0	132.8	355.0	483.1	356.9	487.0
	07:12:00	130.0	132.8	355.0	483.0	356.9	487.0
	07:13:00	130.0	132.8	355.0	483.1	356.9	486.9
average		130.0	132.6	355.0	483.1	356.9	487.0
O_3=0, NO=50%	07:57:00	0.0	0.0	486.1	486.8	486.0	487.2
	07:58:00	0.0	0.0	486.1	486.8	486.0	487.2
	07:59:00	0.0	0.0	486.1	486.8	486.0	487.2
	08:00:00	0.0	0.0	486.1	486.8	486.0	487.2
average		0.0	0.0	486.1	486.8	486.0	487.2
NO_2= 95% 248.43	08:14:00	248.0	249.0	233.8	485.1	251.5	483.5
	08:15:00	248.0	248.9	233.8	485.1	252.0	483.5
	08:16:00	248.0	249.2	233.8	485.1	251.9	483.5
	08:17:00	248.0	248.0	233.8	485.1	249.8	483.5
average		248.0	248.7	233.8	485.1	251.3	483.5
O_3=0, NO=50%	08:27:00	0.0	0.0	483.9	484.8	482.9	484.8

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 14211 (2012) and is presented in 7.1 8.6 Calculation of the total uncertainty in accordance with standard EN 14211 (2012) according to Annex E of EN 14211 (2012)

6.4 Evaluation

The uncertainty calculation was performed in line with standard EN 14211 (2012) and is presented in 7.1 8.6 Calculation of the total uncertainty in accordance with standard EN 14211 (2012) according to Annex E of EN 14211 (2012)

6.5 Assessment

The uncertainty calculation was performed in line with standard EN 14211 (2012) and is presented in 7.1 8.6 Calculation of the total uncertainty in accordance with standard EN 14211 (2012) according to Annex E of EN 14211 (2012)

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

7. Test results in accordance with standard EN 14211 (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 concentration from less than 20 % to about 80 % of the maximum of the certification range of NO 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 for the dead time (rise) as shown in Figure 11. 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 11 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 test shall then be repeated with NO_2 at levels from less than 20 % to about 80 % of the maximum of the certification range of NO_2 and vice versa.

The difference in response times shall be calculated according to:

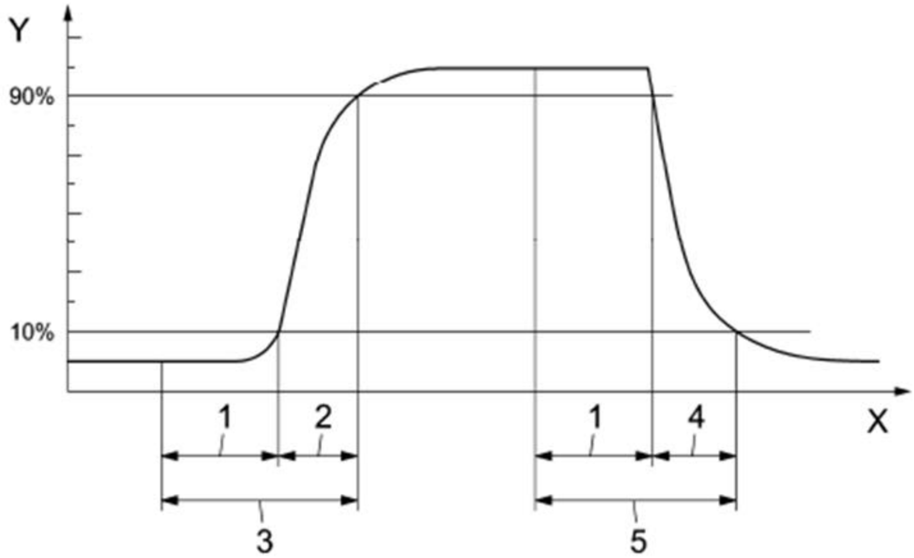
$$t_d = \bar{t}_r - \bar{t}_f$$

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 11: Diagram illustrating the response time

7.3 Testing

The test was performed in line with the requirements of EN 14211 mentioned previously. An external data logger was used to record data.

7.4 Evaluation

Table 12: Response times of the two nCLD AL^2 measuring systems for NO

	requirement	device 1		device 2	
average rise t_r [s]	≤ 180 s	2	✓	2	✓
average fall t_f [s]	≤ 180 s	2	✓	2	✓
difference t_d [s]	≤ 10 s	0.0	✓	0.0	✓

For system 1, the average t_r for NO was 2 sec, the average t_f was 2 sec and the average t_d was 0 sec.

For system 2, the average t_r for NO was 2 sec, the average t_f was 2 sec and the average t_d was 0 sec.

Table 13: Response times of the two nCLD AL^2 measuring systems for NO_2

	requirement	device 1		device 2	
average rise t_r [s]	≤ 180 s	2	✓	2	✓
average fall t_f [s]	≤ 180 s	2	✓	2	✓
difference t_d [s]	≤ 10 s	0.0	✓	0.0	✓

For unit 1, the average t_r for NO_2 was 2 sec, the average t_f was 2 sec and the average t_d was 0 sec.

For unit 2, the average t_r for NO_2 was 2 sec, the average t_f was 2 sec and the average t_d was 0 sec.

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 unit 1 was 2 sec for NO and 2 sec for NO_2. For unit 2 it was 2 sec for NO and 2 sec for NO_2.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 14: Individual results of the response time for NO

		device 1					
	80%	rise			fall		
measuring range	768.00	0.0 0.00	0.9 691.20	1.0 768.00	1.0 768.00	0.1 76.80	0.0 0.00
cycle 1	t = 0	08:58:00	08:58:02	08:59:00	09:04:00	09:04:02	09:05:00
	delta t		00:00:02			00:00:02	
	delta t [s]		2			2	
cycle 2	t = 0	09:10:00	09:10:02	09:11:00	09:16:00	09:16:02	09:17:00
	delta t		00:00:02			00:00:02	
	delta t [s]		2			2	
cycle 3	t = 0	09:22:00	09:22:02	09:23:00	09:28:00	09:28:02	09:29:00
	delta t		00:00:02			00:00:02	
	delta t [s]		2			2	
cycle 4	t = 0	09:34:00	09:34:02	09:35:00	09:40:00	09:40:02	09:41:00
	delta t		00:00:02			00:00:02	
	delta t [s]		2			2	

		device 2					
	80%	rise			fall		
measuring range	768.00	0.0 0.00	0.9 691.20	1.0 768.00	1.0 768.00	0.1 76.80	0.0 0.00
cycle 1	t = 0	08:58:00	08:58:02	08:59:00	09:04:00	09:04:02	09:05:00
	delta t		00:00:02			00:00:02	
	delta t [s]		2			2	
cycle 2	t = 0	09:10:00	09:10:02	09:11:00	09:16:00	09:16:02	09:17:00
	delta t		00:00:02			00:00:02	
	delta t [s]		2			2	
cycle 3	t = 0	09:22:00	09:22:02	09:23:00	09:28:00	09:28:02	09:28:00
	delta t		00:00:02			00:00:02	
	delta t [s]		2			2	
cycle 4	t = 0	09:34:00	09:34:02	09:35:00	09:40:00	09:40:02	09:40:00
	delta t		00:00:02			00:00:02	
	delta t [s]		2			2	

Table 15: Individual results of the response time for NO_2

			device 1				
	80%		rise			fall	
measuring range	209.21	0.0 0.00	0.9 188.28	1.0 209.21	1.0 209.21	0.1 20.92	0.0 0.00
cycle 1	t = 0	15:58:00	15:58:02	15:59:00	16:04:00	16:04:02	16:05:00
	delta t		00:00:02			00:00:02	
	delta t [s]		2			2	
cycle 2	t = 0	16:10:00	16:10:02	16:11:00	16:16:00	16:16:02	16:17:00
	delta t		00:00:02			00:00:02	
	delta t [s]		2			2	
cycle 3	t = 0	16:22:00	16:22:02	16:23:00	16:28:00	16:28:02	16:29:00
	delta t		00:00:02			00:00:02	
	delta t [s]		2			2	
cycle 4	t = 0	16:34:00	16:34:02	16:35:00	16:40:00	16:40:02	16:41:00
	delta t		00:00:02			00:00:02	
	delta t [s]		2			2	

			device 2				
	80%		rise			fall	
measuring range	209.21	0.0 0.00	0.9 188.28	1.0 209.21	1.0 209.21	0.1 20.92	0.0 0.00
cycle 1	t = 0	15:58:00	15:58:02	15:59:00	16:04:00	16:04:02	16:05:00
	delta t		00:00:02			00:00:02	
	delta t [s]		2			2	
cycle 2	t = 0	16:10:00	16:10:02	16:11:00	16:16:00	16:16:02	16:17:00
	delta t		00:00:02			00:00:02	
	delta t [s]		2			2	
cycle 3	t = 0	16:22:00	16:22:02	16:23:00	16:28:00	16:28:02	16:28:00
	delta t		00:00:02			00:00:02	
	delta t [s]		2			2	
cycle 4	t = 0	16:34:00	16:34:02	16:35:00	16:40:00	16:40:02	16:40:00
	delta t		00:00:02			00:00:02	
	delta t [s]		2			2	

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 span 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 14211 mentioned previously. In compliance with the standard, the test has to be performed with the component NO. Pursuant to EN 14211, the test shall be performed at a concentration level of 70% to 80% of the certification range for NO.

7.4 Evaluation

Table 16 indicates the measured value determined for the short-term drift.

Table 16: Results for the short-term drift

	requirements	device 1		device 2	
averange at zero at the beginning [nmol/mol]	-	0.15		0.13	
averange at zero at the end (12h) [nmol/mol]	-	0.11		0.10	
averange at span at the beginning [nmol/mol]	-	715.93		718.65	
averange at span at the end (12h) [nmol/mol]	-	717.55		717.65	
12-hour drift at zero $D_{s,z}$ [nmol/mol]	≤ 2,0	-0.04	✓	-0.03	✓
12-hour drift at span $D_{s,s}$ [nmol/mol]	≤ 6,0	1.66	✓	-0.97	✓

7.5 Assessment

For instrument 1 the value for the short-term drift at zero point was -0.04 nmol/mol/12 h, for instrument 2 it was -0.03 nmol/mol/12 h.

Short-term drift at span point was 1.66 nmol/mol/12 h for instrument 1 and -0.97 nmol/mol/12 h for instrument 2.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 17 and Table 18 present the individual test results.

Table 17: Individual results for the short-term drift test. 1st test gas application

at beginning		
zero level		
	device 1	device 2
time	[nmol/mol]	[nmol/mol]
17:00:00	0.2	0.1
17:01:00	0.1	0.1
17:02:00	0.1	0.1
17:03:00	0.2	0.1
17:04:00	0.2	0.1
17:05:00	0.2	0.2
17:06:00	0.2	0.1
17:07:00	0.1	0.1
17:08:00	0.1	0.1
17:09:00	0.1	0.1
17:10:00	0.1	0.1
17:11:00	0.1	0.1
17:12:00	0.2	0.1
17:13:00	0.1	0.1
17:14:00	0.1	0.1
17:15:00	0.1	0.1
17:16:00	0.1	0.1
17:17:00	0.1	0.1
17:18:00	0.2	0.1
17:19:00	0.1	0.1
average	**0.2**	**0.1**

at beginning		
span level		
	device 1	device 2
time	[nmol/mol]	[nmol/mol]
17:30:00	715.7	718.7
17:31:00	716.0	718.8
17:32:00	716.2	718.7
17:33:00	716.0	718.7
17:34:00	716.0	718.6
17:35:00	715.8	718.6
17:36:00	715.9	718.7
17:37:00	715.8	718.6
17:38:00	715.9	718.6
17:39:00	715.9	718.6
17:40:00	715.8	718.6
17:41:00	715.8	718.6
17:42:00	715.9	718.6
17:43:00	715.9	718.6
17:44:00	715.9	718.7
17:45:00	716.2	718.6
17:46:00	716.0	718.7
17:47:00	716.0	718.6
17:48:00	715.9	718.6
17:49:00	715.7	718.6
average	**715.9**	**718.7**

Table 18: Individual results for the short-term drift test. 2nd test gas application

after 12h		
zero level		
	device 1	device 2
time	[nmol/mol]	[nmol/mol]
05:00:00	0.1	0.1
05:01:00	0.1	0.1
05:02:00	0.1	0.1
05:03:00	0.1	0.1
05:04:00	0.1	0.1
05:05:00	0.1	0.1
05:06:00	0.1	0.1
05:07:00	0.1	0.1
05:08:00	0.1	0.1
05:09:00	0.1	0.1
05:10:00	0.1	0.1
05:11:00	0.1	0.1
05:12:00	0.1	0.1
05:13:00	0.1	0.1
05:14:00	0.1	0.1
05:15:00	0.1	0.1
05:16:00	0.1	0.1
05:17:00	0.1	0.1
05:18:00	0.1	0.1
05:19:00	0.1	0.1
average	**0.1**	**0.1**

after 12h		
span level		
	device 1	device 2
time	[nmol/mol]	[nmol/mol]
05:30:00	716.7	717.7
05:31:00	716.7	717.7
05:32:00	717.6	717.7
05:33:00	717.7	717.7
05:34:00	717.7	717.7
05:35:00	717.7	717.7
05:36:00	717.7	717.7
05:37:00	717.7	717.7
05:38:00	717.7	717.7
05:39:00	717.7	717.7
05:40:00	717.7	717.7
05:41:00	717.7	717.7
05:42:00	717.7	717.7
05:43:00	717.7	717.7
05:44:00	717.7	717.7
05:45:00	717.7	717.7
05:46:00	717.7	717.7
05:47:00	717.7	717.7
05:48:00	717.7	717.7
05:49:00	717.7	717.7
average	**717.6**	**717.7**

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 an NO test concentration (c_t) of (500 ± 50) nmol/mol 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:

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

Where:

s_r the repeatability standard deviation;

x_i the ith measurement;

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

n is the number of measurements.

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

s_r shall comply with the performance criterion indicated above, both at zero and at the test gas concentration c_t.of (500 ± 50) nmol/mol.

The detection limit, lower 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 detection limit, 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 14211 mentioned previously. In compliance with the standard, the test has to be performed with the component NO. Pursuant to EN 14211, the test shall be performed at a concentration level of 500 nmol/mol NO.

7.4 Evaluation

Table 19 presents the results for the repeatability standard deviation.

Table 19: 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	0.00	✓	0.01	✓
repeatability standard deviation $s_{r,ct}$ at c_t [nmol/mol]	≤ 3,0	0.45	✓	0.95	✓
detection limit [nmol/mol]		0.02		0.04	

7.5 Assessment

For instrument 1 the value for the repeatability standard deviation at zero point was 0.00 nmol/mol, for instrument 2 it was 0.01 nmol/mol. Repeatability standard deviation at reference point was 0.45 nmol/mol for instrument 1 and 0.95 nmol/mol for instrument 2.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 20 lists the results of individual measurements.

Table 20: Individual test results obtained for repeatability standard deviation

zero level		
	device 1	device 2
time	[nmol/mol]	[nmol/mol]
11:00:00	0.0	-0.1
11:01:00	0.0	-0.1
11:02:00	0.0	-0.1
11:03:00	0.0	-0.1
11:04:00	0.1	0.0
11:05:00	0.1	0.0
11:06:00	0.1	0.0
11:07:00	0.1	0.0
11:08:00	0.1	0.0
11:09:00	0.1	0.0
11:10:00	0.0	0.0
11:11:00	0.0	0.0
11:12:00	0.0	0.0
11:13:00	0.0	0.0
11:14:00	0.1	0.0
11:15:00	0.1	-0.1
11:16:00	0.1	-0.1
11:17:00	0.1	-0.1
11:18:00	0.1	-0.1
11:19:00	0.1	-0.1
average	0.1	-0.1

c_t level		
	device 1	device 2
time	[nmol/mol]	[nmol/mol]
11:26:00	497.4	499.3
11:27:00	497.4	499.3
11:28:00	497.4	499.3
11:29:00	497.4	499.3
11:30:00	497.4	499.3
11:31:00	497.4	499.3
11:32:00	498.2	499.3
11:33:00	498.3	499.3
11:34:00	498.3	499.1
11:35:00	498.3	498.3
11:36:00	498.3	497.4
11:37:00	498.3	497.4
11:38:00	498.3	497.4
11:39:00	498.3	497.4
11:40:00	498.3	497.4
11:41:00	498.3	497.4
11:42:00	498.3	497.4
11:43:00	498.3	497.4
11:44:00	498.3	497.4
11:45:00	498.3	497.4
average	498.0	498.3

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 of NO, 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 14211. 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 $\left(= \sum (X_i / n)\right)$
X_i is the individual x-value.

The function $Y_i = a + B (X_i - X_z)$ is converted 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 14211 mentioned previously.

7.4 Evaluation

The following linear regressions were established:

Figure 12 and Figure 13 summarise the results of the group averages for NO.

Table 21: Deviation from the analytical function for NO

	requirements	device 1		device 2	
largest value of the relative residuals r_{max} [%]	≤ 4,0	0.55	✓	1.01	✓
residual at zero r_z [nmol/mol]	≤ 5,0	-0.06	✓	0.00	✓

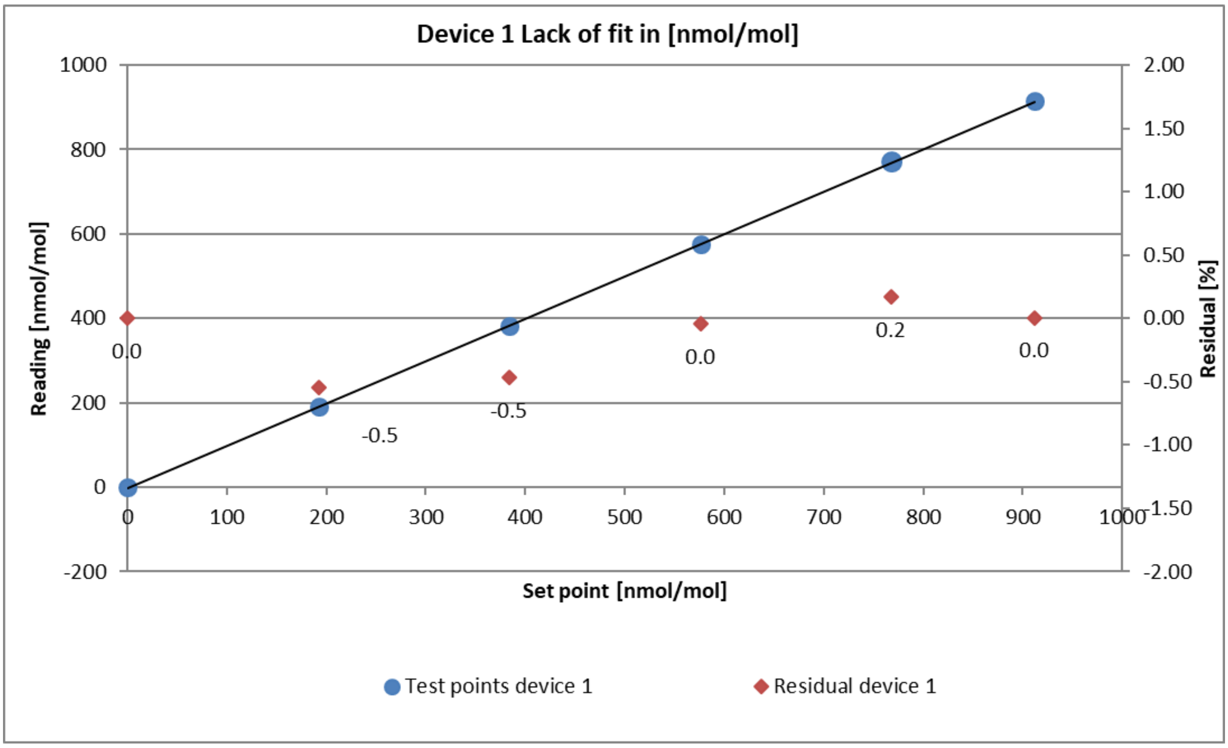


Figure 12: Analyser function obtained from the group averages for system 1

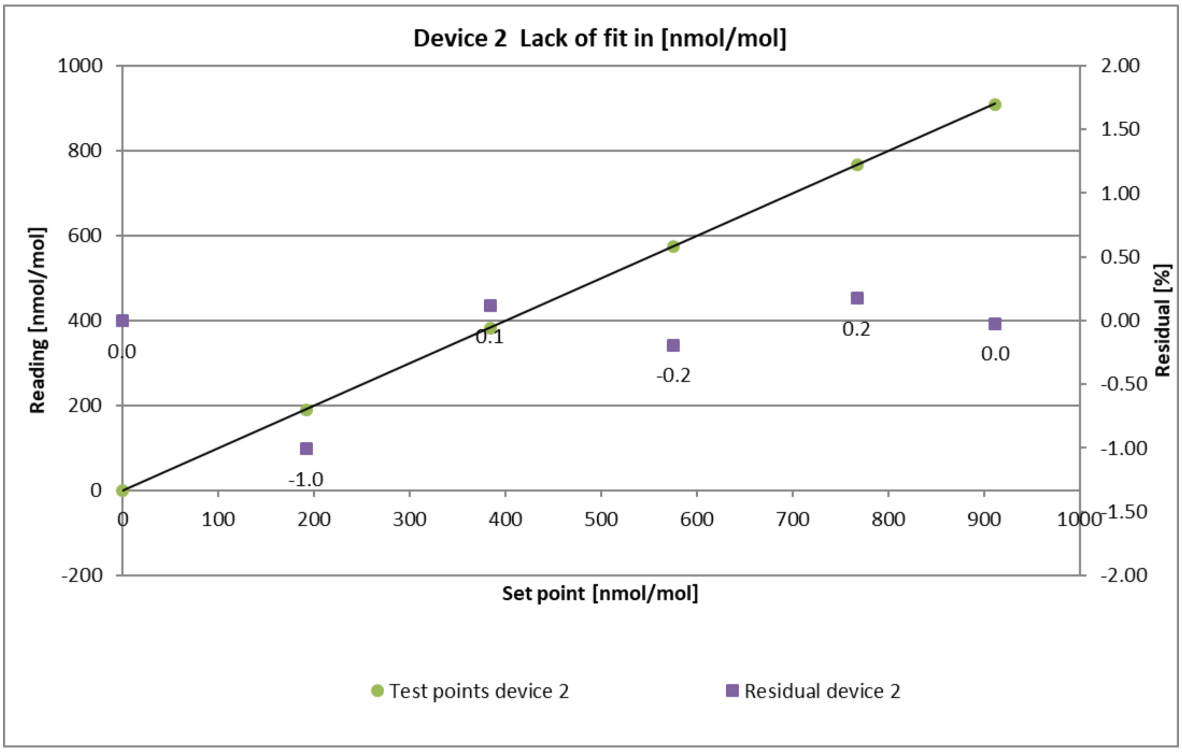


Figure 13: Analyser function obtained from the group averages for system 2

7.5 Assessment

The deviation from the linear regression line for instrument 1 was -0.06 nmol/mol at zero point and no more than 0.55% of the nominal value for concentrations above zero. The deviation from the linear regression line for instrument 2 is 0.00 nmol/mol at zero point and no more than 1.01% of the target value for concentrations above zero.

The residuals from the ideal regression line do not exceed the limit values required by standard EN 14211.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 22 presents the individual test results.

Table 22: Individual results of the lack-of-fit test

		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
10:01:00	80	770.56	768.00	767.68	768.00
10:02:00	80	770.56	768.00	767.68	768.00
10:03:00	80	770.56	768.00	767.68	768.00
10:04:00	80	770.56	768.00	767.68	768.00
10:05:00	80	770.56	768.00	767.68	768.00
average		770.56		767.68	
$r_{c,rel}$		0.17		0.18	
10:11:00	40	381.91	384.00	382.88	384.00
10:12:00	40	381.91	384.00	382.88	384.00
10:13:00	40	381.91	384.00	382.88	384.00
10:14:00	40	381.91	384.00	382.88	384.00
10:15:00	40	381.91	384.00	382.88	384.00
average		381.91		382.88	
$r_{c,rel}$		-0.47		0.12	
10:21:00	0	-0.06	0.00	0.00	0.00
10:22:00	0	-0.06	0.00	0.00	0.00
10:23:00	0	-0.06	0.00	0.00	0.00
10:24:00	0	-0.06	0.00	0.00	0.00
10:25:00	0	-0.06	0.00	0.00	0.00
average		-0.06		0.00	
r_z					
10:31:00	60	576.24	576.00	572.97	576.00
10:32:00	60	576.24	576.00	573.35	576.00
10:33:00	60	576.24	576.00	573.35	576.00
10:34:00	60	576.24	576.00	573.35	576.00
10:35:00	60	576.24	576.00	573.35	576.00
average		576.24		573.28	
$r_{c,rel}$		-0.04		-0.19	
10:41:00	20	190.48	192.00	188.55	192.00
10:42:00	20	190.48	192.00	188.55	192.00
10:43:00	20	189.51	192.00	188.55	192.00
10:44:00	20	189.51	192.00	188.55	192.00
10:45:00	20	189.51	192.00	188.55	192.00
average		189.90		188.55	
$r_{c,rel}$		-0.55		-1.01	
10:51:00	95	913.90	912.00	910.05	912.00
10:52:00	95	913.90	912.00	910.05	912.00
10:53:00	95	913.90	912.00	910.05	912.00
10:54:00	95	913.90	912.00	910.05	912.00
10:55:00	95	913.90	912.00	910.05	912.00
average		913.90		910.05	
$r_{c,rel}$		0.01		-0.02	

7.1 8.4.7 Sensitivity coefficient to sample gas pressure

The sensitivity coefficient to sample gas pressure shall be ≤ 8.0 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.

In compliance with the standard, the test has to be performed with the component NO. Pursuant to EN 14211, the test shall be performed at a concentration level of 70% to 80% of the certification range for NO.

7.3 Testing

The test was performed in line with the requirements of EN 14211 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 a t-piece. The positive pressure was produced by blocking the bypass line. The sample gas pressure was determined by a pressure transducer in the test 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 23: Sensitivity coefficient to the sample gas pressure

	requirement	device 1		device 2	
sensitivity coeff. sample gas pressure b_{gp} [nmol/mol/kPa]	≤ 8,0	0.08	✓	0.06	✓

7.5 Assessment

For instrument 1, the sensitivity coefficient to sample gas pressure was 0.08 nmol/mol/kPa.
For instrument 2, the sensitivity coefficient to sample gas pressure was 0.06 nmol/mol/kPa.
Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 24: Individual results of the sensitivity to changes in sample gas pressure

			device 1	device 2
time	pressure [kPa]	concentration	[nmol/mol]	[nmol/mol]
10:21:00	80	720.00	715.68	715.30
10:22:00	80	720.00	715.68	714.75
10:23:00	80	720.00	715.15	714.63
average C_{P1}			715.50	714.90
10:34:00	110	720.00	713.17	713.16
10:35:00	110	720.00	713.16	713.15
10:36:00	110	720.00	713.16	713.14
average C_{P2}			713.16	713.15

7.1 8.4.8 Sensitivity coefficient to sample gas temperature

The sensitivity coefficient to sample gas temperature shall be ≤ 3.0 µmol/mol/K.

7.2 Test procedures

Measurements shall be performed at sample gas temperatures of $T_{G,1}$ = 0 °C and $T_{G,2}$ = 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.

In compliance with the standard, the test has to be performed with the component NO. Pursuant to EN 14211, the test shall be performed at a concentration level of 70% to 80% of the certification range for NO.

7.3 Testing

The test was performed in line with the requirements of EN 14211 mentioned previously.

For the purpose of this test, the test gas mixture was led through a 40m tube-bundle which was situated in a climatic 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 exactly 0 °C. For the purpose of testing a gas temperature of 30 °C, gas was led through a heated line instead of the tube bundle in the climatic chamber.

7.4 Evaluation

Table 25: Sensitivity coefficient to the sample gas temperature

	requirement	device 1		device 2	
sensitivity coeff. sample gas temperature b_{gt} [nmol/mol/K]	≤ 3,0	0.03	✓	0.01	✓

7.5 Assessment

For instrument 1, the sensitivity coefficient to sample gas temperature was 0.03 nmol/mol/K. For instrument 2, the sensitivity coefficient to sample gas temperature was 0.01 nmol/mol/K.
Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 26: Individual results for the sensitivity to sample gas temperature

			device 1	device 2
time	temp [ºC]	concentration	[nmol/mol]	[nmol/mol]
13:04:00	0	720.00	713.13	714.67
13:05:00	0	720.00	714.77	717.65
13:06:00	0	720.00	714.77	716.79
average $C_{GT,1}$			714.22	716.37
15:58:00	30	720.00	713.80	716.69
15:59:00	30	720.00	713.80	716.69
16:00:00	30	720.00	712.36	716.69
average $C_{GT,2}$			713.32	716.69

7.1 8.4.9 Sensitivity coefficient to surrounding temperature

The sensitivity coefficient to surrounding temperature shall be ≤ 3.0 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.

In compliance with the standard, the test has to be performed with the component NO. Pursuant to EN 14211, the test shall be performed at a concentration level of 70% to 80% of the certification range for NO.

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 14211 mentioned previously.

7.4 Evaluation

The following sensitivity coefficients to surrounding temperature have been determined:

Table 27: Sensitivity coefficient to surrounding temperature

	requirements	device 1		device 2	
sensitivity coefficient at 0 ºC for zero level [nmol/mol/K]	≤ 3,0	0.029	✓	0.018	✓
sensitivity coefficient at 30 ºC for zero level [nmol/mol/K]	≤ 3,0	0.055	✓	0.055	✓
sensitivity coefficient at 0 ºC for span level [nmol/mol/K]	≤ 3,0	0.018	✓	0.128	✓
sensitivity coefficient at 30 ºC for span level [nmol/mol/K]	≤ 3,0	0.269	✓	0.103	✓

As is evident from Table 27, 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 3.0 nmol/mol/K. For the purpose of the uncertainty calculation, the largest value b_{st} is used for both instruments. This would be 0.269 nmol/mol/K for instrument 1 and 0.128 nmol/mol/K for instrument 2.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 28 presents the individual test results.

Table 28: Individual test results for the sensitivity coefficient to ambient 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]
16.03.2021	08:01:00	20	0.0	0.0	08:16:00	20	721.9	721.9
16.03.2021	08:02:00	20	0.0	0.0	08:17:00	20	722.0	721.5
16.03.2021	08:03:00	20	0.0	0.0	08:18:00	20	722.1	721.5
average ($X_{1(TS1)}$)			0.0	0.0			722.0	721.6
16.03.2021	16:10:00	0	0.5	0.1	16:18:00	0	719.6	724.4
16.03.2021	16:11:00	0	0.6	0.2	16:19:00	0	719.6	724.2
16.03.2021	16:12:00	0	0.7	0.8	16:20:00	0	719.6	722.4
average($X_{Ts,1}$)		0	0.6	0.4			719.6	723.6
17.03.2021	07:50:00	20	0.0	0.0	08:00:00	20	717.7	720.5
17.03.2021	07:51:00	20	0.0	0.0	08:01:00	20	717.9	720.5
17.03.2021	07:52:00	20	0.0	0.0	08:02:00	20	718.0	720.5
average ($X_{2(TS1)}$) = ($X_{1(TS2)}$)			0.0	0.0			717.9	720.5
17.03.2021	15:14:00	30	0.5	0.4	15:21:00	30	715.7	718.6
17.03.2021	15:15:00	30	0.6	0.5	15:22:00	30	715.7	718.9
17.03.2021	15:16:00	30	0.6	0.8	15:23:00	30	715.7	719.6
average($X_{Ts,2}$)			0.5	0.5			715.7	719.0
18.03.2021	08:15:00	20	0.0	0.0	08:21:00	20	718.6	719.6
18.03.2021	08:16:00	20	0.0	0.0	08:22:00	20	718.6	719.6
18.03.2021	08:17:00	20	0.0	0.0	08:23:00	20	719.6	719.6
average ($X_{2(TS2)}$)			0.0	0.0			718.9	719.6

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 of NO. 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 14211 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 29: 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	0.00	✓	0.00	✓

7.5 Assessment

At no test item did the sensitivity coefficient to electrical voltage b_v exceed the value of 0.30 nmol/mol/V specified in standard EN 14211. For the purpose of the uncertainty calculation, the largest b_v is used for both instruments. For instrument 1, this was 0.00 nmol/mol/V and for instrument 2 it was 0.00 nmol/mol/V.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 30: Individual results of the sensitivity coefficient to electrical voltage

			device 1	device 2
time	voltage [V]	concentration	[nmol/mol]	[nmol/mol]
11:00:00	207	0	-0.32	-0.28
11:01:00	207	0	-0.32	-0.29
11:02:00	207	0	-0.32	-0.28
average C_{V1} at zero			-0.32	-0.28
11:10:00	253	0	-0.32	-0.28
11:11:00	253	0	-0.32	-0.29
11:12:00	253	0	-0.32	-0.29
average C_{V2} at zero			-0.32	-0.28
11:30:00	207	720.00	723.20	723.67
11:31:00	207	720.00	723.18	723.67
11:32:00	207	720.00	723.20	723.65
average C_{V1} at Span			723.19	723.66
11:40:00	253	720.00	723.19	723.66
11:41:00	253	720.00	723.19	723.65
11:42:00	253	720.00	723.18	723.66
average C_{V2} at Span			723.19	723.66

7.1 8.4.11 Interferents

Interferents at zero and at concentration c_t for NO (500 ± 50 nmol/mol). Deviations for interferents H_2O, CO_2 and NH_3 shall not exceed 5.0 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 shall be performed at zero and at an NO test concentration (c_t) of (500 ± 50) nmol/mol.

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 given in

Table 31. 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 31. With this mixture, one independent measurement of NO followed by two individual measurements of NO 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 of NO 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 of NO 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 14211 mentioned previously. The instruments were set at zero and the concentration c_t (500 ppb). Zero and test gas with the various interfering components were then applied. The interferents listed in

Table 31 were applied in the concentrations indicated. As required by standard EN 14211, the measured NO_x concentration shall be used instead of the NO concentration when testing the interferent NH_3.

Table 31: Interferents in accordance with EN 14211

Interferent	Value
H_2O	19 mmol/mol
CO_2	500 µmol/mol
NH_3	200 nmol/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 32: Influence of the tested interferents (c_t = 500±50 nmol/mol)

	requirements	**device 1**		**device 2**	
influence quantity interferent H_2O at zero [nmol/mol/V]	≤ 5.0 nmol/mol	0.00	✓	-0.34	✓
influence quantity interferent H_2O at c_t [nmol/mol/V]	≤ 5.0 nmol/mol	0.85	✓	-1.17	✓
influence quantity interferent CO_2 at zero [nmol/mol/V]	≤ 5.0 nmol/mol	0.71	✓	0.44	✓
influence quantity interferent CO_2 at c_t [nmol/mol/V]	≤ 5.0 nmol/mol	-0.23	✓	-0.48	✓
influence quantity interferent NH_3 at zero [nmol/mol/V]	≤ 5.0 nmol/mol	0.34	✓	-0.09	✓
influence quantity interferent NH3 at c_t [nmol/mol/V]	≤ 5.0 nmol/mol	0.51	✓	1.45	✓

7.5 Assessment

This resulted in a value for the cross-sensitivity at zero for NO of 0.00 nmol/mol for unit 1 and -0.34 nmol/mol for unit 2 for H_2O, 0.71 nmol/mol for unit 1 and 0.44 nmol/mol for unit 2 for CO_2 and 0.34 nmol/mol for unit 1 and -0.09 nmol/mol for unit 2 for NH_3.

For the cross-sensitivity at the limit value c_t, the values for NO were 0.85 nmol/mol for unit 1 and -1.17 nmol/mol for unit 2 for H2O, -0.23 nmol/mol for unit 1 and -0.48 nmol/mol for unit 2 for CO_2 and 0.51 nmol/mol for unit 1 and 1.45 nmol/mol for NH_3.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 33 presents the individual test results.

Table 33: Individual results for testing interferents

	without interferents			with interferents		
	time	device 1	device 2	time	device 1	device 2
zero gas + H_2O (19 mmol/mol)	10:17:00	0.00	-0.29	10:33:00	0.00	-0.62
	10:18:00	0.00	-0.30	10:34:00	0.00	-0.62
	10:19:00	0.00	-0.30	10:35:00	0.00	-0.66
	average x_z	0.00	-0.29	average x_z	0.00	-0.64
test gas c_t + H_2O (19 mmol/mol)	11:13:00	496.96	498.12	11:28:00	498.06	497.34
	11:14:00	497.19	498.14	11:29:00	498.08	496.77
	11:15:00	497.51	498.14	11:30:00	498.07	496.76
	average x_{ct}	497.22	498.13	average x_{ct}	498.07	496.96
zero gas + CO_2 (500 µmol/mol)	13:12:00	0.00	-1.20	13:27:00	0.71	-0.76
	13:13:00	0.00	-1.20	13:28:00	0.71	-0.76
	13:14:00	0.00	-1.20	13:29:00	0.71	-0.76
	average x_z	0.00	-1.20	average x_z	0.71	-0.76
test gas c_t + CO_2 (500 µmol/mol)	13:43:00	497.91	496.63	13:58:00	497.69	496.16
	13:44:00	497.92	496.64	13:59:00	497.70	496.17
	13:45:00	497.92	496.64	14:00:00	497.68	496.16
	average x_{ct}	497.92	496.64	average x_{ct}	497.69	496.16
zero gas + NH_3 (200 nmol/mol)	12:13:00	0.00	-0.27	12:28:00	0.34	-0.41
	12:14:00	0.00	-0.34	12:29:00	0.34	-0.41
	12:15:00	0.00	-0.35	12:30:00	0.34	-0.41
	average x_z	0.00	-0.32	average x_z	0.34	-0.41
test gas c_t + NH_3 (200 nmol/mol)	12:43:00	498.62	496.13	12:58:00	499.15	497.57
	12:44:00	498.64	496.13	12:59:00	499.15	497.57
	12:45:00	498.64	496.11	13:00:00	499.15	497.57
	average x_{ct}	499.15	496.13	average x_{ct}	499.15	497.57

NO_x reading with interference from NH_3

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 concentration of NO_2 at a concentration $c_{t,NO2}$ which is about twice the hourly limit value; and
- a stepwise varied concentration of NO between zero and 600 nmol/mol (concentration $c_{t,NO}$).

The time period (t_c) of the constant NO concentration shall be at least equal to a period necessary to obtain four independent readings (which is equal to at least sixteen response times). The time period (t_v) of the varying NO concentration shall be at least equal to a period to obtain four independent readings. The time period (t_{NO}) for the NO 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 a time period including a whole number of t_{NO} and t_{zero} pairs, and contains a minimum of 3 such pairs.

The change from t_{NO} 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 the at least four independent measurements during the variable concentration period;

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

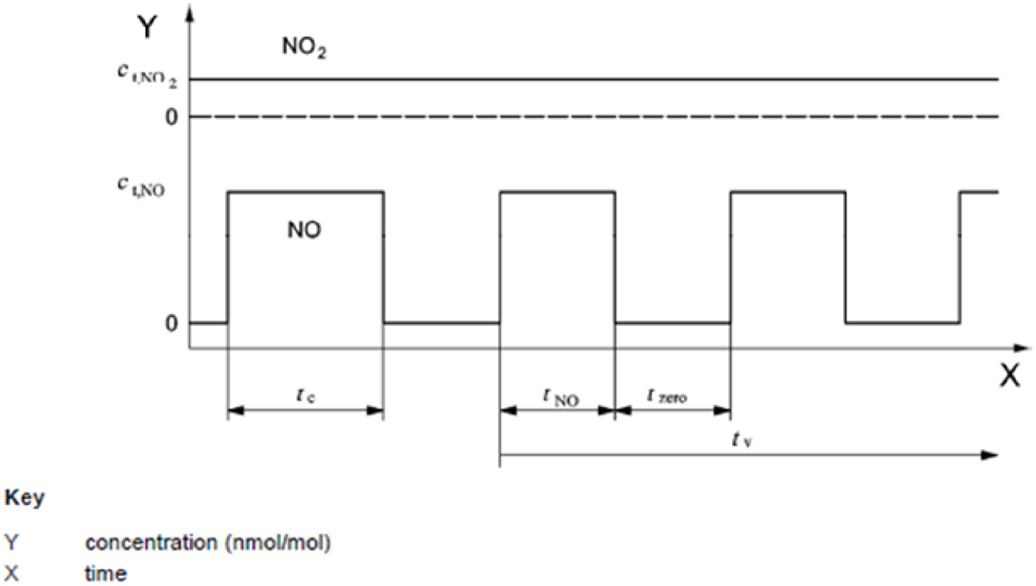


Figure 14: Test of the averaging effect (t_{NO} = t_{zero} = 45 s.)

7.3 Testing

The averaging test was performed in compliance with the requirements specified in EN 14211. With the help of a mass flow controller we applied a step change of the NO concentration between zero and 600 nmol/mol and, at the same time, a constant NO_2 concentration $c_{t,NO2}$ of roughly twice the hourly limit value. 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 34: Results of the averaging tests

	requirement	device 1		device 2	
averaging effect E_{av} [%]	≤ 7%	-1.8	✓	-1.6	✓

This results in the following averaging effects:

System 1 (12): -1.8 %

System 2 (14): -1.6 %

7.5 Assessment

The performance criterion of EN 14211 for the averaging test was fully complied with at -1.8 % and -1.6 % respectively.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 35 presents the individual results of the averaging tests:

Table 35: Results of the averaging tests

		device 1	device 2
	time	[nmol/mol]	[nmol/mol]
average constant concentration $C_{av,c}$	12:07:00	594.2	593.6
	till		
	12:26:00		
average variable concentration $C_{av,c}$	12:27:00	302.5	301.3
	till		
	12:46:00		

		device 1	device 2
	time	[nmol/mol]	[nmol/mol]
average constant concentration $C_{av,c}$	12:58:00	592.6	592.6
	till		
	13:17:00		
average variable concentration $C_{av,c}$	13:18:00	300.6	301.6
	till		
	13:37:00		

		device 1	device 2
	time	[nmol/mol]	[nmol/mol]
average constant concentration $C_{av,c}$	13:48:00	591.6	592.6
	till		
	14:07:00		
average variable concentration $C_{av,c}$	14:08:00	302.4	300.4
	till		
	14:27:00		

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 of NO 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 measuring system is not equipped with a test gas inlet separate from the sample gas inlet. Test gases have to be fed via the sample inlet.

7.4 Evaluation

Not applicable.

7.5 Assessment

This test criterion does not apply. The measuring system is not equipped with a test gas inlet separate from the sample gas inlet. Test gases have to be fed via the sample inlet.

Criterion satisfied? Not applicable

7.6 Detailed presentation of test results

Not applicable.

7.1 8.4.14 Converter efficiency

The converter efficiency should be at least 98%.

7.2 Test procedures

The converter efficiency is determined by measurements with calculated amounts of NO_2. This can be achieved by means of gas-phase titration of NO to NO_2 with ozone.

The test shall be performed at two concentration levels: at about 50% and about 95% of the maximum of the certification range of NO_2.

The NO_x measuring system shall be calibrated applying an NO concentration of about 70% to 80% of the maximum certification range for NO to the NO and NO_x channels. Both channels need to be adjusted to display the same value. The values shall be recorded.

A known NO concentration at 50% of the NO certification range is applied to the measuring system until a stable signal is obtained. This stable period shall be at least as long as four response times. Four individual readings each are performed at the NO and the NO_x channel. Then, NO is brought to react with O_3 to produce NO_2. This mixture containing a constant NO_x concentration is applied to the measuring system until the output signal has stabilised. This stable period shall be at least four response times of the measuring system under test; the NO concentration after gas-phase titration shall be between 10% and 20% of the original NO concentration. Then, four individual readings each are performed at the NO and the NO_x channel. Then, the O_3 supply is cut and only NO is applied to the measuring system until the output signal has stabilised again. This stable period shall be at least as long as four response times of the measuring system. After that the average of the four individual measurements at the NO and the NO_x channel is calculated.

The converter efficiency is calculated as follows:

$$E_{conv} = \left(1 - \frac{(NO_x)_i - (NO_x)_f}{(NO)_i - (NO)_f}\right) \times 100\%$$

Where:

E_{conv}	is the converter efficiency in %;
$(NO_x)_i$	is the average of the four individual measurements at the NO_x channel at the initial NO_x concentration;
$(NO_x)_f$	is the average of the four individual measurements at the NO_x channel at the resulting NO_x concentration after applying O_3;
$(NO)_i$	is the average of the four individual measurements at the NO channel at the initial NO concentration;
$(NO)_f$	is the average of the four individual measurements at the NO channel at the resulting NO concentration after applying O_3;

The lowest value of the two converter efficiencies shall be reported.

7.3 Testing

The test was performed in compliance with the requirements specified in EN 14211. When applying test gas two NO_2 concentrations in the range of 50% to 95% of the certification range for NO_2 were adjusted by means of gas-phase titration.

7.4 Evaluation

During the test, the following converter efficiencies were determined for the two nCLD AL^2 measuring systems. The lowest value of the two NO_2 concentration is reported below.

	requirement	device 1		device 2	
converter efficiency E_c [%]	≥ 98%	99.4	✓	99.2	✓

7.5 Assessment

The performance criterion of EN 14211 was fully met with a converter efficiency of at least 99.2 %.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 36 presents the individual values.

Table 36: Individual results for the converter efficiency

				device 1		device 2	
	time	O_3 [nmol/mol]	NO_2 [nmol/mol]	NO [nmol/mol]	NO_x [nmol/mol]	NO [nmol/mol]	NO_x [nmol/mol]
	14:08:00	start					
O_3=0, NO=50%	14:25:00	0.0	0.0	485.0	483.5	486.3	486.5
	14:26:00	0.0	0.0	485.0	483.5	485.9	486.5
	14:27:00	0.0	0.0	485.0	483.5	485.7	486.5
	14:28:00	0.0	0.0	485.0	483.4	485.7	486.5
average		0.0	0.0	485.0	483.5	485.9	486.5
NO_2= 50%	14:41:00	130.0	132.7	352.9	483.4	353.5	486.2
	14:42:00	130.0	132.7	352.9	482.8	353.5	486.2
130.75	14:43:00	130.0	132.8	352.9	482.1	353.5	486.2
	14:44:00	130.0	132.8	352.9	482.1	353.5	486.2
average		130.0	132.7	352.9	482.6	353.5	486.2
O_3=0, NO=50%	15:34:00	0.0	0.0	482.8	481.3	485.3	485.0
	15:35:00	0.0	0.0	482.8	481.3	485.3	485.0
	15:36:00	0.0	0.0	482.9	481.3	485.3	485.0
	15:37:00	0.0	0.0	483.1	481.3	485.3	484.9
average		0.0	0.0	482.9	481.3	485.3	485.0
NO_2= 95%	15:50:00	248.0	248.5	231.8	480.3	231.2	482.6
	15:51:00	248.0	248.5	231.8	480.3	231.2	482.8
248.43	15:52:00	248.0	248.6	231.7	480.3	231.3	483.0
	15:53:00	248.0	248.7	231.6	480.3	231.7	483.0
average		248.0	248.6	231.7	480.3	231.3	482.9
O_3=0, NO=50%	16:05:00	0.0	0.0	483.4	484.0	482.2	484.4

7.1 8.4.15 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 nCLD AL^2 measuring system is approximately 30.0 ml from the sample inlet to the measuring cell. The typical sample gas flow is at 1.0 l/min. This results in a residence time in the analyser of 1.8 s.

7.4 Evaluation

Not applicable.

7.5 Assessment

Residence time in the analyser was 1.8 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 bi-weekly zero and span check, the drift of the analysers under test shall be calculated at zero and at span following the procedures as given below. 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 37 and Table 38 report the measured values for bi-weekly test gas applications. In compliance with the standard, the test has to be performed with the component NO. Pursuant to EN 14211, the test shall be performed at a concentration level of 70% to 80% of the certification range for NO.

7.4 Evaluation

Table 37: Results for the long-term drift at zero point

		requierment	Device 1		Device 2	
average start $Cz_{,1}$ at zero [nmol/mol]	12.04.2021	≤ 5,0	--	✓	--	✓
long term drift $D_{L,Z}$ at zero [nmol/mol]	26.04.2021	≤ 5,0	0.00	✓	0.00	✓
long term drift $D_{L,Z}$ at zero [nmol/mol]	10.05.2021	≤ 5,0	0.27	✓	0.38	✓
long term drift $D_{L,Z}$ at zero [nmol/mol]	25.05.2021	≤ 5,0	0.00	✓	0.00	✓
long term drift $D_{L,Z}$ at zero [nmol/mol]	07.06.2021	≤ 5,0	0.00	✓	0.96	✓
long term drift $D_{L,Z}$ at zero [nmol/mol]	21.06.2021	≤ 5,0	0.00	✓	0.89	✓
long term drift $D_{L,Z}$ at zero [nmol/mol]	05.07.2021	≤ 5,0	0.00	✓	0.06	✓
long term drift $D_{L,Z}$ at zero [nmol/mol]	19.07.2021	≤ 5,0	0.08	✓	0.00	✓

Table 38: Results for the long-term drift at span point

		requierment	Device 2 1		Device 2	
average start $Cs_{,1}$ at span [nmol/mol]	12.04.2021	≤ 5 %	--	✓	--	✓
long term drift $D_{L,S}$ at span [nmol/mol]	26.04.2021	≤ 5 %	1.03	✓	-0.81	✓
long term drift $D_{L,S}$ at span [nmol/mol]	10.05.2021	≤ 5 %	1.15	✓	-0.04	✓
long term drift $D_{L,S}$ at span [nmol/mol]	25.05.2021	≤ 5 %	0.81	✓	1.25	✓
long term drift $D_{L,S}$ at span [nmol/mol]	07.06.2021	≤ 5 %	0.90	✓	0.40	✓
long term drift $D_{L,S}$ at span [nmol/mol]	21.06.2021	≤ 5 %	0.90	✓	0.25	✓
long term drift $D_{L,S}$ at span [nmol/mol]	05.07.2021	≤ 5 %	1.25	✓	1.04	✓
long term drift $D_{L,S}$ at span [nmol/mol]	19.07.2021	≤ 5 %	1.29	✓	1.30	✓

7.5 Assessment

Maximum long-term drift at zero point $D_{l,z}$ was at 0.27 nmol/mol for instrument 1 and 0.96 nmol/mol for instrument 2. Maximum long-term drift at reference point $D_{l,s}$ was at 1.29% for instrument 1 and 1.30% for instrument 2.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 39 presents the individual values obtained for the determination of the long-term drift.

Table 39: Individual results for the drift tests

Zero Concentration			
		Device 1	Device 2
Date	Time	[nmol/mol]	[nmol/mol]
12.04.2021	10:31:00	0.00	0.00
	10:32:00	0.00	0.00
	10:33:00	0.00	0.00
	average	0.00	0.00
	10:34:00	0.00	0.00
	10:35:00	0.00	0.00
	10:36:00	0.00	0.00
	average	0.00	0.00
	10:37:00	0.00	0.00
	10:38:00	0.00	0.00
	10:39:00	0.00	0.00
	average	0.00	0.00
	10:40:00	0.00	0.00
	10:41:00	0.00	0.00
	10:42:00	0.00	0.00
	average	0.00	0.00
	10:43:00	0.00	0.00
	10:44:00	0.00	0.00
	10:45:00	0.00	0.00
	average	0.00	0.00
Average field start $c_{z,0}$		**0.00**	**0.00**
26.04.2021	09:12:00	0.00	0.00
	09:13:00	0.00	0.00
	09:14:00	0.00	0.00
	09:15:00	0.00	0.00
	09:16:00	0.00	0.00
	aver. $c_{z,1}$	**0.00**	**0.00**
10.05.2021	11:29:00	1.35	0.96
	11:30:00	0.00	0.96
	11:31:00	0.00	0.00
	11:32:00	0.00	0.00
	11:33:00	0.00	0.00
	aver. $c_{z,1}$	**0.27**	**0.38**
25.05.2021	09:51:00	0.00	0.00
	09:52:00	0.00	0.00
	09:53:00	0.00	0.00
	09:54:00	0.00	0.00
	09:55:00	0.00	0.00
	aver. $c_{z,1}$	**0.00**	**0.00**
07.06.2021	11:58:00	0.00	0.96
	11:59:00	0.00	0.96
	12:00:00	0.00	0.96
	12:01:00	0.00	0.96
	12:02:00	0.00	0.96
	aver. $c_{z,1}$	**0.00**	**0.96**
21.06.2021	09:49:00	0.00	0.58
	09:50:00	0.00	0.96
	09:51:00	0.00	0.96
	09:52:00	0.00	0.96
	09:53:00	0.00	0.96
	aver. $c_{z,1}$	**0.00**	**0.89**
05.07.2021	09:05:00	0.00	0.29
	09:06:00	0.00	0.00
	09:07:00	0.00	0.00
	09:08:00	0.00	0.00
	09:09:00	0.00	0.00
	aver. $c_{z,1}$	**0.00**	**0.06**
19.07.2021	08:47:00	0.10	0.00
	08:48:00	0.10	0.00
	08:49:00	0.10	0.00
	08:50:00	0.10	0.00
	08:51:00	0.00	0.00
	aver. $c_{z,1}$	**0.08**	**0.00**

C_t-Concentration			
		Device 1	Device 2
Date	Time	[nmol/mol]	[nmol/mol]
12.04.2021	11:03:00	719.58	720.54
	11:04:00	719.58	720.54
	11:05:00	719.58	720.54
	average	719.58	720.54
	11:06:00	719.58	720.54
	11:07:00	719.58	720.54
	11:08:00	719.77	720.54
	average	719.64	720.54
	11:09:00	720.54	720.54
	11:10:00	720.54	720.54
	11:11:00	720.54	720.54
	average	720.54	720.54
	11:12:00	720.54	720.54
	11:13:00	720.54	720.54
	11:14:00	720.54	720.54
	average	720.54	720.54
	11:15:00	720.54	720.54
	11:16:00	720.54	720.54
	11:17:00	720.54	720.54
	average	720.54	720.54
Average field start $c_{s,0}$		**720.17**	**720.54**
26.04.2021	09:20:00	728.23	714.77
	09:21:00	728.14	714.77
	09:22:00	727.27	714.77
	09:23:00	727.27	714.77
	09:24:00	727.27	714.77
	aver. $c_{s,1}$	**727.64**	**714.77**
10.05.2021	11:36:00	729.97	722.56
	11:37:00	729.48	721.69
	11:38:00	728.04	720.54
	11:39:00	728.23	720.15
	11:40:00	728.23	718.33
	aver. $c_{s,1}$	**728.79**	**720.65**
25.05.2021	10:02:00	725.25	729.00
	10:03:00	723.14	728.33
	10:04:00	727.27	729.20
	10:05:00	727.27	731.50
	10:06:00	727.27	730.16
	aver. $c_{s,1}$	**726.04**	**729.64**
07.06.2021	12:09:00	727.27	724.39
	12:10:00	727.18	724.39
	12:11:00	726.31	724.39
	12:12:00	726.31	724.39
	12:13:00	726.31	724.39
	aver. $c_{s,1}$	**726.68**	**724.39**
21.06.2021	10:00:00	728.43	722.56
	10:01:00	726.31	723.42
	10:02:00	726.31	723.42
	10:03:00	726.31	723.42
	10:04:00	726.31	723.42
	aver. $c_{s,1}$	**726.73**	**723.25**
05.07.2021	09:16:00	731.60	729.58
	09:17:00	731.12	729.20
	09:18:00	730.35	727.66
	09:19:00	726.98	727.27
	09:20:00	726.31	727.27
	aver. $c_{s,1}$	**729.27**	**728.20**
19.07.2021	08:56:00	729.68	730.54
	08:57:00	732.08	731.12
	08:58:00	730.35	729.10
	08:59:00	727.95	730.16
	09:00:00	728.23	729.20
	aver. $c_{s,1}$	**729.66**	**730.02**

7.1 8.5.5 Reproducibility standard deviation for NO_2 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 nitrogen dioxide 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 40: Reproducibility standard deviation based on complete field test data

reproducibility standard deviation in field		
no. of measurments (1h- average)	[n]	2351
average of both analyzers (3 month)	[nmol/mol]	15.89
standard deviation from paired measurements	[nmol/mol]	0.669
reproducibility standard deviation in field $S_{r,f}$	**[%]**	**4.21**
requirement	≤ 5,0 %	✓

The reproducibility standard deviation under field conditions is at 4.21% of the average. The reproducibility standard deviation under field conditions is determined according to VDI 4202-1 and EN 14211 for the component NO_2.

For information, Figure 16 also shows the reproducibility standard deviation for the component NO. NO was enriched over 26 hours to also represent values in the upper section of the certification range.

7.5 Assessment

The reproducibility standard deviation for NO_2 under field conditions was 4.21% as a percentage of the mean value over the three-month field test period. Thus, the requirements of EN 14211 are satisfied.

Criterion satisfied? yes

7.6 Detailed presentation of test results

In Figure 15 the reproducibility standard deviation for the component NO_2 in the field is shown.

In Figure 16 the reproducibility standard deviation for the component NO in the field is shown.

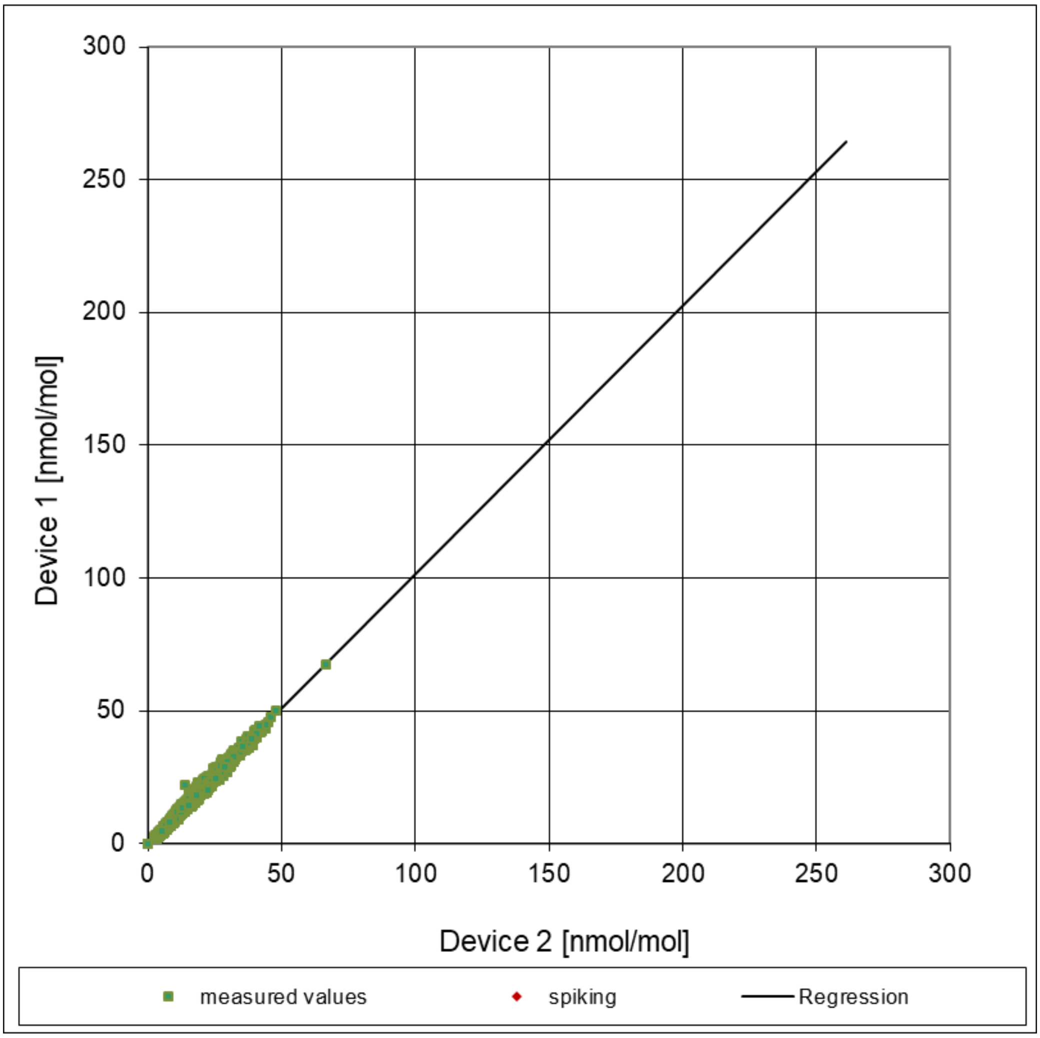


Figure 15: Reproducibility standard deviation for NO_2 under field conditions

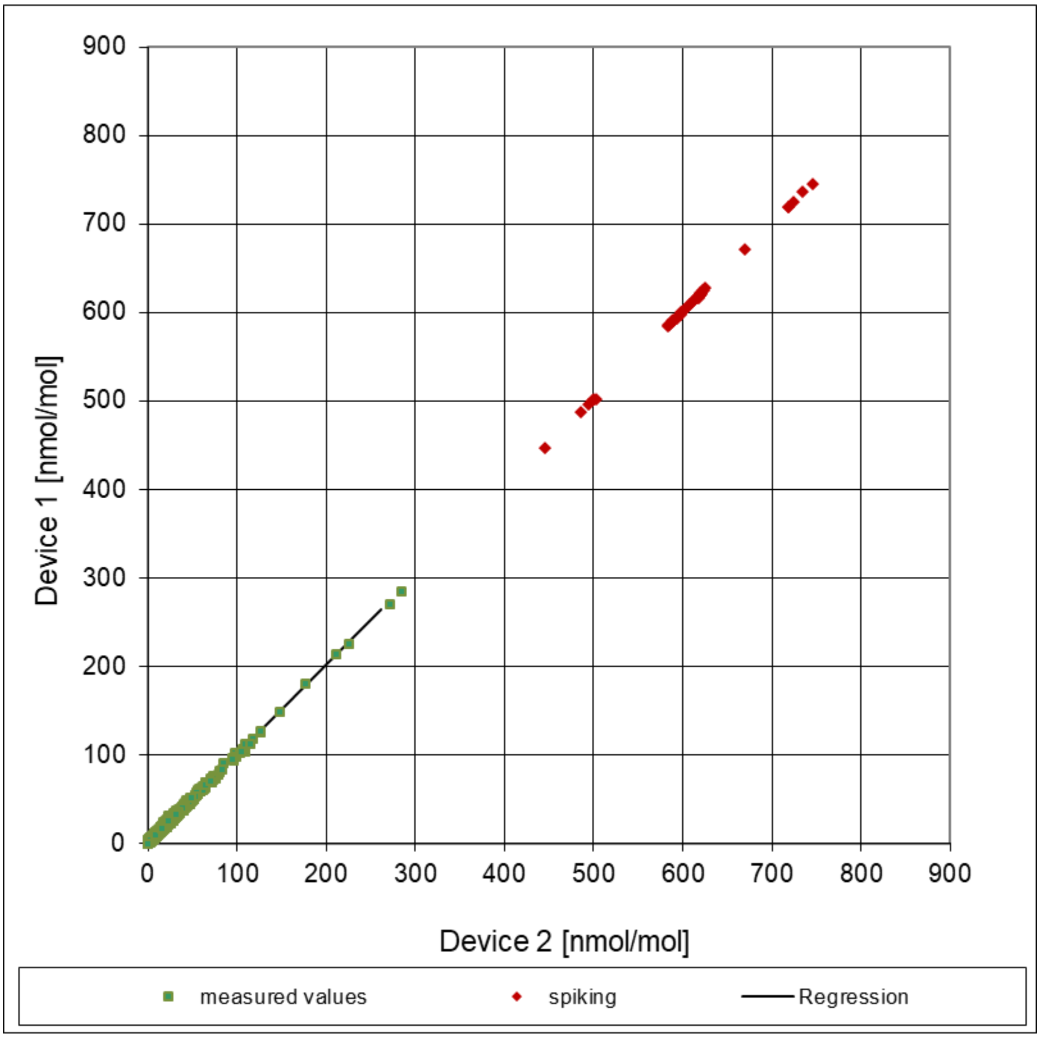


Figure 16: Reproducibility standard deviation for NO under field conditions

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. The replacement rate of the particle filter at the sample gas inlet naturally depends on the dust content of the environment of the installation site. 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 at the test gas inlet must be changed depending on the dust load at the measurement location. EN 14211 requires checking of zero and span points at least once every two weeks.

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 41.

Table 41: Availability of the nCLD AL^2 measuring system

		System 1	System 2
Operation time	h	2351	2351
Outage time	h	0	0
Maintenance time	h	5	5
Actual operating time:	h	2346	2346
Actual operating time incl. maintenance times:	h	2351	2351
Availability	%	100	100

The maintenance times result from the 14-day test gas applications to determine the drift behaviour and the maintenance interval.

7.5 Assessment

The availability is at 100%. Thus, the requirement of EN 14211 is satisfied.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Not applicable.

7.1 8.6 Calculation of the total uncertainty in accordance with standard EN 14211 (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 14211.

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 14211.

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 14211.

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 14211.

7.2 Equipment

Calculation of the total uncertainty in accordance with standard EN 14211 (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 14211.

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 14211.

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 42 summarises the results for items 1 and 3.

Table 43 and Table 45 contain the results regarding item 2.

Table 44 and Table 46 contain the results regarding item 4.

Table 42: Relevant performance characteristics and criteria according to EN 14211

Performance characteristic	Performance criterion	Test result	Satisfied	Page
8.4.5 Repeatability standard deviation at zero	≤ 1.0 nmol/mol	S_r System 1: 0.00 nmol/mol S_r System 2: 0.01 nmol/mol	yes	91
8.4.5 Repeatability standard deviation at concentration level c_t	≤ 3.0 nmol/mol	S_r System 1: 0.45 nmol/mol S_r System 2: 0.95 nmol/mol	yes	91
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 -0.06 nmol/mol X_l System 1: RP 0.55% $X_{l,z}$ System 2: ZP 0.00 nmol/mol X_l System 2: RP 1.01%	yes	94
8.4.7 Sensitivity coefficient of sample gas pressure	≤ 8.0 nmol/mol/kPa	b_{gp} System 1: 0.08 nmol/mol/kPa b_{gp} System 2: 0.06 nmol/mol/kPa	yes	99
8.4.8 Sensitivity coefficient of sample gas temperature	≤ 3.0 nmol/mol/K	b_{gt} System 1: 0.03 nmol/mol/K b_{gt} System 2: 0.01 nmol/mol/K	yes	101
8.4.9 Sensitivity coefficient of surrounding temperature	≤ 3.0 nmol/mol/K	b_{st} System 1: 0.269 nmol/mol/K b_{st} System 2: 0.128 nmol/mol/K	yes	103
8.4.10 Sensitivity coefficient of electrical voltage	≤ 0.3 nmol/mol/V	b_v System 1: RP 0.00 nmol/mol/V b_v System 2: RP 0.00 nmol/mol/V	yes	106
8.4.11 Interferent at zero and at concentration level c_t	H_2O ≤ 5.0 nmol/mol CO_2 ≤ 5.0 nmol/mol NH_3 ≤ 5.0 nmol/mol	H_2O System 1: ZP 0.00 nmol/mol / RP 0.85 nmol/mol System 2: ZP -0.34 nmol/mol / RP -1.17 nmol/mol CO_2 System 1: ZP 0.71 nmol/mol / RP -0.23 nmol/mol System 2: ZP 0.44 nmol/mol / RP -0.48 nmol/mol NH_3 System 1: ZP 0.34 nmol/mol / RP 0.51 nmol/mol System 2: ZP -0.09 nmol/mol / RP 1.45 nmol/mol	yes	108

Performance characteristic	**Performance criterion**	**Test result**	**Satis-fied**	**Page**
8.4.12 Averaging effect	≤ 7.0% of the measured value	E_{av} analyser 1: -1.8% E_{av} analyser 2: -1.6%	yes	111
8.4.13 Difference sample/calibration port	≤ 1.0%	Not applicable	Not applicable	114
8.4.3 Response time (rise)	≤ 180 s	t_r System 1: 2 s (NO) t_r System 2: 2 s (NO) t_r System 1: 2 s (NO_2) t_r System 2: 2 s (NO_2)	yes	82
8.4.3 Response time (fall)	≤ 180 s	t_f System 1: 2 s (NO) t_f System 2: 2 s (NO) t_f System 1: 2 s (NO_2) t_f System 2: 2 s (NO_2)	yes	82
8.4.3 Difference between the rise and fall response time	≤ 10 s	t_d System 1: 0 s (NO) t_d System 2: 0 s (NO) t_d System 1: 0 s (NO_2) t_d System 2: 0 s (NO_2)	yes	82
8.4.14 Converter efficiency	≥ 98%	E_{conv} System 1: 99.4% E_{conv} System 2: 99.2%	yes	115
8.4.15 Residence time	≤ 3.0 s	System 1: 1.8 s System 2: 1.8 s	yes	117
8.5.7 Availability of the analyser	> 90%	A_a System 1: 100% A_a Analyser 2: 100%	yes	127
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: 4.21% $S_{r,f}$ System 2: 4.21%	yes	122
8.5.4 Long-term drift at zero point	≤ 5.0 nmol/mol	$C_{,z}$ System 1: 0.27 nmol/mol $C_{,z}$ System 2: 0.96 nmol/mol	yes	118
8.5.4 Long-term drift at span level	≤ 5.0% of the upper limit of the certification range	$C_{,s}$ Analyser 1: max. 1.29% $C_{,s}$ Analyser 2: max. 1.30%	yes	118
8.4.4 Short-term drift at zero	≤ 2.0 nmol/mol over 12 h	$D_{s,z}$ system 1: -0.04 nmol/mol $D_{s,z}$ system 2: -0.03 nmol/mol	yes	87
8.4.4 Short-term drift at span level	≤ 6.0 nmol/mol over 12 h	$D_{s,s}$ System 1: 1.66 nmol/mol $D_{s,s}$ system 2: -0.97 nmol/mol	yes	87

Table 43: Expanded uncertainty. Laboratory test for system 1

Measuring device:	nCLD AL^2				Serial-No.:		137	
Measured component:	NO_2				1h-limit value:		104.6	nmol/mol
No.	**Performance characteristic**	**Performance criterion**		**Result**	**Partial uncertainty**		**Square of partial uncertainty**	
1	Repeatability standard deviation at zero	≤	1.0 nmol/mol	0.000	$u_{r,z}$	0.00	0.0000	
2	Repeatability standard deviation at 1h-limit value	≤	3.0 nmol/mol	0.450	$u_{r,lh}$	0.00	0.0000	
3	"lack of fit" at 1h-limit value	≤	4.0% of measured value	0.550	$u_{l,lh}$	0.33	0.1103	
4	Sensitivity coefficient of sample gas pressure at 1h-limit value	≤	8.0 nmol/mol/kPa	0.080	u_{gp}	0.20	0.0405	
5	Sensitivity coefficient of sample gas temperature at 1h-limit value	≤	3.0 nmol/mol/K	0.030	u_{gt}	0.08	0.0057	
6	Sensitivity coefficient of surrounding temperature at 1h-limit value	≤	3.0 nmol/mol/K	0.269	u_{st}	0.68	0.4582	
7	Sensitivity coefficient of electrical voltage at 1h-limit value	≤	0.30 nmol/mol/V	0.000	u_V	0.00	0.0000	
8a	Interferent H_20 with 19 mmol/mol	≤	10 nmol/mol (Zero)	0.000	u_{H2O}	0.13	0.0176	
		≤	10 nmol/mol (Span)	0.850				
8b	Interferent CO_2 with 500 µmol/mol	≤	5.0 nmol/mol (Zero)	0.710	$u_{int,pos}$ or $u_{int,neg}$	0.51	0.2634	
		≤	5.0 nmol/mol (Span)	-0.230				
8c	Interferent NH_3 mit 200 nmol/mol	≤	5.0 nmol/mol (Zero)	0.340				
		≤	5.0 nmol/mol (Span)	0.510				
9	Averaging effect	≤	7.0% of measured value	-1.800	u_{av}	-1.09	1.1816	
18	Difference sample/calibration port	≤	1.0%	0.000	$u_{\Delta sc}$	0.00	0.0000	
21	Converter efficiency	≥	98	99.40	u_{EC}	0.63	0.3939	
23	Uncertainty of test gas	≤	3.0%	2.000	u_{cg}	1.05	1.0941	
				Combined standard uncertainty	u_c		1.8882	nmol/mol
				Expanded uncertainty	U		3.7764	nmol/mol
				Relative expanded uncertainty	W		3.61	%
				Maximum allowed expanded uncertainty	W_{req}		15	%

Table 44: Expanded uncertainty. Laboratory and field tests for system 1

Measuring device:	nCLD AL^2				Serial-No.:		137	
Measured component:	NO_2				1h-limit value:		104.6	nmol/mol
No.	**Performance characteristic**	**Performance criterion**		**Result**	**Partial uncertainty**		**Square of partial uncertainty**	
1	Repeatability standard deviation at zero	≤	1.0 nmol/mol	0.000	$u_{r,z}$	0.00	0.0000	
2	Repeatability standard deviation at 1h-limit value	≤	3.0 nmol/mol	0.450	$u_{r,lh}$	not considered, as √2*ur,lh = 0 < ur,f	-	
3	"lack of fit" at 1h-limit value	≤	4.0% of measured value	0.550	$u_{l,lh}$	0.33	0.1103	
4	Sensitivity coefficient of sample gas pressure at 1h-limit value	≤	8.0 nmol/mol/kPa	0.080	u_{gp}	0.20	0.0405	
5	Sensitivity coefficient of sample gas temperature at 1h-limit value	≤	3.0 nmol/mol/K	0.030	u_{gt}	0.08	0.0057	
6	Sensitivity coefficient of surrounding temperature at 1h-limit value	≤	3.0 nmol/mol/K	0.269	u_{st}	0.68	0.4582	
7	Sensitivity coefficient of electrical voltage at 1h-limit value	≤	0.30 nmol/mol/V	0.000	u_V	0.00	0.0000	
8a	Interferent H_20 with 19 mmol/mol	≤	10 nmol/mol (Zero)	0.000	u_{H2O}	0.13	0.0176	
		≤	10 nmol/mol (Span)	0.850				
8b	Interferent CO_2 with 500 µmol/mol	≤	5.0 nmol/mol (Zero)	0.710	$u_{int,pos}$ or $u_{int,neg}$	0.51	0.2634	
		≤	5.0 nmol/mol (Span)	-0.230				
8c	Interferent NH_3 mit 200 nmol/mol	≤	5.0 nmol/mol (Zero)	0.340				
		≤	5.0 nmol/mol (Span)	0.510				
9	Averaging effect	≤	7.0% of measured value	-1.800	u_{av}	-1.09	1.1816	
10	Reproducibility standard deviation under field conditions	≤	5.0% of average over 3 months	4.210	$u_{r,f}$	4.40	19.3922	
11	Long term drift at zero level	≤	5.0 nmol/mol	0.270	$u_{d,l,z}$	0.16	0.0243	
12	Long term drift at span level	≤	5.0% of max. of certification range	1.290	$u_{d,l,lh}$	0.78	0.6069	
18	Difference sample/calibration port	≤	1.0%	0.000	$u_{\Delta sc}$	0.00	0.0000	
21	Converter efficiency	≥	98	99.400	u_{EC}	0.63	0.3939	
23	Uncertainty of test gas	≤	3.0%	2.000	u_{cg}	1.05	1.0941	
				Combined standard uncertainty	u_c		4.8568	nmol/mol
				Expanded uncertainty	U		9.7137	nmol/mol
				Relative expanded uncertainty	W		9.29	%
				Maximum allowed expanded uncertainty	W_{req}		15	%

Table 45: Expanded uncertainty. Laboratory test for system 2

Measuring device: nCLD AL^2 Serial-No.: 138

Measured component: NO_2 1h-limit value: 104.6 nmol/mol

No.	Performance characteristic	Performance criterion		Result	Partial uncertainty		Square of partial uncertainty
1	Repeatability standard deviation at zero	≤	1.0 nmol/mol	0.010	$u_{r,z}$	0.00	0.0000
2	Repeatability standard deviation at 1h-limit value	≤	3.0 nmol/mol	0.950	$u_{r,lh}$	0.01	0.0001
3	"lack of fit" at 1h-limit value	≤	4.0% of measured value	1.010	$u_{l,lh}$	0.61	0.3720
4	Sensitivity coefficient of sample gas pressure at 1h-limit value	≤	8.0 nmol/mol/kPa	0.060	u_{gp}	0.15	0.0228
5	Sensitivity coefficient of sample gas temperature at 1h-limit value	≤	3.0 nmol/mol/K	0.010	u_{gt}	0.03	0.0006
6	Sensitivity coefficient of surrounding temperature at 1h-limit value	≤	3.0 nmol/mol/K	0.128	u_{st}	0.32	0.1037
7	Sensitivity coefficient of electrical voltage at 1h-limit value	≤	0.30 nmol/mol/V	0.000	u_V	0.00	0.0000
8a	Interferent H_20 with 19 mmol/mol	≤	10 nmol/mol (Zero)	-0.340	u_{H2O}	-0.38	0.1469
		≤	10 nmol/mol (Span)	-1.170			
8b	Interferent CO_2 with 500 µmol/mol	≤	5.0 nmol/mol (Zero)	0.440	$u_{int,pos}$ or $u_{int,neg}$	0.28	0.0767
		≤	5.0 nmol/mol (Span)	-0.480			
8c	Interferent NH_3 mit 200 nmol/mol	≤	5.0 nmol/mol (Zero)	-0.090			
		≤	5.0 nmol/mol (Span)	1.450			
9	Averaging effect	≤	7.0% of measured value	-1.600	u_{av}	-0.97	0.9336
18	Difference sample/calibration port	≤	1.0%	0.000	$u_{\Delta sc}$	0.00	0.0000
21	Converter efficiency	≥	98	99.20	u_{EC}	0.84	0.7002
23	Uncertainty of test gas	≤	3.0%	2.000	u_{cg}	1.05	1.0941

Combined standard uncertainty	u_c	1.8577	nmol/mol
Expanded uncertainty	U	3.7154	nmol/mol
Relative expanded uncertainty	W	3.55	%
Maximum allowed expanded uncertainty	W_{req}	15	%

Table 46: Expanded uncertainty. Laboratory and field tests for system 2

Measuring device: nCLD AL^2 Serial-No.: 138

Measured component: NO_2 1h-limit value: 104.6 nmol/mol

No.	Performance characteristic	Performance criterion		Result	Partial uncertainty		Square of partial uncertainty
1	Repeatability standard deviation at zero	≤	1.0 nmol/mol	0.010	$u_{r,z}$	0.00	0.0000
2	Repeatability standard deviation at 1h-limit value	≤	3.0 nmol/mol	0.950	$u_{r,lh}$	not considered, as √2*ur,lh = 0,01 < ur,f	-
3	"lack of fit" at 1h-limit value	≤	4.0% of measured value	1.010	$u_{l,lh}$	0.61	0.3720
4	Sensitivity coefficient of sample gas pressure at 1h-limit value	≤	8.0 nmol/mol/kPa	0.060	u_{gp}	0.15	0.0228
5	Sensitivity coefficient of sample gas temperature at 1h-limit value	≤	3.0 nmol/mol/K	0.010	u_{gt}	0.03	0.0006
6	Sensitivity coefficient of surrounding temperature at 1h-limit value	≤	3.0 nmol/mol/K	0.128	u_{st}	0.32	0.1037
7	Sensitivity coefficient of electrical voltage at 1h-limit value	≤	0.30 nmol/mol/V	0.000	u_V	0.00	0.0000
8a	Interferent H_20 with 19 mmol/mol	≤	10 nmol/mol (Zero)	-0.340	u_{H2O}	-0.38	0.1469
		≤	10 nmol/mol (Span)	-1.170			
8b	Interferent CO_2 with 500 µmol/mol	≤	5.0 nmol/mol (Zero)	0.440	$u_{int,pos}$ or $u_{int,neg}$	0.28	0.0767
		≤	5.0 nmol/mol (Span)	-0.480			
8c	Interferent NH_3 mit 200 nmol/mol	≤	5.0 nmol/mol (Zero)	-0.090			
		≤	5.0 nmol/mol (Span)	1.450			
9	Averaging effect	≤	7.0% of measured value	-1.600	u_{av}	-0.97	0.9336
10	Reproducibility standard deviation under field conditions	≤	5.0% of average over 3 months	4.210	$u_{r,f}$	4.40	19.3922
11	Long term drift at zero level	≤	5.0 nmol/mol	0.960	$u_{d,l,z}$	0.55	0.3072
12	Long term drift at span level	≤	5.0% of max. of certification range	1.300	$u_{d,l,lh}$	0.79	0.6164
18	Difference sample/calibration port	≤	1.0%	0.000	$u_{\Delta sc}$	0.00	0.0000
21	Converter efficiency	≥	98	99.200	u_{EC}	0.84	0.7002
23	Uncertainty of test gas	≤	3.0%	2.000	u_{cg}	1.05	1.0941

Combined standard uncertainty	u_c	4.8751	nmol/mol
Expanded uncertainty	U	9.7502	nmol/mol
Relative expanded uncertainty	W	9.32	%
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
- Instrument status ok
- No error messages
- Perform zero and reference checks using suitable test gas every two weeks in accordance with standard EN 14211;
- Quarterly replacement of the combi-filter and the dust filter on the front and rear panel.

Other than that, follow the manufacturer’s instructions indicated in the user manual.

Environmental Protection / Air Pollution Control

M. Schneid

Guido Baum

Dipl.-Ing. Martin Schneider

Dipl.-Ing. Guido Baum

Cologne, 30 July 2021
936/21250441/A

9. Bibliography

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

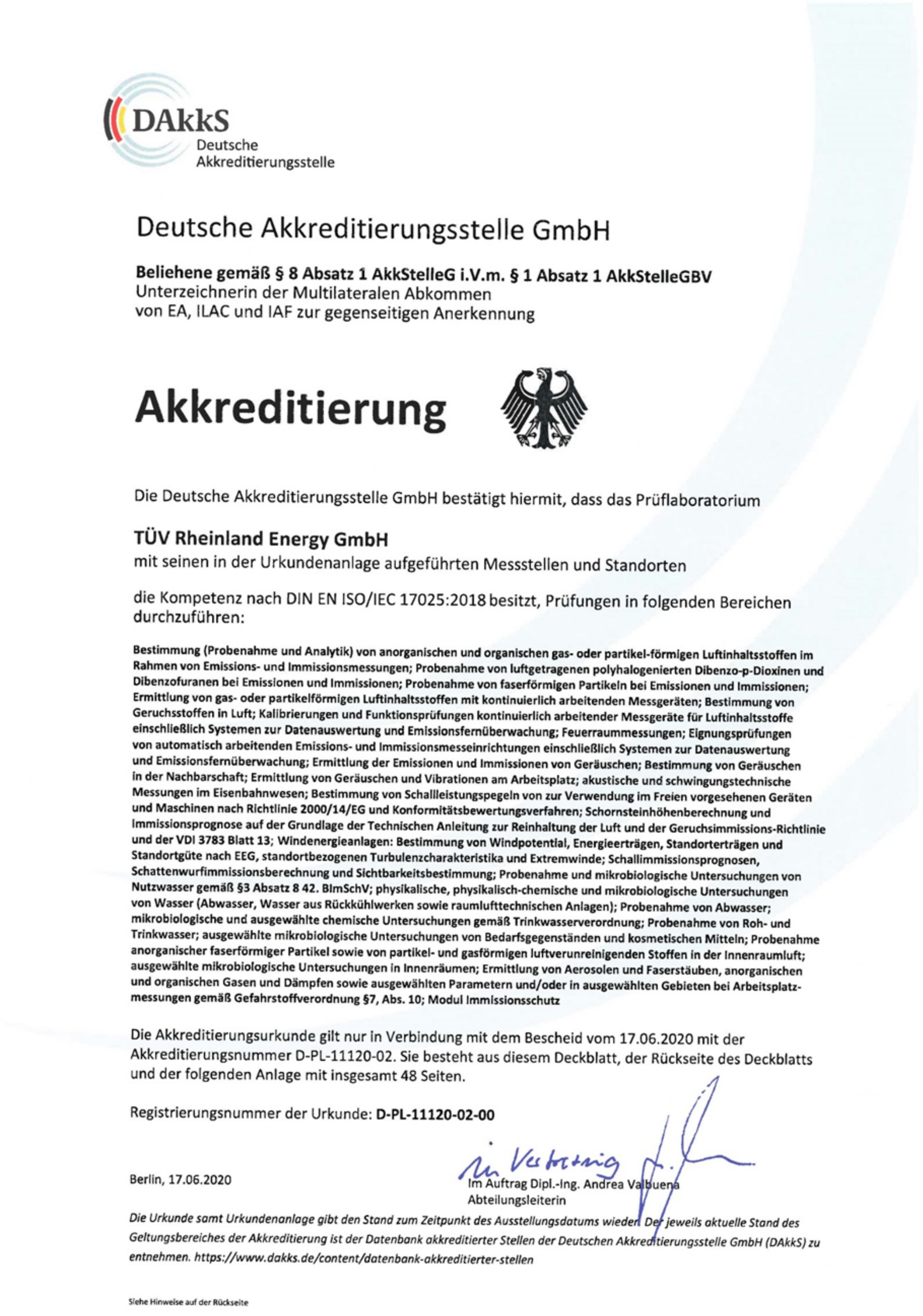
[2] European standard EN 14211 Ambient air - Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence, August 2012

[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.

10. Annexes

Annex 1	**Certificate of Accreditation to EN ISO/IEC 17025:2005**
Annex 2	**Weather data during the field test**
Annex 3	**Measured data of the nCLD 855 Y version**
Annex 4	**Manual**

Annex 1



DAkkS
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Deutsche Akkreditierungsstelle GmbH

Beliehene gemäß § 8 Absatz 1 AkkStelleG i.V.m. § 1 Absatz 1 AkkStelleGBV
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von EA, ILAC und IAF zur gegenseitigen Anerkennung

Akkreditierung

Die Deutsche Akkreditierungsstelle GmbH bestätigt hiermit, dass das Prüflaboratorium

TÜV Rheinland Energy GmbH
mit seinen in der Urkundenanlage aufgeführten Messstellen und Standorten

die Kompetenz nach DIN EN ISO/IEC 17025:2018 besitzt, Prüfungen in folgenden Bereichen durchzuführen:

Bestimmung (Probenahme und Analytik) von anorganischen und organischen gas- oder partikel-förmigen Luftinhaltsstoffen im Rahmen von Emissions- und Immissionsmessungen; Probenahme von luftgetragenen polyhalogenierten Dibenzo-p-Dioxinen und Dibenzofuranen bei Emissionen und Immissionen; Probenahme von faserförmigen Partikeln bei Emissionen und Immissionen; Ermittlung von gas- oder partikelförmigen Luftinhaltsstoffen mit kontinuierlich arbeitenden Messgeräten; Bestimmung von Geruchsstoffen in Luft; Kalibrierungen und Funktionsprüfungen kontinuierlich arbeitender Messgeräte für Luftinhaltsstoffe einschließlich Systemen zur Datenauswertung und Emissionsfernüberwachung; Feuerraummessungen; Eignungsprüfungen von automatisch arbeitenden Emissions- und Immissionsmesseinrichtungen einschließlich Systemen zur Datenauswertung und Emissionsfernüberwachung; Ermittlung der Emissionen und Immissionen von Geräuschen; Bestimmung von Geräuschen in der Nachbarschaft; Ermittlung von Geräuschen und Vibrationen am Arbeitsplatz; akustische und schwingungstechnische Messungen im Eisenbahnwesen; Bestimmung von Schallleistungspegeln von zur Verwendung im Freien vorgesehenen Geräten und Maschinen nach Richtlinie 2000/14/EG und Konformitätsbewertungsverfahren; Schornsteinhöhenberechnung und Immissionsprognose auf der Grundlage der Technischen Anleitung zur Reinhaltung der Luft und der Geruchsimmissions-Richtlinie und der VDI 3783 Blatt 13; Windenergieanlagen: Bestimmung von Windpotential, Energieerträgen, Standorterträgen und Standortgüte nach EEG, standortbezogenen Turbulenzcharakteristika und Extremwinde; Schallimmissionsprognosen, Schattenwurfimmissionsberechnung und Sichtbarkeitsbestimmung; Probenahme und mikrobiologische Untersuchungen von Nutzwasser gemäß §3 Absatz 8 42. BImSchV; physikalische, physikalisch-chemische und mikrobiologische Untersuchungen von Wasser (Abwasser, Wasser aus Rückkühlwerken sowie raumlufttechnischen Anlagen); Probenahme von Abwasser; mikrobiologische und ausgewählte chemische Untersuchungen gemäß Trinkwasserverordnung; Probenahme von Roh- und Trinkwasser; ausgewählte mikrobiologische Untersuchungen von Bedarfsgegenständen und kosmetischen Mitteln; Probenahme anorganischer faserförmiger Partikel sowie von partikel- und gasförmigen luftverunreinigenden Stoffen in der Innenraumluft; ausgewählte mikrobiologische Untersuchungen in Innenräumen; Ermittlung von Aerosolen und Faserstäuben, anorganischen und organischen Gasen und Dämpfen sowie ausgewählten Parametern und/oder in ausgewählten Gebieten bei Arbeitsplatzmessungen gemäß Gefahrstoffverordnung §7, Abs. 10; Modul Immissionsschutz

Die Akkreditierungsurkunde gilt nur in Verbindung mit dem Bescheid vom 17.06.2020 mit der Akkreditierungsnummer D-PL-11120-02. Sie besteht aus diesem Deckblatt, der Rückseite des Deckblatts und der folgenden Anlage mit insgesamt 48 Seiten.

Registrierungsnummer der Urkunde: **D-PL-11120-02-00**

Berlin, 17.06.2020

in Vertretung
Im Auftrag Dipl.-Ing. Andrea Valbuena
Abteilungsleiterin

Die Urkunde samt Urkundenanlage gibt den Stand zum Zeitpunkt des Ausstellungsdatums wieder. Der jeweils aktuelle Stand des Geltungsbereiches der Akkreditierung ist der Datenbank akkreditierter Stellen der Deutschen Akkreditierungsstelle GmbH (DAkkS) zu entnehmen. https://www.dakks.de/content/datenbank-akkreditierter-stellen

Siehe Hinweise auf der Rückseite

Figure 17: Certificate of accreditation according to EN ISO/IEC 17025:2018

Deutsche Akkreditierungsstelle GmbH

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60327 Frankfurt am Main

Standort Braunschweig
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Die auszugsweise Veröffentlichung der Akkreditierungsurkunde bedarf der vorherigen schriftlichen Zustimmung der Deutsche Akkreditierungsstelle GmbH (DAkkS). Ausgenommen davon ist die separate Weiterverbreitung des Deckblattes durch die umseitig genannte Konformitätsbewertungsstelle in unveränderter Form.

Es darf nicht der Anschein erweckt werden, dass sich die Akkreditierung auch auf Bereiche erstreckt, die über den durch die DAkkS bestätigten Akkreditierungsbereich hinausgehen.

Die Akkreditierung erfolgte gemäß des Gesetzes über die Akkreditierungsstelle (AkkStelleG) vom 31. Juli 2009 (BGBl. I S. 2625) sowie der Verordnung (EG) Nr. 765/2008 des Europäischen Parlaments und des Rates vom 9. Juli 2008 über die Vorschriften für die Akkreditierung und Marktüberwachung im Zusammenhang mit der Vermarktung von Produkten (Abl. L 218 vom 9. Juli 2008, S. 30).
Die DAkkS ist Unterzeichnerin der Multilateralen Abkommen zur gegenseitigen Anerkennung der European co-operation for Accreditation (EA), des International Accreditation Forum (IAF) und der International Laboratory Accreditation Cooperation (ILAC). Die Unterzeichner dieser Abkommen erkennen ihre Akkreditierungen gegenseitig an.

Der aktuelle Stand der Mitgliedschaft kann folgenden Webseiten entnommen werden:
EA: www.european-accreditation.org
ILAC: www.ilac.org
IAF: www.iaf.nu

Figure 17: Certificate of accreditation according to EN ISO/IEC 17025:2018 - page 2

Annex 2

Table 47: Weather data (daily averages), April 2021

April 2021	Date	Avg. Air temperature [°C]	Rel. Humidity [%]	Air pressure [hPa]
9	09.04.2021	9.4	52.7	1009.4
10	10.04.2021	9.0	91.8	1005.9
11	11.04.2021	6.1	91.7	1006.3
12	12.04.2021	6.1	91.7	1006.3
13	13.04.2021	4.0	76.6	1020.0
14	14.04.2021	4.6	69.0	1025.0
15	15.04.2021	4.2	71.3	1023.9
16	16.04.2021	4.7	67.1	1022.7
17	17.04.2021	6.7	57.3	1020.2
18	18.04.2021	7.7	56.9	1017.6
19	19.04.2021	9.2	66.3	1015.0
20	20.04.2021	9.8	81.9	1013.1
21	21.04.2021	11.1	68.6	1010.9
22	22.04.2021	11.3	67.3	1010.6
23	23.04.2021	8.2	57.1	1018.3
24	24.04.2021	8.8	59.7	1021.5
25	25.04.2021	8.9	59.5	1019.6
26	26.04.2021	8.0	55.0	1018.9
27	27.04.2021	9.1	48.0	1012.6
28	28.04.2021	11.0	39.7	1003.7
29	29.04.2021	13.3	44.9	997.3
30	30.04.2021	11.2	61.0	999.2

Table 48: Weather data (daily averages), May 2021

May 2021	Date	Avg. Air temperature [°C]	Rel. Humidity [%]	Air pressure [hPa]
1	01.05.2021	9.9	62.2	1007.3
2	02.05.2021	8.2	62.2	1011.4
3	03.05.2021	9.4	53.9	1012.7
4	04.05.2021	11.8	52.7	996.4
5	05.05.2021	7.9	69.2	1000.0
6	06.05.2021	8.2	69.7	1000.9
7	07.05.2021	7.8	71.8	1007.6
8	08.05.2021	11.3	60.6	1008.6
9	09.05.2021	20.2	51.7	998.6
10	10.05.2021	19.7	51.2	999.5
11	11.05.2021	14.6	86.0	1002.5
12	12.05.2021	13.8	76.9	1004.9
13	13.05.2021	12.8	74.7	1001.5
14	14.05.2021	12.6	75.5	1001.6
15	15.05.2021	11.5	80.8	998.8
16	16.05.2021	11.2	81.5	996.2
17	17.05.2021	12.0	79.7	998.3
18	18.05.2021	11.6	81.5	1006.5
19	19.05.2021	11.8	76.1	1010.6
20	20.05.2021	14.4	66.0	1012.7
21	21.05.2021	14.7	55.9	1000.3
22	22.05.2021	11.5	69.5	999.5
23	23.05.2021	12.7	59.5	1007.3
24	24.05.2021	13.3	61.5	1004.2
25	25.05.2021	9.8	79.3	1007.3
26	26.05.2021	10.7	85.3	1007.0
27	27.05.2021	11.4	83.4	1011.5
28	28.05.2021	13.7	69.2	1017.1
29	29.05.2021	14.3	65.2	1018.7
30	30.05.2021	15.7	61.6	1019.8
31	31.05.2021	18.0	54.4	1015.4

Table 49: Weather data (daily averages), June 2021

June 2021	Date	Avg. Air temperature [°C]	Rel. Humidity [%]	Air pressure [hPa]
1	01.06.2021	16.7	54.8	1012.3
2	02.06.2021	20.8	49.1	1008.8
3	03.06.2021	19.9	78.8	1013.0
4	04.06.2021	21.2	80.5	1013.8
5	05.06.2021	17.7	88.8	1014.4
6	06.06.2021	15.8	87.1	1017.1
7	07.06.2021	18.0	78.9	1016.7
8	08.06.2021	19.3	70.6	1016.3
9	09.06.2021	20.6	66.5	1015.2
10	10.06.2021	22.1	55.8	1014.6
11	11.06.2021	22.5	59.7	1013.1
12	12.06.2021	20.1	67.2	1014.3
13	13.06.2021	17.6	58.2	1020.4
14	14.06.2021	21.5	53.4	1015.4
15	15.06.2021	22.1	60.1	1012.8
16	16.06.2021	24.8	54.7	1008.4
17	17.06.2021	28.0	51.4	1004.9
18	18.06.2021	27.7	54.9	1006.2
19	19.06.2021	26.3	53.8	1006.9
20	20.06.2021	23.1	69.0	1002.3
21	21.06.2021	19.6	77.6	1001.0
22	22.06.2021	15.0	84.5	1008.8
23	23.06.2021	16.4	86.5	1013.2
24	24.06.2021	17.5	81.0	1012.9
25	25.06.2021	19.1	63.5	1012.4
26	26.06.2021	19.9	64.1	1012.1
27	27.06.2021	21.0	69.7	1009.5
28	28.06.2021	22.1	79.8	1007.5
29	29.06.2021	21.0	74.7	1005.8
30	30.06.2021	16.7	87.1	1005.6

Table 50: Weather data (daily averages), July 2021

July 2021	Date	Avg. Air temperature [°C]	Rel. Humidity [%]	Air pressure [hPa]
1	01.07.2021	14.0	90.4	1010.0
2	02.07.2021	18.2	70.6	1011.5
3	03.07.2021	19.0	80.6	1009.3
4	04.07.2021	17.8	93.2	1004.8
5	05.07.2021	17.8	85.6	1003.2
6	06.07.2021	19.7	75.0	1001.7
7	07.07.2021	19.8	65.4	1008.9
8	08.07.2021	17.8	84.0	1013.8
9	09.07.2021	18.5	84.5	1014.9
10	10.07.2021	18.8	81.5	1011.0
11	11.07.2021	18.8	81.2	1010.2
12	12.07.2021	19.9	77.4	1005.7
13	13.07.2021	19.4	90.6	1002.9
14	14.07.2021	17.3	98.9	1002.7
15	15.07.2021	18.9	87.9	1006.3
16	16.07.2021	18.6	84.0	1014.3
17	17.07.2021	20.6	75.0	1017.8
18	18.07.2021	21.3	69.6	1016.8
19	19.07.2021	20.9	70.3	1014.6

Annex 3

Repeatability standard deviation calculation according to 7.1 8.4.5 for the nCLD 855 Y model

	Requirement	nCLD 855 Y	
Repeatability standard deviation $s_{r,z}$ at zero [nmol/mol]	≤ 1.0	0.01	✓
Repeatability standard deviation $s_{r,ct}$ at c_t [nmol/mol]	≤ 3.0	0.46	✓
Detection limit [nmol/mol]		0.02	☐

Individual values of the test:

Zero concentration		
	nCLD 855 Y	
Time	[nmol/mol]	
11:00:00	0.0	
11:01:00	0.0	
11:02:00	0.0	
11:03:00	0.0	
11:04:00	0.0	
11:05:00	0.0	
11:06:00	0.0	
11:07:00	0.0	
11:08:00	0.0	
11:09:00	0.0	
11:10:00	0.0	
11:11:00	0.0	
11:12:00	0.0	
11:13:00	0.0	
11:14:00	0.0	
11:15:00	0.0	
11:16:00	0.0	
11:17:00	0.0	
11:18:00	0.0	
11:19:00	0.0	
Average	0.0	

C_t Concentration		
	nCLD 855 Y	
Time	[nmol/mol]	
11:26:00	500.4	
11:27:00	500.4	
11:28:00	500.4	
11:29:00	500.4	
11:30:00	500.4	
11:31:00	500.4	
11:32:00	500.4	
11:33:00	500.4	
11:34:00	500.4	
11:35:00	500.4	
11:36:00	500.4	
11:37:00	500.4	
11:38:00	500.4	
11:39:00	499.4	
11:40:00	499.4	
11:41:00	499.4	
11:42:00	499.4	
11:43:00	499.4	
11:44:00	500.1	
11:45:00	500.1	
Average	500.1	

Ambient temperature sensitivity coefficient test according to 7.1 8.4.9 for the nCLD 855 Y model

	Requirement	nCLD 855 Y	
Rec. coefficient at 0 ºC for zero level [nmol/mol/K]	≤ 3.0	0.010	✓
Rec. coefficient at 30 ºC for zero level [nmol/mol/K]	≤ 3.0	0.032	✓
Rec. coefficient at 0 ºC for span level [nmol/mol/K]	≤ 3.0	0.045	✓
Rec. coefficient at 30 ºC for span level [nmol/mol/K]	≤ 3.0	0.367	✓

Individual values of the test:

	Zero point				Span point			
			nCLD 855 Y				nCLD 855 Y	
Date	Time	Temp [ºC]	[nmol/mol]		Time	Temp [ºC]	[nmol/mol]	
16.03.2021	08:01:00	20	0.0		08:16:00	20	720.8	
16.03.2021	08:02:00	20	0.0		08:17:00	20	720.5	
16.03.2021	08:03:00	20	0.0		08:18:00	20	720.5	
Average ($X_{1(TS1)}$)			0.0				720.6	
16.03.2021	16:10:00	0	0.2		16:18:00	0	719.1	
16.03.2021	16:11:00	0	0.3		16:19:00	0	719.3	
16.03.2021	16:12:00	0	0.2		16:20:00	0	719.3	
Average ($X_{Ts,1}$)			0.2				719.2	
17.03.2021	07:50:00	20	0.1		08:00:00	20	719.6	
17.03.2021	07:51:00	20	0.1		08:01:00	20	719.7	
17.03.2021	07:52:00	20	0.0		08:02:00	20	719.7	
Average ($X_{2(TS1)}$) = ($X_{1(TS2)}$)			0.1				719.7	
17.03.2021	15:14:00	30	0.3		15:21:00	30	716.1	
17.03.2021	15:15:00	30	0.4		15:22:00	30	716.0	
17.03.2021	15:16:00	30	0.4		15:23:00	30	716.0	
Average ($X_{Ts,2}$)			0.4				716.0	
18.03.2021	08:15:00	20	0.1		08:21:00	20	719.8	
18.03.2021	08:16:00	20	0.0		08:22:00	20	719.7	
18.03.2021	08:17:00	20	0.0		08:23:00	20	719.7	
Average ($X_{2(TS2)}$)			0.0				719.7	

Annex 4

Annex 4

Manual