LUBW

Landesanstalt für Umwelt
Baden-Württemberg

Type test of the gas chromatograph

GCX55-601 (PID) for Benzene

Synspec B.V.

LUBW-Report number: SYN143-E01/22E

Baden-Württemberg

IMPRESSUM

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1 Summary of the test results

1.1 Tabular summary of the test results

Minimum requirement	Requirement	Test result	Req. fulfilled	Test date
Measuring value display	Measuring value display shall be available.	Measured value display is available.	Yes	2022
Easy maintenance	Maintenance shall be easy and possible, preferably from outside of the device.	The device does not require any maintenance to be carried out regularly by the user.	Yes	2022
Functional check	Equipment that is necessary for the device operation shall be considered as a part of it and shall be applied in the corresponding sub-tests.	The tested devices do not have test gas generator, so internal function control is not provided. Test is not applicable.	--	2022
Set-up and run-in time	Set-up and run-in time shall be specified in the operating manual.	The operation manual contains detailed description of the commissioning. The set-up and run-in times are specified in the operation manual.	Yes	2022
Design of the measuring device	The operating manual shall include information about the design of the measuring device.	Information on the design is available in the manual operation.	Yes	2023
Unauthorized adjustment	It shall be possible to secure the measuring device against the unintended adjustment.	The measuring device has a password security.	Yes	2022
Data output	The measuring device shall provide digital and/or analogue data output.	Measuring signals, status signals and error signals can be communicated over a serial port.	Yes	2022
Digital interface	The digital interface shall allow the transmission of output data, status signals and information like instrument type, measurement range, measured component and unit. The digital interface shall be described fully in respective standards and guidelines.	During the field test, the devices were connected to the LUBW's monitoring network center. The respective operating states as well as error messages were transmitted telemetrically.	Yes	2022
Data transmission protocol	The measuring device shall contain at least one data transmission protocol.	The output signals could be transmitted by "Bayern-Hessen-protocol". This was checked during the field test. There was a match between the transmitted data and the data stored in the device.	Yes	2022
Measuring range	The upper end of the measuring range shall be greater or equal to the upper limit of the certification range.	The manufacturer does not define the upper end of the measuring range. During the test, concentrations up to 50 µg/m³ were abandoned.	Yes	2022
Negative output signals	Negative output signals shall not be disabled (live zero point).	The device is not equipped with a live zero point.	--	2022

Minimum requirement	Requirement	Test result	Req. fulfilled	Test date
Power failure	Uncontrolled discharge of operating and calibration gases shall be prevented. The device parameters shall be secured by buffering. The measurement shall continue when the power is restored.	The supply of the operating gas (N_2) is stopped during a power failure. Device parameters remain stored. After power recovery, the computer automatically boots the operating system and starts a measurement.	Yes	2022
Operating modus	Monitoring by telemetrically transmittable data shall be possible.	Status signals and error messages can be transmitted via a serial interface.	Yes	2023
Switch-over	Switching between measurement and functional test and/or calibration shall be possible.	The device has no facilities for calibration gas generation, so an internal function control is not provided.	--	--
Device software	The measuring device shall be able to display the software version.	The current software versions for the control of the gas chromatograph can be displayed: Software for GC control: Version 6.4.2.19	Yes	2023
Short-term drift (Requirement of DIN EN 14662-3)	The short-term drift $D_{s,s}$ at test value 2 under laboratory conditions and over a drift period of 12 h shall be less than or equal to 2.0 µg/m³.	The short-term drift $D_{s,s}$ at test value 2 was determined to: GC 80001: $D_{s,s}$ = 0.32 µg/m³ GC 80004: $D_{s,s}$ = 0.43 µg/m³	Yes	2022
Repeatability standard deviation at test value 1 (Requirement of DIN EN 14662-3)	The repeatability standard deviation $s_{r,z}$ at test value 1 shall be less than or equal to 0.20 µg/m³.	The repeatability standard deviation $s_{r,z}$ at test value 1 was determined to: GC 80001: $s_{r,z}$ = 0.01 µg/m³ GC 80004: $s_{r,z}$ = 0.01 µg/m³	Yes	2022
Repeatability standard deviation at limit value (Requirement of DIN EN 14662-3)	The repeatability standard deviation $s_{r,ct}$ at limit value shall be less than or equal to 0.25 µg/m³.	The repeatability standard deviation $s_{r,ct}$ at limit value was determined to: GC 80001: $s_{r,ct}$ = 0.02 µg/m³ GC 80004: $s_{r,ct}$ = 0.02 µg/m³	Yes	2022
Linearity (Lack-of-fit) (Requirement of DIN EN 14662-3)	The residual r_z at zero shall be less than or equal to 0.5 µg/m³. The maximum relative residual r_{max} from the linear regression function shall be less than or equal to 5 %.	The residual r_z at zero was determined to: GC 80001: r_z = 0.5 µg/m³ GC 80004: r_z = 0.3 µg/m³ The maximum relative residual r_{max} was determined to: GC 80001: r_{max} = -2.1 % GC 80004: r_{max} = -3.0 %	Yes	2022
Sensitivity coefficient of sample gas pressure (Requirement of DIN EN 14662-3)	The sensitivity coefficient of sample gas pressure b_{gp} at test value 2 shall be less than or equal to 0.10 (µg/m³)/kPa.	The sensitivity coefficient of sample gas pressure b_{gp} at test value 2 was determined to: GC 80001: b_{gp} = 0.07 (µg/m³)/kPa GC 80004: b_{gp} = 0.06 (µg/m³)/kPa	Yes	2022

Minimum requirement	Requirement	Test result	Req. fulfilled	Test date
Sensitivity coefficient of surrounding temperature (Requirement of DIN EN 14662-3)	The sensitivity coefficient of surrounding temperature b_{st} at test value 2 shall be less than or equal to 0.08 (µg/m³)/K.	The sensitivity coefficient of surrounding temperature b_{st} at test value 2 was determined to: GC 80001: b_{st} = 0.03 (µg/m³)/K GC 80004: b_{st} = 0.06 (µg/m³)/K	Yes	2022
Sensitivity coefficient of supply voltage (Requirement of DIN EN 14662-3)	The sensitivity coefficient of supply voltage b_V at test value 2 shall be less than or equal to 0.08 (µg/m³)/V.	The sensitivity coefficient of supply voltage b_V at test value 2 was determined to: GC 80001: b_V = 0.001 (µg/m³)/V GC 80004: b_V = 0.002 (µg/m³)/V	Yes	2022
Influence of water vapor (Requirement of DIN EN 14662-3)	The sensitivity coefficient b_{H2O} at limit value and H_2O concentration of approx. 19 mmol/mol shall be less than or equal to 0.015 (µg/m³)/(mmol/mol).	The sensitivity coefficient b_{H2O} at limit value and H_2O concentration of approx. 19 mmol/mol was determined to: GC 80001: $b_{H2O,ct}$ = 0.012 (µg/m³)/(mmol/mol) GC 80004: $b_{H2O,ct}$ = -0.006 (µg/m³)/(mmol/mol)	Yes	2022
Influence of organic compounds (Requirement of DIN EN 14662-3)	The contribution of organic compounds Δx_{OC} to the measurement of benzene concentration at limit value shall be less than or equal to 0.25 µg/m³.	The contribution of organic compounds Δx_{OC} was determined to: GC 80001: Δx_{OC} = -0.09 µg/m³ GC 80004: Δx_{OC} = -0.03 µg/m³	Yes	2022
Memory effect (Requirement of DIN EN 14662-3)	The benzene concentration of the first zero gas analysis following the analysis of the test gas at test value 3 shall be less than or equal to 1.0 µg/m³.	The mean value c_m of the first zero gas measurement was determined to: GC 80001: c_m = 0.1 µg/m³ GC 80004: c_m = 0.3 µg/m³	Yes	2022
Long-term drift (Requirement of DIN EN 14662-3)	In the field test, over a drift period of 14 days, the largest value of long-term drift $D_{l,z}$ at zero shall be less than or equal to 0.5 µg/m³ and the largest value of long-term drift $D_{l,s}$ at test value 2 shall be less than or equal to 10%.	The maximum long-term drift $D_{l,z}$ at zero point was determined to: GC 80001: $D_{l,z}$ = -0.01 µg/m³ GC 80004: $D_{l,z}$ = -0.02 µg/m³ The maximum long-term drift $D_{l,s}$ at test value 2 was determined to: GC 80001: $D_{l,s}$ = -7.76 % GC 80004: $D_{l,s}$ = -4.64 %	Yes	2023
Reproducibility standard deviation under field conditions (Requirement of DIN EN 14662-3)	The reproducibility standard deviation under field conditions $s_{r,f}$ of two measuring devices shall be less than or equal to 0.25 µg/m³.	The reproducibility standard deviation under field conditions $s_{r,f}$ of the two measuring devices was determined to: $s_{r,f}$ = 0.17 µg/m³	Yes	2023
Maintenance interval	At least 14 days, preferably three months.	The maintenance interval is three months.	Yes	2023

Minimum requirement	Requirement	Test result	Req. fulfilled	Test date
Availability	At least 90 %.	The availability was determined to: GC 80001: 100 % GC 80004: 100 %	Yes	2023
Expanded uncertainty	The determined value must not exceed the specifications of the EU directives on air quality. For benzene, the relative expanded uncertainty must be less than or equal to 25%.	The determined value for the relative expanded measurement uncertainty W is: GC 80001: W = 15.1 % GC 80004: W = 12.5 %	Yes	2023

Test value 1: 1/10 of the annual limit value = 0.5 µg/m³

Test value 2: 70 – 80 % of the maximum of the certification range

Test value 3: 90 % of the maximum of the certification range

Limit value: Annual limit value of benzene = 5 µg/m³

1.2 Announcement proposal

Based on the positive results obtained, the following recommendation is made for the announcement as a type tested measuring device:

Measuring device:

Gas chromatograph GCX55-601 Version PID

Manufacturer:

Synspec B.V., Groningen, the Netherlands

Approval:

For the continuous detection of benzene immission concentrations in ambient air in stationary use.

Measuring ranges during the performance test:

Component	Certification area	Unit
Benzene	0 – 50	µg/m³

Software version:

6.4.2.19

Limitations:

None

Notes:

1. The measuring device is not equipped with a live zero point.
2. The performance test report can be viewed on the internet at www.qal1.de.

Test report:

Landesanstalt für Umwelt Baden-Württemberg (LUBW), Karlsruhe

Report no. SYN143-E01/22E from 05 April 2023

Testing and reporting

11.04.2023

X Justyna Homa

Dr. Justyna Homa

Signiert von: Homa (LUBW)

Release of the test report

11.04.2023

X Michael Maban

Michael Maban
Sachgebietsleiter / Fachlich Verantwortlicher
Signiert von: Maban (LUBW)

2 Introduction

In a letter, dated 31-08-2020 the company Synspec B.V. give an order to the LUBW to test the gas chromatograph GCX55 version PID for its suitability for measuring ambient concentrations of benzene.

Due to the corona pandemic, the tests could be started first in August 2022. Synspec B.V. provided two gas chromatographs with the following serial numbers:

- GC 1: 80001 (hereinafter referred to as GC 80001)
- GC 2: 80004 (hereinafter referred to as GC 80004).

The tests were carried out according to the specifications of the following guidelines and standards:

VDI-Guideline 4202 part 1 (April 2018)

Automatic measuring systems for air quality monitoring – Performance test, declaration of suitability and certification of point-related measuring systems for gaseous air pollutants.

DIN EN 14662-3 (February 2016)

Ambient air - Standard method for the measurement of benzene concentrations - Part 3: Automated pumped sampling with in situ gas chromatography.

Measuring device:

Gas chromatograph GCX55-601 version PID (serial no. 80001 and 80004)

Fig. 2.1 and Fig. 2.2 show the front and rear views of the GCX55.

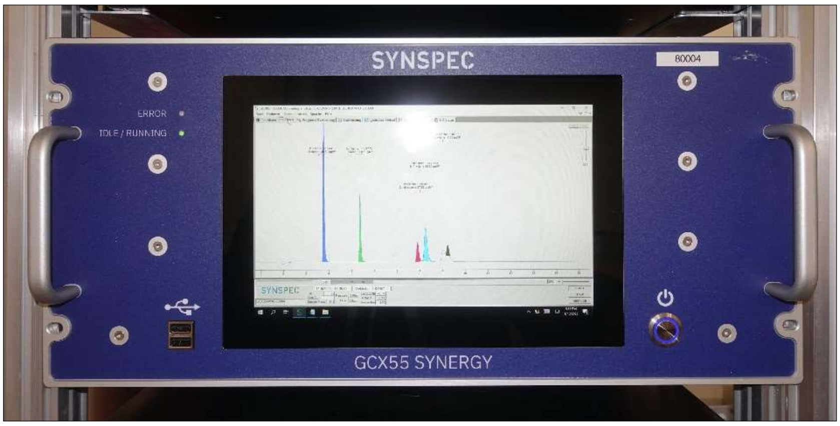


Fig. 2.1: Front view of the gas chromatograph

Fig. 2.2: Rear view of the gas chromatograph

3 Working principle of the gas chromatograph

The GCX55 gas chromatograph is the successor of the GC955. It was developed for the quasi-continuous measurement of organic air pollutants. It allows the detection of low ppb concentrations of e.g. benzene, toluene, ethylbenzene, m/p-xylene and o-xylene in the ambient air.

The GCX55 has a sample pre-concentration of the pollutants to be monitored. At the beginning of each sampling, the sample gas lines are purged by a bypass pump. The sample is then drawn onto an enrichment tube by sampling cylinder. As soon as there is enough sample, the tube is heated and the components are thermally desorbed. The carrier gas (nitrogen) flows through the tube in countercurrent. The organic compounds enter a separation column consisting of two parts: a stripping column and an analysis column. In the stripping column the components start to separate - the components with the lowest boiling points enter the analytical column first. After all components of interest have left the stripping column, the column is purged of components of no interest by switching the 10-way valve in the opposite direction. In this way, a short analysis time can be realized (15 minutes) because it is not necessary to wait for the elution of all compounds.

The organic compounds are quantified by a photoionization detector (PID). In the photoionization detector, electrons are excited by radiation energy during the measurement until they are separated from their atom or molecule. The energy source for the ionization is a discharge lamp filled with inert gas under low pressure, which generates a stable monochromatic energetic light flux of photons. The UV lamp is installed gas-tight in the detector. The light source is separated from the carrier gas flow by a window through which UV light can pass. The measurement signals are registered with an UV detector. The signals are amplified, digitized and stored.

The GCX55 gas chromatograph is equipped with a standard industrial PC with a Windows operating system. All data are stored on the internal hard disk and can be retrieved at any time. The GCX55 is controlled by the GCX55.exe software. The current chromatogram can be followed in real time on the LCD screen. The peak area, peak height and concentration are calculated and displayed for the components. Furthermore, the saved chromatograms can be called up in a menu and the settings of the control program can be changed.

The GCX55 has electronic sensors for monitoring e.g. the carrier gas flow, the oven temperature and the pressure for the valve circuit. The values measured are continuously displayed on the screen and stored in the chromatogram data.

Technical data:

General:

Tested software	6.4.2.19
Housing	19“-rack
Height	5 HE (224 mm)
Depth (without handles)	552 mm
Width (housing)	430 mm
Width (front panel)	483 mm
Weight	19.5 kg
Operating temperature	0 °C to 30 °C
Humidity	0 % to 95 % relative humidity, non-condensing

Instrument supply:

Voltage	230 VAC, 115 VAC (on request)
Power consumption	500 VA (commissioning, 1 Minute), 300 VA (operation)
Carrier gas	Nitrogen, 4 to 5 bar, 15 ml/min
Gas ports	Swagelok 1/8“ fittings
	Calibration gas BTX, pressureless, ≥ 30 ml/min
	Optional: zero air for calibration, 4 to 5 bar, 50 ml/min

Detector:

Type	PID – Photoionization detector

Sampling:

Sampling	Sampling cylinder
Flow rate control	Thermal mass flow controller
	Via sampling cylinder, with pressure and temperature correction
Cycle time	15 min
Flow rate	max. 30 ml/min (flushing of the internal sample line)
	15 ml/min (operation)
Sample volume	35 ml

Sample pre-concentration:

Technology	Enrichment tube with Graphsphere 2016
Enrichment temperature	Room temperature, ≤ 40 °C
Desorption temperature	300 °C
Heating rate	25 °C/s

Specifications:

Gas line switching	10-port valve
Analytical oven	Isothermally set to 70 °C

Communication:

Interfaces	4x RS232
PC ports	4x USB 2.0, 2x Ethernet 1 Gb/s, VGA
Analog outputs	7 digital outputs (including one potential-free relay) 4 analog outputs Optional: E/A-board
Protocols	ASCII (Synspec own protocol) Bayern-Hessen, Gesytec Modbus

4 Test program

4.1 Laboratory tests

The two gas chromatographs from Synspec B.V. (serial no. 80001 and 80004) were installed in a 19" rack in the LUBW test laboratory. To carry out the laboratory tests, a gas mixing system (according to the specifications of DIN EN ISO 6145-6 "Gas analysis - Preparation of calibration gas mixtures using dynamic-volumetric methods - Part 6: Critical orifices") and a catalytic zero air generator from Headline-Filters (Air Purifier CAP 60) were used. Using the gas mixing system, a BTX gas from a traceable test gas cylinder (NPL, No.: NPL-D711530) with a benzene concentration of 16.87 mg/m³ was diluted with zero air to a concentration range of 1.3 – 54.3 µg/m³. The desired dilution was set by varying the two volume flows (zero air and benzene gas). The exact determination of these volume flows was performed with a certified Volumeter from DryCal.

The zero air generator was used to produce the zero air (purified compressed air) for the gas mixing system and some of the measurements.

Before starting the laboratory tests, an auto-linearization was performed. This function is specifically for the PID and runs for several hours. A concentration of approx. 25 µg/m³ was specified. Several concentration levels are automatically generated to achieve a linearization of the PID. Subsequently, a calibration of the gas chromatographs was carried out. The calibration function was determined with five calibration points in a concentration range from 0 µg/m³ to 54.3 µg/m³ and stored in the instruments by the manufacturer.

To carry out the temperature tests, the two test instruments were installed in a climate chamber Clime-Event C/340/40/3 from Weisstechnik.

4.2 Field test

To carry out the field test, the two gas chromatographs were installed and calibrated in an air-conditioned measuring station (T = 22°C ± 3°C) on the test site opposite the LUBW building close to a road with considerable traffic volume (motorway feeder) (see Fig. 4.1).

Fig. 4.1: Measuring station at the LUBW test site

The devices were installed in a 19" rack and connected to the sampling system (sampling tube with a standardized sampling head on the roof) of the station. This ensured representative measurements of the same sample air volume.

For the function check, which shall be carried out by manual switching between zero air and test gas, a gas mixing system was installed.

The average benzene concentrations measured on the test site are between 1 and 3 µg/m³. To determine the reproducibility standard deviation or to measure higher benzene concentration, a capillary dosing device (glass container with a capillary opening) filled with BTX was fixed below the sampling head of the sampling system. Depending on the ambient temperature and air pressure, a certain amount of BTX was emitted, which was randomly added to the sample airflow depending on the wind direction. In this way, benzene concentrations up to 20 µg/m³ could be measured.

For data transfer to the LUBW monitoring network center, the instruments were connected to the station computer via the internal interface RS-232, which is equipped with a data acquisition system. For the communication between the gas chromatographs and the station computer, the "Bayern-Hessen Protocol" was used.

5 Reference measurement methods

The test gases used for the performance test of the gas chromatographs must be traced back to the reference standards.

For this performance test, a certified test gas cylinder from NPL (National Physical Laboratory, national reference laboratory in England) with a volume of 10 l was used. The concentrations of benzene, toluene, ethylbenzene and o-xylene were around 5-ppm and the concentration of m/p-xylene was around 10-ppm.

The NPL test gas cylinder was connected to a gas mixing system, which is a dynamic and continuously working dilution system, based on DIN EN ISO 6145. By its use, different test gas concentrations can be produced by mixing a small flow rate of the certified test gas Q_{PG} (approx. 0.5 - 8 ml/min) with a zero air flow Q_{GG} (approx. 2.3 - 6.7 l/min).

The concentration of the generated test gas is then calculated as follows:

$$\boldsymbol{c = c_{PG} * \frac{Q_{PG}}{Q_{PG}+Q_{GG}}} \qquad \text{(Eq. 5.1)}$$

Where:

c generated test gas concentration, in µg/m³;

c_{PG} concentration of the certified test gas cylinder, in mg/m³;

Q_{PG} flow rate of the certified test gas, in Nml/min;

Q_{GG} flow rate of the zero air, in Nml/min.

Varying the two flow rates Q_{PG} and Q_{GG} is done by changing the corresponding upstream pressure in front of the two critical orifices using precision pressure regulators. The procedure is carried out according to the specifications of the quality management system in the laboratory according to DIN EN ISO/IEC 17025 (Technical Instructions TA 5-6-AM1-207 "Determination of the concentration of test gases for aromatic and chlorinated hydrocarbons").

6 Test results

6.1 Measured value display

6.1.1 Minimum requirement (VDI 4202 part 1 chapter 8.3.1)

The measuring system shall have a measured value display.

6.1.2 Equipment

No additional equipment is required.

6.1.3 Testing

It shall be checked whether the measuring device has a measured value display.

6.1.4 Evaluation

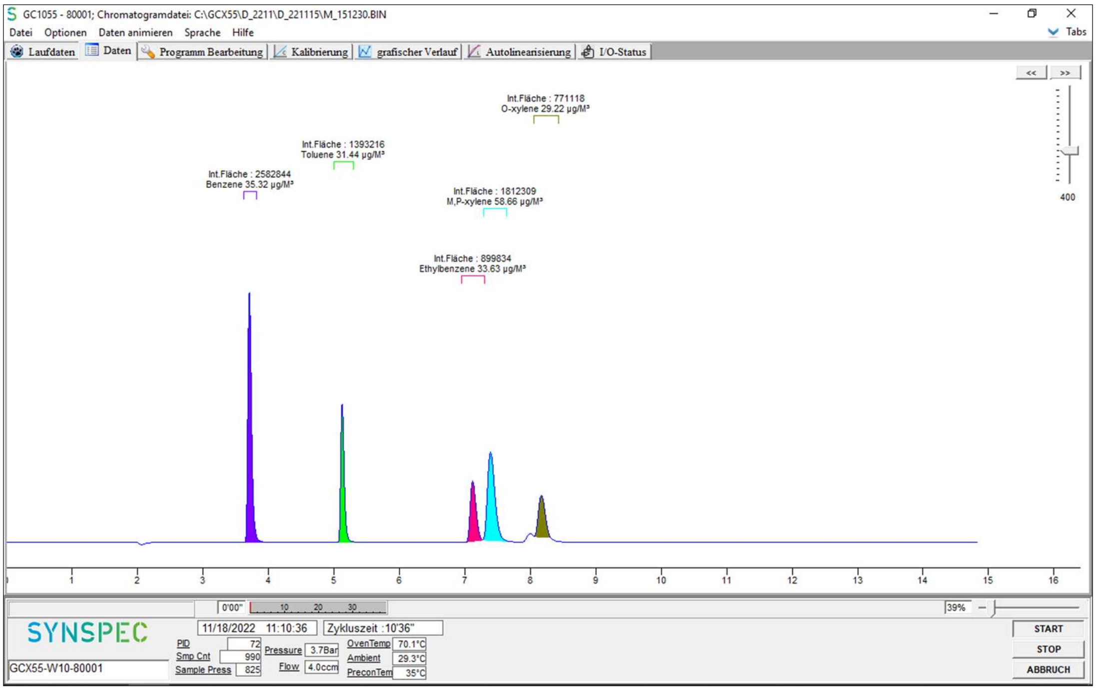
The operability of the measured value display shall be checked.

6.1.5 Assessment

Minimum requirement met? yes

6.1.6 Documentation

The gas chromatograph is equipped with a standard industrial PC with a Windows operating system. A complete PC structure is available for processing the measurement results. All data are stored to the internal SSD and can be recalled at any time. On an LCD screen, the current or the saved chromatogram are displayed.



GC1055 - 80001; Chromatogramdatei: C:\GCX55\D_2211\D_221115\M_151230.BIN

Int.Fläche : 2582844
Benzene 35.32 µg/M³

Int.Fläche : 1393216
Toluene 31.44 µg/M³

Int.Fläche : 899834
Ethylbenzene 33.63 µg/M³

Int.Fläche : 1812309
M,P-xylene 58.66 µg/M³

Int.Fläche : 771118
O-xylene 29.22 µg/M³

11/18/2022 11:10:36

Zykluszeit :10'36"

PID 72
Smp Cnt 990
Sample Press 825
Pressure 3.7Bar
Flow 4.0ccm
OvenTemp 70.1°C
Ambient 29.3°C
PreconTem 35°C

GCX55-W10-80001

Fig. 6.1: Display of a chromatogram on the LCD screen

6.2 Calibration inlet

6.2.1 Minimum requirement (VDI 4202 part 1 chapter 8.3.2)

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

6.2.2 Equipment

No additional equipment is required.

6.2.3 Testing

It shall be checked whether the measuring device has a test gas inlet separate from the sample gas inlet.

6.2.4 Evaluation

See Chap. 6.2.5

6.2.5 Assessment

The tested device does not have a separate test gas inlet for the application of the calibration gas.

Minimum requirement met? not applicable

6.2.6 Documentation

Not applicable

6.3 Easy maintenance

6.3.1 Minimum requirement (VDI 4202 part 1 chapter 8.3.3)

The necessary maintenance of the measuring system shall be performed in accordance with the operation manual and be possible without larger effort, preferably from outside of the instrument.

6.3.2 Equipment

No additional equipment is required.

6.3.3 Testing

It shall be checked whether the necessary maintenance work on the measuring device is possible without larger effort.

6.3.4 Evaluation

The measuring device does not require any maintenance to be carried out regularly by the user. Furthermore, a complete maintenance by the manufacturer is recommended once a year.

6.3.5 Assessment

Minimum requirement met? yes

6.3.6 Documentation

Not applicable

6.4 Functional check

6.4.1 Minimum requirement (VDI 4202 part 1 chapter 8.3.4)

See Chap. 6.4.5

6.4.2 Equipment

No additional equipment is required.

6.4.3 Testing

It shall be checked whether the test gas generator can be controlled telemetrically.

6.4.4 Evaluation

See Chap. 6.4.5

6.4.5 Assessment

The measuring device does not have a test gas generator, so internal function control is not provided.

Minimum requirement met? not applicable

6.4.6 Documentation

Not applicable

6.5 Set-up and run-in times

6.5.1 Minimum requirement (VDI 4202 part 1 chapter 8.3.5)

The set-up and run-in times of the measuring system shall be specified in the operation manual.

6.5.2 Equipment

Testing requires:

- Clock

6.5.3 Testing

The device shall be commissioned according to the operation manual. The required set-up and run-in times shall be measured separately.

6.5.4 Evaluation

The required set-up and run-in times shall be documented.

6.5.5 Assessment

Minimum requirement met? yes

6.5.6 Documentation

<u>Set-up time:</u>

The set-up time is about **1 hour**

Before starting a measurement, the gas chromatograph must be installed in a 19" rack and the carrier gas N_2 (quality 5.0) must be connected. The connections are made via Swagelok 1/8“ fittings at the marked point on the rear of the instrument. A pressure of approximately 4 - 5 bar must be set for the connected carrier gas.

Run-in time:

The run-in time is about **1 hour**

When the device is switched on, the operating system and the chromatography software start automatically. During start-up, a self-test of the electronic is performed and the oven is heated up to the base temperature. Since the sample gas must first be preconcentrated on the enrichment tube, the first measurement results are available after the second measurement cycle.

6.6 Instrument design

6.6.1 Minimum requirement (VDI 4202 part 1 chapter 8.3.6)

The operation manual shall include information on the design of the measuring device.

6.6.2 Equipment

Testing requires:

- AC meter
- Balance

6.6.3 Testing

The design of the measuring devices shall be compared with the description in the operation manual. Furthermore, the installation position, safety requirements and dimensions as well as the weight including accessories shall be determined. The specified energy consumption shall be determined over 24 h during the field test.

6.6.4 Evaluation

The characteristics found shall be compared with the description in the operation manual.

6.6.5 Assessment

Minimum requirement met? yes

6.6.6 Documentation

Device dimensions:

19" housing with 5 HE, width 48.3 cm, height 20.4 cm, depth (without handles) 55.2 cm

Operating voltage:

230 VAC

Weight:

20 kg

Power consumption:

1,7 kWh

6.7 Unauthorized adjustment

6.7.1 Minimum requirement (VDI 4202 part 1 chapter 8.3.7)

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

6.7.2 Equipment

No additional equipment is required.

6.7.3 Testing

It shall be determined whether the adjustment can be changed despite the activated device protection (e.g. password).

6.7.4 Evaluation

See Chap. 6.7.6

6.7.5 Assessment

Minimum requirement met? yes

6.7.6 Documentation

The software for controlling the gas chromatograph is protected by a password and cannot be changed accidentally.

6.8 Data output

6.8.1 Minimum requirement (VDI 4202 part 1 chapter 8.3.8)

The measuring signals shall be provided digitally (e.g. RS 232) and/or analog (e.g. 4 mA to 20 mA).

6.8.2 Equipment

Testing requires:

- Computer for data transmission to the LUBW monitoring network center

6.8.3 Testing

It shall be checked whether the operating states and output signals are correctly recognized and registered by the evaluation system.

6.8.4 Evaluation

An evaluation system shall be connected to the measuring device. The respective operating states and output signals are to be recorded and compared with the set values.

6.8.5 Assessment

Minimum requirement met? yes

6.8.6 Documentation

The output signals could be transmitted by "Bayern-Hessen-protocol". This was checked during the field test. There was a match between the transmitted data and the data stored in the measuring device (see Tab. 6.1).

Tab. 6.1: Comparison between the data transmitted to the LUBW monitoring network center (MNZ) and the data stored in the gas chromatographs

Data/ Time	Concentration	GC-display		Data in MNZ	
		GC 80001	GC 80004	GC 80001	GC 80004
03.01.2023 11:45	35.1 µg/m³	34.8 µg/m³	34.9 µg/m³	34.8 µg/m³	34.9 µg/m³
03.01.2023 12:00		34.5 µg/m³	35.6 µg/m³	34.5 µg/m³	35.6 µg/m³
03.01.2023 12:15		34.6 µg/m³	36.0 µg/m³	34.6 µg/m³	36.0 µg/m³
03.01.2023 12:30		34.7 µg/m³	36.2 µg/m³	34.7 µg/m³	36.2 µg/m³

6.9 Digital interface

6.9.1 Minimum requirement (VDI 4202 part 1 chapter 8.3.9)

The digital interface shall allow the transmission of output signals, status signals and information like instrument type, measuring range, measured component and unit. The digital interface shall be described in the relevant standards and guidelines.

6.9.2 Equipment

See Chap. 6.8 and Chap. 6.14

6.9.3 Testing

See Chap. 6.8 and Chap. 6.14

6.9.4 Evaluation

See Chap. 6.8 and Chap. 6.14

6.9.5 Assessment

Minimum requirement met? yes

6.9.6 Documentation

See Chap. 6.8 and Chap. 6.14

6.10 Data transmission protocol

6.10.1 Minimum requirement (VDI 4202 part 1 chapter 8.3.10)

If the output signals of the device are transmitted digitally, it shall be checked whether the device has at least one data transmission protocol.

6.10.2 Equipment

See Chap. 6.8 and Chap. 6.14

6.10.3 Testing

See Chap. 6.8 and Chap. 6.14

6.10.4 Evaluation

See Chap. 6.8 and Chap. 6.14

6.10.5 Assessment

Minimum requirement met? yes

6.10.6 Documentation

See Chap. 6.8 and Chap. 6.14

6.11 Measuring range

6.11.1 Minimum requirement (VDI 4202 part 1 chapter 8.3.11)

The upper end of the measuring range of the measuring system shall be greater or equal to the upper limit of the certification range.

6.11.2 Equipment

No additional equipment is required.

6.11.3 Testing

The upper end of the measuring range shall be determined.

6.11.4 Evaluation

Not applicable

6.11.5 Assessment

Minimum requirement met? yes

6.11.6 Documentation

The manufacturer does not define the upper limit of the measuring range. During the test, concentrations up to 50 µg/m³ were abandoned.

6.12 Negative output signals

6.12.1 Minimum requirement (VDI 4202 part 1 chapter 8.3.12)

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

6.12.2 Equipment

No additional equipment is required.

6.12.3 Testing

It shall be checked whether the displayed zero point is a live zero point and the device can display both positive and negative signals.

6.12.4 Evaluation

See Chap. 6.12.5

6.12.5 Assessment

The device is not equipped with a live zero.

Minimum requirement met? not applicable

6.12.6 Documentation

Not applicable

6.13 Failure in the mains voltage

6.13.1 Minimum requirement (VDI 4202 part 1 chapter 8.3.13)

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

6.13.2 Equipment

No additional equipment is required.

6.13.3 Testing

A simulated power failure shall be used to check whether the measuring device remains undamaged and is ready for a measurement again when the power is restored.

6.13.4 Evaluation

The trouble-free operation of the device after power recovery shall be determined by comparing the device parameters before and after the power failure.

6.13.5 Assessment

Minimum requirement met? yes

6.13.6 Documentation

During the field test, a 10-minute power failure occurred. After power recovery, the computer automatically boots the operating system and starts a measurement. The supply of the operating gas (N_2) is stopped during a power failure.

6.14 Operating states

6.14.1 Minimum requirement (VDI 4202 part 1 chapter 8.3.14)

The measuring system shall allow the monitoring of its essential functions by telemetrically transmittable status signals.

6.14.2 Equipment

Testing requires:

- Evaluation or data recording system

6.14.3 Testing

An evaluation or data recording system shall be connected to the measuring device. The corresponding operating states (normal operation, maintenance and malfunction) of the measuring system shall be set. A modem shall be connected to the measuring system. The status signals of the measuring system shall be determined by remote data recording.

6.14.4 Evaluation

It shall be checked whether operating states set at the measuring system are correctly determined and recorded by the connected evaluation or data recording system.

6.14.5 Assessment

Minimum requirement met? yes

6.14.6 Documentation

During the field test, the two instruments were connected with the network monitoring center of LUBW. At the end of the field test, the respective operating states (operation and maintenance) were selected on the measuring devices. The instrument shows a plurality of operating states and error messages. Several functional errors (sampling, detector, temperature, flow, pressure, etc.) were simulated. Telemetric transmission of these operating states is guaranteed.

6.15 Switch-over

6.15.1 Minimum requirement (VDI 4202 part 1 chapter 8.3.15)

Switching between measurement and functional check and/or calibration shall be possible telemetrically or manually at the measuring system.

6.15.2 Equipment

No additional equipment is required.

6.15.3 Testing

It shall be checked whether manually or telemetrically switching between measurement and functional check and/or calibration is possible.

6.15.4 Evaluation

See Chap. 6.15.5

6.15.5 Assessment

The tested devices do not have a test gas generator, so internal function control is not provided.

Minimum requirement met? not applicable

6.15.6 Documentation

Not applicable

6.16 Instrument software

6.16.1 Minimum requirement (VDI 4202 part 1 chapter 8.3.16)

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

6.16.2 Equipment

No additional equipment is required.

6.16.3 Testing

It shall be checked whether the version of the device software can be displayed. The version of the device software shall be documented.

6.16.4 Evaluation

See chap. 6.16.3

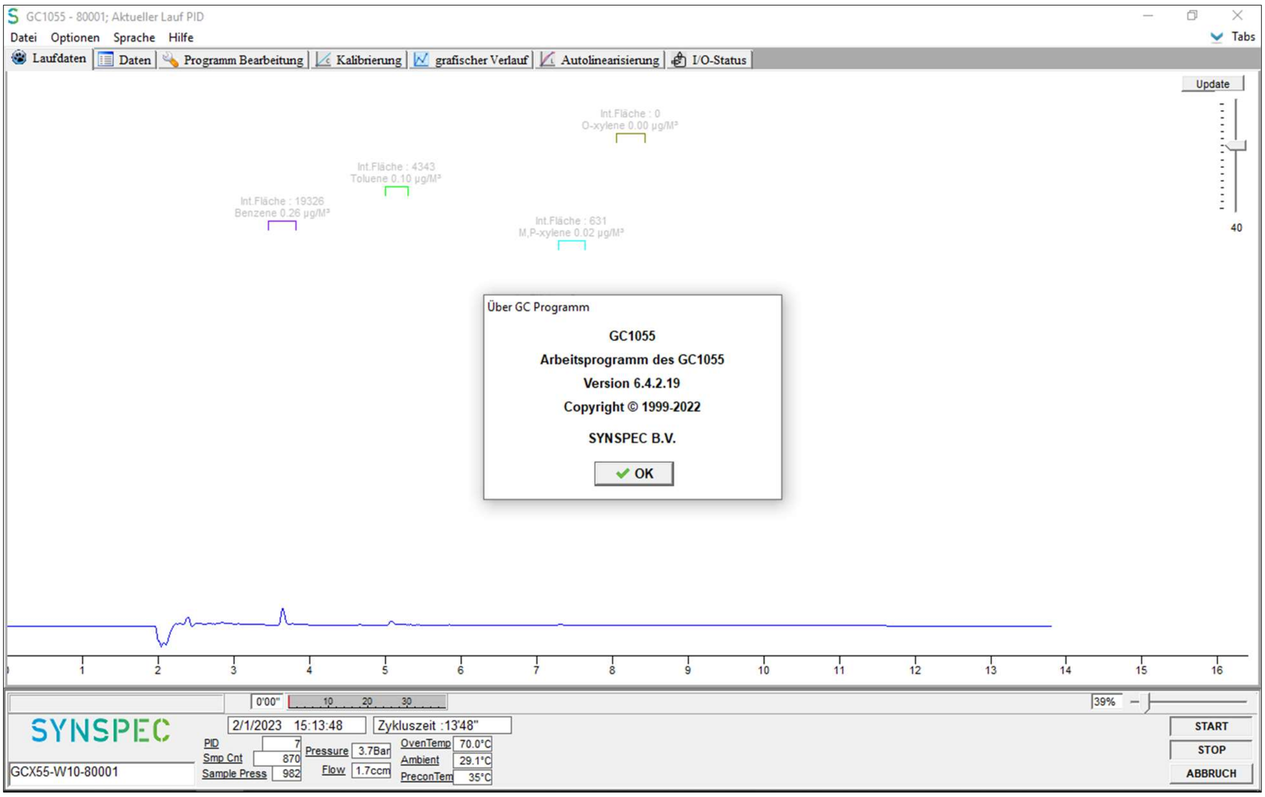
6.16.5 Assessment

Minimum requirement met? yes

6.16.6 Documentation

By clicking on "Help" and "About" in the menu bar of the program, a window with the current software version for the control of the gas chromatograph appears (see Fig. 6.2).

- Software for GC control and communication with external devices: GCX55.exe
- Version 6.4.2.19



Über GC Programm

GC1055

Arbeitsprogramm des GC1055

Version 6.4.2.19

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SYNSPEC B.V.

✓ OK

GCX55-W10-80001

2/1/2023 15:13:48

Zykluszeit :13'48"

PID 7
Smp Cnt 870
Sample Press 982
Pressure 3.7Bar
Flow 1.7ccm
OvenTemp 70.0°C
Ambient 29.1°C
PreconTem 35°C

Fig. 6.2: Software version display

6.17 Short-term drift

6.17.1 Minimum requirement (DIN EN 14662-3: 2016-02 chapter 8.4.3)

The short-term drift $D_{s,s}$ at test value 2 (approx. 70 – 80 % of benzene concentration of 50 µg/m³) under laboratory conditions and over a drift period of 12 h shall be less than or equal to 2.0 µg/m³.

6.17.2 Equipment

Testing requires:

- Test standards (e.g. zero air and test gas of suitable concentration)

6.17.3 Testing

Test gas at test value 2 is applied to the device under laboratory conditions. The mean value is calculated from four successive measurements. After 12 hours of measuring the ambient air, the measurements are repeated at test value 2.

6.17.4 Evaluation

The short-term drift at test-value 2 is calculated as follows:

$$D_{s,s} = (x_{s,2} - x_{s,1}) \quad \text{(Eq. 6.1)}$$

Where:

$D_{s,s}$ the 12-h-drift at test value 2, in µg/m³;

$x_{s,1}$ the mean value of four measurements at the beginning of the drift period, in µg/m³;

$x_{s,2}$ the mean value of four measurements at the end of the drift period, in µg/m³.

The result of the short-term drift is not included in the expanded measurement uncertainty.

6.17.5 Assessment

Minimum requirement met? yes

6.17.6 Documentation

To calculate the short-term drift under laboratory conditions, a concentration of approx. 36.2 µg/m³ was offered to the two gas chromatographs over a period of 75 minutes (five measuring cycles). A mean value was calculated based on four measurements; the result of the first measurement was discarded. After 12 h the measurement was repeated and a mean value was again determined based on four measurements (see Tab. 6.2).

Tab. 6.2: Calculated values for the short-time drift $D_{s,s}$

	GC 80001	**GC 80004**
$x_{s,1}$, in µg/m³	35.80	35.68
$x_{s,2}$, in µg/m³	35.48	35.25
$D_{s,s}$, in µg/m³	**0.32**	**0.43**

6.18 Repeatability standard deviation

6.18.1 Minimum requirement (DIN EN 14662-3: 2016-02 chapter 8.4.4)

The repeatability standard deviation $s_{r,z}$ at test value 1 (10 % of the annual limit value = 0.5 µg/m³) shall be less than or equal to 0.20 µg/m³ and the repeatability $s_{r,c(t)}$ at the annual limit value (= 5µg/m³) shall be less than or equal to 0.25 µg/m³.

6.18.2 Equipment

Testing requires:

- Gas mixing system
- Test standards (e.g. test gas of suitable concentration)

6.18.3 Testing

Eleven measurements are performed with a test gas concentration at test value 1 and at the annual limit value.

6.18.4 Evaluation

From the last ten results, the repeatability standard deviation is calculated according to the following equation:

$$s_{r,c_t} = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}} \qquad \text{(Eq. 6.2)}$$

Where:

$s_{r,ct}$	the repeatability standard deviation at c_t, in µg/m³;
x_i	the result of the i-th measurement, in µg/m³;
$\bar{x}$	the mean value of the 10 measurements;
n	the number of measurements, n = 10.

The standard measurement uncertainty of the repeatability standard deviation u_r is calculated as:

$$u_r = \frac{s_r}{\sqrt{m}} \qquad \text{(Eq. 6.3)}$$

and

$$s_r = \frac{l_a}{c_t} * s_{r,c_t} \qquad \text{(Eq. 6.4)}$$

Where:

u_r	the standard measurement uncertainty of the repeatability standard deviation at the annual limit value, in µg/m³;
s_r	the repeatability standard deviation at the annual limit value, in µg/m³;
m	the number of measurements performed in order to obtain the value s_r;
l_a	the annual limit value, in µg/m³;
c_t	the test gas concentration in the range of the annual limit value, in µg/m³;
$s_{r,ct}$	the repeatability standard deviation at c_t, in µg/m³.

6.18.5 Assessment

Minimum requirement met? yes

6.18.6 Documentation

To calculate the repeatability standard deviation, a test gas in the range of test value 1 (10% of the annual limit value) and then a test gas in the range of the annual limit value were offered with 11 repetitions. The last ten results were used for the calculation (see Tab. 6.3 and Tab. 6.4).

Tab. 6.1: Repeatability standard deviation at the test value 1

	GC 80001	GC 80004
Repeatability standard deviation $s_{r,z}$, in µg/m³	**0.01**	**0.01**
Benzene concentration, in µg/m³	0.53	0.53

Tab. 6.2: Repeatability standard deviation at the annual limit value

	GC 80001	GC 80004
Repeatability standard deviation $s_{r,ct}$, in µg/m³	**0.02**	**0.02**
Standard measurement uncertainty u_r, in µg/m³	0.00*	0.01*
Benzene concentration, in µg/m³	5.3	5.3

*Values are used to calculate the expanded measurement uncertainty

6.19 Lack of fit of linearity of the calibration function

6.19.1 Minimum requirement (DIN EN 14662-3: 2016-02 chapter 8.4.5)

The residual r_z at zero point shall be less than or equal to 0.5 µg/m³ and the largest relative residual r_{max} from the linear regression function shall be less than or equal to 5 %. If one or more relative residuals do not meet the criterion, the analyzer does not pass the linearity test.

6.19.2 Equipment

Testing requires:

- Gas mixing system
- Test standards (e.g. zero gas and test gas of suitable concentration)

6.19.3 Testing

A linear regression function is determined based on the measurement results and the corresponding abandoned concentrations. The residual at each concentration level is equal to the difference between the mean value of the measured signal, expressed as a concentration, and the concentration given by the linear regression function. The linear regression function and the residuals are calculated in accordance with Annex A of DIN EN 14662-3: 2016-02.

The linearity of the analyzer shall be tested in the range between 0 % and 90 % of the maximum of certification range with at least six concentrations (including 0 µg/m³).

6.19.4 Evaluation

The residuals of the mean values for each calibration point (including the zero point) are calculated according to Annex A.2 of DIN EN 14662-3: 20016-02 using the following equations:

$$(y_a)_c = \frac{\sum (y_i)_c}{m} \qquad \text{(Eq. 6.5)}$$

Where:

$(y_a)_c$	the mean y-value at concentration level c;
$(y_i)_c$	the individual y-value at concentration level c;
m	the number of repetitions at one and the same concentration level c.

The residual of each mean value (r_c) at each concentration level is calculated according to:

$$r_c = (y_a)_c - (A + B \cdot c) \qquad \text{(Eq. 6.6)}$$

Where:

A	the intercept of the calibration function;
B	the slope of the calibration function.

The relative deviation (in %) of each mean value at the associated concentration c is calculated according to:

$$r_{c,rel.} = \frac{r_c}{c} * 100 \qquad \text{(Eq. 6.7)}$$

The largest value of $r_{c,\,rel.}$ is indicated as r_{max} and is used for the uncertainty calculation.

The standard measurement uncertainty u_l of the deviation from linearity at the annual limit value is calculated according to:

$$u_l = \frac{r_{max}}{100} * \frac{l_a}{\sqrt{3}} \qquad \text{(Eq. 6.8)}$$

Where:

u_l	the standard uncertainty u_l of the deviation from linearity at the annual limit value, in µg/m³;
r_{max}	the maximum residual from a linear regression function, calculated according to Annex A, in %;
l_a	the annual limit value, in µg/m³.

6.19.5 Assessment

Minimum requirement met? yes

6.19.6 Documentation

Using a gas mixing system, five different test gas concentrations and zero gas were applied to the two gas chromatographs in the order: 50%, 10%, 30%, 5%, 90% and 0% of the maximum value of the certification range of benzene (= 50 µg/m³).

Each concentration was applied for 60 minutes (4 measuring cycles of 15 minutes). The first measured value at each concentration level was discarded as a run-in value, i.e. only the last three measured values were used for the determination of the mean values. A regression calculation was used to calculate the calibration function (see Tab. 6.5).

Tab. 6.3: Calibration function of the gas chromatographs GC 80001 and GC 80004

	GC 80001	**GC 80004**
Calibration function	y = 1.0013 x – 0.4728	y = 0.9967 x – 0.2375

Fig. 6.3 and Fig. 6.4 show the calibration functions of the two gas chromatographs.

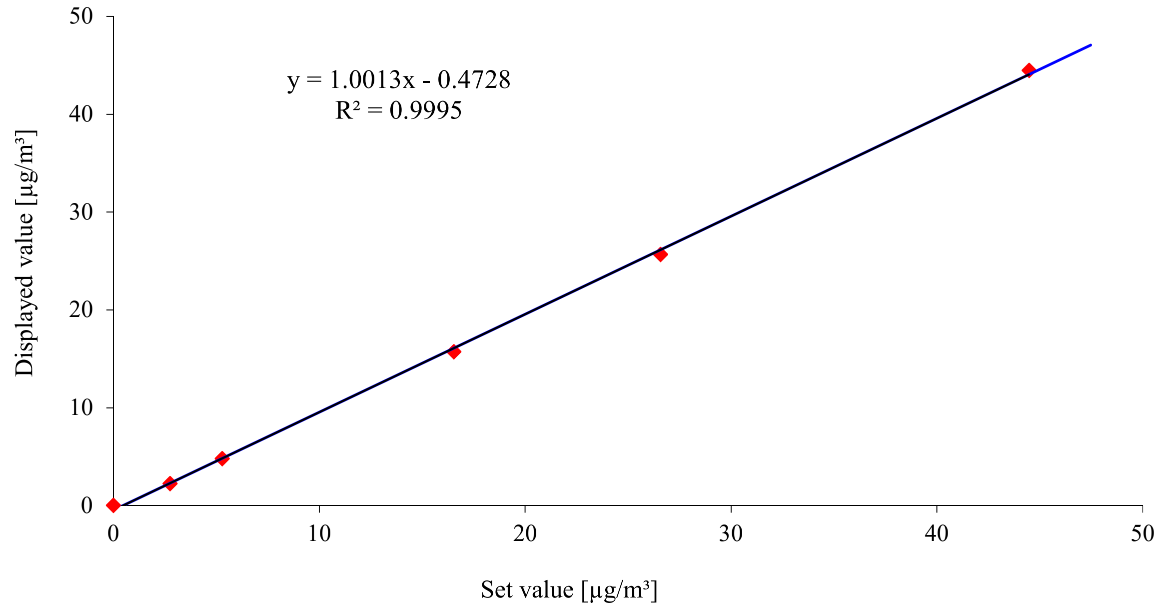


Fig. 6.1: Calibration function of the GC 80001

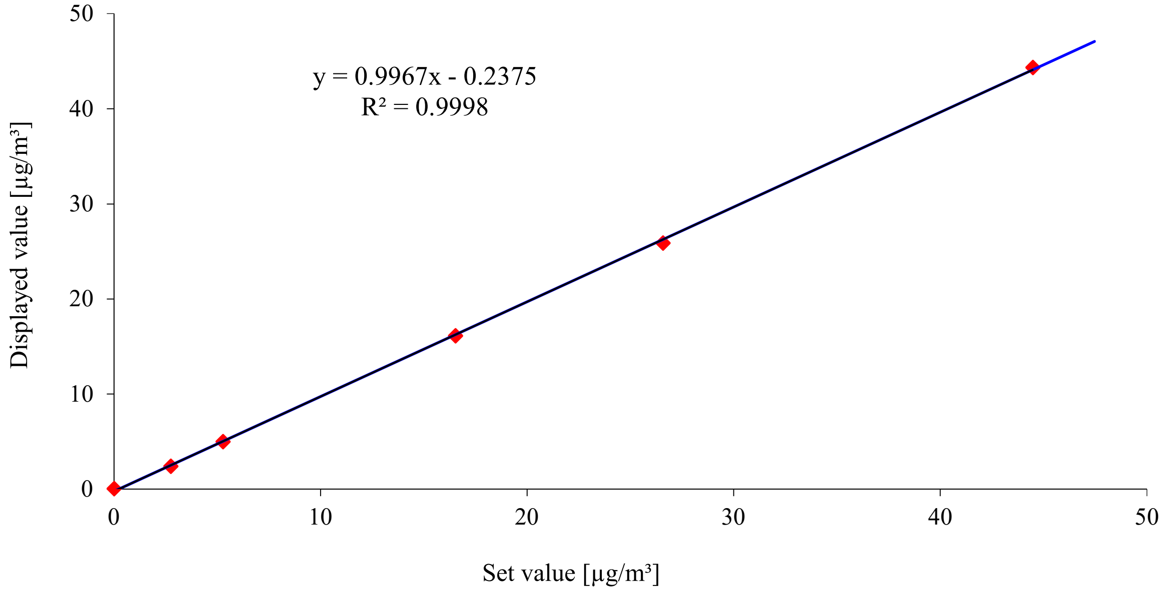


Fig. 6.2: Calibration function of the GC 80004

Tab. 6.4: Residuals of the mean values for each calibration point (including zero) for GC 80001

	c, in µg/m³	**$(y_a)_c$, in µg/m³**	**(A + B *c)**	**r_c, in µg/m³**	**$r_{c,rel.}$, in %**
50 % of MR	26.57	25.67	26.1	-0.5	-1.7
10 % of MR	5.27	4.77	4.8	0	-0.7
30 % of MR	16.52	15.73	16.1	-0.3	**-2.1**
5 % of MR	2.75	2.22	2.3	-0.1	**-2.1**
90 % of MR	44.47	44.47	44.1	0.4	0.9
0 % of MR	0	0.02	-0.5	**0.5**	-

The results for GC 80001

Standard uncertainty u_l, in µg/m³	-0.06*
Residual at zero r_z, in µg/m³	0.5
Largest residual r_{max}, in %	-2.1

*Values are used to calculate the expanded measurement uncertainty

Tab. 6.5: Residuals of the mean values for each calibration point (including zero) for GC 80004

	c, in µg/m³	**$(y_a)_c$, in µg/m³**	**(A + B *c)**	**r_c, in µg/m³**	**$r_{c,rel.}$, in %**
50 % of MR	26.57	25.88	26.2	-0.4	-1.4
10 % of MR	5.27	5.01	5.0	0	-0.2
30 % of MR	16.52	16.14	16.2	-0.1	-0.6
5 % of MR	2.75	2.42	2.5	-0.1	**-3.0**
90 % of MR	44.47	44.35	44.1	0.3	0.6
0 % of MR	0	0.05	-0.2	**0.3**	-

The results for GC 80004

Standard uncertainty u_l, in µg/m³	-0.09*
Residual at zero r_z, in µg/m³	0.3
Largest residual r_{max}, in %	-3.0

*Values are used to calculate the expanded measurement uncertainty

6.20 Sensitivity coefficient of sample gas pressure

6.20.1 Minimum requirement (DIN EN 14662-3: 2016-02 chapter 8.4.6)

The sensitivity coefficient b_{gp} for the influence of the sample gas pressure at test value 2 (70 – 80% of the maximum of the certification range) shall be less than or equal to 0.10 (µg/m³)/kPa.

6.20.2 Equipment

Testing requires:

- Gas mixing system
- Test standards (e.g. test gas of suitable concentration)
- Pressure measuring system

6.20.3 Testing

Five measurements shall be performed with concentrations at test value 2 and at sample gas pressures of 80 kPa (± 0.2 kPa) and 110 kPa (± 0.2 kPa). For each pressure, the mean value from the last four measurements shall be calculated.

6.20.4 Evaluation

The influence of the sample gas pressure b_{gp} is calculated according to the following equation:

$$b_{gp} = \left|\frac{(x_{p2}-x_{p1})}{(p_1-p_2)}\right| \qquad \text{(Eq. 6.9)}$$

The standard uncertainty u_{gp} depending on the change of sample gas pressure at the annual limit value is calculated as follows:

$$u_{gp} = \frac{l_a}{c_t} * b_{gp} * \sqrt{\frac{(p_2-p_1)^2}{3}} \qquad \text{(Eq. 6.10)}$$

Where:

b_{gp}	the sensitivity coefficient to sample gas pressure, in (µg/m³)/kPa;
x_{p1}	the mean value of the measurements at sample gas pressure p_1, in µg/m³;
x_{p2}	the mean value of the measurements at sample gas pressure p_2, in µg/m³;
p_1	the lowest sample gas pressure, in kPa;
p_2	the highest sample gas pressure, in kPa;
u_{gp}	the standard uncertainty depending on the change of sample gas pressure at the annual limit value, in µg/m³;
l_a	the annual limit value, in µg/m³;
c_t	the test gas concentration in the range of test value 2 (70-80% of the maximum of the certification range), in µg/m³.

6.20.5 Assessment

Minimum requirement met? yes

6.20.6 Documentation

The two gas chromatographs were supplied via a T-piece with a test gas in excess. To set a sample gas overpressure, the excess line was constricted with a needle valve. The correct pressure was monitored with a Vacuubrand DVR 2 pressure measuring system.

To set a sample gas vacuum, the needle valve was installed on the sample gas side of the T-piece. An additional small pump was used to generate vacuum in the sampling line. The correct pressure was monitored with a Vacuubrand DVR 2 pressure measuring system.

For the calculation of the sensitivity coefficient b_{gp} of the sample gas pressure and the associated standard measurement uncertainty u_{gp}, five successive measurements with concentrations at test value 2 were carried out at a pressure of 85 kPa and at a pressure of 110 kPa. For each pressure, the mean values of the last four measured values were used for the evaluation (see Tab. 6.8).

Tab. 6.6: Measured data of p_1, p_2, x_{p1} and x_{p2}

	GC 80001	**GC 80004**
Pressure p_1, in kPa	80.0	80.0
Pressure p_2, in kPa	110.0	110.0
Concentration x_{p1}, in µg/m³	34.4	34.8
Concentration x_{p2}, in µg/m³	36.5	36.5

The following values of sensitivity coefficient b_{gp} and the associated standard uncertainty u_{gp} were calculated (see Tab. 6.9).

Tab. 6.7: Calculate values of b_{gp}, u_{gp}

	GC 80001	**GC 80004**
Sensitivity coefficient b_{gp}, in (µg/m³)/kPa	**0.07**	**0.06**
Standard uncertainty u_{gp}, in µg/m³	0.16*	0.13*

*Values are used to calculate the expanded measurement uncertainty

6.21 Sensitivity coefficient of surrounding temperature

6.21.1 Minimum requirement (DIN EN 14662-3: 2016-02 chapter 8.4.7)

The sensitivity coefficient b_{st} for the influence of surrounding temperature at test value 2 (70 – 80% of the maximum of the certification range) shall be less than or equal to 0.08 (µg/m³)/K.

6.21.2 Equipment

Testing requires:

- Test standards (e.g. test gas of suitable concentration)
- Climate chamber

6.21.3 Testing

The influence of the surrounding temperature on the measured value is determined by measurements at a minimum temperature of 0°C and a maximum temperature of 30°C (or within manufacturer's specifications). Five measurements with concentrations at test value 2 shall be performed at each temperature. The mean value of the last four measurements shall be calculated.

6.21.4 Evaluation

The influence of the surrounding temperature b_{st} is calculated according to the following equation:

$$b_{st} = \left| \frac{(x_2 - x_1)}{(T_{S,2} - T_{S,1})} \right| \qquad \text{(Eq. 6.11)}$$

The standard uncertainty u_{st} depending on the change of surrounding temperature at the annual limit value is calculated as follows:

$$u_{st} = \frac{l_a}{c_t} * b_{st} * \sqrt{\frac{(T_{S,2} - T_{S,1})^2}{3}} \qquad \text{(Eq. 6.12)}$$

Where:

b_{st}	the sensitivity coefficient for the influence of surrounding temperature, in (µg/m³)/K;
x_1	the mean value of the measurements at $T_{S,1}$, in µg/m³;
x_2	the mean value of the measurements at $T_{S,2}$, in µg/m³;
$T_{S,1}$	the lowest surrounding temperature, in K;
$T_{S,2}$	the highest surrounding temperature, in K;
u_{st}	the standard uncertainty depending on the change of surrounding temperature at the annual limit value, in µg/m³;
l_a	the annual limit value, in µg/m³;
c_t	the test gas concentration in the range of test value 2, in µg/m³.

6.21.5 Assessment

The sensitivity coefficient b_{st} of the influence of surrounding temperature does not exceed the minimum requirement.

Minimum requirement met? yes

6.21.6 Documentation

To determine the influence of the ambient temperature on the measured value, the devices were placed in a climate chamber. The sensitivity coefficient was determined at a minimum temperature of 0°C and a maximum temperature of 30°C. Humidity was set to near 50 %. The following temperature program was set:

20°C → 0°C → 30°C → 20°C

At each temperature setting, the two gas chromatographs were supplied with test gas concentration in the range of test value 2. After an equilibration time of the climatic chamber (approx. 2 h), the last four measurement cycles at each temperature level were used for evaluation (see Tab. 6.10).

Tab. 6.8: Results of the ambient temperature dependence

	GC 80001	GC 80004
Benzene concentration C, in µg/m³	38.7	38.7
Lowest surrounding temperature $T_{S,1}$, in K	273.0	273.0
Highest surrounding temperature $T_{S,2}$, in K	303.0	303.0
Sensitivity coefficient b_{st}, in (µg/m³)/K	**0.03**	**0.06**
Standard uncertainty u_{st}, in µg/m³	0.06*	0.12*

*Values are used to calculate the expanded measurement uncertainty

6.22 Sensitivity coefficient of electrical voltage

6.22.1 Minimum requirement (DIN EN 14662-3: 2016-02 chapter 8.4.8)

The sensitivity coefficient b_V for the influence of the electrical voltage at the test value 2 (70 – 80% of the maximum of the certification range) shall be less than or equal to 0.08 (µg/m³)/V.

6.22.2 Equipment

Testing requires:

- Test standards (e.g. test gas of suitable concentration)
- Transformer with a controlled range for mains voltages from 210 V to 245 V

6.22.3 Testing

The voltage dependence shall be tested at the minimum and maximum voltage range specified by the manufacturer. Five measurements with concentration at the test value 2 shall be performed at each voltage. The mean value of the last four measurements shall be calculated.

6.22.4 Evaluation

The influence of the electric voltage b_V is calculated according to the following equation:

$$b_V = \left|\frac{(x_{V,2} - x_{V,1})}{(V_2 - V_1)}\right| \qquad \text{(Eq. 6.13)}$$

The standard uncertainty u_V depending on the change of electric voltage at the annual limit value is calculated as follows:

$$u_V = \frac{l_a}{c_t} * b_V * \sqrt{\frac{(V_2 - V_1)^2}{3}} \qquad \text{(Eq. 6.14)}$$

Where:

b_V	the sensitivity coefficient for the influence of electric voltage, in (µg/m³)/V;
$x_{V,1}$	the mean value of the measurements at V_1, in µg/m³;
$x_{V,2}$	the mean value of the measurements at V_2, in µg/m³;
V_1	the lowest electric voltage, in V;
V_2	the highest electric voltage, in V;

u_V the standard uncertainty depending on the change of electric voltage at the annual limit value, in µg/m³;

l_a the annual limit value, in µg/m³;

c_t the test gas concentration in the range of test-value 2, in µg/m³.

6.22.5 Assessment

The sensitivity coefficient b_V of the influence of electric voltage does not exceed the minimum requirement.

Minimum requirement met? yes

6.22.6 Documentation

To test the influence of electric voltage, the mains voltage was varied using a programmable AC voltage source (AC voltage source ACS-4600-PS). The following settings were made:

230 V → 210 V → 245 V → 230 V

At each voltage setting, the two gas chromatographs were supplied with test gas concentration in the range of test value 2. The last four measurement cycles at each voltage level were used for evaluation (see Tab.6.11).

Tab. 6.9: Results of the electric voltage dependence

	GC 80001	**GC 80004**
Benzene concentration C, in µg/m³	36.2	36.2
Lowest electric voltage V_1, in V	210	210
Highest electric voltage V_2, in V	245	245
Sensitivity coefficient b_V, in (µg/m³)/V	**0.001**	**0.002**
Standard uncertainty u_V, in µg/m³	0.002*	0.006*

*Values are used to calculate the expanded measurement uncertainty

6.23 Interferents

The instrument response to certain interferents, which are to be expected to be present in ambient air, shall be tested. The cross-sensitivity to water vapor and to organic compounds shall be determined at test gas concentration in the range of the annual limit value (= 5.0 µg/m³).

6.23.1 Water vapor

6.23.1.1 Minimum requirement (DIN EN 14662-3: 2016-02 chapter 8.4.9.2)

The influence of water vapor b_{H2O} shall be tested in the range of the annual limit value and shall be less than or equal to 0.015 (µg/m³)/(mmol/mol).

6.23.1.2 Testing

The influence of water vapor is tested at a H_2O-concentration of 19 mmol/mol. The test shall be performed at a benzene concentration c_t, which is similar to the annual limit value.

6.23.1.3 Evaluation

The influence of water vapor b_{H2O} at a benzene concentration c_t is calculated according to the following equation:

$$b_{H_2O} = \frac{(X_{+W} - X_{-W})}{c_W} \qquad \text{(Eq. 6.15)}$$

The standard measurement uncertainty u_{H2O} due to the interference by water vapor at the annual limit value is calculated as follows:

$$u_{H_2O} = \frac{l_a}{c_t} * b_{H_2O} * \sqrt{\frac{(c^2_{H_2O,max} + c_{H_2O,max}*c_{H_2O,min} + c^2_{H_2O,min}}{3}} \qquad \text{(Eq. 6.16)}$$

Where:

b_{H2O}	the sensitivity coefficient to water vapor, in (µg/m³)/(mmol/mol);
x_{+W}	the mean value of the measurements at c_t with water vapor, in µg/m³;
x_{-W}	the mean value of the measurements at c_t without water vapor, in µg/m³;
c_W	the concentration of water vapor in the test gas, in mmol/mol;
u_{H2O}	the standard measurement uncertainty due to the disturbance caused by water vapor, in µg/m³;
l_a	the annual limit value, in µg/m³;
c_t	the test gas concentration in the range of the annual limit value, in µg/m³;
$c_{H2O,max}$	the highest concentration of water vapor (= 21 mmol/mol), in mmol/mol;
$c_{H2O,min}$	the lowest concentration of water vapor (= 6 mmol/mol), in mmol/mol.

6.23.1.4 Assessment

Minimum requirement met? yes

6.23.1.5 Documentation

To determine the cross-sensitivity, test gas in the range of the annual limit value (= 5.0 µg/m³) with interfering component was offered to the measuring devices. For this purpose, the dilution air was passed over a Nafion membrane, which was moistened with distilled water in countercurrent. A defined moisture content was set via the temperature of the water bath. The same measurement was carried out in the absence of the interfering component. To calculate the deviation between the measured value in the "dry" and "wet" test gas, the measured value of the "wet" test gas was corrected using the volume fraction of water vapor in the dilution air (see Tab. 6.12).

Tab. 6.10: The cross-sensitivity to water vapor

	GC 80001	**GC 80004**
Concentration of water vapor in the test gas c_W, in mmol/mol	19.0	19.0
Minimum water vapor concentration $c_{H2O,min}$, in mmol/mol	6	6
Maximum water vapor concentration $c_{H2O,max}$, in mmol/mol	21	21
Benzene concentration c_t, in µg/m³	5.3	5.3
Sensitivity coefficient b_{H2O}, in (µg/m³)/(mmol/mol)	**0.012**	**-0.006**
Standard uncertainty u_{H2O}, in µg/m³	0.163*	-0.081*

*Values are used to calculate the expanded measurement uncertainty

6.23.2 Organic compounds

6.23.2.1 Minimum requirement (DIN EN 14662-3: 2016-02 chapter 8.4.9.3)

The contribution of the mixture of organic compounds Δx_{OC} to the measurement signal of benzene at a concentration in the range of the annual limit value (= 5.0 µg/m³) shall be less than or equal to 0.25 µg/m³.

6.23.2.2 Testing

A possible cross-sensitivity due to organic compounds is tested by adding a gas mixture of different organic compounds with concentrations of about 5 µg/m³ to the test gas with a benzene concentration in the range of the annual limit value (= 5.0 µg/m³).

6.23.2.3 Evaluation

The interference test with the organic compounds is a test to ensure that the contributions of organic compounds that may co-elute with benzene to the signal of benzene are insignificant. The results of the test shall meet the minimum requirement.

$$\Delta x_{OC} = x_{+} - x_{-} \qquad \text{(Eq. 6.17)}$$

Where:

Δx_{OC}	the contribution of the mixture of organic compounds to the signal of benzene, in µg/m³;
x_+	the mean value of the measured signal for benzene at the concentration ct (at the annual limit value) in the presence of interfering components, in µg/m³;
x_-	the mean value of the measured signal for benzene at the concentration ct (at the annual limit value) in the absence of interfering components, in µg/m³.

6.23.2.4 Assessment

Minimum requirement met? yes

6.23.2.5 Documentation

To determine the cross-sensitivity, test gas in the range of the annual limit value (= 5.0 µg/m³) with 11 organic interfering components was offered to the measuring devices. The organic components were added to the benzene test gas using a thermal mass flow controller (MFC). Since the test gas volume flow was considerably higher than the volume flow of the added interfering components (about a factor of 3300), a correction of the initial benzene concentration was not necessary. The same measurement was then carried out in the absence of the interfering components.

The following 11 interfering organic components were used: methylcyclopentane (5.1 µg/m³); 2,2,3-trimethylbutane (5.0 µg/m³); 2,4-dimethylpentane (4.9 µg/m³); 2,2,4-trimethylpentane (5.1 µg/m³); cyclohexane (5.3 µg/m³); 2,3-dimethylpentane (5.0 µg/m³); 2-methylhexane (4.9 µg/m³); 3-ethylpentane (5.0 µg/m³); trichloroethene (5.3 µg/m³); n-heptane (5.0 µg/m³); 1-butanol (5.2 µg/m³).

The results of the tests on the cross-sensitivity to organic compounds are shown in Tab. 6.13.

Tab. 6.11: The cross-sensitivity to organic compounds

	GC 80001	**GC 80004**
Contribution interference component Δx_{OC}, in µg/m³	**-0.09**	**-0.03**

6.24 Memory-effect

6.24.1 Minimum requirement (DIN EN 14662-3: 2016-02 chapter 8.4.10)

The benzene concentration of the first zero gas analysis following the analysis at test value 3 (90 % of the maximum value of the certification range of benzene) shall be less than or equal to 1.0 µg/m³.

6.24.2 Equipment

Testing requires:

- Test standards (e.g. zero gas and test gas of suitable concentration)

6.24.3 Testing

The influence of a memory effect caused by retention of benzene in the measuring system due to unsuitable materials or a large dead volume shall be tested. Two measurements shall be performed at test value 3, after which the gas supply is switched to zero air. The result of the first measurement of zero air is used to calculate the concentration of benzene c_m resulting from memory effect. The test sequence shall be repeated three times.

6.24.4 Evaluation

The first zero gas analysis immediately following the high benzene concentration analysis (90% of the maximum of certification range) shall not exceed a measured benzene concentration of 1.0 µg/m³.

The standard uncertainty u_m due to memory effect is calculated according to:

$$u_m = \frac{l_a}{c_t} * c_m * \sqrt{3} \qquad \text{(Eq. 6.18)}$$

Where:

u_m	the standard uncertainty due to memory effect, in µg/m³;
c_m	the influence of memory effect, in µg/m³;
c_t	the test concentration of benzene (around 90 % of the maximum of the certification range), in µg/m³;
l_a	the annual limit value, in µg/m³.

6.24.5 Assessment

Minimum requirement met? yes

6.24.6 Documentation

To determine the memory effect, two measurements were carried out at a concentration corresponding to approximately 90% of the maximum value of the certification range. Then the gas supply was switched to zero air. This procedure was repeated three times. The mean value from each of the first three zero gas values was used to determine the memory effect.

Table 6.14 shows the result of the determination of the memory effect.

Tab. 6.12: Results of the memory effect test

	GC 80001	GC 80004
Influence of memory effect c_m, in µg/m³	**0.1**	**0.3**
Standard uncertainty u_m, in µg/m³	0.01*	0.02*

*Values are used to calculate the expanded measurement uncertainty

6.25 Long-term drift

6.25.1 Minimum requirement (DIN EN 14662-3: 2016-02 chapter 8.5.4)

In the field test, over a drift period of 14 days, the largest value of long-term drift at zero point $D_{l,z}$ shall be less than or equal to 0.5 µg/m³ and the largest value of long-term drift at test value 2 (70 - 80 % of the maximum value of the certification range) $D_{l,s}$ shall be less than or equal to 10 %.

6.25.2 Equipment

Testing requires:

- Test standards (e.g. test gas of suitable concentration)

6.25.3 Testing

During the first 14 days of the field test, measurements at zero point and at test value 2 shall be performed at least every two days. During the rest of the field test, these measurements shall be performed at least every two weeks. Five successive measurements shall be carried out. The long-term drift is then determined from the mean values of the last four measurements. During the field test, no adjustments of the zero point and the reference point shall be carried out.

6.25.4 Evaluation

The long-term drift at the zero point $D_{l,z}$ is calculated using the following equation:

$$D_{l,z} = (x_{z,1} - x_{z,0}) \qquad \text{(Eq. 6.19)}$$

The long-term drift at test value 2 $D_{l,s}$ is calculated using the following equation:

$$D_{l,s} = \frac{(x_{s,1} - x_{s,0}) - D_{l,z}}{x_{s,1}} * 100 \qquad \text{(Eq. 6.20)}$$

The standard uncertainty $u_{d,l,la}$ due to the long-term drift at level of the annual limit value is calculated according to:

$$u_{d,l,l_a} = \frac{D_{l,s}}{100} * \frac{l_a}{\sqrt{3}} \qquad \text{(Eq. 6.21)}$$

Where:

$D_{l,z}$ the long term drift at zero point, in µg/m³;

$x_{z,0}$ the mean value of the measurements at the zero point at the beginning of the drift period, in µg/m³;

$x_{z,1}$ the mean value of the measurements at the zero point at the end of the drift period, in µg/m³;

$D_{l,s}$ the long-term drift at test-value 2, in %;

$x_{s,0}$ the mean value of the measurements at test value 2 at the beginning of the drift period, in µg/m³;

$x_{s,1}$ the mean value of the measurements at test value 2 at the end of the drift period, in µg/m³;

$u_{d,l,la}$ the standard measurement uncertainty due to the long-term drift at the annual limit value, in µg/m³;

l_a the annual limit value, in µg/m³.

6.25.5 Assessment

Minimum requirement met? yes

6.25.6 Documentation

During the first two weeks of the field test, five measurements cycles of zero air and test gas (benzene concentration of approx. 35.1 µg/m³) were performed every two or three days. During the rest of the field test these measurements were perform every one or two weeks. For evaluation of the long-term drift four measurement cycles were used in each case. The first measurement cycle was discarded.

The results of the long-term drift test are shown in Tab. 6.15 and Tab. 6.16.

Tab. 6.13: Long-term drift $D_{l,z}$ at zero point

	GC 80001	**GC 80004**
	$D_{1,z}$, in µg/m³	**$D_{1,z}$, in µg/m³**
Mean value	-0.01	-0.01
Minimum value	0.00	0.00
Maximum value	**-0.01**	**-0.02**

Tab. 6.14: Long-term drift $D_{l,s}$ at test value 2 (set point: 35.1 µg/m³)

	GC 80001		**GC 80004**	
	$D_{1,s}$, in %	**$u_{d,l,la}$, in µg/m³**	**$D_{1,s}$, in %**	**$u_{d,l,la}$, in µg/m³**
Mean value	-1.78	-	-0.28	-
Minimum value	-0.15	-	0.10	-
Maximum value (after 3 month)	**-7.76**	**-0.22***	**-4.64**	**-0.13***

*Values are used to calculate the total measurement uncertainty

The specified drift limit was not exceeded by both gas chromatographs in the field test (see Fig. 6.5 and Fig. 6.6). Therefore, three months are set as the maintenance interval.

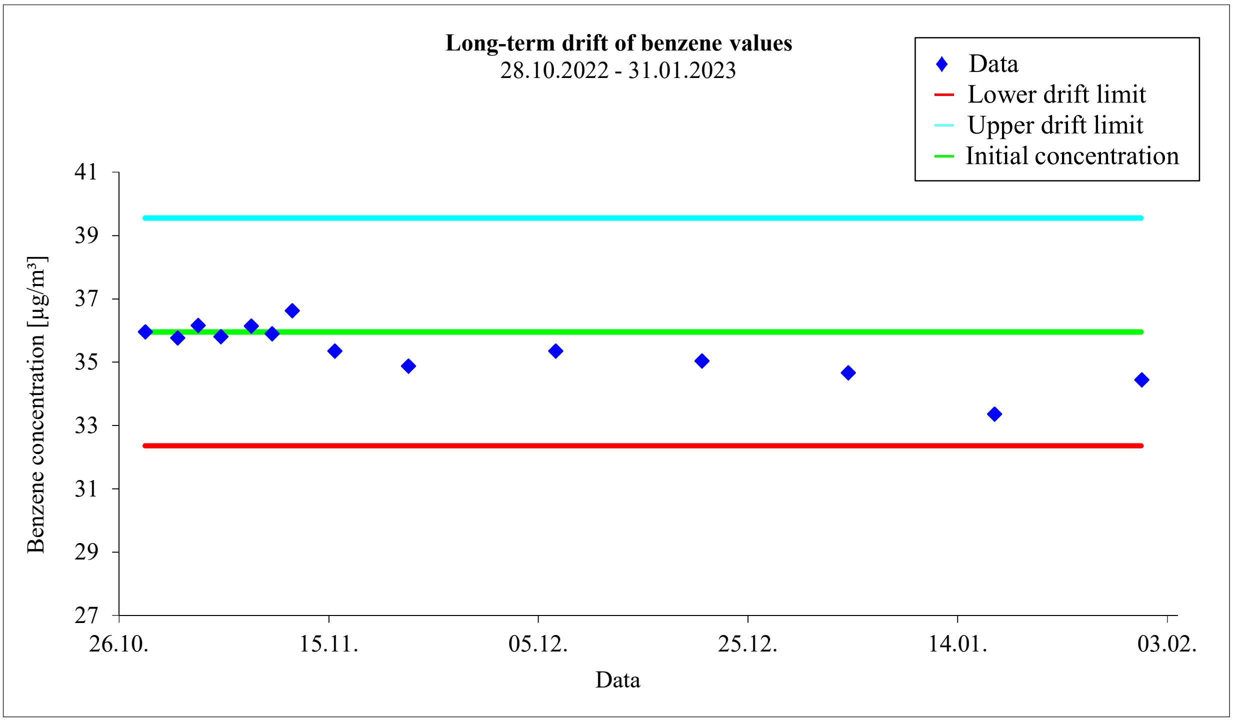


Fig. 6.3: Long term drift $D_{l,s}$ at test value 2 (set point: 35.1 µg/m³) - GC 80001

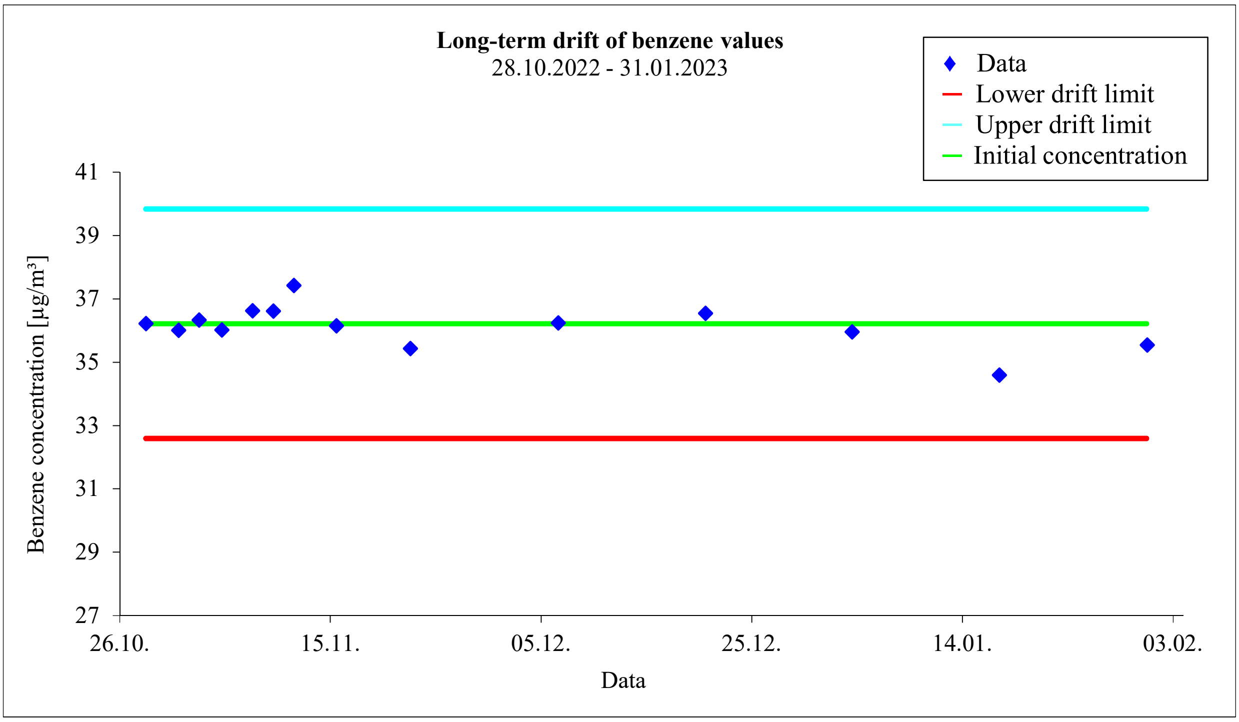


Fig. 6.4: Long term drift $D_{l,s}$ at test value 2 (set point: 35.1 µg/m³) - GC 80004

6.26 Reproducibility standard deviation under field conditions

6.26.1 Minimum requirement (DIN EN 14662-3: 2016-02 chapter 8.5.5)

The reproducibility standard deviation under field conditions $s_{r,f}$ of the two devices shall be less than or equal to 0.25 µg/m³.

6.26.2 Equipment

Testing requires:

- Test standards (e.g. test gas of suitable concentration)

6.26.3 Testing

The standard deviation under field conditions is determined during the three-month field test. The simultaneous, continuous measurements with two identical measuring devices shall be performed at the same site as a double determination. For taking the air samples, a common sampling system may be used. The sampling system shall allow both measuring devices to make a representative measurement of the same ambient air sample. This reduces systematic errors caused by spatial and/or temporal inhomogeneities of the mass concentration distribution of the measured objects in the ambient air. The output signals of the measuring systems shall be recorded with electronic data storage as single measured values.

6.26.4 Evaluation

The reproducibility standard deviation under field conditions is calculated from the measured values of the three-month period.

The difference $\Delta x_{f,i}$ for each (i-th) parallel measurement is calculated according to:

$$\Delta x_{f,i} = x_{f,1,i} - x_{f,2,i} \qquad \text{(Eq. 6.22)}$$

The reproducibility standard deviation under field conditions $s_{r,f}$ is calculated as follows:

$$s_{r,f} = \sqrt{\frac{\sum_{i=1}^{n} \Delta x_{f,i}^2}{2n}} \qquad \text{(Eq. 6.23)}$$

The standard uncertainty $u_{r,\,f}$ due to the reproducibility under field conditions at the annual limit value is calculated according to:

$$u_{r,f} = s_{r,f} \qquad \text{(Eq. 6.24)}$$

Where:

$\Delta x_{f,i}$	the i-th difference in a parallel measurement, in µg/m³;
$x_{f,1,i}$	the i-th measurement result of device 1, in µg/m³;
$x_{f,2,i}$	the i-th measurement result of device 2, in µg/m³;
$s_{r,f}$	the reproducibility standard deviation under field conditions, in µg/m³;
n	the number of parallel measurements.

6.26.5 Assessment

Minimum requirement met? yes

6.26.6 Documentation

All values of the ambient air measurements during the field test were used for evaluation. The data for functional check with test gas and zero gas were not included.

The determined data used to calculate the standard deviation are summarized in Tab. 6.17.

Tab. 6.15: Data used to calculate the reproducibility standard deviation under field conditions

	GC 80001	**GC 80004**
Number of parallel measurements n	8782	
Mean difference Δx_f, in µg/m³	-0.13	
Mean benzene concentration, in µg/m³	0.98	1.11
Maximum benzene concentration, in µg/m³	17.53	19.53
$s_{r,f}$ = $u_{r,f}$, in µg/m³	**0.17***	

*Values are used to calculate the expanded measurement uncertainty

Fig. 6.7 shows the data obtained from the two gas chromatographs during the field test.

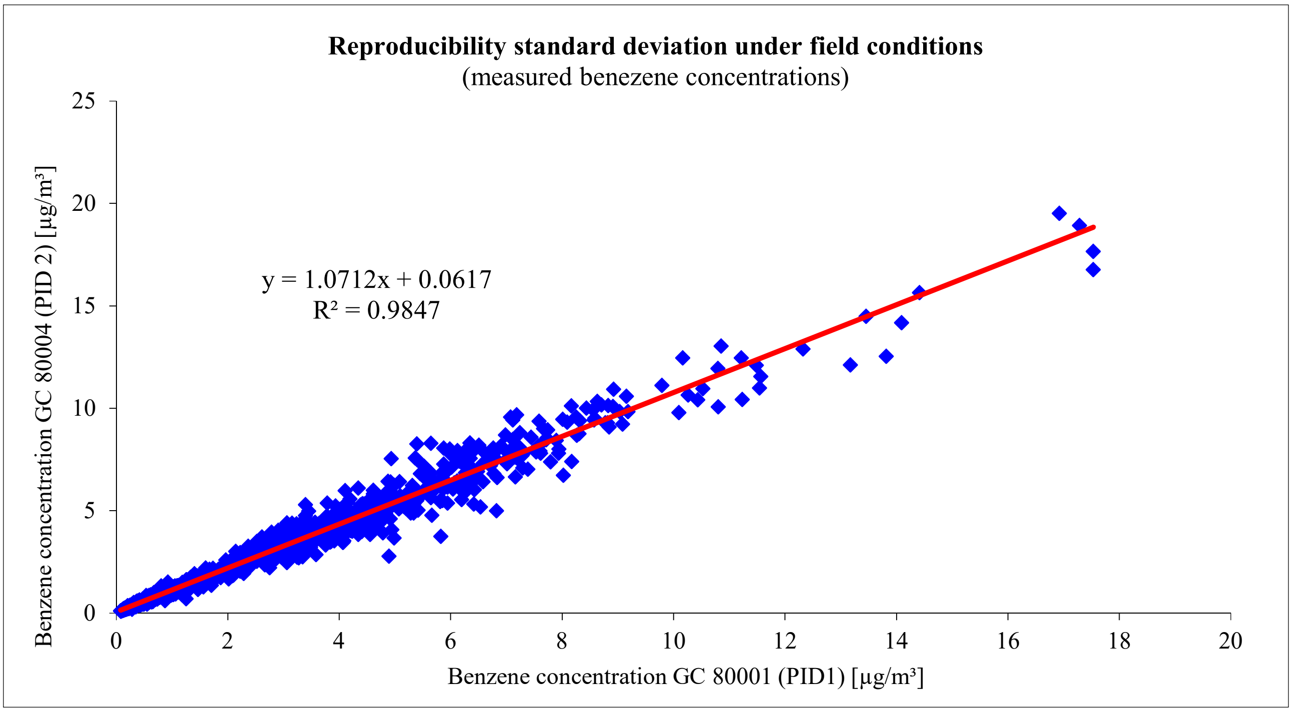


Fig. 6.5: Benzene concentrations measured during the field test

6.27 Period of unattended operation

6.27.1 Minimum requirement (DIN EN 14662-3: 2016-02 chapter 8.5.6)

The control interval is either the period of time in which the drift is within the performance criterion for long-term drift or the manufacturer's specified maintenance interval, whichever is shorter.

6.27.2 Equipment

Testing requires:

- Test standards (e.g. zero gas and test gas of suitable concentration)

6.27.3 Testing

During the field test, it shall be determined which maintenance work is required at which intervals to ensure the proper functioning of the measuring system As far as no maintenance work at shorter intervals is necessary in terms of equipment, the maintenance interval essentially results from the drift behavior of the measuring device (see Chap. 6.25).

If one of the measuring instruments malfunctions during the field test, these shall be determined and corrected. The field test shall be restarted if the malfunction has an effect on the determination of the maintenance interval.

6.27.4 Evaluation

The respective measured values are compared with the start values. The deviations are determined for the zero point and the reference point. The end of the maintenance interval is reached when the deviations exceed the permissible drift.

A shorter maintenance interval than the one determined by the drift analysis is given if other maintenance work is required at shorter intervals.

6.27.5 Assessment

No maintenance work was required on the measuring devices during the three-month field test. The carrier gas consumption (nitrogen 5.0) is approx. 15 ml/min per device. This results for a 50-liter compressed gas cylinder in a service life of more than one year.

The maintenance interval is determined only by the drift behavior of the measuring devices. (see Chap. 6.25). During the measurement period of 95 days, the specified drift limit was not exceed by both gas chromatographs. For this reason, three months are set as the maintenance interval.

Minimum requirement met? yes

6.27.6 Documentation

See Chap. 6.25.

6.28 Availability

6.28.1 Minimum requirement (DIN EN 14662-3: 2016-02 chapter 8.5.7)

The availability of the measuring system shall be determined during the field test and shall be at least 90 %.

6.28.2 Equipment

No additional equipment is required.

6.28.3 Testing

The availability of the measuring system shall be determined in the field test. The start and end time of the field test shall be documented. Furthermore, all interruptions of the test, e.g. due to malfunctions or maintenance work, shall be documented with the respective start and end times.

6.28.4 Evaluation

From the difference between the end time and the start time, the operating time shall be calculated as the reference time of availability. Furthermore, the times in which the device did not provide any usable measured values shall be determined.

The total time period with useable measuring data is the period during which valid measuring data of the ambient air concentrations are obtained. The time needed for calibration, conditioning of sample lines and filters and maintenance shall not be considered.

The availability of the device shall be calculated according to the following equation:

$$A = \frac{t_\mathrm{u}}{t_\mathrm{t}} \cdot 100\ \% \qquad \text{(Eq. 6.25)}$$

Where:

A the availability of the device;

t_u the total time period with valid measured values, in h;

t_t the total time period of the field test minus time for calibration, conditioning and maintenance, in h.

6.28.5 Assessment

Minimum requirement met? yes

6.28.6 Documentation

The field test was carried out in the period from 28.10.2022 to 31.01.2023 at the LUBW test site. During this time, a function check was carried out by externally connecting zero gas and test gas at intervals of two or three days during the first two weeks. After the first two weeks, the function check was carried out every one or two weeks.

The results for calculating availability are summarized in Table 6.18.

Tab. 6.16: Data needed for the determination of the availability of GC 80001 and GC 80004

		GC 80001	**GC 80004**
Start of the field test		28.10.2022; 10:30 AM	
End of the field test		31.01.2023; 03:00 PM	
Total time t_E*	h:min	2238:00	2238:00
Calibration time t_K	h:min	42:30	42:30
Failure time t_A	h:min	0:00	0:00
Maintenance time t_W	h:min	0:00	0:00
Availability A.	**%**	**100**	**100**

With: $t_u = t_E - t_A - t_K - t_W$ and $t_t = t_E - t_K - t_W$

*During the field test, various maintenance work had to be carried out at the station and on the sampling system. Furthermore, there were problems with the dosing of benzene. Since this led to an impairment of the measurements, the corresponding measured values were not taken into account in the evaluations. This resulted in a failure of 46 h30°min. The field test was accordingly extended by three days.

6.29 Expanded Uncertainty

6.29.1 Minimum requirement (DIN EN 14662-3: 2016-02 chapter 8.6 und annex E)

The expanded measurement uncertainty of the device shall be determined. The determined value shall not exceed the requirements of the EU daughter directives for air quality (data quality requirement: for benzene, a maximum value of 25% for the relative expanded uncertainty is allowed for continuous measurements).

6.29.2 Equipment

No additional equipment is required.

6.29.3 Testing

The expanded uncertainty of the measured values shall be compile together for the determined performance characteristics during the performance test of the instruments.

6.29.4 Evaluation

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

a) The value of each individual performance characteristic tested in the laboratory shall fulfil the criterion stated in Table 1 of the DIN EN 14662-3: 2016-02.

b) The expanded measurement uncertainty calculated from the standard uncertainties based on the values of the specific performance characteristics determined in the laboratory tests shall fulfil the criterion of 25 % (for fixed measurements) given in Annex I to Directive 2008/50/EC. This criterion is the maximum permissible uncertainty of individual measurements for continuous measurements at the limit value.

c) The value of each of the individual performance characteristics tested in the field shall fulfil the criterion stated in Table 1 of the DIN EN 14662-3: 2016-02.

d) The expanded measurement uncertainty calculated from the standard uncertainties based on the values of the specific performance characteristics determined in the laboratory and field tests shall fulfil the criterion of 25 % (for fixed measurements) given in Annex I to Directive 2008/50/EC. This criterion is the maximum permissible uncertainty of individual measurements for continuous measurements at the limit value.

The instrument can be type approved when all four requirements are met.

The combined standard uncertainty u_c shall be calculated according to:

$$u_c = \sqrt{\sum u_i^2} \qquad \text{(Eq. 6.26)}$$

The absolute expanded uncertainty U shall be calculated according to:

$$U = k * u_c \qquad \text{(Eq. 6.27)}$$

The relative expanded uncertainty W shall be calculated according to:

$$W = \frac{U}{l_a} * 100\% \qquad \text{(Eq. 6.28)}$$

Where:

u_c the combined standard uncertainty, in µg/m³;

u_i the partial contribution to the combined standard uncertainty, in µg/m³;

U the absolute expanded uncertainty, in µg/m³;

k the expansion factor (here k=2) with a confidence level of 95 %;

W the relative expanded uncertainty, in %;

l_a the annual limit value, in µg/m³.

The uncertainties listed below are to be included in the calculation of the expanded measurement uncertainty after the laboratory tests (Tab. 6.19) and after the laboratory and field tests (Tab. 6.20), respectively.

Tab. 6.17: Standard uncertainties included in the calculation of the expanded measurement uncertainty after the laboratory tests

Standard uncertainty due to	**Symbol**
Repeatability standard deviation at annual limit value	u_r
Deviation of linearity at annual limit value	u_l
Change of the sample gas pressure at annual limit value	u_{gp}
Change of the surrounding temperature at annual limit value	u_{st}
Change of the electrical voltage at annual limit value	u_V
Interfering component H_2O (at 19 mmol/mol) at annual limit value	u_{H2O}
Memory effect	u_m
Difference sample/calibration port	$u_{\Delta sc}$
Uncertainty of the test gas	u_{cg}

Tab. 6.18: Standard uncertainties included in the calculation of the expanded measurement uncertainty after the laboratory and field tests

Standard uncertainty due to	**Symbol**
Repeatability standard deviation at annual limit value[a]	u_r
Deviation of linearity at annual limit value	u_l
Change of the sample gas pressure at annual limit value	u_{gp}
Change of the surrounding temperature at annual limit value	u_{st}
Change of the electrical voltage at annual limit value	u_V
Interfering component H_2O (at 19 mmol/mol) at annual limit value	u_{H2O}
Memory effect	u_m
Reproducibility standard deviation under field conditions[a]	$u_{r,f}$
Long-term drift at annual limit value	$u_{d,l,la}$
Difference sample/calibration port	u_{Dsc}
Uncertainty of the test gas	u_{cg}

[a] For the calculation of the combined standard uncertainty, either the uncertainty due to the repeatability standard deviation at the annual limit value or the uncertainty due to the reproducibility standard deviation under field conditions has to be taken, whichever is greater.

6.29.5 Assessment

Minimum requirement met? yes

6.29.6 Documentation

The calculation of the expanded uncertainty was carried out according to the requirements of Annex E of the DIN EN 14662-3: 2016-02. Tab. 6.21 and Tab. 6.22 show the expanded measurement uncertainties of the laboratory tests and the laboratory and field tests, respectively, which were calculated using the process parameters determined in the laboratory and field tests.

Tab. 6.19: Expanded measurement uncertainties for GC 80001

Parameter	Minimum requirement	Value		Given benzene-conc. C_t		Sensitivity coefficient		X_{min}		X_{max}		u		u^2	
Repeatability standard deviation	≤ 0,25 µg/m³	0,02	µg/m³	5,3	µg/m³							0,005	µg/m³	0,00002	(µg/m³)²
Largest deviation of linearity	≤ 5,0 %	-2,15	%	2,7	µg/m³							-0,06	µg/m³	0,004	(µg/m³)²
Change of the sample gas pressure	≤ 0,1 (µg/m³)/kPa	0,07	(µg/m³)/kPa	36,2	µg/m³	0,07	(µg/m³)/kPa	80	kPa	110	kPa	0,16	µg/m³	0,027	(µg/m³)²
Change of the surrounding temperature	≤ 0,08 (µg/m³)/K	0,03	(µg/m³)/K	38,7	µg/m³	0,03	(µg/m³)/K	273	K	303	K	0,06	µg/m³	0,003	(µg/m³)²
Change of the electrical voltage	≤ 0,08 (µg/m³)/V	0,001	(µg/m³)/V	36,2	µg/m³	0,00	(µg/m³)/V	210	V	245	V	0,002	µg/m³	0,000003	(µg/m³)²
Interfering component H_2O (19 mmol/mol)	≤ 0,015 (µg/m³)/(mmol/mol)	0,012	(µg/m³)/(mmol/mol)	5,3	µg/m³	0,0121	(µg/m³)/(mmol/mol)	0,6	Vol-%	2,1	Vol-%	0,162	µg/m³	0,02615	(µg/m³)²
Carry over (memory-effect)	≤ 1,0 µg/m³	0,10	µg/m³	44,5	µg/m³							0,01	µg/m³	0,00004	(µg/m³)²
Reproducibility standard deviation under field conditions	≤ 0,25 µg/m³	0,17	µg/m³									0,17	µg/m³	0,03	(µg/m³)²
Long term drift at span-value	≤ 10,0 %	-7,8	%	35,1	µg/m³							-0,22	µg/m³	0,050	(µg/m³)²
Short term drift at span-value	≤ 2,0 µg/m³	0,32	µg/m³	36,2	µg/m³										
Difference sample/calibration port*	≤ 1,0 %	k. A.	%												
Maintenance interval	14 Tage	3	Monate												
Availability	≥ 90 %	100,00	%												
test gas	k. A.	2,1	%									0,05	µg/m³	0,003	(µg/m³)²

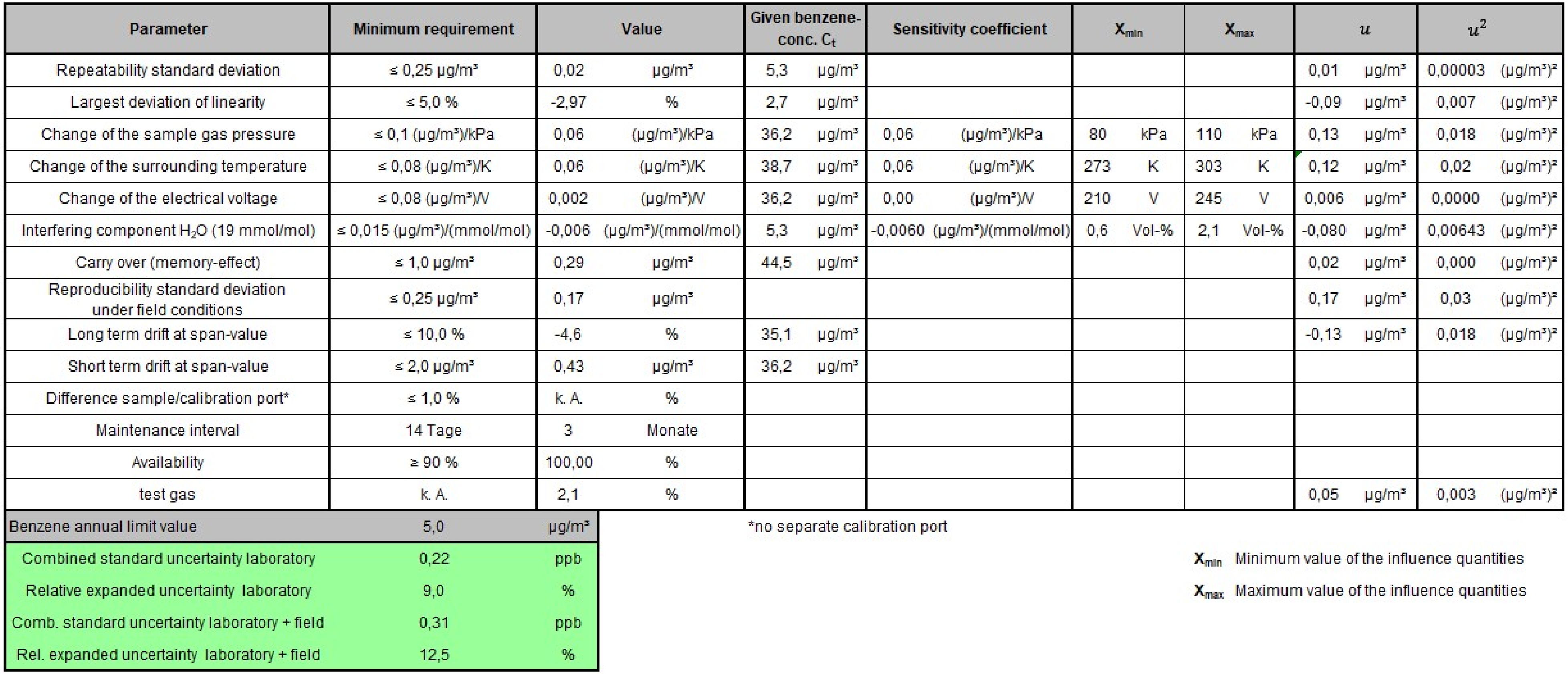
Benzene annual limit value	5,0	µg/m³
Combined standard uncertainty laboratory	0,25	ppb
Relative expanded uncertainty laboratory	10,1	%
Comb. standard uncertainty laboratory + field	0,38	ppb
Rel. expanded uncertainty laboratory + field	15,1	%

*no separate calibration port

X_{min} Minimum value of the influence quantities

X_{max} Maximum value of the influence quantities

Tab. 6.20: Expanded measurement uncertainties for GC 80004



Parameter	Minimum requirement	Value	Given benzene-conc. C_t	Sensitivity coefficient	X_{min}	X_{max}	u	u^2
Repeatability standard deviation	≤ 0,25 µg/m^3	0,02 µg/m^3	5,3 µg/m^3				0,01 µg/m^3	0,00003 (µg/m^3)^2
Largest deviation of linearity	≤ 5,0 %	-2,97 %	2,7 µg/m^3				-0,09 µg/m^3	0,007 (µg/m^3)^2
Change of the sample gas pressure	≤ 0,1 (µg/m^3)/kPa	0,06 (µg/m^3)/kPa	36,2 µg/m^3	0,06 (µg/m^3)/kPa	80 kPa	110 kPa	0,13 µg/m^3	0,018 (µg/m^3)^2
Change of the surrounding temperature	≤ 0,08 (µg/m^3)/K	0,06 (µg/m^3)/K	38,7 µg/m^3	0,06 (µg/m^3)/K	273 K	303 K	0,12 µg/m^3	0,02 (µg/m^3)^2
Change of the electrical voltage	≤ 0,08 (µg/m^3)/V	0,002 (µg/m^3)/V	36,2 µg/m^3	0,00 (µg/m^3)/V	210 V	245 V	0,006 µg/m^3	0,0000 (µg/m^3)^2
Interfering component H_2O (19 mmol/mol)	≤ 0,015 (µg/m^3)/(mmol/mol)	-0,006 (µg/m^3)/(mmol/mol)	5,3 µg/m^3	-0,0060 (µg/m^3)/(mmol/mol)	0,6 Vol-%	2,1 Vol-%	-0,080 µg/m^3	0,00643 (µg/m^3)^2
Carry over (memory-effect)	≤ 1,0 µg/m^3	0,29 µg/m^3	44,5 µg/m^3				0,02 µg/m^3	0,000 (µg/m^3)^2
Reproducibility standard deviation under field conditions	≤ 0,25 µg/m^3	0,17 µg/m^3					0,17 µg/m^3	0,03 (µg/m^3)^2
Long term drift at span-value	≤ 10,0 %	-4,6 %	35,1 µg/m^3				-0,13 µg/m^3	0,018 (µg/m^3)^2
Short term drift at span-value	≤ 2,0 µg/m^3	0,43 µg/m^3	36,2 µg/m^3					
Difference sample/calibration port*	≤ 1,0 %	k. A. %						
Maintenance interval	14 Tage	3 Monate						
Availability	≥ 90 %	100,00 %						
test gas	k. A.	2,1 %					0,05 µg/m^3	0,003 (µg/m^3)^2

Benzene annual limit value	5,0	µg/m^3
Combined standard uncertainty laboratory	0,22	ppb
Relative expanded uncertainty laboratory	9,0	%
Comb. standard uncertainty laboratory + field	0,31	ppb
Rel. expanded uncertainty laboratory + field	12,5	%

*no separate calibration port

X_{min} Minimum value of the influence quantities

X_{max} Maximum value of the influence quantities

AED SYNTECH SPECTRAS

1.1 Order data

Serial number	80001		
Model	GCX55		
Type	601		
Orderd by	Synspec BV	Customer nr.:	
Order number		Our order nr.:	
Order date			
Delivery date	1-1-2021		

1.2 GC description

		Serial number
Application	BTEX	
Detector 1	PID	P302
Detector 2	-	
Valve 1	AFP ELDV2	147823007
Valve 2	-	
Pump	KNF-NMP830 KNDC	16.12509264
Sample system	Steursma V02	
Sample loop (ml)		
Precon system	Graphsphere 2016	
MFC	Bronkhorst IQ+	M20209146G
Oven	Isothermal	
Analysis column type	CP70003	1025589
Analysis column packing	SY-1	
Analysis column length (m)	26	
Backflush column type	CP70003	
Backflush column packing	SY-1	
Backfush column length (m)	4	

1.3 Hardware and software data

Industrial computer type	ASRock SBC-210			
Processor type	Intel® Baytrail /Baytrail-I SoC Processor			
Memory	4Gb			
Hard disk type	InnoDisk Corp. - mSATA 3ME4 ATA Device			
Hard disk size	64GB			
Oparating system	Windows 10 Enterprise LTSC 2019			
Oparating system service pack				
Oparating system version	GCX55-W10-64B-V01			
Oparating system language	English (United States)			
Watch dog version	WDAUTO			
GC software version	6.4.2.19			
GC software language	Duits			
MX board version	9			
PIC software versions	010B	0204	0305	1.9
Options	temperature controller board firmware V3 2018			

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1.4 General data

AED SYNTECH SPECTRAS

1.1 Order data

Serial number	80004		
Model	GCX55		
Type	601		
Orderd by	Synspec BV	Customer nr.:	
Order number		Our order nr.:	
Order date			
Delivery date	1-1-2021		

1.2 GC description

		Serial number
Application	BTEX	
Detector 1	PID	
Detector 2	-	
Valve 1	AFP ELDV2	
Valve 2	-	
Pump	KNF-NMP830 KNDC	16.12509294
Sample system	Steursma V02	2430
Sample loop (ml)		
Precon system	Graphsphere 2016	
MFC	Bronkhorst IQ+	
Oven	Isothermal	
Analysis column type	CP70003	1025736
Analysis column packing	SY-1	
Analysis column length (m)	26	
Backflush column type	CP70003	
Backflush column packing	SY-1	
Backfush column length (m)	4	

1.3 Hardware and software data

Industrial computer type	ASRock SBC-210	
Processor type	Intel® Baytrail /Baytrail-I SoC Processor	
Memory	4Gb	
Hard disk type	InnoDisk Corp. - mSATA 3ME4 ATA Device	
Hard disk size	64GB	
Oparating system	Windows 10 Enterprise LTSC 2019	
Oparating system service pack		
Oparating system version	GCX55-W10-64B-V01	
Oparating system language	English (United States)	
Watch dog version	WDAUTO	
GC software version	6.4.2.19	
GC software language	Duits	
MX board version	9	
PIC software versions	010B 0204 0305 1.9	
Options	Temperature controller board firmware V3 2018	

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1.4 General data