TÜV RHEINLAND ENERGY GMBH

Deutsche Akkreditierungsstelle
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Report on the performance test of the VOC72e ambient air quality measuring system for benzene manufactured by ENVEA

TÜV Report No. 936/21244174/A
Cologne, 13 June 2019

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Report on the performance test of the VOC72e ambient air quality measuring system for benzene manufactured by ENVEA

AMS designation:	VOC72e
Manufacturer:	ENVEA 111 Bd Robespierre 78300 Poissy France
Test period:	November 2018 to June 2019
Date of report:	Cologne, 13 June 2019
Report Number:	936/21244174/A
Editor:	Dipl.-Ing. Martin Schneider martin.schneider@de.tuv.com
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Scope of the report:	Report:	110	pages
	Manual	110	
	Manual	138	pages
	Total	255	pages

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1. Summary and certification proposal

1.1 Summary Overview

ENVEA commissioned TÜV Rheinland Energy GmbH to submit the VOC72e air quality monitor for benzene to performance testing. The test was performed in respect of the following standards and requirements:

- VDI Guideline 4202 part 1: Performance test, declaration of suitability, and certification of point-related measuring systems for gaseous air pollutants of April 2018
- EN 14662 part 3: Ambient air – Standard method for the measurement of benzene concentrations – Automated pumped sampling with in situ gas chromatography, German version of November 2015

The VOC72e measuring system tested here uses in situ gas chromatography to measure benzene. The measuring principle thus corresponds to the EU reference method described in standard EN 14662, part 3. The tests were performed in a laboratory and in a three-months field test in Cologne. The following measuring ranges were tested:

Table 1: Measuring ranges tested

Measured components:	measuring range in [µg/m³] [1]	Measuring range in [ppb] or [nmol/mol]
Benzene	0 - 50	0 - 15.4

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

The requirements defined in the standards mentioned were complied with during performance testing.

TÜV Rheinland Energy GmbH therefore recommend the instrument’s approval as a performance-tested measuring system for continuous monitoring of air quality affected by benzene.

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:

VOC72e for benzene

Manufacturer:

ENVEA, Poissy, France

Field of application:

For continuous ambient air monitoring of benzene (stationary operation)

Measuring ranges during performance testing:

Component	Certification range	Unit
Benzene	0 - 50	µg/m³

Software version:

1.0.a

Restriction:

None

Note:

1. Given its measuring principle, the instrument does not provide a life zero.
2. The test report on performance testing is available on the internet at www.qal1.de.

Test Report:

TÜV Rheinland Energy GmbH, Cologne
Report no.: 936/21244174/A dated Cologne, 13 June 2019

1.3 Summary report on test results

Performance criterion	Requirement	Test result	Satisfied	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 instrument front.	yes	27
7.3.2 Calibration inlet	The measuring system may have a test gas inlet separate from the sample gas inlet.	The measuring system does not have a test gas inlet separate from the sample gas inlet at the instrument back. Test gases have to be fed to the instrument via the sample inlet.	yes	28
7.3.3 Easy maintenance	Maintenance should be possible without larger effort, if possible from outside.	Maintenance takes reasonable effort and is possible with standard tools.	yes	29
7.3.4 Functional check	Particular instruments required to this effect shall be considered as part of the measuring system and be applied in the corresponding sub-tests and included in the assessment.	The tested measuring system does not have internal devices for operating the functional check.	not applicable	30
7.3.5 Set-up times and warm-up times	The instruction manual shall include specifications in this regard.	Set-up times and warm-up times have been determined.	yes	31
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	33
7.3.7 Unintended adjustment	Shall secure measuring system against that.	The measuring system is secured against unintended and unauthorised adjustment of instrument parameters by way of a password.	yes	34
7.3.8 Data output	The output signals shall be provided digitally and/or as analogue signals.	Measured signals are provided as analogue (0–20 mA, 4–20 mA or 0–1 V, 0–10 V) and digital signals (via TCP/IP, RS 232, USB).	yes	35
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 access.	Digital transmission of measured values operates correctly.	yes	36

Performance criterion	Requirement	Test result	Satis-fied	Page
Data transmission protocol	Shall meet the requirements stipulated in Table 1 of VDI Guideline 4202 part 1.	By default, the measuring system comes with an installed Modbus protocol. Measured and status signals are transmitted correctly.	yes	37
7.3.11 Measuring range	The upper limit of measurement shall be greater or equal to the upper limit of the certification range.	The measuring range for benzene is set to 0–50 µg/m³ by default. Different measuring ranges up to 0–1000 µg/m³ are also possible. The measuring system's upper limit of measurement exceeds the upper limit of the certification range in each case.	Yes	38
7.3.12 Negative output signals	May not be suppressed (life zero).	Given its measuring principle, the measuring system is unable to output negative measured signals.	not applicable	39
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. No outflow of operating materials (H2 carrier gas in this case) was detected.	yes	40
7.3.14 Operating states	The measuring system shall allow their control by telemetrically transmitted status signals.	The measuring system provides various ports to ensure comprehensive monitoring and control via an external computer.	yes	41
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	43
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	44

Performance criterion	Requirement	Test result	Satis-fied	Page
7.4 Requirements on performance characteristics for testing in the laboratory				
7.4.1 General requirements	The manufacturer's specifications in the instruction manual shall not contradict the results of the performance test.	Tests were performed using the performance characteristics specified in VDI standard 4202, part 1 (2018) and standard EN 14662 (2015).	yes	45
7.4.2 Test requirements	Has to comply with the requirements set out in VDI standard 4202-1:2018.	Tests were performed using the performance characteristics specified in VDI standard 4202, part 1 (2018) and standard EN 14662 (2015).	yes	46
Section 8.4 provides a summary of the evaluation of performance characteristics determined in the laboratory.				
7.5 Requirements on performance characteristics for testing in the field				
7.5.1 General requirements	Has to comply with the requirements set out in VDI standard 4202-1:2018.	Tests were performed using the performance characteristics specified in VDI standard 4202, part 1 (2018) and standard EN 14662 (2015).	not applicable	61
7.5.2 Location for the field test	The monitoring station for the field test is to be chosen according to the requirements of 39. 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.	The field test location was selected in compliance with the 39th BImSchV.	Yes	62
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	63
Section 8.5 provides a summary of the evaluation of performance characteristics determined in the laboratory.				

Performance criterion	Requirement	Test result	Satis-fied	Page
8.4 Procedures for determination of the performance characteristics during the laboratory test according to EN 14662				
8.4.3 Short-term drift	Short-term drift at a test gas concentration of 70–80% of the certification range shall not exceed 2.0 µg/m³ over a period of 12 h. For benzene measuring system, short term drift only needs to be determined at reference point.	Short-term drift at reference point was -0.125 µg/m³ for instrument 1 and -0.216 µg/m³ for instrument 2.	yes	71
8.4.4 Repeatability standard deviation	Repeatability standard deviation at zero point shall be tested at a concentration of 10% of the annual limit value and shall not exceed 0.20 µg/m³. The repeatability standard deviation at reference point shall not exceed 0.25 µg/m³.	Repeatability standard deviation at 10% of the annual limit value was at 0.006 µg/m³ for instrument 1 and 0.010 µg/m³ for instrument 2. Repeatability standard deviation at the annual limit value was at 0.012 µg/m³ for instrument 1 and 0.010 µg/m³ for instrument 2.	yes	73
8.4.5 Lack of fit of linearity of the calibration function	The deviation from the linearity of the calibration function at zero shall not exceed 0.5 µg/m³ At concentrations above zero, it shall not exceed 5% of the measured value.	The deviation from the linear regression line for instrument 1 is 0.049 µg/m³ at zero point and no more than 2.205% of the target value for concentrations above zero. The deviation from the linear regression line for instrument 2 is 0.038 µg/m³ at zero point and no more than 1.398% of the target value for concentrations above zero.	yes	75
8.4.6 Sensitivity coefficient to sample gas pressure	The sensitivity coefficient of sample gas pressure at reference point shall not exceed 0.10 (µg/m³l)/kPA.	For instrument 1, the sensitivity coefficient to sample gas pressure is 0.035 (µg/m³)/kPa. For instrument 2, the sensitivity coefficient to sample gas pressure is 0.035 (µg/m³)/kPa.	yes	80
8.4.7 Sensitivity coefficient to surrounding temperature	The sensitivity coefficient of surrounding temperature shall not exceed 0.08 (µg/m³)/K.	The sensitivity coefficient to ambient temperature did not exceed the requirement of 0.08 (µg/m³)/K. For the uncertainty calculation the largest sensitivity coefficient bst is selected for both instrument. For instrument 1, this is 0.053 (µg/m³)/K and for instrument 2 it is 0.029 µg/m³.	yes	82

Performance criterion	**Requirement**	**Test result**	**Satis-fied**	**Page**
8.4.8 Sensitivity coefficient of electrical voltage	The sensitivity coefficient of electrical voltage shall not exceed 0.08 (µg/m³)/V.	At no criterion did the sensitivity coefficient to electrical voltage bv exceed the requirements specified in standard EN 14662-3 of 0.08 (µg/m³)/V. For the uncertainty calculation, bv was at 0.000 (µg/m³)/V for instrument 1 and 0.001 (µg/m³)/V for instrument 2.	yes	85
8.4.9 Interferents	Interfering substances at a concentration c_t (annual limit value = 5 µg/m³ for benzene). The maximum permissible deviation for the mixture of organic interferents is ≤ 0.025 µg/m³. The maximum permissible deviation for H_2O is ≤ 0.015 µg/m³/(mmol/mol).	For the influence of humidity, the cross sensitivity value for the test gas value ct is -0.003 µg/m³ for instrument 1 and -0.002 µg/m³ for instrument 2. For the influence of the mixture of organic compounds, the cross sensitivity value for the test gas value ct is -0.181 µg/m³ for instrument 1 and -0.102 µg/m³ for instrument 2.	yes	87
8.4.10 Memory effect)	The benzene concentration of the second zero gas analysis immediately following the analysis of a high benzene concentration shall not exceed 1.0 µg/m³. As a performance criterion for the presence of benzene in the measuring instrument (memory effect), VDI 4202-1 (2018) requires a value of < 10 % of the limit value (= 0.5 µg/m³) for the first analysis after switching to zero gas. At < 1.0 µg/m³, the limit specified by standard EN 14662-3 (2016) is less strict.	The average value cm is at 0.134 µg/m³ for instrument 1 and 0.128 µg/m³ for instrument 2. Thus the requirements of both standard DIN 14662-3 (2016) and VDI 4202-1 (2016) are complied with.	yes	90
8.4.11 Difference sample/calibration port	The difference between the sample and calibration ports shall not exceed 1.0%.	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	92

Performance criterion	**Requirement**	**Test result**	**Satis-fied**	**Page**
8.5 Determination of the performance characteristics during the field test according to EN 14662-3				
8.5.4 Long-term drift	The long-term drift at zero point shall not exceed ≤ 0.5 µg/m³. Long-term drift at span level shall not exceed 10% of the certification range.	Maximum long-term drift at zero point $Dl_{,z}$ was at 0.07 µg/m³ for instrument 1 and 0.04 µg/m³ for instrument 2. Maximum long-term drift at reference point $Dl_{,s}$ was at 3.15% for instrument 1 and 3.51% for instrument 2.	yes	93
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 supply of the required carrier gas medium (hydrogen) must be ensured. EN 14662-3 requires checking of zero and span points at least once every two weeks.	yes	100
8.5.5 Reproducibility standard deviation for benzene under field conditions	Reproducibility standard deviation under field conditions shall not exceed 0.25 µg/m³ of the mean value over a period of three months.	The reproducibility standard deviation for benzene under field conditions was at 0.186 µg/m³. Thus, the requirements of EN 14662-3 are satisfied.	yes	97
8.5.7 Period of availability of the analyser	Availability of the analyser shall be at least 90%.	The availability is 100%. Thus, the requirement of EN 14662-3 is satisfied.	yes	101

2. Task Definition

2.1 Nature of the test

ENVEA commissioned TÜV Rheinland Energy GmbH to submit the VOC72e air quality monitor to performance testing. The test was carried out as a complete performance test.

2.2 Objectives

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

Component	Certification range	Unit
Benzene	0 – 50 [1)]	µg/m³

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

The VOC72e measuring system uses in-situ gas chromatography to measure benzene.

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

- VDI standard 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 14662 part 3: Ambient air – Standard method for the measurement of benzene concentrations – Automated pumped sampling with in situ gas chromatography, German version of November 2015

3. Description of the AMS tested

3.1 Measuring principle

The VOC72e measuring system analyses volatile organic compounds. The AMS' measuring principle is based on gas chromatography for the separation of the measured compounds coupled with photo-ionisation detection.

Figure1: Illustration of the VOC72e measuring system

A gas trap filled with a specific sorbent is used for sampling. The sample flow through the trap is about 12 ml/min which gives a sampled volume of 165 ml with the standard 15 minute cycle (sampling time > 90 % of cycle time). A bypass flow (approx. 35 ml/min) is added in order to maintain a sample input flow when the trap is not sampling

A bypass flow (approx. 35 ml/min) is added in order to maintain a sample input flow when the trap is not sampling. The compounds are thermally desorbed and flushed with nitrogen into the gas chromatography column. Then the trap is cooled with a fan for a new sampling cycle.

Inside the gas chromatography column, the compounds are moved forward by the nitrogen flow (the mobile phase) and retained by the internal coating (the stationary phase) causing a selective retardation of the compounds. In order to achieve an optimal separation within a minimal time, the gas chromatography column follows a multi ramp thermal cycle from a cold step (25°C) for the injection to a hot step (160°C). This multi-ramp thermal cycle aims at eliminating heavy compounds (i.e. compounds with a high boiling point): At the end of the hot step, the gas chromatography column is cooled to the cold step for the next injection.

The gas chromatography column output is connected to a photo-ionisation detector, where the compound concentration is converted into an electric signal. This signal is amplified and digitised by the electrometer board built into the instrument. The time recording of this signal is the chromatogram, which exhibits a peak for each detected compound.

The chromatographic peaks are detected and integrated with a baseline correction. The peak timing (retention time) is also recorded. When a peak retention time falls into a compound retention time window, this peak is identified as caused by that compound. The peak area is corrected with the calculated volume taken from the gas trap. This calculation is based on the trap pressure during sampling. A correction of the atmospheric pressure is also carried out in order to include the response of the PID detector.

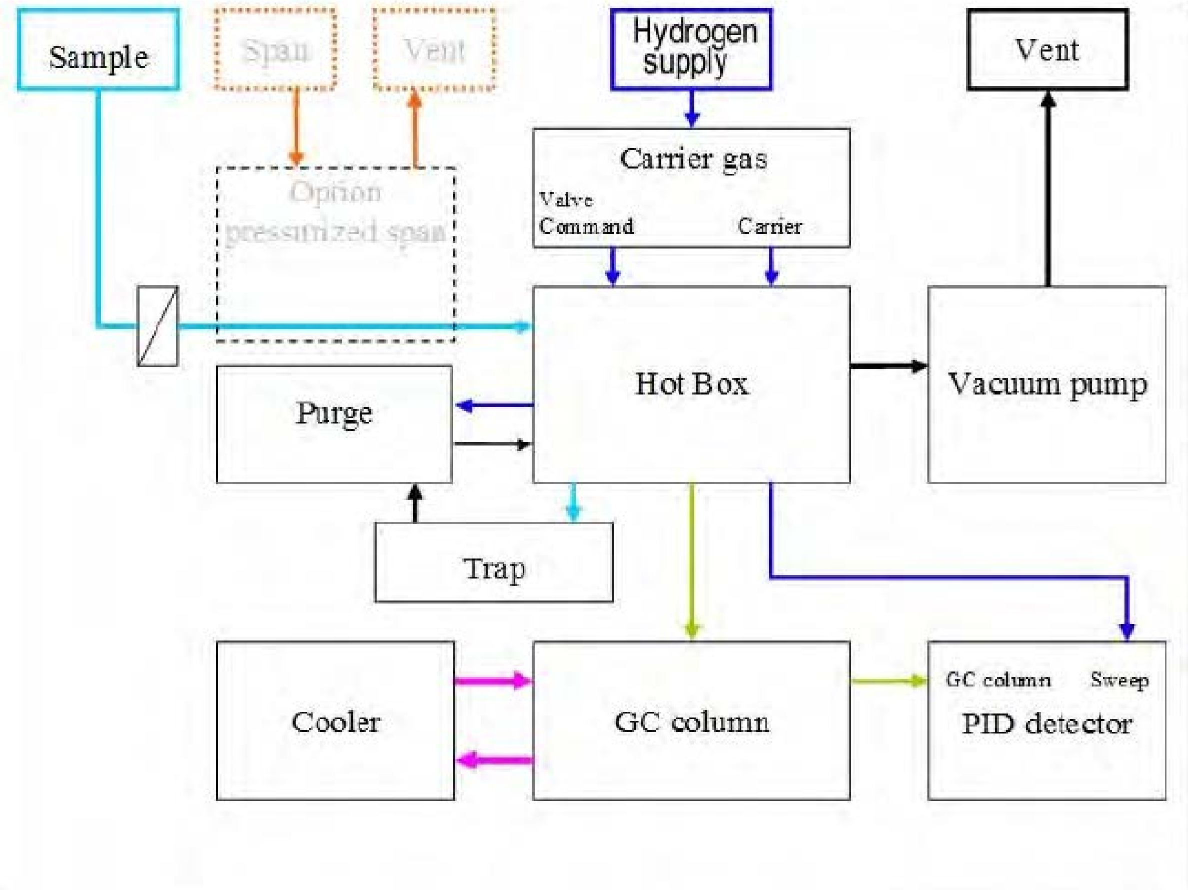
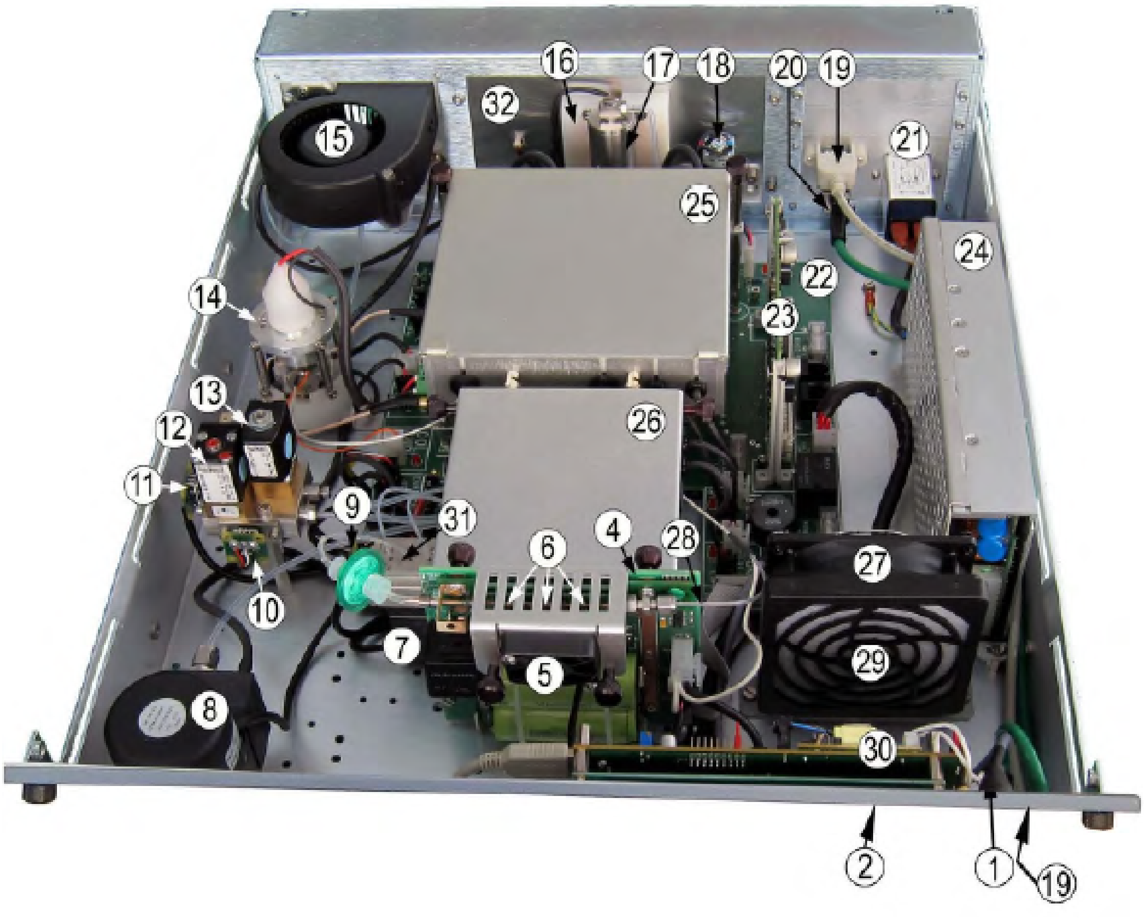


Figure 2: Flow chart of VOC72e

3.2 AMS scope and set-up

The VOC72e ambient air quality measuring system consists of a compact housing. The measuring system is operated via a display at the front of the instrument. The user is able to check measurement data and instrument information, change parameters and check correct functionality of the AMS.



(1) ON-OFF switch, (2) LCD display, (3) sensitive 6-key keyboard, (4) desorber board, (5) trap cooling fan, (6) trap, (7) purge solenoid valve, (8) vacuum pump, (9) trap pressure sensor, (10) pressure sensor of chromatography column, (11) pressure sensor if hydrogen input, (12) proportional solenoid valve, (13) pilot solenoid valve, (14) photo-ionization detector (PID), (15) internal cooling fan, (16) thermo cooler assembly, (17) expansion tank, (18) cooling pump, (19) USB port, (20) Ethernet output, (21) mains socket, (22) interconnection board, (23) module board, (24) 24V DC power supply, (25) GC column box, (26) Hot box, (27) mixing fan, (28) transfer line, (29) dust filter, (30) ARM20 board, (31) purge assembly, (32) heat sink.

Figure 3: *Inside view of the VOC72e*

Table 2 lists a number of important instrument characteristics of the VOC72e.

Table 2: VOC72e instrument characteristics (manufacturer specification)

Measuring scale	Max 1000 µg/m³ (programmable)
Units	ppb or µg/m³ (programmable)
Measured compounds	Benzene (tested), plus toluene, ethene benzene, m+p-xylene, o-xylene (not performance tested)
Analysis cycle time	15 min during performance testing, further intervals are programmable
Sample flow rate	50 ml/minute
Trap flow; trap volume	12 ml/minute; (165 ml in a 15-minute cycle)
Flow control	Internal vacuum pump + heated micro capillary
Sampling rate	>90 % of cycle duration
Trap adsorbent / sampling temperature	Carbopack® / 35 °C
Desorption temperature / heating rate	380 °C / >160 °C / second
Injection valve	6-port (heated), pneumatically controlled
Chromatography column Carrier gas control Temperature control Cooling	Stainless steel 15 m x 0.25 mm x 1µm apolar Electronic pressure control 20 - 170 °C ± 0.1 °C, 5 ramps up to 30 °C/minute Liquid heat exchanger and thermo-electric cooler
Detector Temperature control	Photo-ionisation (PID) 10.6 eV with nitrogen curtain 140 °C (programmable)
Analogue outputs	4 analogue outputs 0- 1 V, 0 – 10 V, 0 – 20 mA, 4 – 20 mA 4 analogue outputs 0 – 2.5 V
Ethernet port	RJ45 socket, UDP protocol
Digital outputs	USB, RS232 and RS422
Input voltage	100 – 240 V + ground; 50 – 60 Hz
Power	Average 130 VA, peak 200 VA
Gas supply	Hydrogen 5.5; 3.2 ± 0.2 bar; 15 ml/minute
Dimensions (l x w x h)/weight	606 x 483 x 133 mm / 12.5 kg

3.3 AMS settings during performance testing

The measuring system was commissioned according to manufacturer instructions. No internal adjustment cycle was activated during performance testing. Hydrogen served as carrier gas. One analysis cycle took 15 minutes.

4. Test programme

4.1. General

Two identical VOC72e instruments with the following serial numbers were submitted to performance testing:

Instrument 1: SN 323 and
Instrument 2: SN 324

The tests were performed with software version „1.0.a".

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.

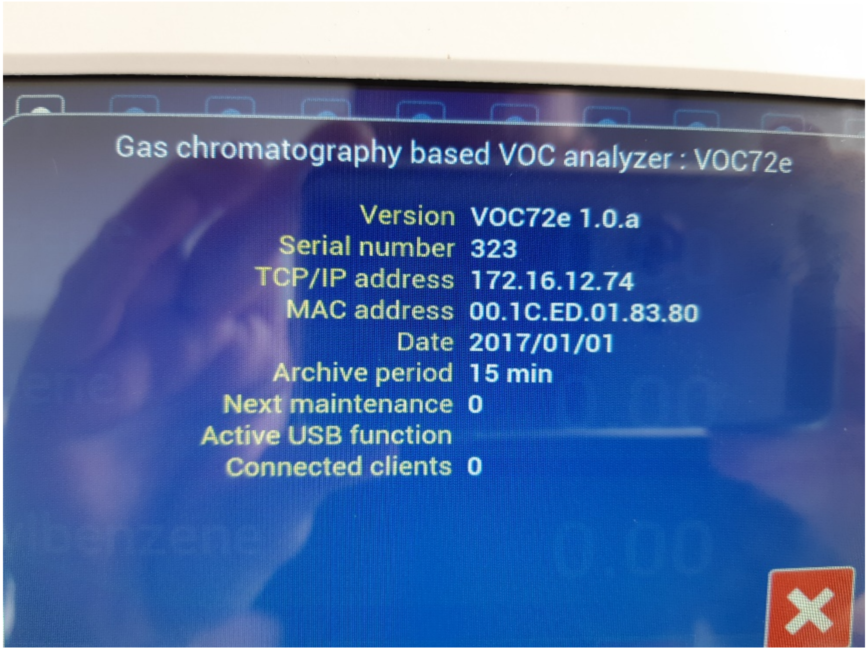


Figure 4: Software version of the tested VOC72e instruments

4.2 Laboratory test

The laboratory test was carried out with two identical instruments, type VOC72e, with serial numbers S/N 323 and SN: 324. Standards [1] and [2] specify the following test programme for the laboratory test:

- Description of instrument functions
- General requirements
- Short-term drift
- Repeatability standard deviation
- Linearity
- Sensitivity coefficient of sample gas pressure
- Sensitivity coefficient to the surrounding temperature
- Sensitivity coefficient of electrical voltage
- Interferents
- Memory effect

Measured values were recorded using an external data logger.

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

4.3 Field test

The field test was performed between 11/02/2019 and 21/05/2019 using two identical VOC72e measuring systems. The instruments used were identical with those used for laboratory testing. The serial numbers were:

instrument 1:	SN 323
instrument 2:	SN 324

The following test programme was determined for the field test:

- Long-term drift
- Inspection interval
- Period of availability of the analyser
- Reproducibility standard deviation

Measured values were recorded using an external data logger.

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

5. Reference Measurement Method

5.1 Method of measurement

Test gases used for adjustment purposes during the test

Certified benzene test gases were used to test the performance criteria. The specified test gases were used during the entire test and, where necessary, were diluted with the help of a (type Hovacal) mass flow controller.

Test gas bottle (S/N 4378141) 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 C_6H_6:	**28.7 µg/m³ in synth. air**
Number of test gas cylinder:	4378141
Manufacturer / date of manufacture:	Linde / 18/09/2018
Stability guarantee / certified:	12 months
Checking of the certificate by / on:	20/11/2018 / UBA Langen Calibration certificate No. 063-2018
Measurement uncertainty as per calibration certificate:	+/- 1.4 µg/m³

Test gas C_6H_6:	**117.1 µg/m³ in synth. air**
Number of test gas cylinder:	3841706
Manufacturer / date of manufacture:	Linde / 18/09/2018
Stability guarantee / certified:	12 months
Checking of the certificate by / on:	Proprietary laboratory / 03/12/2018
Rel. uncertainty according to certificate:	5 %

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 instrument front.

6.5 Assessment

The measuring system has an operative measured value display at the instrument front.
Criterion satisfied? yes

6.6 Detailed presentation of test results

Figure 5 shows the tested AMS with integrated measured value display.

Figure 5: Tested VOC72e instrument 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 measuring system does not have a test gas inlet separate from the sample gas inlet at the instrument back. Test gases have to be fed to the instrument via the sample inlet.

6.5 Assessment

The measuring system does not have a test gas inlet separate from the sample gas inlet at the instrument back. Test gases have to be fed to the instrument via the sample inlet.

Criterion satisfied? not applicable

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.3.3 Easy maintenance

Necessary maintenance of the measuring systems should be possible without larger 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 maintenance work to be carried out regularly according to the AMS manufacturer is listed in Chapter 4 (Preventive Maintenance) of the operation manual. 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. Hydrogen normal pressure as well as instrument parameters such as pressure, temperature and voltage supply should be checked regularly (~ every two weeks).
3. The internal sample filter and the filter of the internal fan should be replaced every two months.
4. The heat sink should be checked for contamination every 2 months and cleaned if necessary. During the performance test reported on here, it was not necessary to clean the heat sink.

The steps required to carry out preventive maintenance work are described in detail in Chapter 4 of the operation manual.

6.5 Assessment

Maintenance takes reasonable effort and is possible with standard tools.

Criterion satisfied? yes

6.6 Detailed presentation of test results

The work on the instruments was carried out during the test on the basis of the intervals and work procedures described in the manual. 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 to the measuring system that they are ready for operation. It must be possible to control them directly or remotely.-

6.2 Equipment

Operation 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 reference 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

Operation 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 manual does not specify the set-up time. It will of course depend on the situation given at the site of installation as well as the local voltage supply. Since the VOC72e is a compact analyser, the set-up time is mainly determined by the following tasks:

- Connecting the AMS to supply voltage;
- The tubing (hydrogen, sampling, exhaust air)
- Establishing the hydrogen supply (H_2 purity 5.5, 3.2 bar inlet pressure).

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 ~1.5 h.

The warm-up time is specified in the manual as 15 minutes. This is the time needed to heat up the "Hot Box" and the detector and could be confirmed in the test. When switching on from a completely cold state, the instrument requires approx. 4–10 measuring cycles (corresponding to approx. 1 - 2 h) to stabilise the reading.

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.

The measuring system requires 5.5 (99.9995%) hydrogen during operation. The relevant safety instructions for handling hydrogen must be observed.

6.5 Assessment

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

It is possible to operate the measuring system at different locations with limited effort. Set-up time is 1.5 hours and warm-up time ranges between 1 and 2 hours depending on the necessary stabilisation.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable. The relevant safety instructions for handling hydrogen must be observed.

HAZARD INFORMATION for HYDROGEN

Hydrogen is the chromatography carrier gas of VOC72e.

When mixed with ambient air, hydrogen may IGNITE with a spark as soon as its VOLUMIC CONCENTRATION EXCEEDS **4%.**

AT HIGHER CONCENTRATIONS **(8%), the ignition may become EXPLOSIVE.**

Note : A non-hermetic room can tolerate without hazard a permanent hydrogen leak of at least 200ml / min (more than 10 times the hydrogen consumption of VOC72e) because hydrogen is a non-persistent gas that dilutes rapidly in the air unlike hydrocarbons that accumulate. The following SAFETY INSTRUCTIONS should therefore be applied to prevent the risk of massive hydrogen leak:

SAFETY INSTRUCTIONS

- Secure the hydrogen bottle to prevent it from falling and destruction of the regulator.
- Install the hydrogen cylinder and its pressure regulator outside the room where the VOC72e is located (under an outdoor shelter or in a ventilated room).
- If the cylinder is inside the room, connect the safety valve of the cylinder pressure regulator to an external vent.
- Connect the VOC72e to the hydrogen source by a small diameter stainless steel tube (1/16 "x 1/32" i.e. 1.6 x 0.8mm) in order to limit the hydrogen flow in case of important leak.
- Connect the VOC72e vent to an external vent. In normal operation, the VOC72e vent exhaust rejects a small amount of hydrogen, but if the pilot injection valve fails, the hydrogen flow rate can increase strongly.
- Install a hydrogen detector at 25% LEL (Lower Explosive Limit) in the room.

Figure 6: Information on handling hydrogen

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

Operation 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 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 operation manual.

The manufacturer has specified a maximum power consumption of approx. 130 W (peaks in energy demand of up to 200 W). The total energy requirement of the measuring system was determined in a 24-hour test. The specified values were not exceeded at any point during the test.

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 user 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 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

External data logger, PC

6.3 Testing

The test was carried out using an external analogue data logger and a PC which was connected to the measuring system via Ethernet.

The measuring system was connected to a PC via Ethernet to download the data to that PC. At the same time, the data were recorded and evaluated via an external analogue data logger. The test was performed by way of comparing the two data sets to each other and to the display.

In addition to the option of connecting the measuring system to a computer via Ethernet, there is also the option of outputting analogue signals (max. 4 analogue outputs) as well as outputting the measured signals / communication via serial interface RS 232 or RS422.

6.4 Evaluation

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

Output:	0–20 mA, 4–20 mA or 0-1 V, 0–10 V, selectable concentration range
Digital:	Modbus, RS232, RS485, USB, digital inputs and outputs, TCP/IP network

6.5 Assessment

Measured signals are provided as analogue (0–20 mA, 4–20 mA or 0–1 V, 0–10 V) and digital signals (via TCP/IP, RS 232, 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: Modbus, RS232, RS485, USB, 10 digital outputs, TCP/IP network. 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:

Modbus, RS232, RS485, USB, TCP/IP network

The digital output signals were checked using a PC connected to the measuring systems. All relevant pieces of information such as measured signals, status signals, measured component, measuring range, unit and further instrument information can be transmitted digitally.

Digital data retrieval always requires entry of the correct password.

6.5 Assessment

Digital transmission of measured values operates correctly.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion

6.1 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 shall allow to transmit at minimum the following data:
identification of the measuring system
identification of measured components
Unit
output signal with time signature (date and time)
operation and error status
operating commands for remote control of the measuring systems

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

6.2 Equipment

A PC

6.3 Testing

By default, the measuring system comes with an installed Modbus protocol (UDP protocol). The verification of the data transmission was checked together with the manufacturer when the measuring instruments were put into operation in the laboratory.

6.4 Evaluation

By default, the measuring system comes with an installed Modbus protocol. Measured and status signals are transmitted correctly. The Modbus commands are available to ENVEA customers on the Internet.

6.5 Assessment

By default, the measuring system comes with an installed Modbus protocol. Measured and status signals are transmitted correctly.

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 principle, measuring ranges of up to 0–1000 µg/m³ can be adjusted on the AMS.

Possible measuring range:	1000 µg/m³
Upper limit of the certification range for benzene:	50 µg/m³

6.5 Assessment

The measuring range for benzene is set to 0–50 µg/m³ by default. Different measuring ranges up to 0–1000 µg/m³ are also possible.

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

Criterion satisfied? Yes

6.6 Detailed presentation of test results

VDI standard 4202, part 1 and standard EN 14662-3 define the following minimum requirements for the certification ranges of continuous air quality monitoring systems for benzene:

Table 3: Certification ranges VDI 4202-1 and EN 14662-3

Measured components:	CR lower limit	CR upper limit	Limit value	Evaluation period
	in µg/m³	in µg/m³	in µg/m³	
Benzene	0	50	5	1 calendar year

6.1 7.3.12 Negative output signals

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

6.2 Equipment

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

6.3 Testing

The possibility of displaying negative signals was tested both in the laboratory and in the field test.

6.4 Evaluation

Given its measuring principle, the measuring system is unable to output measured values below zero.

6.5 Assessment

Given its measuring principle, the measuring system is unable to output negative measured signals.

Criterion satisfied? not applicable

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

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 signalled via various temperature alerts.

No outflow of operating materials (H_2 carrier gas in this case) was detected.

6.5 Assessment

On return of mains voltage, the instrument returns to normal operating mode and automatically resumes measuring. No outflow of operating materials (H_2 carrier gas in this case) was detected.

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 possesses various interfaces such as RS232, USB, digital and analogue inputs and outputs, TCP/IP network. A simple connection can be established between the analyser (VOC72e) and an external computer via a web browser. This enables telemetrically transferring data, adjusting configurations and displaying the analyser reading on the computer screen. In this mode it is possible to access and operate all the information and features from the analyser display via the computer. Moreover, “remote operation” provides a useful tool for checking instrument operational and parameter values.

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

Figure 7 shows the representation of a PC connected to the encoder via Ethernet.

Figure 7: Tested VOC72e instrument with PC

6.1 7.3.15 Switch-over

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

6.2 Equipment

Not required for this performance criterion.

6.3 Testing

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

6.4 Evaluation

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

6.5 Assessment

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 his obligation to communicate any changes to the instrument software to the test laboratory.

6.4 Evaluation

The current software version is displayed when switching on the instrument. It can also be viewed at any time in the information menu on the start screen of the measuring system.

The tests were performed with software version „1.0.a“.

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 4 shows the software version displayed by the measuring system.

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 39. 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 de-scribed in Section 8.4.

6.2 Equipment

Not required for this performance criterion.

6.3 Testing

Tests were performed using the performance characteristics specified in VDI standard 4202, part 1 (2018) and standard EN 14662 (2015).

6.4 Evaluation

Not applicable.

6.5 Assessment

Tests were performed using the performance characteristics specified in VDI standard 4202, part 1 (2018) and standard EN 14662 (2015).

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 be-fore 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 sys-tem, 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

Tests were performed using the performance characteristics specified in VDI standard 4202, part 1 (2018) and standard EN 14662 (2015).

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 particle filters.

Hydrogen served as carrier gas. One analysis cycle took 15 minutes.

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

6.5 Assessment

Tests were performed using the performance characteristics specified in VDI standard 4202, part 1 (2018) and standard EN 14662 (2015).

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.

In the case of benzene, the memory effect shall be determined instead of the response time.

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 14662 (2015). The reader is therefore referred to chapter 7.1 8.4.10 Memory effect).

6.4 Evaluation

See Section 7.1 8.4.10 Memory effect).

6.5 Assessment

See Section 7.1 8.4.10 Memory effect).

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.4.4 Short-term drift

Short-term drift at a test gas concentration of 70–80% of the certification range shall not exceed 2.0 µg/m³ over a period of 12 h.

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 14662-3 (2015). The reader is therefore referred to chapter 7.1 8.4.3 Short-term drift.

6.4 Evaluation

See chapter7.1 8.4.3 Short-term drift.

6.5 Assessment

See chapter 7.1 8.4.3 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

Repeatability standard deviation at zero point shall be tested at a concentration of 10% of the annual limit value and shall not exceed 0.20 µg/m³.
The repeatability standard deviation at reference point shall not exceed 0.25 µg/m³.

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 14662-3 (2015). The reader is therefore referred to chapter 7.1 8.4.4 Repeatability standard deviation.

6.4 Evaluation

See chapter 7.1 8.4.4 Repeatability standard deviation.

6.5 Assessment

See chapter 7.1 8.4.4 Repeatability standard deviation.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.4.6Linearity

The analytical function describing the relationship between the measured values and the desired values shall be linear. Reliable linearity is
The deviation from the linearity of the calibration function at zero shall not exceed 0.5 µg/m³ At concentrations above zero, it shall not exceed 5% 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 14662-3 (2015). The reader is therefore referred to chapter 7.1 8.4.5 Lack of fit of linearity of the calibration function.

6.4 Evaluation

See chapter 7.1 8.4.5 Lack of fit of linearity of the calibration function.

6.5 Assessment

See chapter 7.1 8.4.5 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 0.10 (µg/m³l)/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 14662-3 (2015). The reader is therefore referred to chapter 7.1 8.4.6 Sensitivity coefficient to sample gas pressure.

6.4 Evaluation

See chapter 7.1 8.4.6 Sensitivity coefficient to sample gas pressure.

6.5 Assessment

See chapter 7.1 8.4.6 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

No maximum sensitivity coefficient to sample gas temperature is specified for benzene.

6.2 Equipment

Not applicable

6.3 Testing

It is not required to determine and assess the sensitivity coefficient to sample gas temperature for benzene measuring systems.

6.4 Evaluation

Not applicable

6.5 Assessment

It is not required to determine and assess the sensitivity coefficient to sample gas temperature for benzene measuring systems.

Criterion satisfied? not applicable

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 0.08 (µg/m³)/K.

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 14662-3 (2015). The reader is therefore referred to chapter 7.1 8.4.7 Sensitivity coefficient to surrounding temperature.

6.4 Evaluation

See chapter7.1 8.4.7 Sensitivity coefficient to surrounding temperature.

6.5 Assessment

See chapter7.1 8.4.7 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 of electrical voltage shall not exceed 0.08 (µg/m³)/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 14662-3 (2015). The reader is therefore referred to chapter 7.1 8.4.8 Sensitivity coefficient to electrical voltage.

6.4 Evaluation

See chapter 7.1 8.4.8 Sensitivity coefficient to electrical voltage.

6.5 Assessment

See chapter 7.1 8.4.8 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 Interferents

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 reference point.

For measuring principles deviating from EN standards the absolute values of the sum of the positive and the sum of negative deviations caused by interfering components in the sample gas shall not exceed 3% of the upper limit of the certification range at zero and reference point. A value c_t at 70% to 80% of the upper limit of the certification range shall be used as reference point.

6.2 Equipment

Not applicable

6.3 Testing

Determination and evaluation of the Cross sensitivities corresponds exactly to determining the Interferents in accordance with standard EN 14662-3 (2015). The reader is therefore referred to chapter 7.1 8.4.9 Interferents.

6.4 Evaluation

See chapter 7.1 8.4.9 Interferents.

6.5 Assessment

See chapter 7.1 8.4.9 Interferents.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.4.12 Averaging effect

No maximum averaging effect has been specified for benzene.

6.2 Equipment

Not applicable

6.3 Testing

It is not required to determine and assess the sensitivity coefficient to sample gas temperature for benzene measuring systems.

6.4 Evaluation

Not applicable

6.5 Assessment

It is not required to determine and assess the sensitivity coefficient to sample gas temperature for benzene measuring systems.

Criterion satisfied? not applicable

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.4.13 Difference between sample and calibration port

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

6.2 Equipment

Not applicable

6.3 Testing

The VOC72e 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

Not applicable

6.5 Assessment

The VOC72e 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

The tested measuring system does not use a converter.

6.4 Evaluation

Not applicable

6.5 Assessment

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

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.4.15 Residence time in the analyser

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

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

6.2 Equipment

Not applicable

6.3 Testing

The system under test is no NO_x or ozone analyser. Thus, this criterion does not apply.

6.4 Evaluation

Not applicable

6.5 Assessment

The system under test is no NO_x or ozone analyser. Thus, this criterion does not apply.
Criterion satisfied? not applicable

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.5 Requirements on performance characteristics for testing in the field

6.1 7.5.1 General requirements

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

6.2 Equipment

Not required for this performance criterion.

6.3 Testing

Tests were performed using the performance characteristics specified in VDI standard 4202, part 1 (2018) and standard EN 14662 (2015).

6.4 Evaluation

Not applicable.

6.5 Assessment

Tests were performed using the performance characteristics specified in VDI standard 4202, part 1 (2018) and standard EN 14662 (2015).

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 7.5.2 Location for the field test

The monitoring station for the field test is to be chosen according to the requirements of 39. 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. The measuring station for the field test was located at a car park on the premises of TÜV Rheinland.

6.5 Assessment

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

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 ≤ 0.50 µg/m³.
The long-term drift at reference point c_t shall not exceed 10% 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 14662-3 (2015). The reader is therefore referred to chapter 7.1 8.5.4 Long-term drift.

6.4 Evaluation

See chapter 7.1 8.5.4 Long-term drift.

6.5 Assessment

See chapter 7.1 8.5.4 Long-term drift.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.5.5 Reproducibility standard deviation under field conditions

The standard deviation from paired measurements under field conditions shall be determined with two identical measuring systems by paired measurements in the field test.
The standard deviation under field conditions shall not exceed 0.25 µg/m³.

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 14662-3 (2015). The reader is therefore referred to chapter 7.1 8.5.5 Reproducibility standard deviation for benzene under field conditions.

6.4 Evaluation

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

6.5 Assessment

See chapter 7.1 8.5.5 Reproducibility standard deviation for benzene 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 14662-3 (2015). 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 90%.

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 14662-3 (2015). 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

Not applicable

6.3 Testing

The tested measuring system does not use a converter.

6.4 Evaluation

Not applicable

6.5 Assessment

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

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.6 Type approval and calculation of the measurement uncertainty

The type approval of the measuring system re-quires the following:

1) The value of each individual performance characteristic tested in the laboratory shall fulfil the criterion stated in Table C1 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 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 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.

6.2 Equipment

Not applicable

6.3 Testing

Uncertainty calculation was performed in line with standard EN 14662-3 (2016) and is presented in 7.1 8.6 Calculation of the total uncertainty in accordance with standard EN 14662-3 (2015) according to Annex E of EN 14662-3 (2016).

6.4 Evaluation

Uncertainty calculation was performed in line with standard EN 14662-3 (2016) and is presented in 7.1 8.6 Calculation of the total uncertainty in accordance with standard EN 14662-3 (2015) according to Annex E of EN 14662-3 (2016).

6.5 Assessment

Uncertainty calculation was performed in line with standard EN 14662-3 (2016) and is presented in 7.1 8.6 Calculation of the total uncertainty in accordance with standard EN 14662-3 (2015) according to Annex E of EN 14662-3 (2016).

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

7. Test results in accordance with standard EN 14662-3

7.1 8.4.3 Short-term drift

Short-term drift at a test gas concentration of 70–80% of the certification range shall not exceed 2.0 µg/m³ over a period of 12 h.
For benzene measuring systems, short term drift only needs to be determined at reference point.

7.2 Testing

After the time required for stabilisation, the measuring system is adjusted at a test gas concentration (approximately 70 % to 80 % of the maximum value of the benzene certification range). Five consecutive measurements shall be performed and the average of the last four measurements shall be calculated.

The analyser shall be kept running under the laboratory conditions with ambient air being measured. After a period of 12h, sample gas is applied to the measuring system again. Five consecutive measurements shall be performed and the average of the last four measurements shall be calculated.

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

$$D_{s,s} = x_{s,2} - x_{s,1}$$

Where:

$D_{s,s}$	is the 12h-drift of the signal at the test gas concentration
$D_{s,1}$	is the average concentration at the beginning of the drift period;
$D_{s,2}$	is the average concentration 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 14662-3 mentioned before. Pursuant to EN 14662-3, the test shall be performed at a concentration level of 70% to 80% of the certification range for benzene.

7.4 Evaluation

Table 4 indicates the measured value determined for the short-term drift.

Table 4: Results for the short-term drift

	requirements	device 1		device 2	
averange at zero at the beginning [µg/m³]	-	36.688		36.777	
averange at zero at the end (12h) [µg/m³]	-	36.563		36.561	
12-hour drift at span $D_{s,s}$ [µg/m³]	≤ 2,0	-0.125	✓	-0.216	✓

7.5 Assessment

Short-term drift at reference point was -0.125 µg/m³ for instrument 1 and -0.216 µg/m³ for instrument 2.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 5 and Table 6 present the individual test results.

Table 5: Individual results for the short-term drift 1 Test gas application:

at beginning		
span level		
	device 1	device 2
time	[µg/m³]	[µg/m³]
17:00:00	36,669*	36,750*
17:15:00	36.676	36.778
17:30:00	36.712	36.810
17:45:00	36.687	36.718
18:00:00	36.677	36.802
average	**36.688**	**36.777**

* EN 14662-3 requires that five consecutive measurements be performed and the average of the last four measurements be calculated.

Table 6: Individual results for the short-term drift 2 Test gas application:

after 12h		
span level		
	device 1	device 2
time	[µg/m³]	[µg/m³]
05:00:00	36,492*	36,458*
05:15:00	36.521	36.552
05:30:00	36.550	36.544
05:45:00	36.558	36.569
06:00:00	36.623	36.581
average	**36.563**	**36.561**

* EN 14662-3 requires that five consecutive measurements be performed and the average of the last four measurements be calculated.

7.1 8.4.4 Repeatability standard deviation

Repeatability standard deviation at zero point shall be tested at a concentration of 10% of the annual limit value and shall not exceed 0.20 µg/m³.
The repeatability standard deviation at reference point shall not exceed 0.25 µg/m³.

7.2 Test procedure

After the time required for stabilisation, the measuring system is adjusted at a test gas concentration (approximately 70 % to 80 % of the maximum value of the benzene certification range).

Eleven consecutive measurements shall be performed with test gas concentrations at 10% of the annual limit value level and test gas concentrations at the annual limit value level.

From the last 10 results of these measurements, the repeatability standard deviations (sr) at 10% of the annual limit value and at the annual limit value shall be calculated as follows:

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

Where:

s_r the repeatability standard deviation;

x_i the ith measurement;

$\overline{x}$ is the average of the 10 measurements;

n is the number of measurements.

The repeatability standard deviation is calculated separately for both series of measurements.

s_r shall meet the performance criterion indicated above both at 10% of the annual limit value and at the annual limit value.

The detection limit of the measuring system is calculated from the repeatability standard deviation at 10% of the annual limit value and the slope of the calibration function determined in accordance with Chapter 8.4.5 according to the following equation:

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

Where:

$l_{\det}$ is the detection limit of the measuring system, in µg/m³;

$s_{r,z}$ is the repeatability standard deviation at zero, in µg/m³;

B is the slope of the calibration function according to Annex A on the data from 8.4.5.

7.3 Testing

The test was performed in line with the requirements of EN 14662-3 mentioned before. In accordance with EN 14662-3, the test shall be carried out at a concentration level of 10% of the annual limit value (0.5 µg/m³ benzene) and at the annual limit value (5 µg/m³ benzene).

7.4 Evaluation

Table 7 presents the results for the repeatability standard deviation.

Table 7: Repeatability standard deviation VOC72e

	requirement	device 1		device 2	
repeatability standard deviation $s_{r,z}$ at 10% YLV [µg/m³]	≤ 0,20	0.006	✓	0.010	✓
repeatability standard deviation $s_{r,ct}$ at c_t [µg/m³]	≤ 0,25	0.012	✓	0.010	✓
detection limit [µg/m³]		0.019		0.032	

7.5 Assessment

Repeatability standard deviation at 10% of the annual limit value was at 0.006 µg/m³ for instrument 1 and 0.010 µg/m³ for instrument 2. Repeatability standard deviation at the annual limit value was at 0.012 µg/m³ for instrument 1 and 0.010 µg/m³ for instrument 2.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 8 lists the results of individual measurements.

Table 8: Individual test results obtained for the repeatability standard deviation

zero level		
	device 1	device 2
time	[µg/m³]	[µg/m³]
14:00:00	0,544*	0,509*
14:15:00	0.539	0.527
14:30:00	0.551	0.514
14:45:00	0.546	0.498
15:00:00	0.541	0.517
15:15:00	0.541	0.494
15:30:00	0.551	0.505
15:45:00	0.555	0.515
16:00:00	0.539	0.509
16:15:00	0.549	0.506
16:30:00	0.541	0.516
average	0.545	0.510

c_t level		
	device 1	device 2
time	[µg/m³]	[µg/m³]
14:00:00	5,036*	5,217*
14:15:00	5.023	5.215
14:30:00	5.033	5.223
14:45:00	5.032	5.210
15:00:00	5.039	5.202
15:15:00	5.053	5.217
15:30:00	5.046	5.187
15:45:00	5.034	5.208
16:00:00	5.024	5.205
16:15:00	5.027	5.204
16:30:00	5.012	5.208
average	5.032	5.208

* EN 14662-3 requires that eleven consecutive measurements be performed and the repeatability standard deviation be calculated from the last ten measurements.

7.1 8.4.5 Lack of fit of linearity of the calibration function

The analytical function describing the relationship between the measured values and the desired values shall be linear. Reliable linearity is
The deviation from the linearity of the calibration function at zero shall not exceed 0.5 µg/m³ At concentrations above zero, it shall not exceed 5% 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 90% 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 50% of the maximum of the certification range. At each concentration (including zero) at least four individual measurements shall be performed. The first measurement of each series shall not be included in the regression function.

The concentrations shall be applied in the following sequence: 50%, 10%, 30%, 5%, 90% and 0%. After each change in concentration, the first measurement is discarded.

The regression function and the deviations are calculated in accordance with Annex A of standard EN 14662-3. 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.

Is the individual x-value. The function $Y_i = a + B (X_i – X_z)$is converted to $Y_i = A + B * X_i$through the calculation of A:

$$A = a – B * X_z$$

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

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

Where:

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

The 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 14662-3 mentioned before.

7.4 Evaluation

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

Table 9: Deviations of the analytical function for benzene

	requirements	device 1		device 2	
largest value of the relative residuals r_{max} [%]	≤ 5,0	2.205	✓	1.398	✓
residual at zero r_z [µg/m³]	≤ 0,5	0.049	✓	0.038	✓

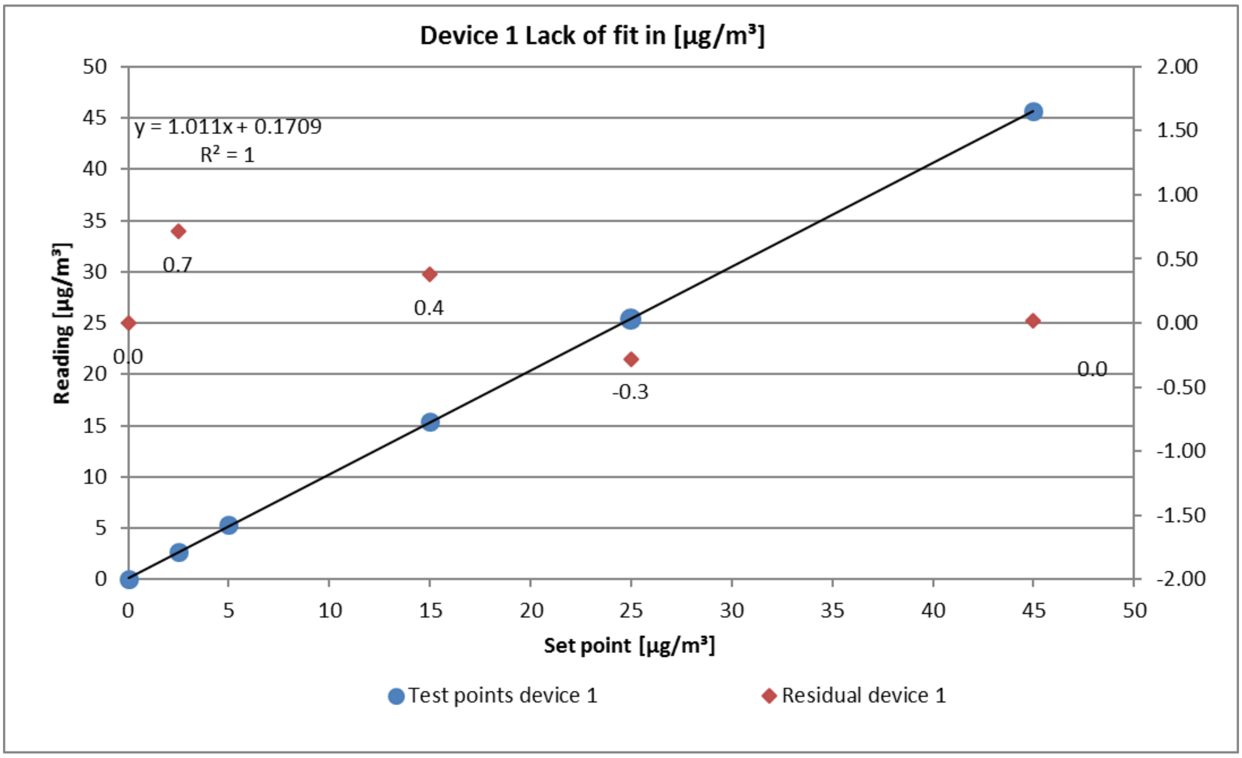


Figure 8: *Analytical function obtained from the group averages for system 1*

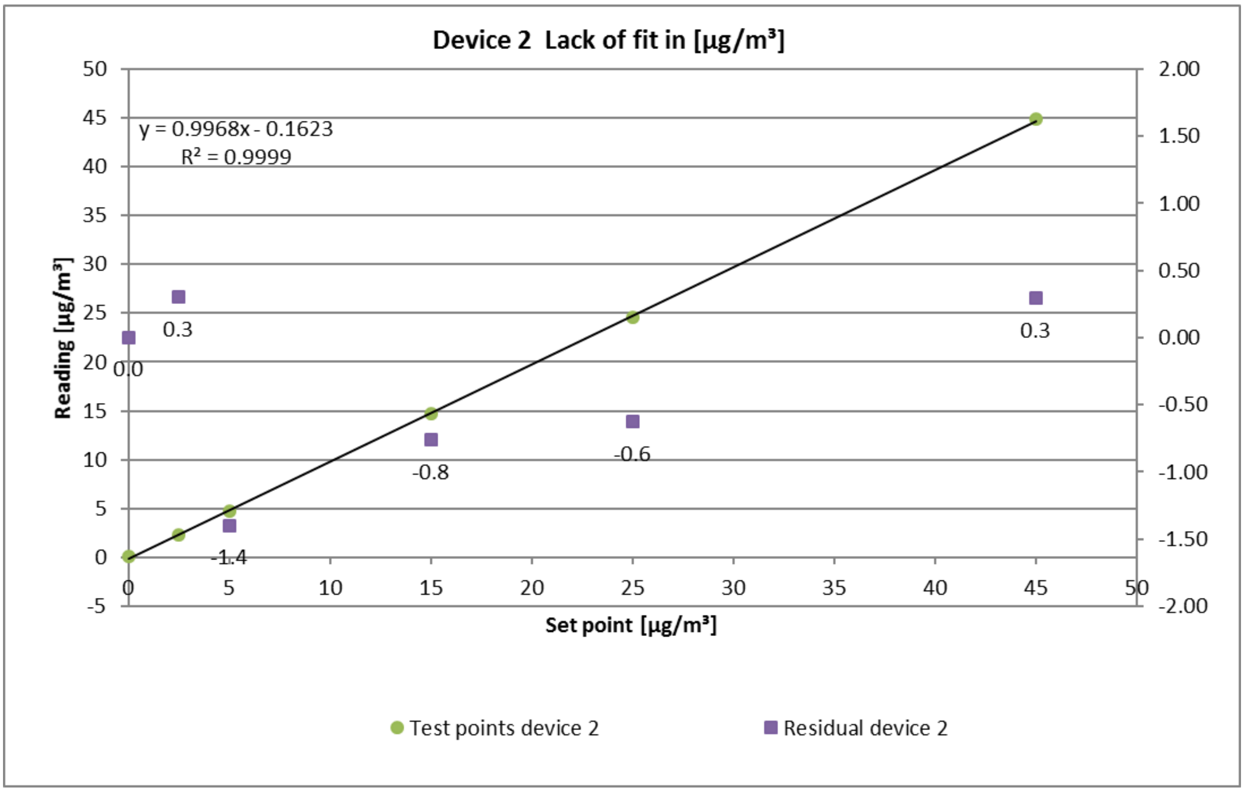


Figure 9: *Analytical function obtained from the group averages for system 2*

7.5 Assessment

The deviation from the linear regression line for instrument 1 is 0.049 µg/m³ at zero point and no more than 2.205% of the target value for concentrations above zero.

The deviation from the linear regression line for instrument 2 is 0.038 µg/m³ at zero point and no more than 1.398% 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 14662-3.

Criterion satisfied? Yes

7.6 Detailed presentation of test results

Table 10 presents the individual test results.

Table 10: Individual results of the lack-of-fit test

		device 1 [µg/m³]		device 2 [µg/m³]	
time	level [%]	actual value y_i	set value x_i	actual value y_i	set value x_i
10:00:00	50	25,410*	25.000	24,61*	25.000
10:15:00	50	25.387	25.000	24.564	25.000
10:30:00	50	25.404	25.000	24.622	25.000
10:45:00	50	25.374	25.000	24.594	25.000
11:00:00	50	25.340	25.000	24.626	25.000
average		25.376		24.602	
$r_{c,rel}$		-0.278		-0.626	
11:15:00	10	5,312*	5.000	4,781*	5.000
11:30:00	10	5.349	5.000	4.728	5.000
11:45:00	10	5.338	5.000	4.758	5.000
12:00:00	10	5.328	5.000	4.752	5.000
12:15:00	10	5.330	5.000	4.770	5.000
average		5.336		4.752	
$r_{c,rel}$		2.205		-1.398	
12:30:00	30	12,586*	15.000	11,697*	15.000
12:45:00	30	15.396	15.000	14.659	15.000
13:00:00	30	15.398	15.000	14.688	15.000
13:15:00	30	15.393	15.000	14.700	15.000
13:30:00	30	15.384	15.000	14.657	15.000
average		15.393		14.676	
r_z					
13:45:00	5	2,742*	2.500	2,358*	2.500
14:00:00	5	2.732	2.500	2.339	2.500
14:15:00	5	2.713	2.500	2.338	2.500
14:30:00	5	2.706	2.500	2.332	2.500
14:45:00	5	2.714	2.500	2.340	2.500
average		2.716		2.337	
$r_{c,rel}$		0.713		0.300	
15:00:00	90	45,503*	45.000	46,035*	45.000
15:15:00	90	45.694	45.000	46.262	45.000
15:30:00	90	45.651	45.000	44.742	45.000
15:45:00	90	45.647	45.000	44.159	45.000
16:00:00	90	45.697	45.000	44.145	45.000
average		45.672		44.827	
$r_{c,rel}$		0.014		0.294	
16:15:00	0	13,420*	0.000	12,177*	0.000
16:30:00	0	0.067	0.000	0.063	0.000
16:45:00	0	0.058	0.000	0.035	0.000
17:00:00	0	0.039	0.000	0.031	0.000
17:15:00	0	0.033	0.000	0.024	0.000
average		0.049		0.038	
$r_{c,rel}$		.-		.-	

* EN 14662-3 requires that four consecutive measurements be performed. After each change in concentration, the first measurement is discarded.

7.1 8.4.6 Sensitivity coefficient to sample gas pressure

The sensitivity coefficient of sample gas pressure at reference point shall not exceed 0.10 (µg/m³l)/kPA.

7.2 Test procedures

Five consecutive measurements of test gas (at a concentration of approximately 70 % to 80 % of the maximum benzene certification range) shall be performed at an absolute pressure of approximately (80 ± 0.2) kPa and at an absolute pressure of approximately (110 ± 0.2) kPa. For each pressure, the average from the last four measurements shall be calculated.

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

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

Where:

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

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

x_{P2} is the average concentration of the measurements at sampling gas pressure P_2;

P_1 is the lowest sample gas pressure

P_2 is the highest sample gas pressure

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

7.3 Testing

The test was performed in line with the requirements of EN 14662-3 mentioned before.

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 tee. The positive pressure was produced by blocking the bypass line. The test gas pressure was determined with the help of a pressure sensor located in the sample gas path.

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

7.4 Evaluation

The following sensitivity coefficients to sample gas pressure were determined:

Table 11: Sensitivity coefficient of sample gas pressure

	requirement	device 1		device 2	
sensitivity coeff. sample gas pressure b_{gp} [µg/m³/kPa]	≤ 0,10	0.035	✓	0.035	✓

7.5 Assessment

For instrument 1, the sensitivity coefficient to sample gas pressure is 0.035 (µg/m³)/kPa.
For instrument 2, the sensitivity coefficient to sample gas pressure is 0.035 (µg/m³)/kPa.
Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 12: Individual results of the sensitivity to changes in sample gas pressure

			device 1	device 2
time	pressure [kPa]	concentration	[µg/m³]	[µg/m³]
11:30:00	80	37.00	36,896*	36,898*
11:45:00	80	37.00	36.913	36.845
12:00:00	80	37.00	36.969	36.848
12:15:00	80	37.00	36.882	36.895
12:30:00	80	37.00	36.863	36.884
average C_{P1}			36.907	36.868
13:00:00	110	37.00	35,777*	35,779*
13:15:00	110	37.00	35.856	35.807
13:30:00	110	37.00	35.888	35.790
13:45:00	110	37.00	35.875	35.795
14:00:00	110	37.00	35.766	35.824
average C_{P2}			35.846	35.804

* EN 14662-3 requires that five consecutive measurements be performed and the average of the last four measurements be calculated.

7.1 8.4.7 Sensitivity coefficient to surrounding temperature

The sensitivity coefficient of surrounding temperature shall not exceed 0.08 (µg/m³)/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_1 = 20 °C;
3) at the maximum temperature T_{max} = 30 °C.

For these tests, a climate chamber is necessary.

The test shall be performed wit a test gas (~ 70% to 80% of the upper limit of the certification range). At this concentration, the measuring system must be adjusted to the prescribed target temperature (20 °C).

Five consecutive measurements are performed at each temperature. For each temperature, the first measurement in the series shall be discarded.

The sensitivity coefficient to the ambient temperature is calculated as follows:

$$b_{st} = \left|\frac{x_2 - x_1}{T_{S,2} - T_{S,1}}\right|$$

Where:

b_{st} is the sensitivity coefficient to ambient temperature

x_1 is the average of measurement at ambient temperature $T_{s,1}$

x_2 is the average of measurement at ambient temperature $T_{s,2}$

$T_{S,1}$ is the minimum ambient temperature

$T_{S,2}$ is the maximum ambient temperature

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

The requirement is that the values of x_1 and x_2 must not deviate by more than 2.5 µg/m³ from the level measured when adjusting the measuring system.

7.3 Testing

The test was performed in line with the requirements of EN 14662-3 mentioned before.

7.4 Evaluation

The following sensitivity coefficients to surrounding temperature have been determined:

Table 13: Sensitivity coefficients to surrounding temperature

	requirements	device 1		device 2	
sensitivity coefficient at 0 ºC for span level [µg/m³/K]	≤ 0,08	0.038	✓	0.029	✓
sensitivity coefficient at 30 ºC for span level [µg/m³/K]	≤ 0,08	0.053	✓	0.028	✓

As is evident from Table 13, the sensitivity coefficient to the surrounding temperature meets the performance criteria.

7.5 Assessment

The sensitivity coefficient to ambient temperature did not exceed the requirement of 0.08 (µg/m³)/K. For the uncertainty calculation the largest sensitivity coefficient b_{st} is selected for both instrument. For instrument 1, this is 0.053 (µg/m³)/K and for instrument 2 it is 0.029 µg/m³.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 14 presents the individual test results.

Table 14: Individual test results for the sensitivity coefficient to ambient temperature

	span level			
			device 1	device 2
date	time	temp [ºC]	[µg/m³]	[µg/m³]
21.01.2019	08:00:00	20	35,205*	34,454*
21.01.2019	08:15:00	20	35.958	34.662
21.01.2019	08:30:00	20	35.972	34.033
21.01.2019	08:45:00	20	35.738	34.920
21.01.2019	09:00:00	20	35.636	34.771
average ($X_{1(TS1)}$)			35.826	34.597
21.01.2019	16:30:00	0	35,105*	34,127*
21.01.2019	16:45:00	0	35.158	34.145
21.01.2019	17:00:00	0	35.068	34.235
21.01.2019	17:15:00	0	35.122	34.451
21.01.2019	17:30:00	0	35.057	34.192
average($X_{Ts,1}$)		0	35.101	34.256
22.01.2019	09:30:00	20	35,882*	35,374*
22.01.2019	09:45:00	20	35.920	35.454
22.01.2019	10:00:00	20	35.895	34.962
22.01.2019	10:15:00	20	35.897	35.033
22.01.2019	10:30:00	20	35.938	34.920
average ($X_{2(TS1)}$) = ($X_{1(TS2)}$)			35.913	35.092
22.01.2019	17:00:00	30	36,175*	35,264*
22.01.2019	17:15:00	30	36.178	35.317
22.01.2019	17:30:00	30	36.176	35.493
22.01.2019	17:45:00	30	36.192	35.340
22.01.2019	18:00:00	30	36.175	35.329
average($X_{Ts,2}$)			36.180	35.370
23.01.2019	10:15:00	20	35,375*	35,042*
23.01.2019	10:30:00	20	35.376	35.065
23.01.2019	10:45:00	20	35.363	35.054
23.01.2019	11:00:00	20	35.376	35.087
23.01.2019	11:15:00	20	35.407	35.111
average ($X_{2(TS2)}$)			35.381	35.079

According to EN 14662-3, five consecutive measurements are performed at each temperature. For each temperature, the first measurement in the series shall be discarded.

7.1 8.4.8 Sensitivity coefficient to electrical voltage

The sensitivity coefficient of electrical voltage shall not exceed 0.08 (µg/m³)/V.

7.2 Test procedures

The sensitivity coefficient to electrical voltage is determined at the two limits of the voltage range specified by the manufacturer, V_1 and V_2, at a concentration of approximately 70% to 80% of the maximum value of the benzene certification range. Five consecutive measurements shall be performed for each voltage and the average of the last four measurements shall be calculated.

The sensitivity coefficient to electrical voltage in accordance with EN 14662-3 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 reference point at various voltages.

7.4 Evaluation

The following sensitivity coefficients to electrical voltage have been determined:

Table 15: Sensitivity coefficient to electrical voltage

	requirement	device 1		device 2	
sensitivity coeff. of voltage b_v at span level [µg/m³/V]	≤ 0,08	0.000	✓	0.001	✓

7.5 Assessment

At no criterion did the sensitivity coefficient to electrical voltage b_v exceed the requirements specified in standard EN 14662-3 of 0.08 (µg/m³)/V. For the uncertainty calculation, b_v was at 0.000 (µg/m³)/V for instrument 1 and 0.001 (µg/m³)/V for instrument 2.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 16: Individual results of the sensitivity coefficient to electrical voltage

			device 1	device 2
time	voltage [V]	concentration	[µg/m³]	[µg/m³]
10:00:00	210	36.00	36,638*	36,558*
10:15:00	210	36.00	36.488	35.707
10:30:00	210	36.00	36.515	35.735
10:45:00	210	36.00	36.489	35.758
11:00:00	210	36.00	36.470	35.695
average C_{V1} at Span			36.491	35.724
11:30:00	250	36.00	36,506*	35,697*
11:45:00	250	36.00	36.429	35.700
12:00:00	250	36.00	36.504	35.689
12:15:00	250	36.00	36.510	35.677
12:30:00	250	36.00	36.473	35.677
average C_{V2} at Span			36.479	35.686

According to EN 14662-3, five consecutive measurements are performed at each voltage. For each voltage, the first measurement in the series shall be discarded.

7.1 8.4.9 Interferents

Interfering substances at a concentration c_t (annual limit value = 5 µg/m³ for benzene). The maximum permissible deviation for the mixture of organic interferents is ≤ 0.025 µg/m³. The maximum permissible deviation for H_2O is ≤ 0.015 µg/m³/(mmol/mol).

7.2 Test procedures

The analyser response to certain interferents expected to be present in ambient air shall be tested. The interferents can give a positive or negative response. The test shall be performed at a test gas concentration (c_t) of benzene similar to the annual limit value.

After adjusting the measuring instrument to the test gas concentration, a test gas with a concentration (c_t) of benzene similar to the annual limit shall be applied to the measuring instrument. This mixture shall be used for three measurements, the results of the last two of which shall be used. This process must be repeated with a mixture of benzene at concentration c_t and the interfering substance to be investigated.

Water vapour

The influence of water vapour is determined at a concentration of 19 mmol/mol. The sensitivity coefficient at a test gas concentration c_t of benzene is calculated as follows:

$$b_{H2O} = \frac{x_{+w} - x_{-w}}{c_w}$$

Where:

b_{H2O} = is the sensitivity coefficient to water vapour

x_{+w} = is the average from the measurements in the presence of water vapour

x_{-w} = is the average from measurements in the absence of water vapour

c_w = is the concentration of water vapour in the test gas

b_{H2O} shall comply with the performance criterion indicated above.

Organic compounds

Testing for interferences with the mixture of organic compounds ensures that organic compounds which may elute together with benzene do not significantly contribute to the measurement signal of benzene.

The contribution of the mixture of organic compounds to the test gas concentration c_t of benzene is calculated as follows:

$$\Delta x_{oc} = x_+ - x_-$$

Where:

Δx_{oc} = is the contribution from organic compounds to the measured signal of benzene

x_+ = is the average from the measurements in the presence of organic interferents

x_- = is the average from measurements in the absence of organic interferents

The contribution from the mixture of organic compounds must comply with the performance criterion indicated above.

A possible influence caused by organic compounds is tested with the help of a gas mixture of the substances listed in Table 17 at concentrations of 5 µg/m³ each.

7.3 Testing

The test was performed in line with the requirements of EN 14662-3 mentioned before. The instruments were set at the test gas concentration c_t. Subsequently, test gas with and without the various interferents was applied.

To generate a defined moisture content, the dilution air of the test gas mixture was humidified. To calculate the difference between wet and dry test gas, the measured value of the wet test gas was corrected using the volume fraction of water vapour in the test gas.

A possible influence caused by organic compounds is tested with the help of a gas mixture of the substances listed in Table 17 at concentrations of 5 µg/m³ each.

Table 17: Mixture of organic interferents

Mixture of interferents
Methylcyclopentane
2,2,3-trimethylbutane
2,4-Dimethylpentane
2,2,4-Trimethylpentane
Cyclohexane
2,3-Dimethylpentane
2-Methylhexane
3-Ethylpentane
Trichloroethylene
1-Heptane
1-Butanol

A vapour pressure device was used to test cross-sensitivities to organic compounds. The various interferents were available as solutions and were transferred to the gaseous phase at different temperatures according to their vapour pressure properties. The resulting mixture of the interfering substances was then strongly diluted using a diluter (approx. factor 3000).

7.4 Evaluation

The following tables list the influencing variables of the various interferents: When determining the influence of moisture, the dilution effect which occurs inside the test gas generation system was also taken into account.

Table 18: Influence of moisture

	requirements	**device 1**		**device 2**	
influence quantity interferent H_2O at c_t [µg/m³]	≤ 0,015 µg/m³	-0.003	✓	-0.002	✓

Table 19: Influence of the mixture of organic interferents

	requirement	**device 1**		**device 2**	
Δ_{xoc} influence quantity org. mixture at c_t [µg/m³]	≤ 0,25 µg/m³	-0.181	✓	-0.102	✓

7.5 Assessment

For the influence of humidity, the cross sensitivity value for the test gas value ct is -0.003 µg/m³ for instrument 1 and -0.002 µg/m³ for instrument 2.

For the influence of the mixture of organic compounds, the cross sensitivity value for the test gas value c_t is -0.181 µg/m³ for instrument 1 and -0.102 µg/m³ for instrument 2.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 20 and Table 21present the individual test results.

Table 20: Individual results for testing against moisture

	without interferent			with interferent		
	time	device 1	device 2	time	device 1	device 2
span gas + H_2O (19 mmol/mol)	12:30:00	5,391*	5,059*	14:30:00	5,345*	4,981*
	12:45:00	5.406	5.042	14:45:00	5.328	5.003
	13:00:00	5.381	4.997	15:00:00	5.333	4.970
	average x_{-w}	5.394	5.020	average x_{+w}	5.331	4.987

According to EN 14662-3, three consecutive measurements shall be performed in each case, the results of the last two of each shall be used.

Table 21: Individual results for testing against the organic test gas mixture

	without interferent			with interferent		
	time	device 1	device 2	time	device 1	device 2
span gas + org. mixture	08:00:00	5,477*	5,238*	09:00:00	5,249*	5,149*
	08:15:00	5.476	5.215	09:15:00	5.293	5.123
	08:30:00	5.470	5.219	09:30:00	5.291	5.108
	average x_-	5.473	5.217	average x_+	5.292	5.116

According to EN 14662-3, three consecutive measurements shall be performed in each case, the results of the last two of each shall be used.

7.1 8.4.10 Memory effect)

The benzene concentration of the first zero gas analysis immediately following the analysis of at least two high benzene concentrations shall be less than 1.0 µg/m³.

7.2 Testing

The retention of benzene in the measurement system after a measurement (carry-over) is determined by applying a high concentration (about 90% of the upper limit of the certification range of benzene) followed by zero gas.

At the high concentration, at least two consecutive measurements are performed, after which the gas supply is switched to zero gas. The result of the zero gas measurement shall be used to calculate the concentration c_m of benzene caused by carry-over.

The test sequence must be repeated at least three times. The average from the results for c_m shall be indicated in the test report and meet the above criterion.

7.3 Testing

The test was performed in line with the requirements of EN 14662-3 mentioned before.

As a performance criterion for the presence of benzene in the measuring instrument (memory effect), VDI 4202-1 (2018) requires a value of < 10 % of the limit value (= 0.5 µg/m³) for the first analysis after switching to zero gas. At < 1.0 µg/m³, the limit specified by standard EN 14662-3 (2016) is less strict.

7.4 Evaluation

The following table shows an overview of the mean values of the concentration c_m caused by carryover. Table 23 presents the individual test results.

Table 22: Memory effect of the VOC72e measuring system

	requirement	device 1		device 2	
memory-effect c_m [µg/m³]	≤ 1,0	0.134	✓	0.128	✓

The average c_m for instrument 1 is at 0.134 µg/m³.

The average c_m for instrument 2 is at 0.128 µg/m³.

7.5 Assessment

The average value cm is at 0.134 µg/m³ for instrument 1 and 0.128 µg/m³ for instrument 2. Thus the requirements of both standard DIN 14662-3 (2016) and VDI 4202-1 (2016) are complied with.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Individual results of determining the memory effect.

Table 23: Individual results for the memory effect

Memoryeffect		
1. cycle		
	device 1	device 2
time	[µg/m³]	[µg/m³]
12:15:00	46.054	46.896
12:30:00	46.107	46.903
12:45:00	0.126	0.122
13:00:00	0.046	0.055
c_{m1}	**0.126**	**0.122**

Memoryeffect		
2. cycle		
	device 1	device 2
time	[µg/m³]	[µg/m³]
14:15:00	46.021	46.892
14:30:00	45.978	46.855
14:45:00	0.137	0.145
15:00:00	0.056	0.055
c_{m2}	**0.137**	**0.145**

Memoryeffect		
3. cycle		
	device 1	device 2
time	[µg/m³]	[µg/m³]
16:15:00	46.362	46.203
16:30:00	46.436	46.237
16:45:00	0.139	0.118
17:00:00	0.054	0.061
c_{m3}	**0.139**	**0.118**

c_m	**0.134**	**0.128**

Values highlighted in grey were used to calculate the concentration c_m caused by carry-over.

7.1 8.4.11 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;
Δx_{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 8.5.4 Long-term drift

The long-term drift at reference point c_t shall not exceed 10% of the upper limit of the certification range.

7.2 Test procedures

After each bi-weekly calibration, the drift of the analysers under test was 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 measurements at zero and the test gas concentration are recorded immediately after the calibration. In both cases, the first measurement shall be discarded.

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

The test was performed in line with the requirements of EN 14662-3 (2016) mentioned before. According to the requirements of VDI 4202-1 (2018), a zero and reference point check must also be carried out for benzene every other day during the first two weeks.

After that, test gas was applied every other week. Table 24 and Table 25 report the measured values for bi-weekly test gas applications.

7.4 Evaluation

Table 24: Results for the long-term drift at zero point

		requierment	Device 1		Device 2	
average start $Cz_{,1}$ at zero [µg/m³]	11.02.2019	≤ 0,5	--	✓	--	✓
long term drift $D_{L,z}$ at zero [µg/m³]	13.02.2019	≤ 0,5	0.02	✓	0.00	✓
long term drift $D_{L,z}$ at zero [µg/m³]	15.02.2019	≤ 0,5	0.01	✓	0.00	✓
long term drift $D_{L,z}$ at zero [µg/m³]	18.02.2019	≤ 0,5	0.03	✓	-0.03	✓
long term drift $D_{L,z}$ at zero [µg/m³]	20.02.2019	≤ 0,5	0.02	✓	0.03	✓
long term drift $D_{L,z}$ at zero [µg/m³]	22.02.2019	≤ 0,5	0.07	✓	0.04	✓
long term drift $D_{L,z}$ at zero [µg/m³]	26.02.2019	≤ 0,5	0.02	✓	0.03	✓
long term drift $D_{L,z}$ at zero [µg/m³]	12.03.2019	≤ 0,5	0.03	✓	0.03	✓
long term drift $D_{L,z}$ at zero [µg/m³]	26.03.2019	≤ 0,5	0.05	✓	-0.02	✓
long term drift $D_{L,z}$ at zero [µg/m³]	09.04.2019	≤ 0,5	0.03	✓	0.03	✓
long term drift $D_{L,z}$ at zero [µg/m³]	23.04.2019	≤ 0,5	0.01	✓	-0.01	✓
long term drift $D_{L,z}$ at zero [µg/m³]	07.05.2019	≤ 0,5	0.04	✓	0.01	✓
long term drift $D_{L,z}$ at zero [µg/m³]	21.05.2019	≤ 0,5	0.00	✓	-0.02	✓

Table 25: Results for the long-term drift at reference point

		requierment	Device 2 1		Device 2	
average start $Cs_{,1}$ at span	11.02.2019	≤ 10 %	--	✓	--	✓
long term drift $D_{L,s}$ at span [%]	13.02.2019	≤ 10 %	-0.41	✓	1.42	✓
long term drift $D_{L,s}$ at span [%]	15.02.2019	≤ 10 %	0.43	✓	0.24	✓
long term drift $D_{L,s}$ at span [%]	18.02.2019	≤ 10 %	-1.62	✓	0.84	✓
long term drift $D_{L,s}$ at span [%]	20.02.2019	≤ 10 %	-0.37	✓	-0.43	✓
long term drift $D_{L,s}$ at span [%]	22.02.2019	≤ 10 %	1.18	✓	0.66	✓
long term drift $D_{L,s}$ at span [%]	26.02.2019	≤ 10 %	2.49	✓	2.44	✓
long term drift $D_{L,s}$ at span [%]	12.03.2019	≤ 10 %	3.15	✓	0.11	✓
long term drift $D_{L,s}$ at span [%]	26.03.2019	≤ 10 %	0.94	✓	2.02	✓
long term drift $D_{L,s}$ at span [%]	09.04.2019	≤ 10 %	0.04	✓	1.75	✓
long term drift $D_{L,s}$ at span [%]	23.04.2019	≤ 10 %	2.56	✓	2.24	✓
long term drift $D_{L,s}$ at span [%]	07.05.2019	≤ 10 %	2.97	✓	3.51	✓
long term drift $D_{L,s}$ at span [%]	21.05.2019	≤ 10 %	2.55	✓	2.19	✓

7.5 Assessment

Maximum long-term drift at zero point $D_{l,z}$ was at 0.07 µg/m³ for instrument 1 and 0.04 µg/m³ for instrument 2. Maximum long-term drift at reference point $D_{l,s}$ was at 3.15% for instrument 1 and 3.51% for instrument 2.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 26 presents the individual values obtained for the determination of the long-term drift.

Table 26: Individual results of the drift checks, part 1 (during the first two weeks)

Zero Concentration			
		Device 1	Device 2
Date	Time	[µg/m³]	[µg/m³]
11.02.2019	08:00:00	0.09*	0.08*
	08:15:00	0.01	0.04
	08:30:00	0.04	0.04
	08:45:00	0.04	0.04
	09:00:00	0.03	0.02
		0.03	0.04
Average field start $c_{z,0}$		**0.03**	**0.04**
13.02.2019	09:15:00	0.03*	0.08*
	09:30:00	0.07	0.09
	09:45:00	0.09	0.02
	10:00:00	0.01	0.01
	10:15:00	0.02	0.02
	aver. $c_{z,1}$	**0.05**	**0.04**
15.02.2019	11:15:00	0.08*	0.05*
	11:30:00	0.06	0.03
	11:45:00	0.05	0.05
	12:00:00	0.07	0.09
	12:15:00	0.01	0.07
	aver. $c_{z,1}$	**0.04**	**0.06**
18.02.2019	09:15:00	0,06*	0,01*
	09:30:00	0.06	0.01
	09:45:00	0.06	0.01
	10:00:00	0.06	0.01
	10:15:00	0.05	0.01
	aver. $c_{z,1}$	**0.06**	**0.01**
20.02.2019	13:15:00	0,06*	0,09*
	13:30:00	0.03	0.10
	13:45:00	0.08	0.06
	14:00:00	0.05	0.05
	14:15:00	0.04	0.04
	aver. $c_{z,1}$	**0.05**	**0.06**
22.02.2019	10:15:00	0,09*	0,07*
	10:30:00	0.10	0.08
	10:45:00	0.10	0.08
	11:00:00	0.10	0.07
	11:15:00	0.10	0.07
	aver. $c_{z,1}$	**0.10**	**0.07**
26.02.2019	08:15:00	0,06*	0,06*
	08:30:00	0.07	0.09
	08:45:00	0.07	0.05
	09:00:00	0.03	0.06
	09:15:00	0.05	0.06
	aver. $c_{z,1}$	**0.06**	**0.07**

C_t-Concentration			
		Device 1	Device 2
Date	Time	[µg/m³]	[µg/m³]
11.02.2019	09:30:00	35.44*	35.42*
	09:45:00	35.44	35.44
	10:00:00	35.45	35.45
	10:15:00	35.42	35.45
	10:30:00	35.41	35.45
		35.43	35.45
Average field start $c_{s,0}$		**35.43**	**35.45**
13.02.2019	10:45:00	34.11*	35.86*
	11:00:00	35.30	35.97
	11:15:00	35.35	35.94
	11:30:00	35.26	35.93
	11:45:00	35.31	35.99
	aver. $c_{s,1}$	**35.30**	**35.96**
15.02.2019	12:45:00	35.60*	35.57*
	13:00:00	35.59	35.55
	13:15:00	35.59	35.57
	13:30:00	35.64	35.59
	13:45:00	35.58	35.51
	aver. $c_{s,1}$	**35.60**	**35.55**
18.02.2019	10:30:00	35,11*	34,86*
	10:45:00	35.03	35.82
	11:00:00	34.93	35.73
	11:15:00	34.85	35.68
	11:30:00	34.77	35.65
	aver. $c_{s,1}$	**34.89**	**35.72**
20.02.2019	14:45:00	35,34*	35,31*
	15:00:00	35.33	35.32
	15:15:00	35.32	35.32
	15:30:00	35.31	35.32
	15:45:00	35.32	35.32
	aver. $c_{s,1}$	**35.32**	**35.32**
22.02.2019	11:45:00	36,07*	35,81*
	12:00:00	36.04	35.78
	12:15:00	35.99	35.76
	12:30:00	35.86	35.68
	12:45:00	35.80	35.66
	aver. $c_{s,1}$	**35.92**	**35.72**
26.02.2019	09:45:00	36,53*	36,52*
	10:00:00	36.42	36.49
	10:15:00	36.43	36.69
	10:30:00	36.40	36.41
	10:45:00	36.20	35.86
	aver. $c_{s,1}$	**36.36**	**36.36**

* EN 14662-3 requires that five consecutive measurements be performed and the average of the last four measurements be calculated.

Table 27: Individual results of the drift checks, part 2

Zero Concentration			
		Device 1	Device 2
Date	Time	[µg/m³]	[µg/m³]
12.03.2019	07:15:00	0,08*	0,08*
	07:30:00	0.06	0.05
	07:45:00	0.03	0.08
	08:00:00	0.10	0.07
	08:15:00	0.08	0.06
	aver. $c_{z,1}$	**0.07**	**0.07**
26.03.2019	12:45:00	0,09*	0,02*
	13:00:00	0.09	0.02
	13:15:00	0.08	0.02
	13:30:00	0.08	0.02
	13:45:00	0.08	0.02
	aver. $c_{z,1}$	**0.08**	**0.02**
09.04.2019	08:15:00	0,09*	0,03*
	08:30:00	0.03	0.07
	08:45:00	0.02	0.07
	09:00:00	0.09	0.04
	09:15:00	0.09	0.09
	aver. $c_{z,1}$	**0.06**	**0.07**
23.04.2019	10:15:00	0,03*	0,02*
	10:30:00	0.04	0.03
	10:45:00	0.04	0.03
	11:00:00	0.04	0.03
	11:15:00	0.04	0.03
	aver. $c_{z,1}$	**0.04**	**0.03**
07.05.2019	08:15:00	0,20*	0,05*
	08:30:00	0.10	0.06
	08:45:00	0.01	0.05
	09:00:00	0.08	0.04
	09:15:00	0.08	0.04
	aver. $c_{z,1}$	**0.07**	**0.05**
21.05.2019	13:15:00	0,02*	0,02*
	13:30:00	0.03	0.02
	13:45:00	0.03	0.02
	14:00:00	0.03	0.02
	14:15:00	0.03	0.02
	aver. $c_{z,1}$	**0.03**	**0.02**

C_t-Concentration			
		Device 1	Device 2
Date	Time	[µg/m³]	[µg/m³]
12.03.2019	08:45:00	36,62*	35,48*
	09:00:00	36.59	35.49
	09:15:00	36.61	35.51
	09:30:00	36.62	35.51
	09:45:00	36.66	35.55
	aver. $c_{s,1}$	**36.62**	**35.52**
26.03.2019	14:15:00	35,78*	36,14*
	14:30:00	35.82	36.16
	14:45:00	35.83	36.19
	15:00:00	35.83	36.14
	15:15:00	35.81	36.15
	aver. $c_{s,1}$	**35.82**	**36.16**
09.04.2019	09:45:00	35,82*	36,03*
	10:00:00	35,61*	36.93
	10:15:00	35.43	35.88
	10:30:00	35.53	35.83
	10:45:00	35.47	35.81
	aver. $c_{s,1}$	**35.47**	**36.11**
23.04.2019	11:45:00	36,38*	36,26*
	12:00:00	36.37	36.24
	12:15:00	36.37	36.26
	12:30:00	36.35	36.24
	12:45:00	36.40	36.25
	aver. $c_{s,1}$	**36.37**	**36.25**
07.05.2019	09:45:00	35,92*	35,83*
	10:00:00	36.68	36.69
	10:15:00	36.19	36.89
	10:30:00	36.77	36.73
	10:45:00	36.59	36.67
	aver. $c_{s,1}$	**36.56**	**36.75**
21.05.2019	14:45:00	36,31*	36,20*
	15:00:00	36.36	36.22
	15:15:00	36.36	36.21
	15:30:00	36.35	36.25
	15:45:00	36.38	36.23
	aver. $c_{s,1}$	**36.36**	**36.23**

7.1 8.5.5 Reproducibility standard deviation for benzene under field conditions

The reproducibility standard deviation under field conditions shall not exceed 0.25 µg/m³.

7.2 Test procedures

The reproducibility standard deviation under field conditions is calculated from the data measured during the three-month period (4 values per hour each).

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:

$$S_{r,f} = \sqrt{\frac{\sum_{i=1}^{n} \Delta x^2 f,i}{2n}}$$

Where:

$s_{r,f}$	is the reproducibility standard deviation for NO2 under field conditions (%);
n	is the number of parallel measurements;
c_f	is the average concentration of benzene 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 measured values (4 per hour) over the field test period according to the equation stated above. For benzene, the calculation is performed directly from the measured data.

As the ambient air in Central Europe usually has a benzene concentration close to zero, the sample air was enriched with benzene in various concentrations over a period of 18 days. This served to demonstrate that the measuring systems work identically even at higher concentrations. For the purpose of enrichment, a small amount of highly concentrated benzene test gas was dosed into the sampling system of the measuring station using a needle valve. Apart from the benzene concentration, the gas matrix was hardly changed with regard to humidity, pressure, temperature and the other measurable air constituents.

7.4 Evaluation

Table 28: Determination of the reproducibility standard deviation

reproducibility standard deviation in field		
no. of measurments (1h- average)	[n]	9541
average of both analyzers (3 month)	[µg/m³]	2.46
reproducibility standard deviation in field $S_{r,f}$	**[µg/m³]**	**0.186**
requirement	≤ 0,25 µg/m³	✓

The result is a reproducibility standard deviation under field conditions, calculated from 9541 pairs of measured values of 0.186 µg/m³.

7.5 Assessment

The reproducibility standard deviation for benzene under field conditions was at 0.186 µg/m³. Thus, the requirements of EN 14662-3 are satisfied.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Figure 10 provides an illustration of the reproducibility standard deviation under field conditions.

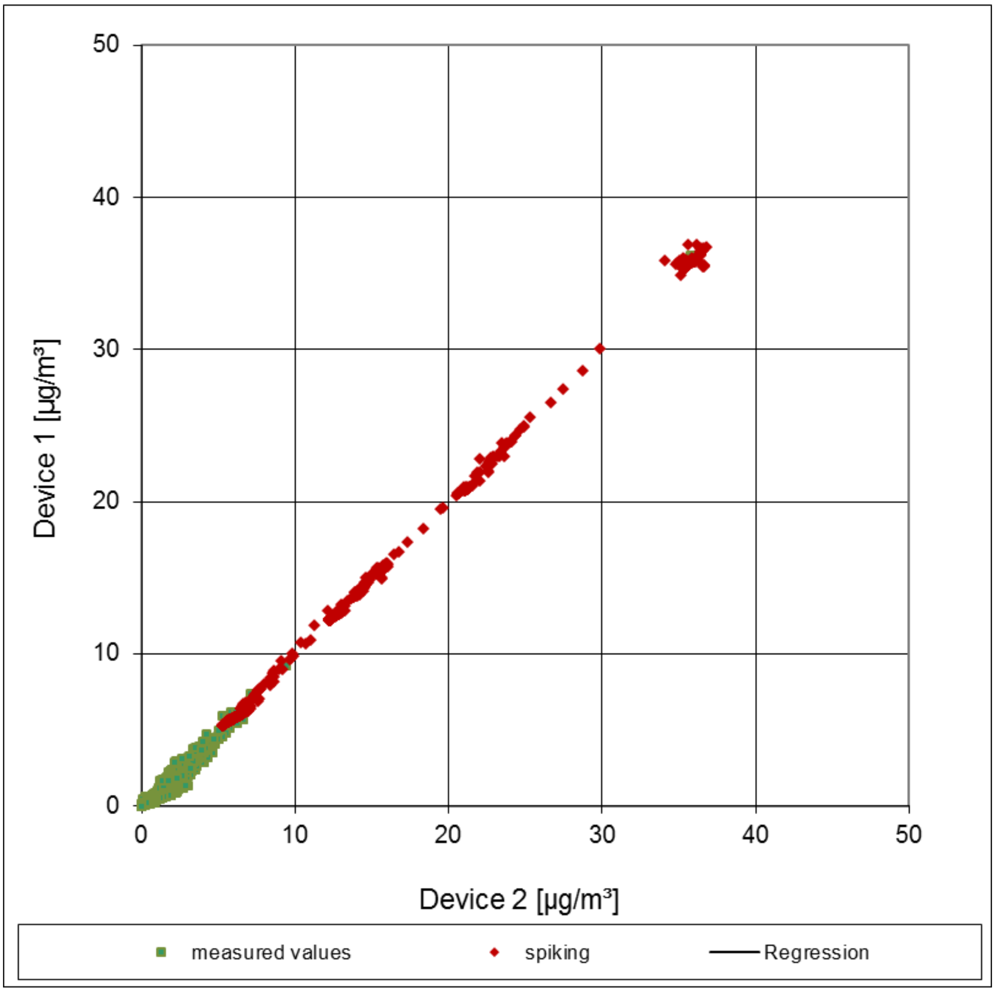


Figure 10: Diagram of the reproducibility standard deviation under field conditions

7.1 8.5.6 Inspection interval

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

7.2 Equipment

Not required for this performance criterion

7.3 Testing

With regard to this minimum requirement, the maintenance tasks required in a specific period and the length of that period for the correct functioning of the measuring system were identified. Furthermore, in determining the maintenance interval, the drift determined for zero and reference 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.

The maintenance work to be carried out regularly according to the AMS manufacturer is listed in Chapter 4 (Preventive Maintenance) of the operation manual. 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. Hydrogen normal pressure as well as instrument parameters such as pressure, temperature and voltage supply should be checked regularly (~ every two weeks).
3. The internal sample filter and the filter of the internal fan should be replaced every two months.
4. The heat sink should be checked for contamination every 2 months and cleaned if necessary. During the performance test reported on here, it was not necessary to clean the heat sink.

The steps required to carry out preventive maintenance work are described in detail in Chapter 4 of the operation manual.

The supply of the required carrier gas medium (hydrogen) must be ensured.

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 supply of the required carrier gas medium (hydrogen) must be ensured. EN 14662-3 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 to perform this check 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 have occurred during this period.

7.4 Evaluation

Outage times which have occurred during the field test are listed in Table 29.

Table 29: Availability of the VOC72e measuring system

		System 1	System 2
Operation time	h	2385	2385
Outage time	h	0	0
Maintenance times (test gas application)	h	78	78
Actual operating time:	h	2307	2307
Actual operating time incl. maintenance times:	h	2385	2385
Availability	%	100	100

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

7.5 Assessment

The availability is 100%. Thus, the requirement of EN 14662-3 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 14662-3 (2015)

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 14662-3.*

***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 (25% for fixed measurements or 30% for indicative measurements). This criterion is the maximum uncertainty of individual measurements for continuous measurements at the annual limit value. The relevant specific performance characteristics and the calculation procedure are given in Annex E of standard EN 14662-3.*

***3)** The value of each individual performance characteristic tested in the laboratory shall fulfil the criterion stated in Table E.1 of EN 14662-3.*

***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 (25% for fixed measurements or 30% for indicative measurements). This criterion is the maximum uncertainty of individual measurements for continuous measurements at the annual limit value. The relevant specific performance characteristics and the calculation procedure are given in Annex E of standard EN 14662-3.*

7.2 Equipment

Calculation of the total uncertainty in accordance with standard EN 14662-3 (2016), 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 14662-3.

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 14662-3.

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 30 summarises the results for items 1 and 3.

Table 31 and Table 33 contain the results regarding item 2.

Table 32 and Table 34 contain the results regarding item 4.

Table 30: Relevant performance characteristics and criteria according to EN 14662-3

Performance characteristic	Performance criterion	Test result	Satisfied	Page
8.4.4 Repeatability standard deviation at zero	≤ 0.20 µg/m³	S_r system 1: 0.006 µg/m³ S_r system 2: 0.010 µg/m³	yes	73
8.4.4 Repeatability standard deviation at concentration level c_t	≤ 0.25 µg/m³	S_r system 1: 0.012 µg/m³ S_r system 2: 0.010 µg/m³	yes	73
8.4.5 “Lack of fit” (deviation from the linear regression)	Largest deviation from the linear regression function > 0, ≤ 5.0% of the reading Deviation at zero ≤ 0.5 µg/m³	$X_{l,z}$ system 1: ZP 0.049 µg/m³ X_l system 1: RP 2.205% $X_{l,z}$ system 2: ZP 0.038 µg/m³ X_l system 2: RP 1.398%	yes	75
8.4.6 Sensitivity coefficient of sample gas pressure	≤ 0.10 (µg/m³)/kPa	b_{gp} system 1: ≤ 0.035 (µg/m³)/kPa b_{gp} system 2: ≤ 0.035 (µg/m³)/kPa	yes	80
8.4.7 Sensitivity coefficient of surrounding temperature	≤ 0.08 (µg/m³)/K	b_{st} system 1: ≤ 0.053 (µg/m³)/K b_{st} system 2: ≤ 0.029 (µg/m³)/K	yes	82
8.4.8 Sensitivity coefficient of electrical voltage	≤ 0.08 (µg/m³)/V	b_v system 1: RP 0.000 (µg/m³)/V b_v system 2: RP 0.001 (µg/m³)/V	yes	85
8.4.9 Interferents at concentration c_t	H2O ≤ 0.015 µg/m³ mmol/mol Org. compounds ≤ 0.25 µg/m³	H_2O system 1: -0.003 µg/m³/(moml/mol) system 2: -0.002 µg/m³/(moml/mol) Organic compounds system 1: -0.181 µg/m³ system 2: -0.102 µg/m³	yes	87

Performance characteristic	**Performance criterion**	**Test result**	**Satis-fied**	**Page**
8.4.10 Memory effects	≤ 1.0 µg/m³	C_m system 1: 0.134 µg/m³ C_m system 2: 0.128 µg/m³	yes	90
8.4.11 Difference sample/calibration port	≤ 1.0%	Δ_{SC} system 1: --- Δ_{SC} system 2: ---	Not applicable	92
8.5.7 Availability of the analyser	> 90%	A_a system 1: 100% A_a system 2: 100%	yes	101
8.5.5 Reproducibility standard deviation under field conditions	≤ 0.25 µg/m³ of the average over a period of 3 months	$S_{r,f}$ system 1: 0.186 µg/m³ $S_{r,f}$ system 2: 0.186 µg/m³	yes	97
8.5.4 Long-term drift at zero point	≤ 0.5 µg/m³	$C_{,z}$ system 1: 0.07 µg/m³ $C_{,z}$ system 2: 0.04 µg/m³	yes	93
8.5.4 Long-term drift at span level	≤ 10.0% of the upper limit of the certification range	$C_{,s}$ system 1: max. 3.15% $C_{,s}$ system 2: max. 3.51%	yes	93
8.4.3 Short-term drift at span level	≤ 2.0 µg/m³ over 12 h	$D_{s,s}$ system 1: -0.125 µg/m³ $D_{s,s}$ system 2: -0.216 µg/m³	yes	71

Table 31 Expanded uncertainty in laboratory for analyser 1

Measuring device:	VOC72e				Serial-No.:		323	
Measured component:	Benzene				annual limit value:		5.0	µg/m³
No.	**Performance characteristic**	**Performance criterion**		**Result**	**Partial uncertainty**		**Square of partial uncertainty**	
2	Repeatability standard deviation annual limit vale	≤	0,25 µg/m³	0.012	$u_{r,c}$	0.00	0.0000	
3	"lack of fit" at annual limit value	≤	5,0% of gas level	2.205	u_l	0.06	0.0041	
4	Sensitivity coefficient of sample gas pressure at annual limit value	≤	0,40 (µg/m³)/kPa	0.035	u_{gp}	0.08	0.0068	
5	Sensitivity coefficient of surrounding temperature at annual limit value	≤	0,08 (µg/m³)/K	0.053	u_{st}	0.13	0.0172	
6	Sensitivity coefficient of electrical voltage at annual limit value	≤	0,080 (µg/m³)/V	0.000	u_V	0.00	0.0000	
7a	Interferent H20 with 19 mmol/mol	≤	0,015 (µg/m³)/mmol/mol	-0.003	u_{H2O}	-0.04	0.0016	
8	Memory-Effect	≤	1,0 µg/m³	0.134	u_m	0.01	0.0001	
12	Difference sample/calibration port	≤	1%	0.000	$u_{\Delta sc}$	0.00	0.0000	
15	Uncertainty of test gas	≤	3,0%	3.000	u_{cg}	0.08	0.0056	
		Combined standard uncertainty			u_c		0.1880	µg/m³
		Expanded uncertainty			U		0.3761	µg/m³
		Relative expanded uncertainty			W		7.52	%
		Maximum allowed expanded uncertainty			W_{req}		25	%

Table 32 Expanded uncertainty in laboratory and field for analyser 1

Measuring device:	VOC72e				Serial-No.:		323	
Measured component:	Benzene				annual limit value:		5.0	µg/m³
No.	**Performance characteristic**	**Performance criterion**		**Result**	**Partial uncertainty**		**Square of partial uncertainty**	
2	Repeatability standard deviation annual limit vale	≤	0,25 µg/m³	0.012	$u_{r,lh}$	not respected, as ur,lh = 0 < ur,f	-	
3	"lack of fit" at annual limit value	≤	5,0% of gas level	2.205	$u_{l,lh}$	0.06	0.0041	
4	Sensitivity coefficient of sample gas pressure at annual limit value	≤	0,40 (µg/m³)/kPa	0.035	u_{gp}	0.08	0.0068	
5	Sensitivity coefficient of surrounding temperature at annual limit value	≤	0,08 (µg/m³)/K	0.053	u_{st}	0.13	0.0172	
6	Sensitivity coefficient of electrical voltage at annual limit value	≤	0,080 (µg/m³)/V	0.000	u_V	0.00	0.0000	
7a	Interferent H20 with 19 mmol/mol	≤	0,015 (µg/m³)/mmol/mol	-0.003	u_{H2O}	-0.04	0.0016	
8	Memory-Effect	≤	1,0 µg/m³	0.134	u_{av}	0.01	0.0001	
9	Repeatability standard deviation in field	≤	0,25 µg/m³ of average of 3 month	0.186	$u_{r,f}$	0.19	0.0346	
10	Long term drift at span	≤	10 % of cert. range	3.150	$u_{d,l,lh}$	0.09	0.0083	
12	Difference sample/calibration port	≤	1,0%	0.000	$u_{\Delta sc}$	0.00	0.0000	
15	Uncertainty of test gas	≤	3,0%	3.000	u_{cg}	0.08	0.0056	
		Combined standard uncertainty			u_c		0.3359	µg/m³
		Expanded uncertainty			U		0.6717	µg/m³
		Relative expanded uncertainty			W		13.43	%
		Maximum allowed expanded uncertainty			W_{req}		25	%

Table 33: Expanded uncertainty in laboratory for analyser 2

Measuring device:	VOC72e				Serial-No.:		324	
Measured component:	Benzene				annual limit value:		5.0	µg/m³
No.	**Performance characteristic**	**Performance criterion**		**Result**	**Partial uncertainty**		**Square of partial uncertainty**	
2	Repeatability standard deviation annual limit vale	≤	0,25 µg/m³	0.010	$u_{r,c}$	0.00	0.0000	
3	"lack of fit" at annual limit value	≤	5,0% of gas level	1.398	u_l	0.04	0.0016	
4	Sensitivity coefficient of sample gas pressure at annual limit value	≤	0,40 (µg/m³)/kPa	0.035	u_{gp}	0.08	0.0068	
5	Sensitivity coefficient of surrounding temperature at annual limit value	≤	0,08 (µg/m³)/K	0.029	u_{st}	0.07	0.0051	
6	Sensitivity coefficient of electrical voltage at annual limit value	≤	0,080 (µg/m³)/V	0.001	u_V	0.00	0.0000	
7a	Interferent H20 with 19 mmol/mol	≤	0,015 (µg/m³)/mmol/mol	-0.002	u_{H2O}	-0.03	0.0008	
8	Memory-Effect	≤	1,0 µg/m³	0.128	u_m	0.01	0.0001	
12	Difference sample/calibration port	≤	1%	0.000	$u_{\Delta sc}$	0.00	0.0000	
15	Uncertainty of test gas	≤	3,0%	3.000	u_{cg}	0.08	0.0056	
				Combined standard uncertainty	u_c		0.1417	µg/m³
				Expanded uncertainty	U		0.2833	µg/m³
				Relative expanded uncertainty	W		5.67	%
				Maximum allowed expanded uncertainty	W_{req}		25	%

Table 34: Expanded uncertainty in laboratory and field for analyser 2

Measuring device:	VOC72e				Serial-No.:		324	
Measured component:	Benzene				annual limit value:		5.0	µg/m³
No.	**Performance characteristic**	**Performance criterion**		**Result**	**Partial uncertainty**		**Square of partial uncertainty**	
2	Repeatability standard deviation annual limit vale	≤	0,25 µg/m³	0.010	$u_{r,lh}$	not respected, as ur,lh = 0 < ur,f	-	
3	"lack of fit" at annual limit value	≤	5,0% of gas level	1.398	$u_{l,lh}$	0.04	0.0016	
4	Sensitivity coefficient of sample gas pressure at annual limit value	≤	0,40 (µg/m³)/kPa	0.035	u_{gp}	0.08	0.0068	
6	Sensitivity coefficient of surrounding temperature at annual limit value	≤	0,08 (µg/m³)/K	0.029	u_{st}	0.07	0.0051	
7	Sensitivity coefficient of electrical voltage at annual limit value	≤	0,080 (µg/m³)/V	0.001	u_V	0.00	0.0000	
8a	Interferent H20 with 19 mmol/mol	≤	0,015 (µg/m³)/mmol/mol	-0.002	u_{H2O}	-0.03	0.0008	
9	Memory-Effect	≤	1,0 µg/m³	0.128	u_{av}	0.01	0.0001	
10	Repeatability standard deviation in field	≤	0,25 µg/m³ of average of 3 month	0.186	$u_{r,f}$	0.19	0.0346	
12	Long term drift at span	≤	10 % of cert. range	3.510	$u_{d,l,lh}$	0.10	0.0103	
18	Difference sample/calibration port	≤	1,0%	0.000	$u_{\Delta sc}$	0.00	0.0000	
21	Uncertainty of test gas	≤	3,0%	3.000	u_{cg}	0.08	0.0056	
				Combined standard uncertainty	u_c		0.3155	µg/m³
				Expanded uncertainty	U		0.6309	µg/m³
				Relative expanded uncertainty	W		12.62	%
				Maximum allowed expanded uncertainty	W_{req}		25	%

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
- Checking the instrument 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. No error messages.
- Hydrogen normal pressure as well as instrument parameters such as pressure, temperature and voltage supply should be checked regularly (~ every two weeks).
- The internal sample filter and the filter of the internal fan should be checked every two months and replaced if necessary.
- Perform zero and reference checks using suitable test gas every two weeks in accordance with standard EN 14662-3;

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

Environmental Protection/Air Pollution Control

M. Schneider　　　　Guido Baum

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

Cologne,Cologne, 13 June 2019
936/21244174/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 14662-3: Ambient Air – Method for the measurement of benzene using ultra-violet photometry, November 2015

[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

Appendix 1 Certificate of Accreditation to EN ISO/IEC 17025:2005

Annex 2 Manual

DAkkS
Deutsche
Akkreditierungsstelle

Deutsche Akkreditierungsstelle GmbH

Beliehene gemäß § 8 Absatz 1 AkkStelleG i.V.m. § 1 Absatz 1 AkkStelleGBV
Unterzeichnerin der Multilateralen Abkommen
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

die Kompetenz nach DIN EN ISO/IEC 17025:2005 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; 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 Turbulenz-charakteristika und Extremwinde; Schallimmissionsprognosen, Schattenwurfimmissionsberechnung und Sichtbarkeits-bestimmung; 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 02.08.2018 mit der Akkreditierungsnummer D-PL-11120-02-00 und ist gültig bis 10.12.2022. Sie besteht aus diesem Deckblatt, der Rückseite des Deckblatts und der folgenden Anlage mit insgesamt 55 Seiten.

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

Berlin, 02.08.2018

Im Auftrag Dipl.-Ing. Andrea Valbuena
Abteilungsleiterin

Siehe Hinweise auf der Rückseite

Figure 11: Certificate of accreditation according to EN ISO/IEC 17025:2005

Deutsche Akkreditierungsstelle GmbH

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10117 Berlin

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

Standort Braunschweig
Bundesallee 100
38116 Braunschweig

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 11: Certificate of accreditation according to EN ISO/IEC 17025:2005 - page 2

Annex 2:

Manual

TECHNICAL MANUAL

VOC72e

GAS CHROMATOGRAPHY
VOC ANALYZER

- APRIL 2019 -

111, Bd Robespierre / CS 80004 - 78304 Poissy Cedex 4 - FRANCE
Tél : +33(0)1 39 22 38 00 – Fax : +33(0)1 39 65 38 08 – www.envea.global

GENERAL CHARACTERISTICS

PRINCIPLE OF OPERATION

OPERATING INSTRUCTIONS

PREVENTIVE MAINTENANCE

CORRECTIVE MAINTENANCE

WARNING

The information contained in this document is subject to change without notice.

The designer reserves the right to modify his equipment without updating this document, consequently the document is not contractual.

HAZARD INFORMATION for HYDROGEN

Hydrogen is the chromatography carrier gas of VOC72e.

When mixed with ambient air, hydrogen may IGNITE with a spark as soon as its VOLUMIC CONCENTRATION EXCEEDS **4%.**

AT HIGHER CONCENTRATIONS **(8%), the ignition may become EXPLOSIVE.**

<u>Note</u> : A non-hermetic room can tolerate without hazard a permanent hydrogen leak of at least 200ml / min (more than 10 times the hydrogen consumption of VOC72e) because hydrogen is a non-persistent gas that dilutes rapidly in the air unlike hydrocarbons that accumulate. The following SAFETY INSTRUCTIONS should therefore be applied to prevent the risk of massive hydrogen leak:

SAFETY INSTRUCTIONS

- Secure the hydrogen bottle to prevent it from falling and destruction of the regulator.
- Install the hydrogen cylinder and its pressure regulator outside the room where the VOC72e is located (under an outdoor shelter or in a ventilated room).
- If the cylinder is inside the room, connect the safety valve of the cylinder pressure regulator to an external vent.
- Connect the VOC72e to the hydrogen source by a small diameter stainless steel tube (1/16 "x 1/32" i.e. 1.6 x 0.8mm) in order to limit the hydrogen flow in case of important leak.
- Connect the VOC72e vent to an external vent. In normal operation, the VOC72e vent exhaust rejects a small amount of hydrogen, but if the pilot injection valve fails, the hydrogen flow rate can increase strongly.
- Install a hydrogen detector at 25% LEL (Lower Explosive Limit) in the room.

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CHAPTER 4. PREVENTIVE MAINTENANCE

CHAPTER 5. CORRECTIVE MAINTENANCE

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CHAPTER 1

GENERAL - CHARACTERISTICS

1. GENERAL - CHARACTERISTICS

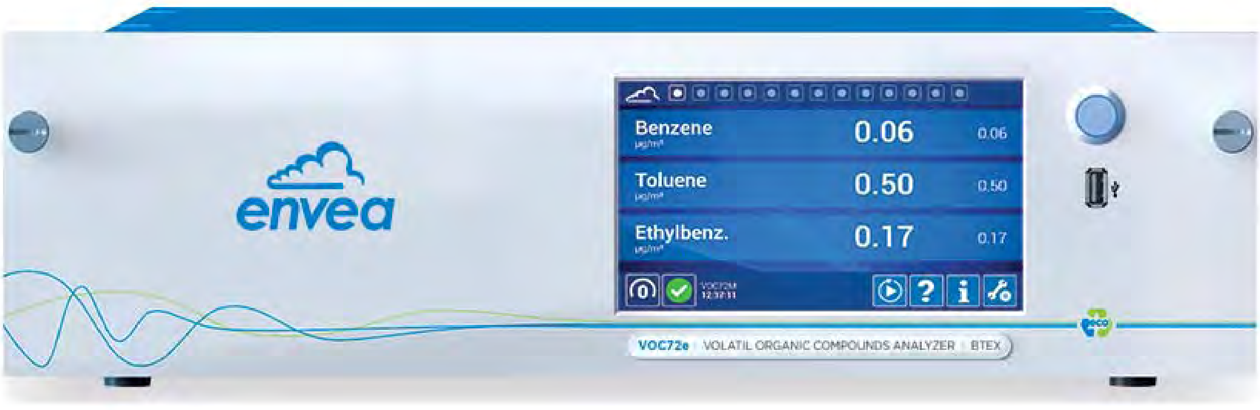


Figure 1–1 – Presentation of the VOC72e

1.1 GENERAL

1.1.1 PRESENTATION

The VOC72e is an analyzer of volatile organic compounds (VOC). VOCs are organic molecules (based on carbon chemistry) present in ambient outdoor air at low concentration (typically in the low ppb range).

The VOC72e is particularly suitable for pollution measurement station (urban and industrial sites). It is a compact rack (3U). However, its characteristics are comparable to laboratory chromatographs.

Its metrology, in accordance with EN14662-3 standard for benzene measurement, is based on gas chromatography (GC) for the separation of the measured compounds coupled with a photo-ionization detection.

The VOC72e performs three main analytical functions:

- the sampling,
- the GC (Gas Chromatography) analysis,
- The data processing.

1.1.1.1 The sampling

The sampling is carried out with a single trap filled with a specific adsorbent.

The sample flow through the trap is about 12 ml/min which gives a sampled volume of 165 ml with the standard 15 minute cycle (sampling time > 90% of cycle time). Other cycle durations are possible from 10 to 30 minutes.

A bypass flow of 35 ml/min is added in order to ensure the permanent input flow of the sample even if the trap is not in sampling mode.

1.1.1.2 The GC analysis

At the end of the sampling cycle, the trap is connected to the GC column inlet, and then quickly heated (from 35 to 380°C in less than 2 seconds). The compounds are thermally desorbed and flushed with hydrogen into the GC column. Finally, the trap is quickly cooled by a fan for a new sampling cycle.

Inside the GC column, the compounds are moved forward by the hydrogen flow (the mobile phase) and retained by the internal coating (the stationary phase) causing a selective retardation of the compounds. In order to achieve an optimal separation within a minimal time, the GC column follows a multi ramp thermal cycle from a cold step (25°C) for the injection to a hot step (160°C) for flushing all the heavy compounds (i.e.-e compounds with a high boiling point). At the end of the hot step, the GC column is cooled to the cold step for the next injection.

The GC column outlet is connected to a photo ionization detector where the compounds concentration is converted into a small electric signal. This signal is amplified and digitized in the electrometer board present in the analyzer. The time recording of this signal is the chromatogram which exhibits a peak for each detected compound. An ambient air chromatogram may include more than 100 peaks.

1.1.1.3 The data processing

The chromatogram processing is carried out by the ARM20 board.

The peaks are detected and integrated with a baseline correction. The peak timing (retention time) is also recorded.

When the retention time of a peak is located inside the retention time window of a compound (typically +/-2 seconds), the peak is identified as corresponding this compound.

The peak surface is corrected by the calculation of the trap-sampled volume. This calculation is based on the trap pressure during the sampling. A correction of atmospheric pressure is applied to take into account the PID detector response.

The corrected area value, multiplied by the compound response factor (also named “compound sampling factor”), gives the concentration of this compound.

1.1.2 DESCRIPTION

1.1.2.1 Front panel

The front panel includes the following:

– General switch (1).

– Backlit color TFT LCD (Thin Film Transistor Liquid Crystal Display) (2):

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

– Capacitive touch-screen projected on glass.

– USB port (3).

(1) General switch, (2) backlit liquid crystal display, (3) USB port

Figure 1–2 – Front panel

1.1.2.2 Rear panel

(1) Empty slot for the optional ESTEL board, (2) mains fuse, (3) cooling fan exhaust, (4) screw of sample input filter assembly, (5) sample inlet for 4mm OD (overall diameter) tube, (6) hydrogen inlet for 1/16" OD tube, (7) vent exhaust for 4mm OD tube, (8) heat sink cooling fan, (10) Ethernet socket, (11) identification plate, (12) power socket, (13) optional span inlet (if fitting Ø is 4 mm OD ⇨ span option, if fitting Ø is 1/16'' OD ⇨ pressure span option), (14) optional span vent, (15) RS4i board.

Figure 1–3 – Rear panel of VOC72e

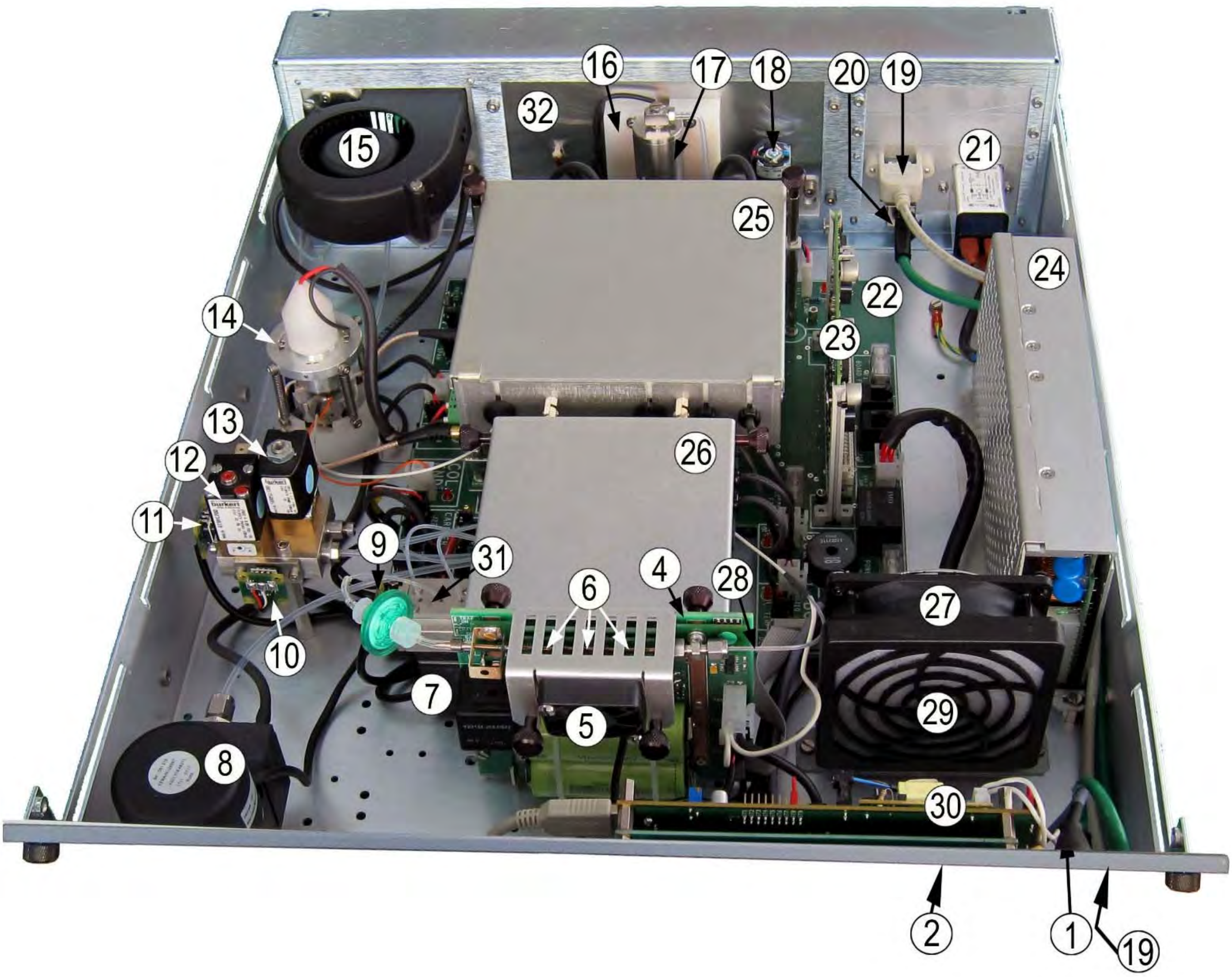
1.1.3 INTERNAL VIEW

Unscrew the two knurled screws at the rear of the instrument to remove the cover and have access to the internal components.

STOP

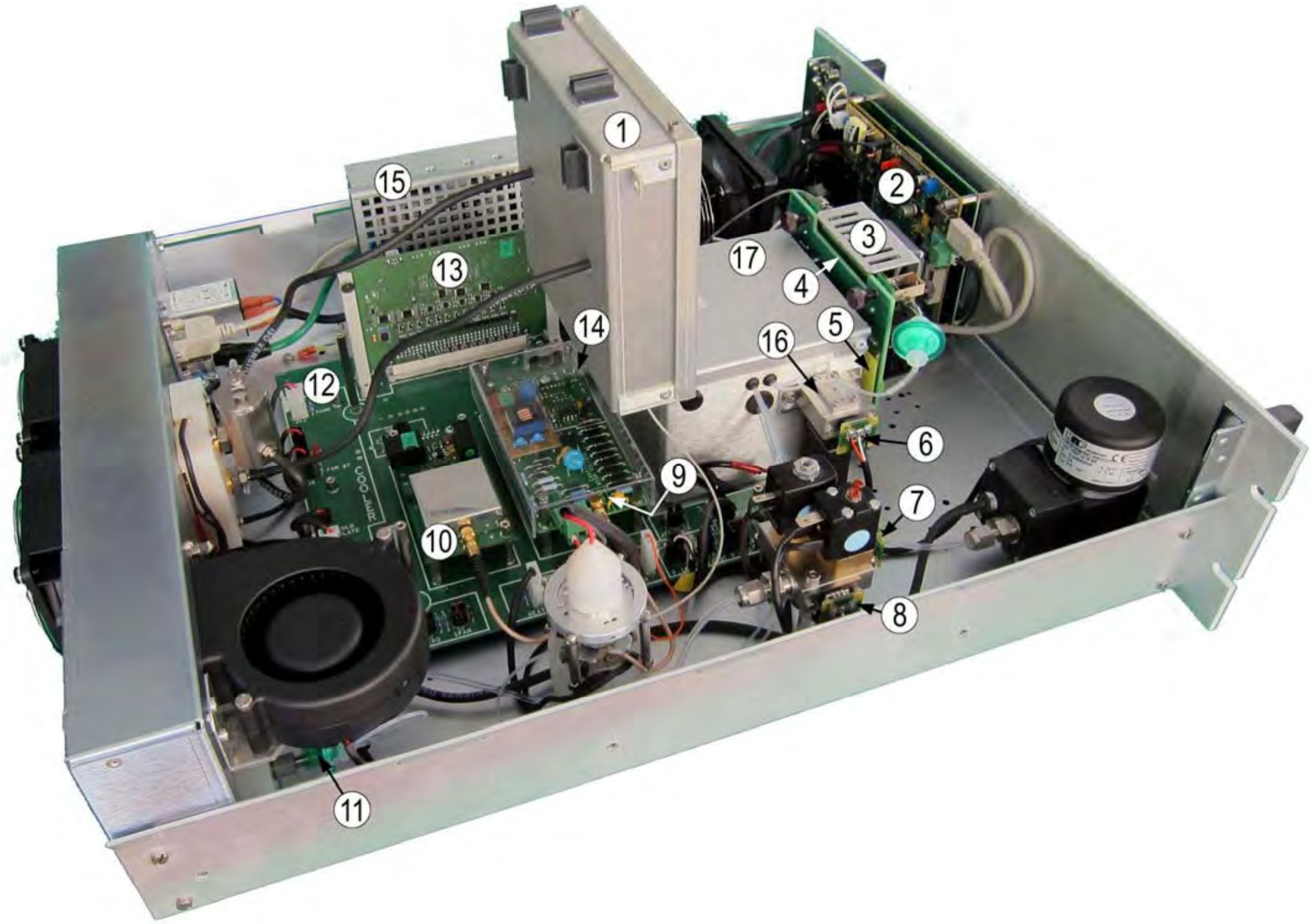
CAUTION : The instrument is to be only serviced by trained technician. Please, note that the following risks must be taken into account when working inside the instrument :

- Lethal voltages (300V) are present inside the 24VDC power supply as far as the power cord is connected to mains voltage. Do not remove the protective grid. (mark 15 of Figure 1–5) of this supply.
- The PID power board features a 1800 V / 3 mA source: do not remove its transparent protection cover (mark 14 of Figure 1–5).
- The trap is able to heat from ambient temperature to 380°C (716°F) in less than 2 seconds. Do not run the instrument without the trap fan in position (mark 5 of Figure 1–4): its cover is also designed to avoid direct contact with the trap tube (mark 6 of Figure 1–4).
- Keep in mind that **the front switch is not a mains switch.** The correct rule is: to always remove the mains power cord from the instrument before handling any connector inside it.



(1) ON-OFF switch, (2) LCD display, (3) sensitive 6-key keyboard, (4) desorber board, (5) trap cooling fan, (6) trap, (7) purge solenoid valve, (8) vacuum pump, (9) trap pressure sensor, (10) pressure sensor of chromatography column, (11) pressure sensor if hydrogen input, (12) proportional solenoid valve, (13) pilot solenoid valve, (14) photo-ionization detector (PID), (15) internal cooling fan, (16) thermo cooler assembly, (17) expansion tank, (18) cooling pump, (19) USB port, (20) Ethernet output, (21) mains socket, (22) interconnection board, (23) module board, (24) 24V DC power supply, (25) GC column box, (26) Hot box, (27) mixing fan, (28) transfer line, (29) dust filter, (30) ARM20 board, (31) purge assembly, (32) heat sink.

Figure 1–4 – Internal view



(1) GC column box, (2) ARM20 board, (3) Trap grid (hot tube below), (4) Desorber board, (5) Desorber protective plate (do not remove), (6) Trap pressure sensor, (7) Column pressure sensor, (8) Pressure sensor of hydrogen input, (9) PID power board (caution 1.8 kV / 3 mA), (10) Electrometer board, (11) Sample input filter, (12) Interconnection board, (13) Module board, (14) PID power protective cover (high voltage below), (15) 24V power supply protective grid (do not remove: lethal voltage below), (16) purge assembly, (17) hot box.

Figure 1–5 – Internal side view with tilted GC column box.

1.1.3.1 Physical part

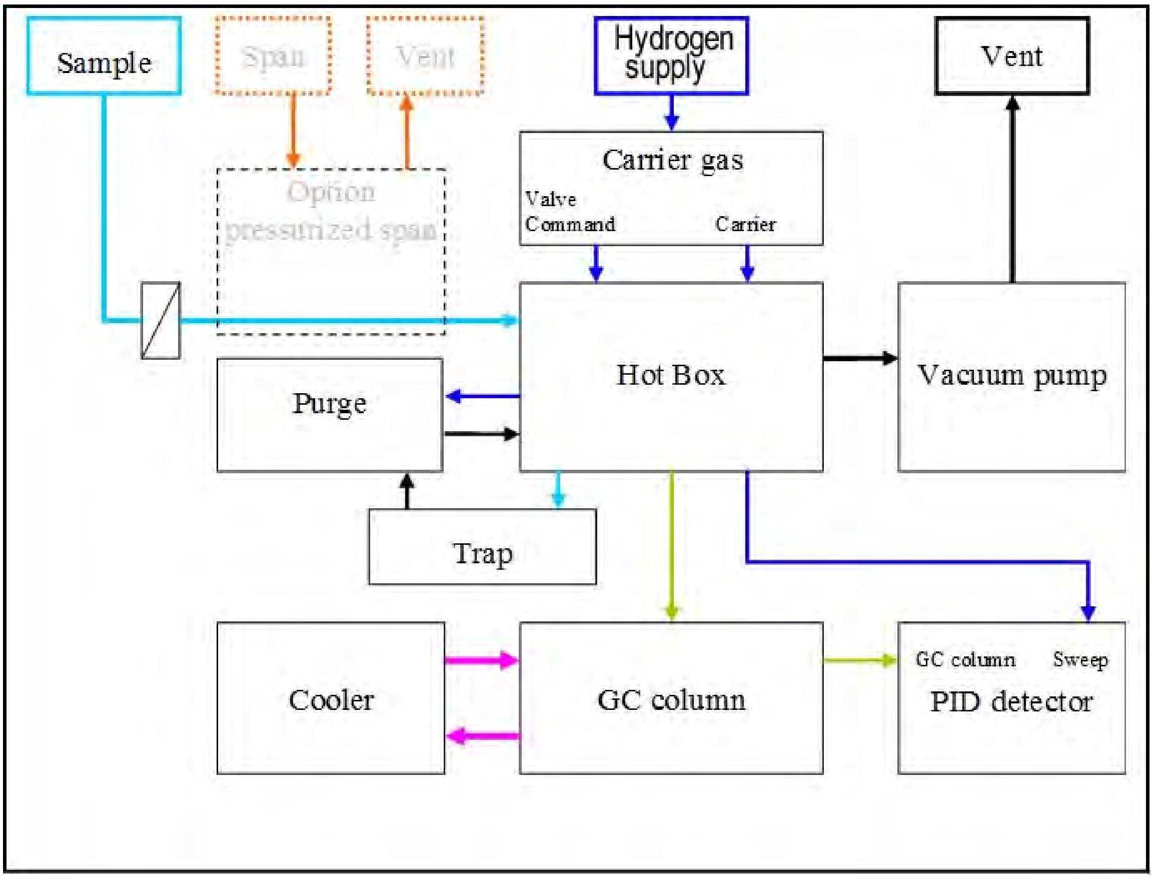


Figure 1–6 – Fluid block diagram

1.1.3.1.1 <u>The carrier gas assembly.</u>

Refer to marks (10), (11), (12), (13) of Figure 1–4.

This assembly receives the hydrogen from the hydrogen supply. The block is equipped with two solenoid valves (12) (13) and two pressure sensors (10) (11):

- A 3/2 solenoid valve (13) is used as pilot valve for the 6-port injection valve located in the hot box (26).
- A proportional solenoid valve (12) generates a stable hydrogen pressure used to supply the GC column (25), the purge flow and the scavenging flow of the PID detector.
- A 5 bar pressure sensor (11) monitors the hydrogen input pressure (6) of Figure 1–3.
- A 0.5 bar pressure sensor (10) monitors the regulated hydrogen pressure applied on the chromatography column, and controls the proportional valve (12) (electronic pressure control).

1.1.3.1.2 The purge assembly.

Refer to marks (31) of Figure 1–4 and (16) of Figure 1–5.

This assembly is attached on the left side of the hot box: (26) Figure 1–4 and (17) Figure 1–5.

The purge assembly is equipped with a 3/2 solenoid valve (mark 7 of Figure 1–4) and a pressure sensor (mark 6 of Figure 1–5).

When the 3/2 solenoid valve is OFF, the trap (6) is connected to the vacuum pump (8) through a restrictor and the sample is flowing from the transfer line (28) through the trap. The trap pressure sensor measures the absolute pressure resulting from the sample pressure minus the pressure drop in the sampling line and the trap. (Figure 1–4)

When the 3/2 solenoid valve (7) is activated, the trap (6) is connected to the regulated hydrogen source (10-11-12-13) through a restrictor and hydrogen is flowing through the trap towards the transfer line (28) and the 6-way injection valve. The trap pressure sensor (9) measures the vacuum pump pressure (typically less than 200 mbar). (Figure 1–4).

1.1.3.1.3 The cooler assembly.

Refer to Figure 1–4, (16) (17) (18).

This assembly is mounted on the rear panel. Its function is to cool the GC column (25) from the hot step to the cold step.

The expansion tank (17) stores the cooled fluid.

The cooling pump (18) moves the cold cooling fluid from the expansion tank (17) towards the GC column assembly (25) during the cooling operation.

The Peltier heat exchanger (located at 16) receives the hot cooling fluid from the GC column assembly to be cooled, transfers the heat to the cold plate and directs the cold fluid to the expansion tank.

The cold plate is heated by the Peltier heat exchanger and cooled by the Peltier module. A temperature sensor measures the cold plate temperature and controls the power sent to the Peltier module.

The Peltier module is mounted between the cold plate and the heat sink (32). The Peltier module is a thermal pump.

The Peltier heat sink is heated by the Peltier module and cooled by two external fans (8) on Figure 1–3. A temperature sensor measures the heat sink temperature and controls the fans operation.

1.1.3.1.4 The GC column assembly.

Refer to (25) of Figure 1–4 and (17) of Figure 1–5.

This assembly includes:

- The 15-meter length stainless steel GC column.
- The column plate supports the GC column and receives two temperature sensors: one for the temperature control of the chromatography column, the other for the safety system. If the two temperature readings do not match, the safety system will stop the column heating.
- The column heater is a flat resistor that heats the column plate.
- The column heat exchanger cools the column plate. The exchanger is connected to the cooler with two cooling hoses.

The assembly is disposed in an insulated box in order to reduce the thermal losses that impair the GC column temperature control which leads to unstable retention times. The column box can be tilted to access to the electrometer and PID power boards - See (9) (10) of Figure 1–5.

NOTE : The instrument is still able to run in the configuration shown at Figure 1–5.

The GC column ends are thermally insulated.

The input is grounded through its connection to the injection valve. The output is connected to the photo ionization detector (PID) where a contact blade delivers the column end voltage.

When the GC column is heating, the column end voltage is activated and the column ends are directly heated by the resultant current flowing through the stainless steel column from the contact blade to the injection valve. Both voltage and intensity are measured in order to ensure that this heating is effective.

When the GC column is heating, the cooling pump (18) is OFF. The column assembly is heated including the GC column coil, the column plate, the heat exchanger and its coolant fluid but the heat remains inside the insulating box (25) as the coolant fluid can't move.

When the GC column is cooling, the heater is OFF and the cooling pump is ON: the coolant fluid moves between the column heat exchanger and the cooler.

1.1.3.1.5 The vacuum pump.

Refer to (8) of Figure 1–4.

The vacuum pump is connected to two restrictors (located inside the hot box – mark 26) which generate the sampling flow and the by-pass flow. The vacuum is measured by the trap pressure (9) sensor when the purge valve (7) is activated.

1.1.3.1.6 The internal temperature control.

Refer to marks (27), (15), (22) of Figure 1–4

The internal temperature control includes:

- The mixing fan (27).
- The internal cooling fan (15).
- The internal temperature sensor (22), plugged on the interconnection board.

The mixing fan is always activated. It cools the 24V power supply (24) and moves the air inside the analyzer.

The internal temperature sensor measures the air temperature close to the mixing fan.

The module board (23) adjusts the power to the internal cooling fan according to the internal set point temperature (35°C). The cooling fan extracts the hot air at the top of the rack enclosure. The hot air is replaced by fresh air coming from the front of the instrument, causing the internal temperature to decrease.

The instrument is protected against internal overheating with a triple level safety device located on the module board (23):

- Level 1: within 43°C – 45 °C, a default temperature is detected, but the analysis cycle goes on.
- Level 2: within 45°C – 46 °C, an alarm temperature is detected, the analyzer switches to the Stand-by mode, the power requirement of which is reduced, and consequently the heat production is reduced.
- Level 3: a safety temperature is detected when temperature exceeds 46°C, the analyzer switches the safety 24V relay to OFF.

1.1.3.1.7 The hot box.

Refer to mark (27) of Figure 1–4.

The hot box includes a heated plate that receives two elements:

- The 6-port injection valve which is pressure controlled by the solenoid pilot valve (13).
- The restrictor block achieves the connections between the restrictors, the hydrogen pressure-regulated source, the vacuum source, the sample input and the 6-port injection valve.

A sensor measures the temperature of the heated plate and controls the power applied to the heating resistor located below.

1.1.3.1.8 The trap and the transfer line.

Refer to mark (6) of Figure 1–4.

The trap (6) is a stainless steel tube filled with a specific sorbent.

At room temperature, the sorbent stores the volatile compounds present in the air flowing through the tube.

At high temperature, the sorbent releases the compounds in the hydrogen flowing through the tube in the opposite direction.

The tube is mounted on the trap board which provides 2 electrical connections:

- A power connection through the two M3 threaded screws. The tube is directly heated with a 3 Volts 60 A. current delivered by the desorber board.
- A signal connection through the two pads for the thermocouple. The thermocouple is a fast temperature sensor required by the quick heating rate (over 160°C per second).

On the left side, the trap is connected to the purge assembly through the trap filter.

On the right side, the trap is connected to the injection valve through the transfer line.

In sampling mode, the transfer line cools the sample coming from the hot box. In desorption mode, the transfer line is heated and it keeps the desorbed sample heated on its path to the injection valve.

The transfer line is heated by direct Joule effect in very low voltage. The power is delivered by the desorber board.

The heating power is software adjustable and the resulting intensity is measured on the desorber board in order to ensure that the heating is effective.

1.1.3.1.9 The photo ionization detector (PID).

The PID detector includes a 10.6 eV (I.P.) lamp. This lamp generates a UV beam that is able to ionize all the compounds which ionization potential (IP) is less than 10.6eV.

I.P.: ionization potential

Compounds	**IP (eV)**	**Detection status**
Benzene	9.25	Detected
Carbon dioxide	13.79	Not detected
Ethylbenzene	8.76	Detected
Nitrogen	15.58	Not detected
Hydrogen	15.43	Not detected
Oxygen	12.08	Not detected
Toluene	8.82	Detected
Water	12.59	Not detected
m-Xylene	8.56	Detected
o-Xylene	8.56	Detected
p-Xylene	8.45	Detected

The simplified UV ionization process for compound M is:

$$M \rightarrow M^{+} + e^{-}$$

NOTE : A small (but reproducible) proportion of the compound is ionized (typically less than 1%) and most of the created ions finally recombine into the original compound. The PID is considered as a non-destructive detector.

The 240 volt electric field between the polarization electrode (– 240 volt) and the signal electrode (0 volt) moves the ionized particles (positive ions and negative electrons) towards the electrodes creating a small electrical conduction.

The resulting electric current is amplified and converted into a voltage in the electrometer board.

An additional hydrogen flow called “scavenge flow” is added below the lamp window:

- It provides a faster response time to the detector, in order to keep the natural GC peak resolution.
- It prevents the GC column flow from reaching the lamp window, eliminating the need for cleaning the lamp window and the resulting drift.
- It acts as a hydrogen curtain between the lamp and the reaction chamber which lets the UV ray passing through, but prevents the effluents to move up from the chromatography column towards the lamp window. The lamp window remains clean, which eliminates the drift due to its dirtiness and the necessary periodic cleaning.

The “scavenge flow” is generated in the hot box from the regulated hydrogen pressure via a heated micro capillary restrictor.

1.1.3.2 Electronic part

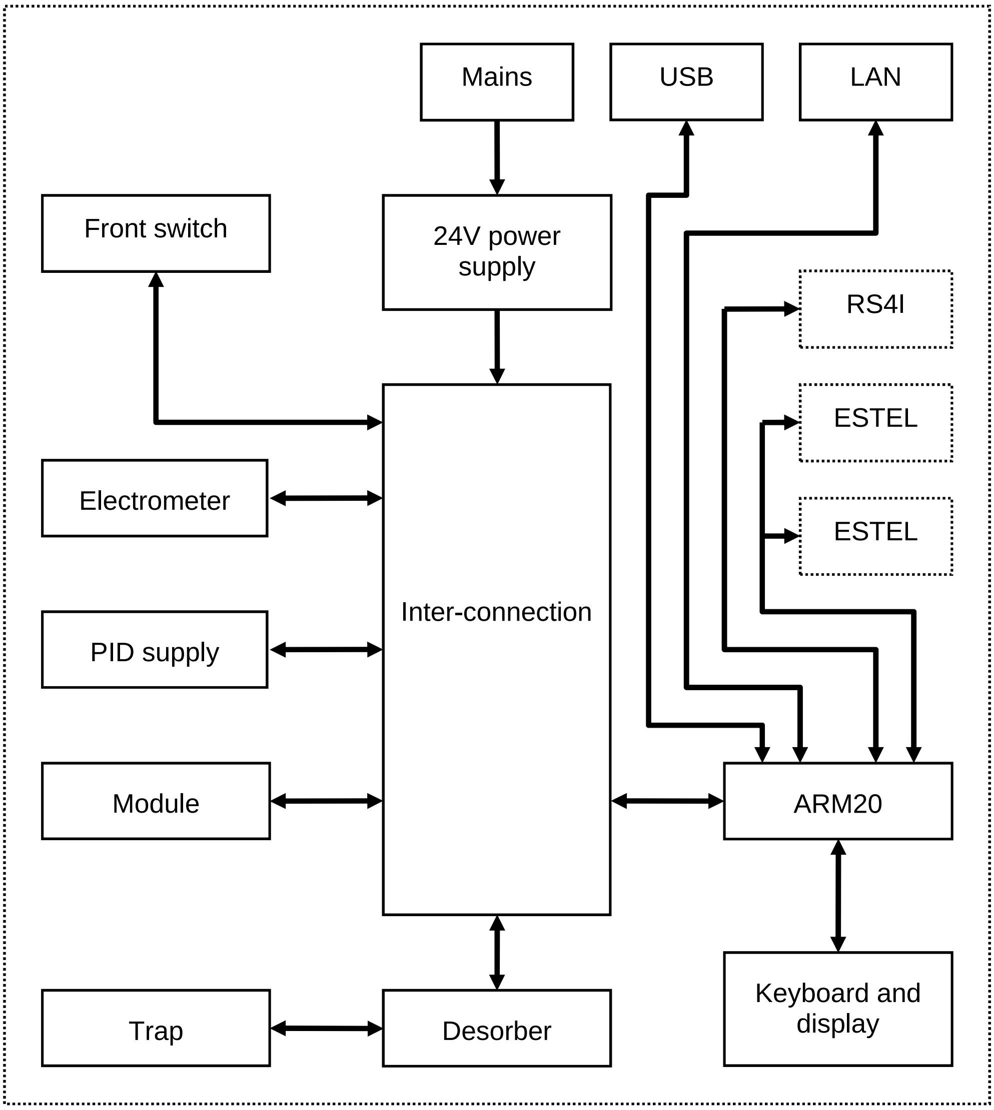


Figure 1–7 – Electronic block diagram

WARNING : The front switch (mark 1, of Figure 1–2) does not switch OFF the mains voltage. Always disconnect the external power cable before attempting to replace electronic boards. Do not remove the power supply protective grid (mark 15, of Figure 1–5): lethal voltages (300 V) are present on the power supply internal components such as heat sinks.

1.1.3.2.1 The 24V power supply.

Refer to (24) of Figure 1–4 and (15) of Figure 1–5.

The 24V power supply converts the mains voltage into 24VDC which is used as a power source for all the internal parts.

1.1.3.2.2 The electrometer board.

Refer to (10) of Figure 1–5 and Figure 5-2.

This board converts the weak current from the PID collector electrode into a voltage which is amplified in a programmable gain amplifier (gain x1.x2.x4.x8.x16.x32.x64) and digitized with a 24 bit ADC converter. The resulting data is processed by the on-board microprocessor and sent to the module board temporary buffer through a serial link.

1.1.3.2.3 The PID supply board.

Refer to (9) of Figure 1–5 and Figure 5-3.

This board delivers two negative DC voltages to the photo ionization detector:

- – 240 V for the polarization electrode. The intensity is limited to 0.2 mA.
- – 1600 V for the UV lamp. This high voltage is required to fire the lamp (same function as a neon lamp starter). When the UV lamp is ON, the voltage drops towards -300 V and the intensity is limited to 0.6 mA with a ballast resistor.

NOTE : The red cable to the PID lamp is the negative supply cable (i.e.-e the high voltage versus ground).

The board measures the PID lamp voltage to ensure that both lamp and HV power supply are OK. The 0.6 mA current to the lamp powers the red led indicator close to the HV terminal.

The lamp voltage measurement circuit discharges the high voltage accumulated on the lamp when the power is OFF.

NOTE : The board internal voltage source is rated 1800 V / 3 mA :

⇨ Keep the protective cover in place.

⇨ Always remove the power cord before attempting to remove the board or its protective cover.

⇨Make sure that PID power is OFF when removing the UV lamp.

WARNING : After a power OFF/ON action (front switch or power outage), the VOC72e returns (after warm-up) to the previous state. If the PID UV lamp was ON before the power outage, the PID power supply will automatically restart after some warm-up delay generating a high voltage on the board and the PID lamp.

1.1.3.2.4 The module board.

Refer to (13) of Figure 1–5 and Figure 5-4..

The module board is the main electronic board. It is connected to the sensors (pressure, temperature, intensity, voltage) and directly powers most of the physical parts of the analyzer: pumps, fans, heaters, solenoid valves, Peltier module.

The module board receives the cycle program from the ARM20 board at the beginning of each cycle and sends the resulting data to the ARM20 board.

The module board collects the chromatogram data points from the electrometer board and stores them in a memory which is periodically emptied by the ARM20 board.

1.1.3.2.5 The desorber board.

Refer to (4) of Figure 1–5 and Figure 5-1.

The desorber board is a voltage converter and a power booster. Its main function is to deliver the low voltage (3 Volts / 60 A.) that heats the trap from ambient to 380°C within 2 seconds. An auxiliary circuit heats the transfer line.

The heating power, which exceeds the 24V power supply capacity, is delivered by an integrated power accumulator. The power accumulator recovers the heating energy from the 24V power supply with a small charger during the analysis cycle.

The board includes a safety relay which isolates the power accumulator when:

– VOC72e is OFF.

– Flat cable is not connected.

– Module board detects a failure.

The desorber board also features a trap temperature limiter.

WARNING : The power accumulator can deliver 120 A in continuous mode and much more in short circuit condition. Take precautions to avoid short circuits: considerable heat will occur through the shorting conductor. The resultant high temperature can cause severe injuries or initiate a fire if flammable materials are present. Take the necessary precautions to avoid short circuits:

- Remove the main power cord before disconnecting the desorber board or replacing the trap.
- Keep the protective cover attached on the back of the board.
- Always store the desorber board (when out of the instrument) without the trap and in an insulated bag away from metallic pieces (screws, nuts…).
- Always keep the trap fan in place when the instrument is ON.

1.1.3.2.6 The trap board.

The trap board is the trap mechanical support. It has no electronic component. Its purpose is to connect the trap tube to the heating circuit and the thermocouple to the temperature amplifier. See also § *1.1.3.1.8 The trap and the transfer line.*

1.1.3.2.7 The ARM20 board.

Refer to (30) of Figure 1–4

The ARM20 board is a rapid calculation and interfacing board.

The ARM20 board sends the cycle program (temperature set points, timings) to the module board at the beginning of each cycle and collects the chromatogram and all the data required for calculating the compound concentration. The ARM20 board also collects data from the module board for the default and alarm messages.

The ARM20 board is also an interface board for the touch screen, the optional ESTEL boards (analog I/O and relays), the optional RS4I (serial interface) and includes the LAN and USB ports.

1.1.3.2.8 The interconnection board.

Refer to (22) of Figure 1–4, and Figure 5-5.

The interconnection board provides an electrical connection between the 96-pin connector of the module board and the electrical parts (fans, pumps, solenoid valves, sensors, heaters).

It also includes the 24V power distribution (power relay and fuses), the electrical filter for the internal cooling fan and the communication between the electrometer board, the module board and the ARM20 board.

1.2 CHARACTERISTICS

1.2.1 TECHNICAL CHARACTERISTICS

Measuring range	:	Maximum 1000 µg/m^3 (programmable)
Units	:	ppb or µg/m^3 (programmable)
Measured compounds	:	Benzene, toluene, ethyl benzene, m+p-xylene, o-xylene, (additional compounds possible on demand)
Cycle duration	:	10, 12, 15, 20, 30 minutes (programmable)
Measuring noise(σ)	:	≤ 0,025 µg/m^3 at 0,5 µg/m^3 benzene
Low detection limit (2σ)	:	≤ 0,05 µg/m^3 benzene
Carry-over (memory effect)	:	≤ 0,5% on the first zero
Long term span drift	:	≤ 4% on 15 days
Lack of fit ; largest residual	:	≤ 4% of the measured value.
Repeatability standard deviation	:	≤ 0,05 µg/m^3 at 5 µg/m^3 benzene (<1% of the annual limit)
Sample flow	:	50 ml/minute
Trap flow ; trapped volume	:	12 ml/minute; 165 ml (15-minute cycle)
Flow control	:	Built-in vacuum pump + heated micro capillary tube
Sampling rate	:	> 90% of cycle duration (15-minute cycle)
Trap adsorbent / sampling temperature	:	Carbopack® / 35°C
Desorption temperature / heating rate	:	380°C (programmable) / > 160°C/second
Injection valve	:	6-way (heated) pneumatic control
GC column	:	Stainless steel 15 m x 0,25 mm x 1 µm, a-polar
⇨ Carrier gas control	:	Electronic pressure control
⇨ Temperature control		20-170°C +/– 0.1°C, 5 ramps up to 30°C/minute.
⇨ Cooling	:	Liquid heat exchanger and Peltier cooler
GC detector	:	Photo-ionization (PID) 10,6eV with hydrogen curtain
⇨ Detector temperature	:	140°C (programmable)
Display	:	Backlit color TFT LCD, Resolution of 800 x 480 (pixels), 7” screen,
Commands	:	Touch screen

Analog I/O (ESTEL board option; maximum 2 boards)	:	– 4 analog outputs 0–1V, 0–10V, 0–20mA, 4–20mA – 4 analog inputs 0–2,5V – 4 remote control input – 6 contact output NO, potential free
Ethernet output	:	RJ45 socket, UDP protocol
USB port	:	USB port format 2.0
Serial port (RS4i option)	:	1 serial port format RS232 or RS422
Mains voltage	:	100–240V + ground ; 50–60Hz
Power demand	:	Average 130VA, peak 200VA
Gas supply	:	Hydrogen 5.5 (99,9995%) 3,2 +/– 0,2 bar 15 ml/minute
Working temperature	:	+ 0°C to + 30°C
Dimensions (L x l x H) / Weight	:	606 x 483 x 133 mm / 12,5 kg
Alarm checking	:	– Permanent – Detection and indication of abnormal functioning: temperature, pressures, electrical parameters – Compound limit thresholds (programmable)
Tests and diagnostics for maintenance	:	Direct selection on the touch screen and remote selection on the embedded web server.
Backup duration of stored-in-RAM data	:	1 year

1.2.2 OPERATING CHARACTERISTICS

Not applicable.

1.2.3 STORAGE CHARACTERISTICS

– Temperature: – 10 °C to 60 °C.

1.2.4 INSTALLATION CHARACTERISTICS

1.2.4.1 Connections between instruments

The VOC72e requires the supplies and external connections shown in black below.

The connections shown in *italics* are not mandatory or optional.

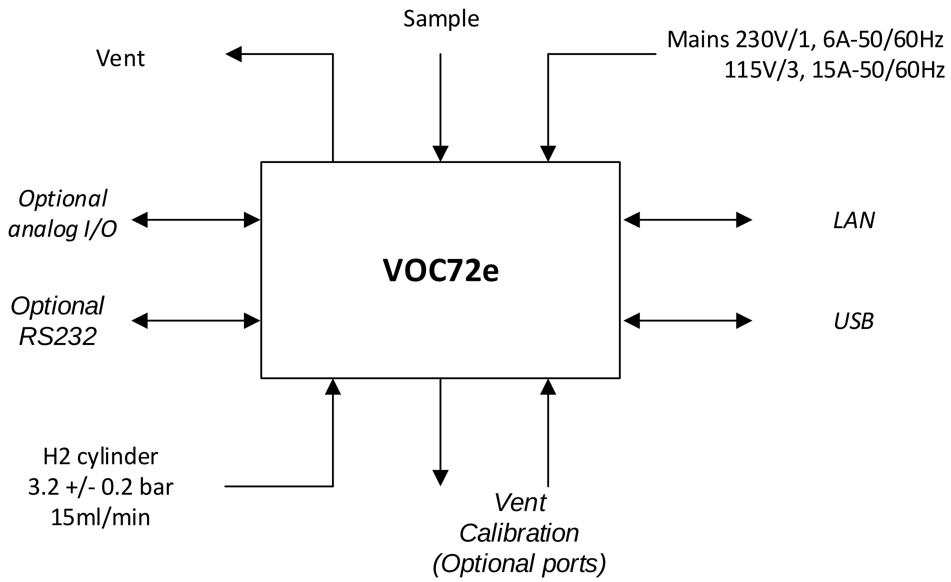


Figure 1–8 – Links between units

1.2.4.2 Dimensions and weight

The instrument is contained in a standard 19-inch 3-unit rack.

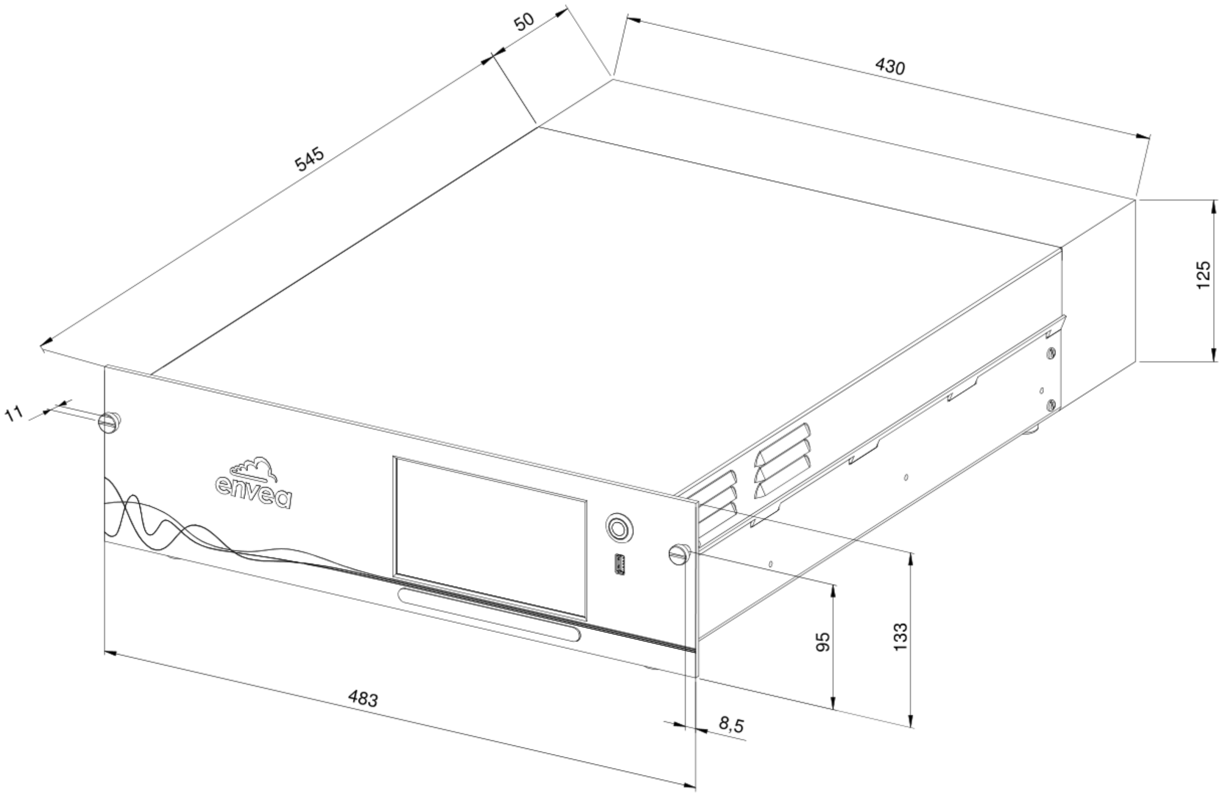
Length	:	606 mm
Width	:	483 mm
Height	:	133 mm
Weight	:	12.5 kg

1.2.4.3 Handling and storage

The VOC72e must be handled with care to avoid damage to the various connectors and fittings on the rear panel.

Ensure the fluid inlets and outlets on the unit are protected with caps whenever storing the monitor.

The unit is stored in a foam-packed case provided for this purpose. It is advised to keep the case for shipping the instrument.



When the analyzer is installed against a wall, it is required to leave a 100 mm-space between the rear panel and the wall necessary for the fans to suck-in air.

Figure 1–9 – Overall dimensions

1.2.4.4 Sample probe.

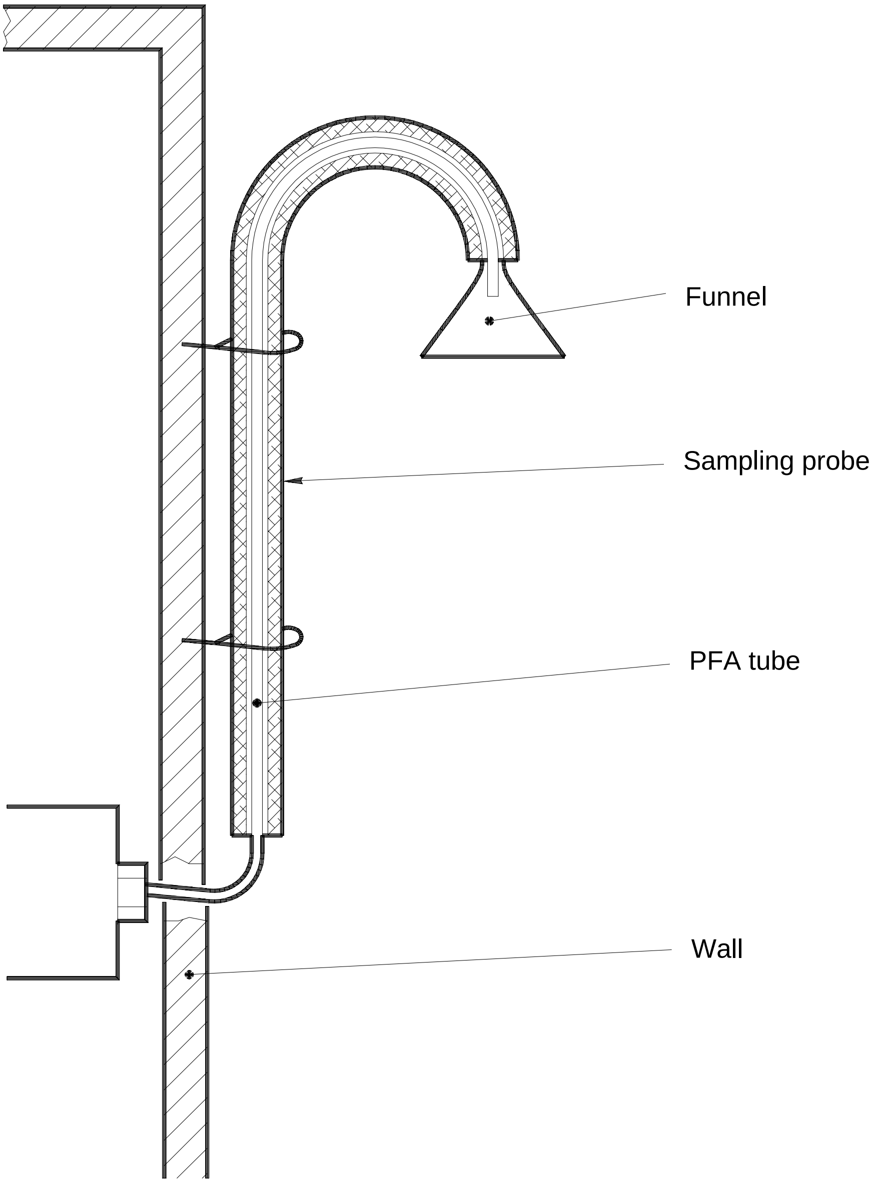


Figure 1–10 – Installation of the “sample gas” connector

NOTE : Recommended overall height for the sample connector: 2.50 m.
Maximum recommended length of the PFA sample gas tube: 6 m.

CHAPITRE 2

PRINCIPLE OF OPERATION

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2. PRINCIPLE OF OPERATION

The VOC72e metrology, in accordance with EN14662-3 standard for benzene measurement, is based on gas chromatography (GC) for the measured compound separation, coupled with a photo-ionization detection.

VOC72e is made up with a single trap: as the trap concentrates sample N, the GC column analyzes sample N-1.

2.1 END OF PREVIOUS CYCLE

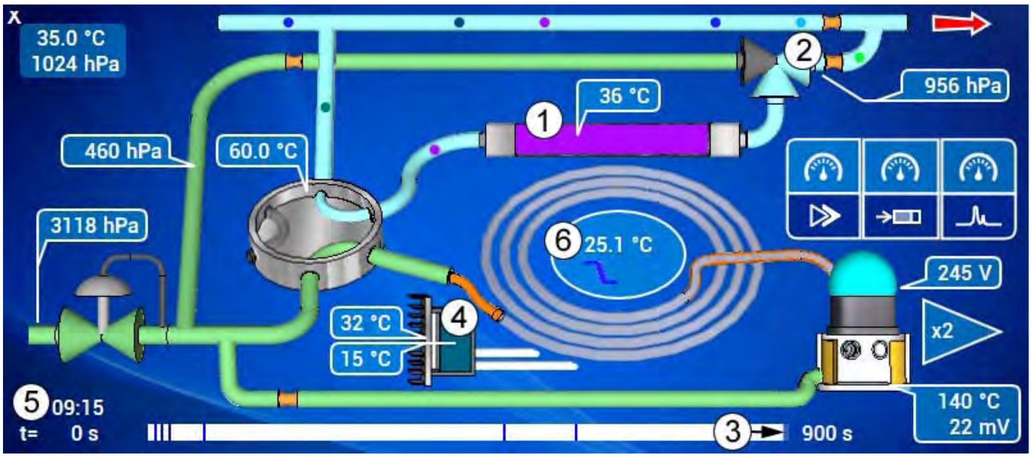

Figure 2-1 – End of previous cycle

As the progression bar approaches the cycle mark end (3), the Module board keeps the GC column temperature (6) on the cold step due to the cooler action (4).

The “Waiting for synchro” message (5) appears as the trap (1) is still in the sampling position on sample N defined by the purge valve status (2).

2.2 COLD PURGE

0 < t < 10 seconds (standard 15-minute cycle).

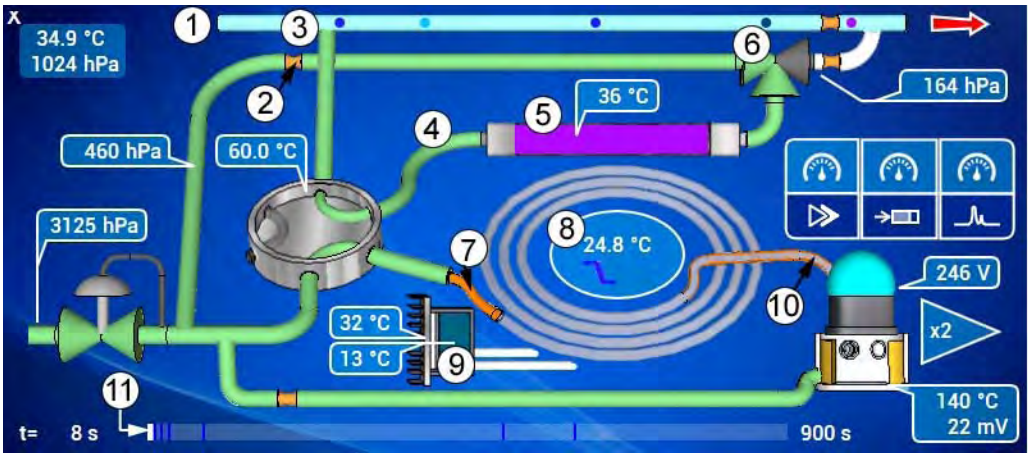

Figure 2-2 – Cold purge

As the progression bar returns to the cycle start mark (11), the Module board activates the heating of the transfer line (4) and the column ends (7) (10) in order to create a heated fluid circuit between the trap and the GC column.

Meanwhile, the Module board activates the purge valve (6) which terminates taking the sample N.

Now, hydrogen (green) flows from the purge restrictor (2) through the purge valve (6) and the trap (5) where it drains oxygen and humidity towards the by-pass line (3).

NOTE : The by-pass flow (35 ml/min) is greater than the hydrogen purge flow (15 ml/min), so the analyzer is still aspirating the sample on its inlet (1).

The GC column temperature remains on the cold step (8) due to the cooler action (9).

2.3 COUPLING

10 < t < 11 seconds (standard 15-minute cycle).

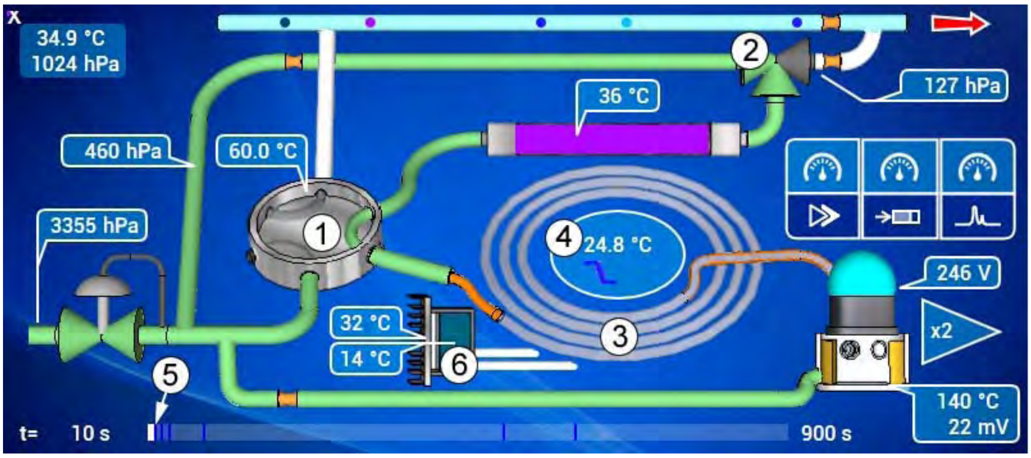

Figure 2-3 – Coupling

As the progression bar reaches the coupling mark (5), the Module board activates the 6-port injection valve (1) and stops the trap fan.

The trap is now connected to the GC column (3).

The GC column hydrogen supply is carried out from the purge valve (2).

The GC column is kept on the cold step (4) due to the cooler action (6).

The trap is ready for the thermal desorption.

2.4 INJECTION

11 < t < 20 seconds (standard 15-minute cycle).

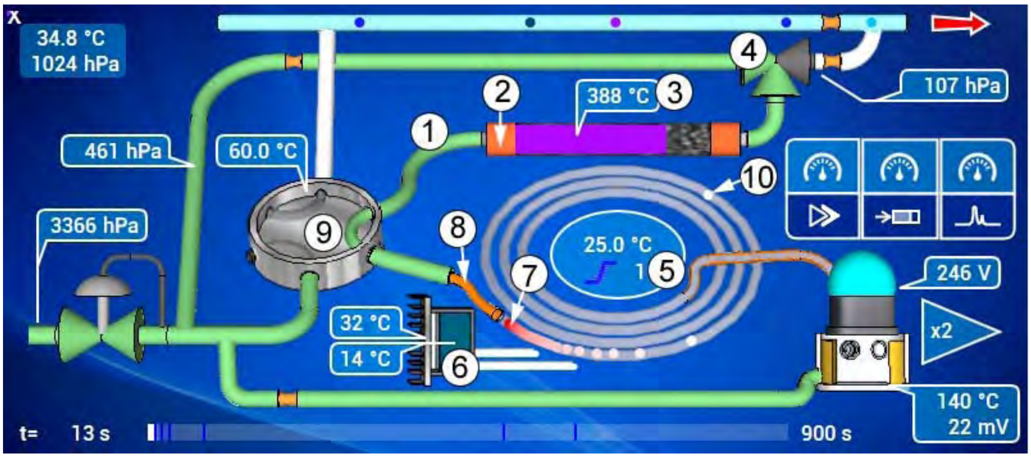

Figure 2-4 – Injection

The Module board activates the trap heating (2).

Within 2 seconds, the trap temperature (3) reaches the hot set point (380°C) causing the thermal desorption of the compounds trapped during the previous cycle.

The hydrogen coming from the purge valve (4) drains the compounds desorbed through the heated circuit (transfer line (1), 6-port valve (9), column end (8)) towards the cold GC column (7).

The heavy compounds focus on the column head while the light compounds, pushed by hydrogen, begin to migrate through the GC column (10).

Meanwhile, the Module board stops the cooler (6), starts the data acquisition of the detector signal for the chromatogram (sample N) and begins the first temperature ramp on the GC column (5): 5°C/minute.

2.5 HOT PURGE

20 < t < 30 seconds (standard 15-minute cycle).

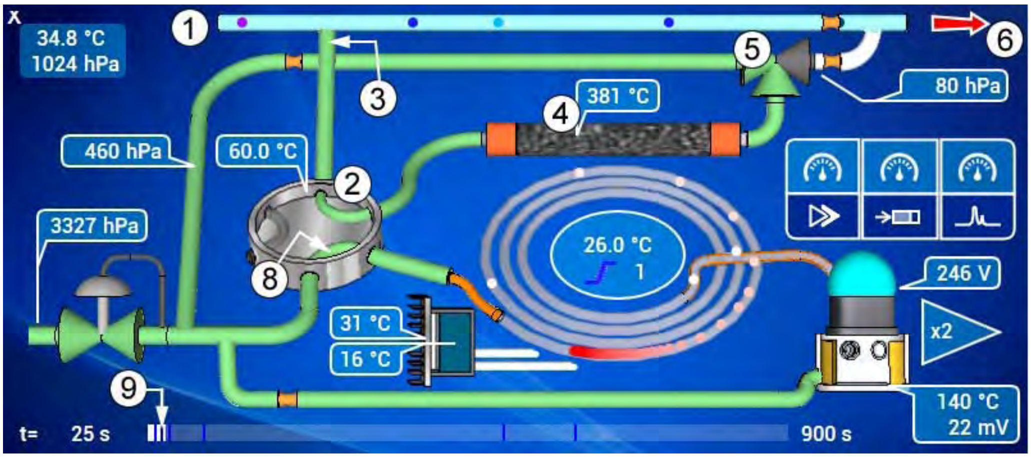

Figure 2-5 – Hot purge

When the progression bar reaches the purge mark (9), the Module board deactivates the 6-port injection valve (2) that returns to its de-energized position.

The fluid diagram is similar to the cold purge, excepted that trap temperature remains on its hot step of desorption (4).

Hydrogen coming from the purge valve (5) flows through the hot trap (4) and eliminates the residual compounds towards the by-pass circuit (3).

NOTE : The by-pass flow (35 ml/min) is greater than the hydrogen flow (15 ml/min), so the analyzer is still aspirating the sample on its inlet (1).

Both sample flow and hot purge flow are aspirated by the vacuum pump (6) and then directed towards the vent port.

Now, the carrier gas of the GC column directly comes from the 6-port injection valve (8).

2.6 TRAP COOLING

30 seconds < t < 80 seconds (standard 15-minute cycle).

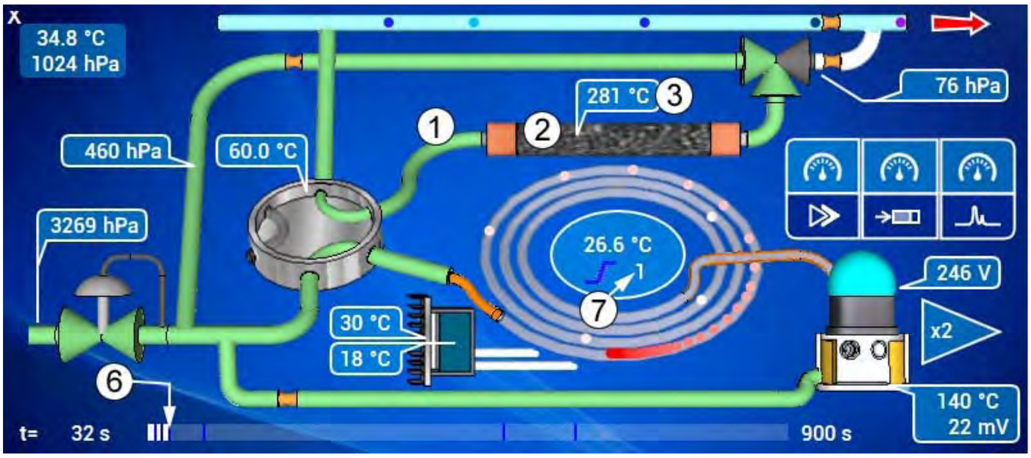

Figure 2-6 – Trap cooling (thermal ramp N°1)

When the progression bar reaches the trap cooling mark (6):

– The Module board switches OFF the trap heating (2) and the transfer line heating (1).

– The Module board activates the trap fan which accelerates its cooling (3).

– The chromatographic column is in its first thermal ramp (7).

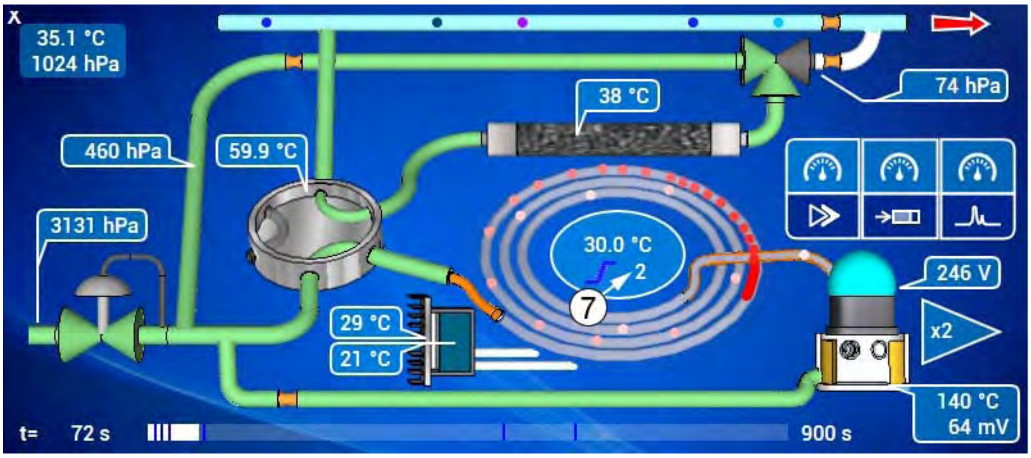

Figure 2-7 – Trap cooling (thermal ramp N°2)

The GC column starts its second thermal ramp (7): 15°C/minute.

2.7 TRAP SAMPLING

80 seconds < t < 900 seconds (standard 15-minute cycle).

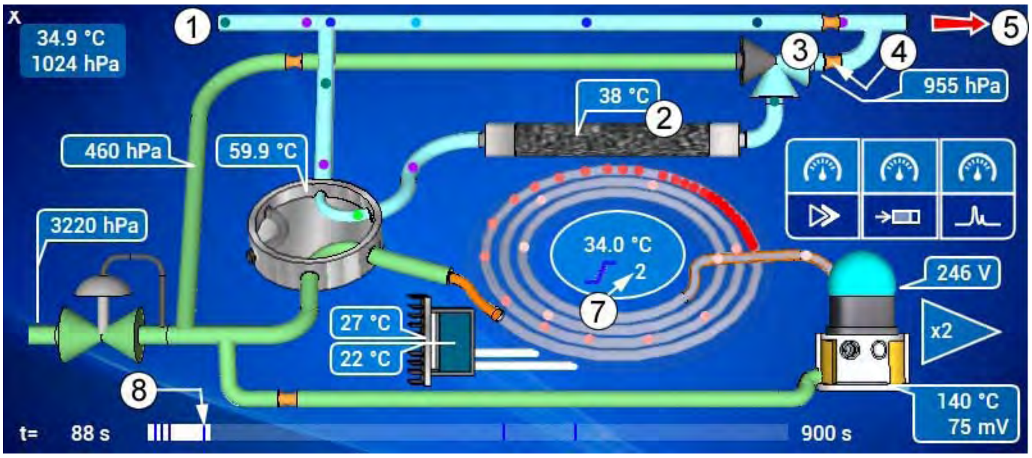

Figure 2-8 – Trap sampling (thermal ramp n°2)

When the progression bar reaches the sampling mark (8), the trap is cold (2).

The Module board deactivates the purge valve (3) and the sample flows again from the sample line (1) through the trap (2) towards the purge valve (3), the restrictor (4) and the vacuum pump (5).

Now, the trap concentrates the sample N+1.

The GC column continues its second thermal ramp (7).

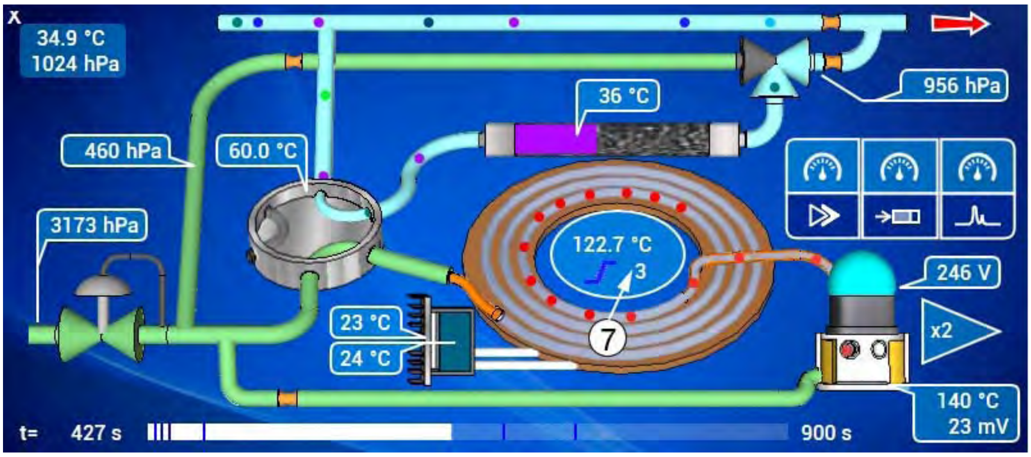

Figure 2-9 – Trap sampling (thermal ramp n°3)

The third thermal ramp (7) starts: 30°C/minute from 115 to 160°C.

2.8 DATA PROCESSING

The data processing screen is as follow:

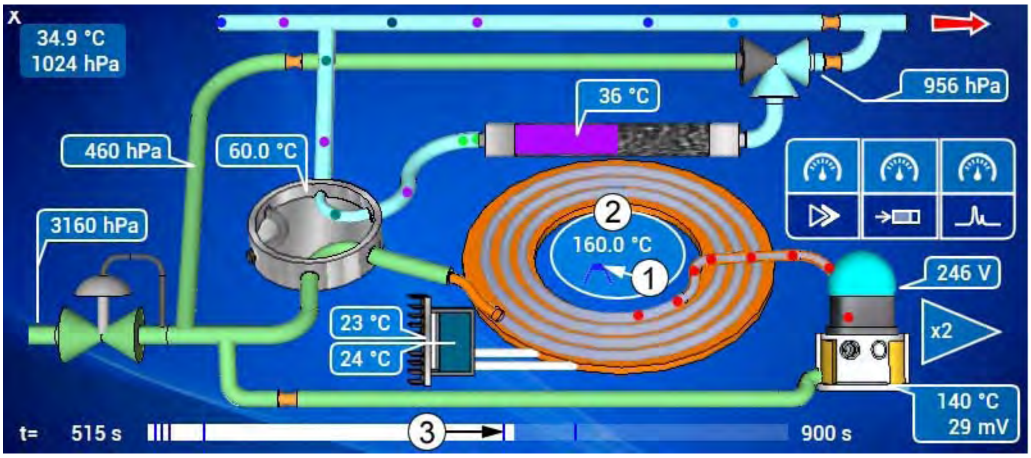

Figure 2-10 – Data processing

The third thermal ramp is finished and the GC column reaches the hot step (1) at 160°C (2).

The chromatogram acquisition stops and the ARM20 board recovers the last data points from the buffer memory of the Module board.

When the progression bar reaches the calculation mark (3), the ARM20 board now processes the chromatogram:

- The chromatographic peaks are detected, the corresponding baselines are calculated, and the peak areas are calculated.
- Among the detected chromatographic peaks, peaks whose retention time of which is included into a compound detection window, are identified as compound peaks.
- The peak areas are corrected with the calculation of the trapped volume (based on the average pressure of the trap during taking-in of the sample N) and the compensation of atmospheric pressure for the response of the PID detector (based on the average atmospheric pressure during the GC analysis of the sample N).
- The compound peak areas are multiplied by the response factor of this compound to gives the concentration of these compounds.

The chromatographic column remains on the hot step (2), which allows it to eliminate the heavy compounds.

The trap is still taking the sample N+1.

2.9 GC COLUMN COOLING

The GC column cooling screen is as follow:

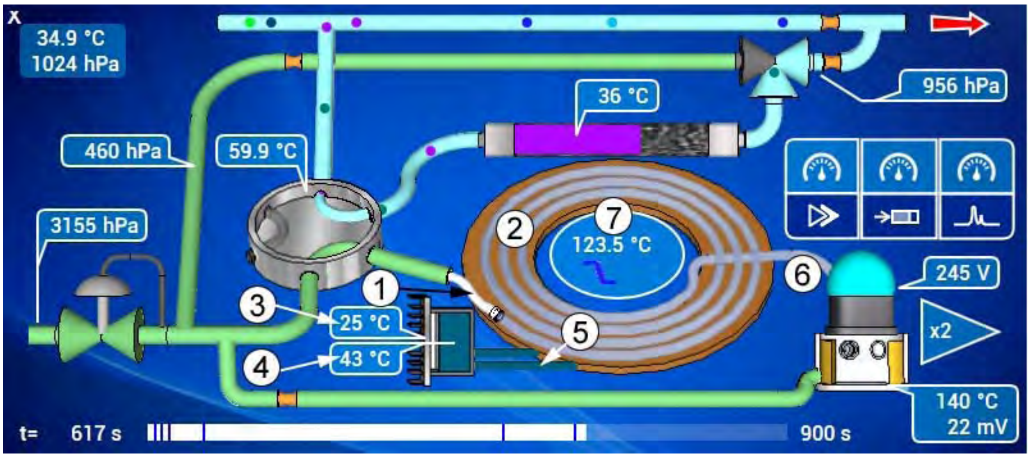

Figure 2-11 – Column cooling

At the end of the hot step, the GC column has eliminated all the compounds of the sample N and must now return to the cold step for the injection of the sample N+1.

The Module board switches OFF the column heating (2) and the column end heating (1) (6).

Meanwhile, the Module board activates the cooler (5): its pump moves the cooling fluid between the GC column heat exchanger and those of the Peltier:

- The GC column temperature quickly decreases (7).
- The cold plate temperature slowly increases (4).

The Peltier module, which is now supplied, extracts the calories from the cold plate to the Peltier heat sink whose temperature increases slowly (3).

2.10 CYCLE END

The end cycle screen is as follow:

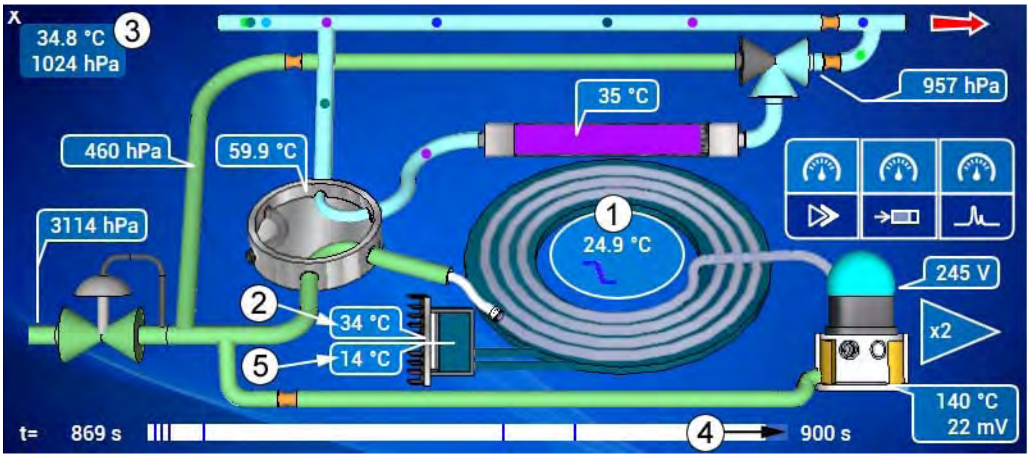

Figure 2-12 – GC column cooling (end)

The cold plate temperature (5) returns to its set point (typically 10°C below the GC column cold step).

The cooling pump passes into discontinuous operation to keep the GC column temperature on the cold step (1).

NOTE : The cold step (1) is typically 10°C below the internal temperature (3).

As the cooling demand is reduced, the Peltier radiator temperature (2) slowly decreases.

The trap carries on with sampling the sample N+1 until the progression bar reaches the end cycle mark (4)…

…and a new cycle starts again (see 2.1.1).

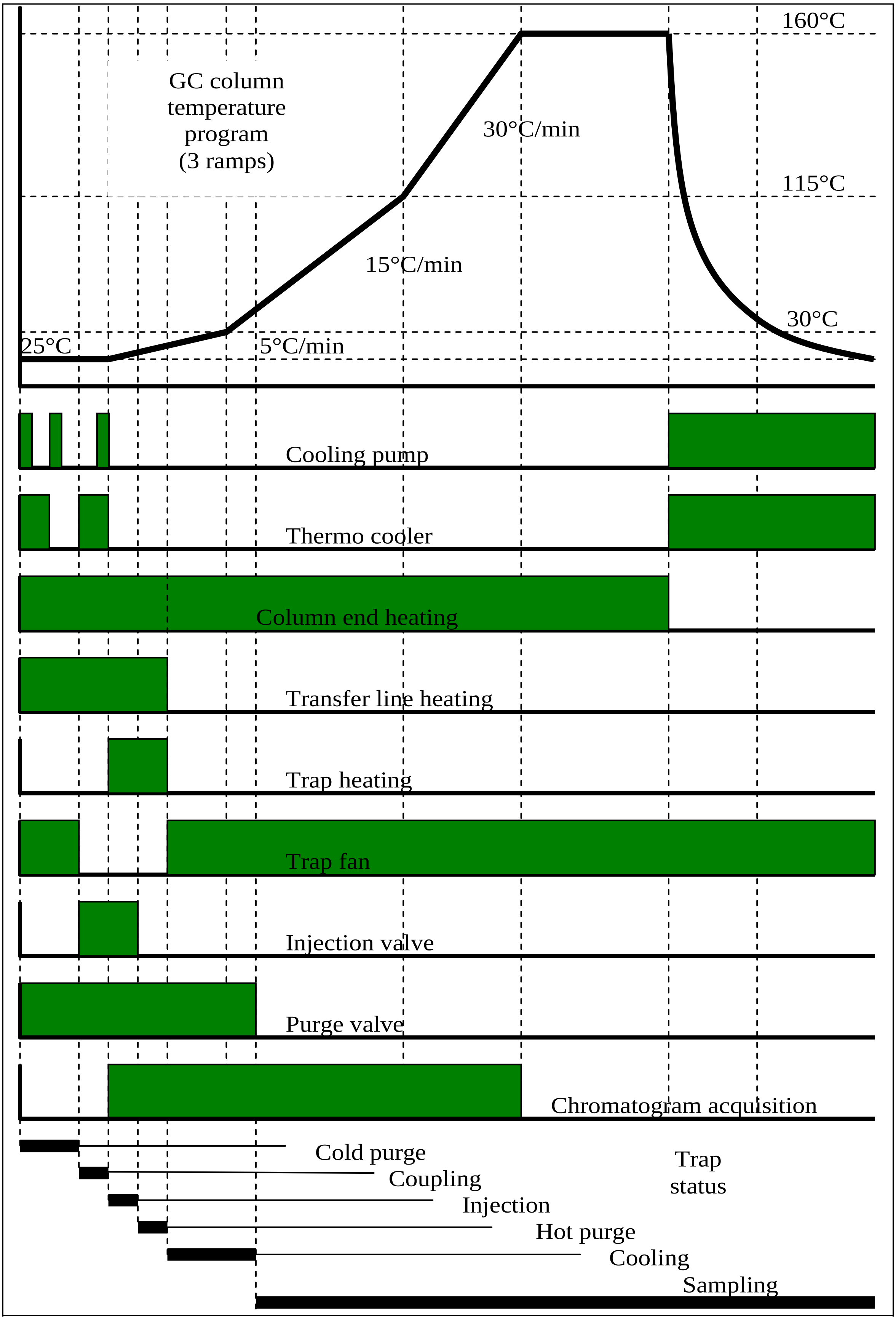

Figure 2-13 – Chronogram

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CHAPTER 3
OPERATING INSTRUCTIONS

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3. OPERATING INSTRUCTIONS

3.1 INITIAL START-UP

Before delivery, the analyzer is checked and calibrated in factory.

3.1.1 UTILITY REQUIREMENTS

– Hydrogen 5.5 (99,9995%) source at a regulated pressure of 3.2 bar +/-0.2 bar.

A gas cylinder with a clean double stage pressure reducer is a convenient source.

HAZARD INFORMATION for HYDROGEN

Hydrogen is the chromatography carrier gas of VOC72e.

When mixed with ambient air, hydrogen may IGNITE with a spark as soon as its VOLUMIC CONCENTRATION EXCEEDS **4%.**

AT HIGHER CONCENTRATIONS **(8%), the ignition may become EXPLOSIVE.**

__Note__ : A non-hermetic room can tolerate without hazard a permanent hydrogen leak of at least 200ml / min (more than 10 times the hydrogen consumption of VOC72e) because hydrogen is a non-persistent gas that dilutes rapidly in the air unlike hydrocarbons that accumulate. The following SAFETY INSTRUCTIONS should therefore be applied to prevent the risk of massive hydrogen leak:

SAFETY INSTRUCTIONS

- Secure the hydrogen bottle to prevent it from falling and destruction of the regulator.
- Install the hydrogen cylinder and its pressure regulator outside the room where the VOC72e is located (under an outdoor shelter or in a ventilated room).
- If the cylinder is inside the room, connect the safety valve of the cylinder pressure regulator to an external vent.
- Connect the VOC72e to the hydrogen source by a small diameter stainless steel tube (1/16 "x 1/32" i.e. 1.6 x 0.8mm) in order to limit the hydrogen flow in case of important leak.
- Connect the VOC72e vent to an external vent. In normal operation, the VOC72e vent exhaust rejects a small amount of hydrogen, but if the pilot injection valve fails, the hydrogen flow rate can increase strongly.
- Install a hydrogen detector at 25% LEL (Lower Explosive Limit) in the room.

– Hydrogen tube between the source and the analyzer.

  1/16" tube GC grade (stainless steel) is suitable.

  DO NOT USE PLASTIC FOR THE HYDROGEN TUBE.

– Electricity

  A mains socket equipped with a ground conductor (3 wires) is required.

– Clearance

  A 10 cm (4") clearance is required between the rear panel of the VOC72e and the wall (or the partition) in order to ensure ambient air circulation for enabling sufficient cooling of heat sink by the fans.

3.1.2 BEFORE OPENING THE PACKING

– Visually examine the packing of the device in order to ensure that it was not damaged during transport.

– If the case was stored in a cold place, wait for the necessary time to reach the room temperature before opening.

– Unpack the analyzer, and remove the cover.

– Check that all the internal modules are still in place. Check that the knurled screws are correctly tightened.

– Remove the capsules on the sample inlet and the vent port.

DO NOT REMOVE THE CAPSULE ON THE HYDROGEN INLET BEFORE ITS CONNECTION TO THE HYDROGEN TUBE.

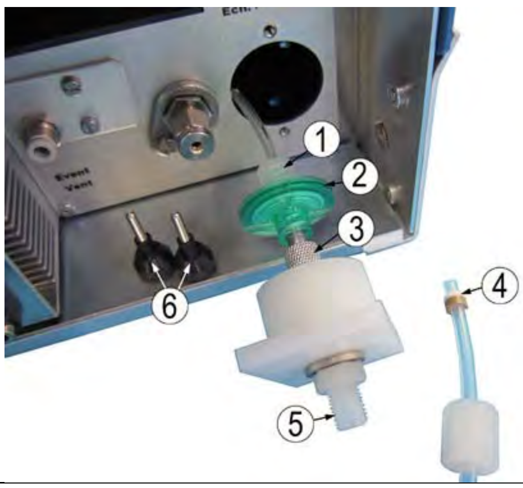
3.1.3 CONNEXION

(1) Empty slot for the optional ESTEL board, (2) mains fuse, (3) cooling fan exhaust, (4) screw of sample input filter assembly, (5) sample inlet for 4mm OD (overall diameter) tube, (6) hydrogen inlet for 1/16” OD tube, (7) vent exhaust for 4mm OD tube, (8) heat sink cooling fan, (10) Ethernet socket, (11) identification plate, (12) power socket, (13) optional span inlet (if fitting Ø is 4 mm OD ⇨ span option, if fitting Ø is 1/16’’ OD ⇨ pressure span option), (14) optional span vent, (15) RS4i board.

Figure 3-1 – VOC72e rear panel connections

3.1.3.1 Sample inlet connection

Remove the screws (4) and check that the sample filter is connected.



(1) Luer-Lok male connector.

(2) Sample filter.

(3) Luer-Lok female connector.

(4) Sample 4mm OD PFA tube with white/brown ferules.

(5) Sample inlet for 4mm OD tube.

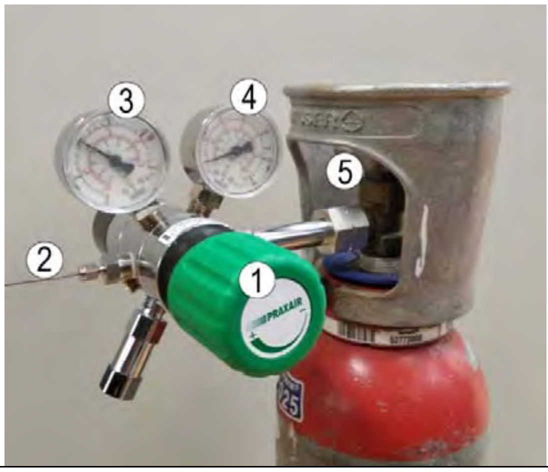
(6) Assembling screws.

Figure 3-2 – Sample input connection

- Re-install the sample inlet block with the two screws (6).
- Connect the 4mm OD sample tube (4) to the sample inlet fitting (5).

The sample input union fitting 4mm OD (5) is screwed with a 1/8” parallel threading (BSPP type or Gas) and a flat gasket.

3.1.3.2 Hydrogen connection



(1) Pressure adjustment knob.

(2) Hydrogen tube 1/16” stainless.

(3) Output regulated pressure indicator.

(4) Cylinder high pressure indicator.

(5) Hydrogen cylinder valve. (1)

Figure 3-3 – Hydrogen cylinder connection

- Mount the pressure reducer on the hydrogen cylinder (5.5 (99,9995%) grade) and connect the hydrogen tube (2) to the pressure reducer outlet.
- Slowly open the cylinder valve (5) and immediately close it when the high pressure indicator (4) goes up. Then slowly turn the pressure adjustment knob (1) clockwise until hydrogen is released in the tube, and then unscrew again the knob.
- Repeat this operation three times in order to purge both the tubing and the pressure reducer.
- Remove the H_2 protection cap from the H_2 inlet of the VOC72e rear panel and connect the hydrogen tube to the Swagelok® 1/16” inlet union.
- Open the cylinder valve (5) and adjust the output pressure to 3 bar (42 PSI) with the knob (1).
- Check for leaks:
  - Close the cylinder valve (5) and write down the cylinder pressure (4).
  - 30 minutes later, check again the pressure without any action on the cylinder valve (always kept closed). If the pressure value did not vary, there is no leak.

NOTE : Never use liquid soap (Snoop®) for leak search on 5.5 (99,9995%) grade hydrogen. Use a katharometer leak detector for GC.

3.1.3.3 Vent outlet connection

- Connect a 4 mm OD plastic tube to vent exhaust (mark 7 of figure 3-1) in order to collect the vacuum pump exhaust and throw it out of the room where the VOC72e is installed. The vent gas composition is similar to sample.

NOTE : A blocked vent port can damage the vacuum pump. Always make sure that the vent outlet is connected to the atmospheric pressure.

3.1.3.4 Electrical connections

- Check that the available voltage fits the voltage indicated on the identification plate.
- Connect the power cord to the power socket of the VOC72e.

3.1.4 STARTING UP THE UNIT

1/ Plug the power cord to the mains socket and **press the ON / OFF pushbutton** on the VOC72e front panel. The analyzer starts and switches to the warm-up cycle. After a few seconds, the display shows the home-page: it allows you to view the warm-up progress.

Touch/click here (1) in the above screen to display the synoptic screen shown below:

(1) Warm-up icon, (2) PID detector temperature (cold), (3) Hot box temperature, (4) Hydrogen supply pressure (relative)

Figure 3-4 – «Warm-up» synoptic display

Slowly screw clockwise the cylinder pressure reducer knob until the supply pressure (4) indicates 3200 +/-200 hPa on the synoptic display.

NOTE : – If the H_2 pressure is too high, unscrew a little turn the cylinder pressure reducer knob and loosen the nut of the H_2 inlet fitting of the analyzer to release the excess of hydrogen. Then tighten again the nut and readjust the pressure with the knob.

– Without a valid supply pressure of H_2, (3.2 +/- 0.2 bar or 3200 ± 200 hPa), the VOC72e remains in warm-up condition until the warm-up time is out, then it will display a pressure alarm message.

The warm-up should last less than 15 minutes i.e. the time required to allow the hot box (3) and the PID detector (2) to reach the set point temperature.

After 30 minutes without action on any key, the screen switches into stand-by mode (screen backlighting off). Touch the screen with your finger to restore the display.

(1) Stand-by icon, (2) PID at set point temperature, (5) hot box at set point temperature, (6) hydrogen supply pressure adjusted.

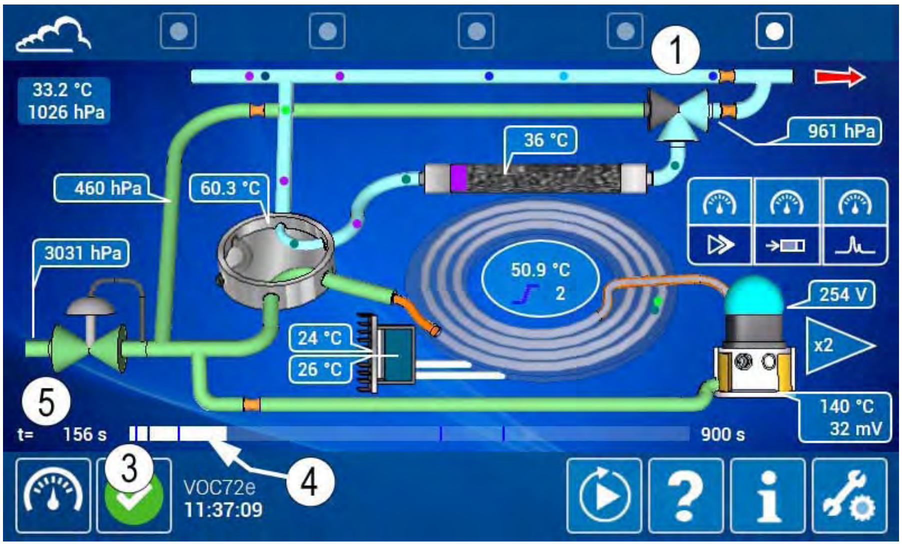
Figure 3-5 – Stand-by synoptic display

Touch/click on then to enter the READY mode:

(1) READY icon, (2) PID lamp ON, (3) PID voltage, (4) proportional valve is active, (5) regulated pressure at set point, (6) hydrogen supply pressure is adjusted.

Figure 3-6 – READY synoptic display

Touch/click on then to enter the START mode:



(1) the vacuum pump is active, (3) START icon, (4) the progression bar is active, (5) the cycle clock is active.

Figure 3-7 – START synoptic screen

The first cycle starts with a trap thermal desorption which cleans it in anticipation of the first sampling cycle. The GC column also carries out a thermal cycle for purging it before the next cycle.

(1) concentration display, (2) averaged display, (3) unit, (4) compound name.

Figure 3-8 – Home page on cycle #1 and #2

The VOC72e now starts the second sampling cycle and the analysis of the first sampling cycle. The below table shows that the concentration display remains at 0.00 until the beginning of the 3rd cycle after the start (30 minutes) and is only taken into account in the stored data at the beginning of the 4th cycle after the start (45 minutes).

Trap sampling	Cycle #1	Cycle #2	Cycle #3	Cycle #4
Chromatogram	Invalid	Cycle #1	Cycle #2	Cycle #3
Concentration display	0.00	0.00	Cycle #1	Cycle #2
Averaged display	0.00	0.00	0.00	Cycle #1
Recorded display	0.00	0.00	0.00	Cycle #1
Time from start (minutes)	0	15	30	45

(1) concentration display, (2) averaged display = 0.00

Figure 3-9 – Home page on cycle #3

Caution: if the analysis cycle is interrupted:

– sample contained in the trap is lost,

– sample being analyzed is lost,

– concentration display returns to zero.

And it takes 30 minutes after the restart to display a valid (non-zero) concentration.

In addition to warm-up, the analyzer has 4 operating modes:

– STAND-BY mode: is symbolized by the icon . The PID detector and the hot box are kept at their operating temperature, the internal temperature is regulated at 35 ° C.

– READY mode: is symbolize by the icon . This is the STAND-BY mode (i.e. the PID detector and the hot box are kept at their operating temperature, the internal temperature is regulated at 35°C) with, additionally, the column pressure control active and the PID lamp on.

– START mode: is symbolized by the icon . This is the READY mode with, additionally, the vacuum pump activated and the column temperature control activated.

– WAITING FOR START mode: is symbolized by the icon . It is the same than the READY mode, and specific to the START DELAYED mode

The functional diagram shown below indicates how to switch from one mode to another using the analyzer controls.

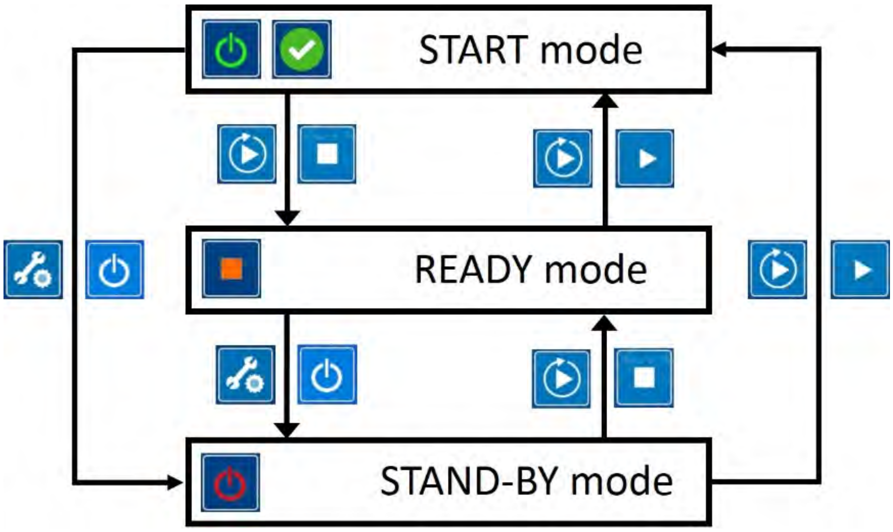


Figure 3-10 – Functional diagram

In case of alarm during the analysis cycle, the analyzer switches automatically from the START mode to the STAND-BY mode. Therefore, it is the analyzer status after an alarm.

Be careful when the VOC72e is automatically restarted: after a power OFF/ON action (either front switch activation or after power outage), the VOC72e automatically returns (after warm-up) to the previous operation mode :

– If the PID UV lamp was ON before powering OFF, the PID power board will automatically restart after the warm-up delay and generate a high voltage on the PID lamp.

– If the OFF/ON action occurs during an analysis cycle (START mode), a new cycle will restart automatically after warm-up, and involve the high temperature heating (380°C) of the trap.

2/ Access to the standard analyzer functionalities:

The screen below is the homepage of the standard analyzer functions.

It contains the additional pages that are displayed by activating the buttons to present at the screen top. These pages allow the measurement channel display, the real-time graph of the instantaneous measurement channel values, and the analyzer synoptic giving the main parameter values, as seen previously at Figure 3-4, Figure 3-5, Figure 3-6, and Figure 3-7.

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

By using a remote PC: a password is required to be input in the pop-up that will appear. Enter the User password given in the Quick-Start, and validate with .

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

By using the touch screen mounted on the analyzer front panel: touch the button of the home page to open the User password input pop-up (1). Touch the input field (2) to display the QWERTY keyboard (3) for the English / AZERTY for the French, in the lower half part of the screen.

Touch ?123 to switch alphanumeric to numeric keyboard. Enter the User password and validate with : the pop-up and the keyboard close, and the advanced functionality homepage is displayed on the screen.

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

closes the pop-up without validating the entry.

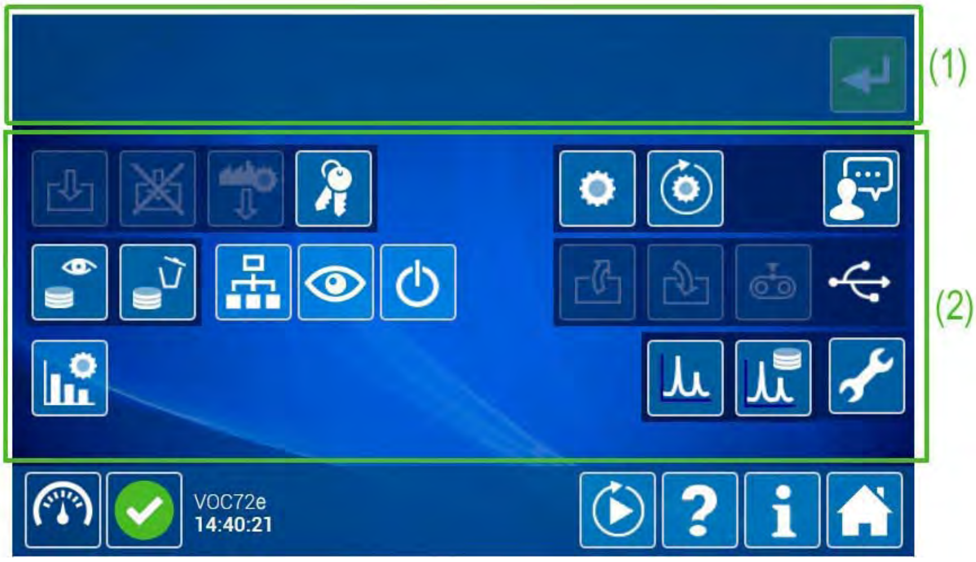
NOTE : Access to the advanced functions depends on the hierarchical level of the user's password. There are three hierarchical levels: User, Advanced, Expert.

The **factory passwords** available in the analyzer on delivery are the following, symbolized by the icons:

Password level	**Login**	**Icon**
User	12345	1
Advanced	78300	2
Expert	00007	3

On the initial starting-on, it is advised to change the factory passwords. To do this, activate in the advanced functions home page to display the password management pop-up. Enter the new passwords in the corresponding fields, activate to validate the entry and close the pop-up.

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



The accessible User functions appear in white on a blue background, in zone (2). As explained above, the function access depends on the hierarchical level password entered by the user.

Each accessible function is activated by contact, it changes color from blue to green, a message indicating the corresponding screen use is displayed in zone (1), and  is highlighted to . By double clicking on the function icon or by activating , the user accesses the corresponding screen.

3.2 PROGRAMMING THE VOC72E

3.2.1 SCREEN AND KEYBORAD DESCRIPTION AND USE INSTRUCTIONS

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

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

3.2.1.1 Definition of the control screen areas

The areas of control screens are defined as follow:

(1)	Browsing area proper to the standard function screen shown above: activating the button to displays the corresponding page.
(2)	Measurement or configuration area: used to display the measurement parameters (gas, value, units...) or the configurable parameters associated with the selected screen.
(3)	Area of manual controls, information and advanced function access. Fluid inlet selection and manual cycle start. Status icon display.

The functions, icons and buttons in zone (3) are available in all screens. They are described in paragraph 3.3 related to ergonomy browsing.

3.2.1.2 Keyboard input

3.2.1.2.1 From the touch screen of the front analyzer panel

A virtual screen with a touch-sensitive keyboard is displayed instantly in the bottom half part of the screen when the user touches a field to be filled in.

Two keyboard types are available: digital and alphanumeric (QWERTY for English / AZERTY for French). They are displayed depending on the input field nature: numeric keyboard if the field is numeric type, alphanumeric keyboard if the field requires number and letter inputs.

The examples below are showing the keyboard display in the *« General configuration »* screen.

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

NOTE : Field inputs are indexed.

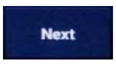
These keyboard keys work like Android system keys found on tablets and smart-phones.

The numeric keyboard:

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

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

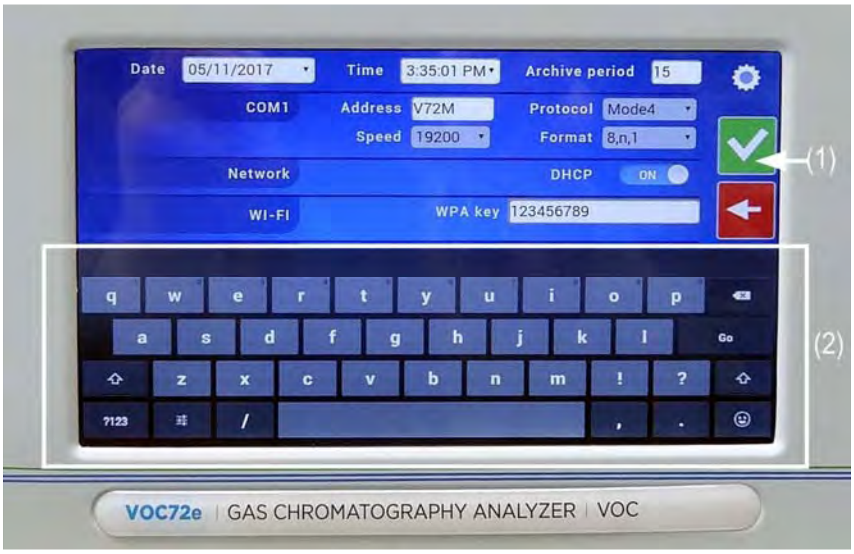
 : clears digits during input.



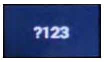
: used to move from an input field to another according to its indexation.

: switches from numeric to alphanumeric keyboard.

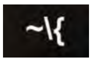
<u>The alphanumeric keyboard:</u>



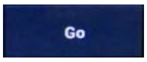
(1) button for input validation, (2) alphanumeric keyboard with touchscreens.



: switches from alphanumeric to numeric keyboard.



: switches from numeric to symbol keyboard.



: validates input of the considered field.

3.2.1.2.2 From a remote computer

Use the computer keyboard and mouse.

3.2.2 OPERATION PARAMETER PROGRAMMING

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

3.2.2.1 Field requiring keyboard input

– Using the front panel touchscreen:

Touch the input field to be modified: as indicated previously, if the field is alphanumeric, the QWERTY keyboard is displayed for English or the AZERTY for French, if the field is numeric, the numeric keyboard is displayed.

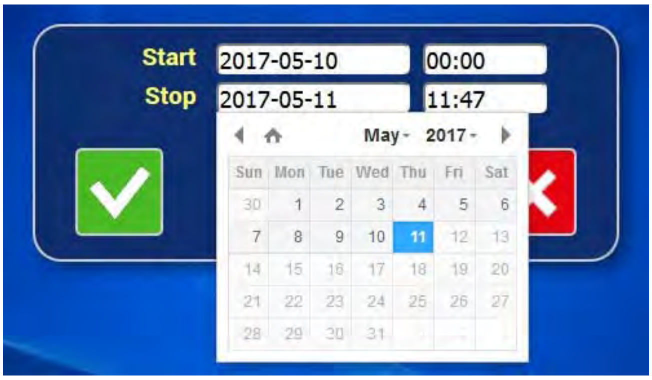
Input with the touch keys, and validate with . The keyboard closes and the input field is displayed properly filled in the control screen.

– From a remote PC:

Use keyboard and mouse of remote PC to enter, modify and validate the field inputs.

3.2.2.2 Fields requiring parameter selection in a list

Touch the field to be modified. The parameter or value list to be selected is displayed (see the two examples below): the current parameter or value is displayed in white on blue background. Touch (or click on with the remote computer mouse) the new parameter or value to be selected. They pass from grey to white on blue background, and the previously selected values or parameters return to grey. Validate with .



3.2.2.3 OFF/ON status button

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

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

3.3 BROWSING ERGONOMY

As indicated above, the VOC72e home page is the following:

The home page displays up to three measurement channels.

From the touch screen mounted on analyzer front panel, the home page gives access to the standard functions without using a password.

From a remote computer, the following page is displayed first:

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

The home page includes two navigation bars:

– Top screen navigation bar

By activating [icon] to [icon], the user drags the display sideways to view the other measurement channels, the real time graph of the instantaneous values of the selected measurement channels, and the analyzer synoptic giving the main operating parameter values. This navigation bar is specific to the home page.

– Bottom screen navigation bar

Due to this bar, the user activates the standard functions, views the status and information icons and accesses the advanced functions of the analyzer. This navigation bar is available in all the graphic interface screens.

The standard functions and icons displayed in this navigation bar are described in the table below:

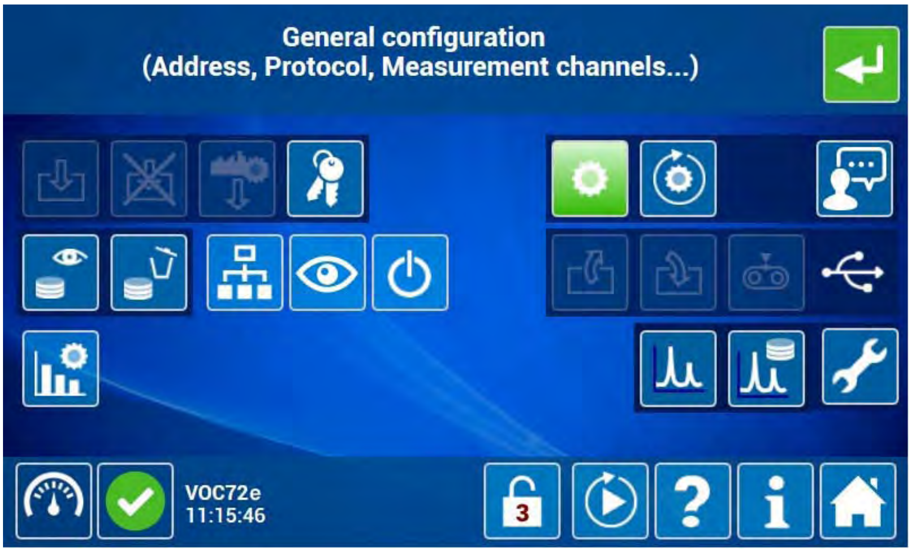
[Fluid inlet icon]	Fluid inlet selection button. It allows to view the manual selection buttons of the analyzer fluid inlet: [icon] sample inlet, [icon] zero inlet, [icon] span inlet.
[Status icon]	The icon displayed in this place indicates the analyzer status during operation. The various status icons are described below: [icon] Status icon indicating that the analyzer is in normal operation. It corresponds to the START mode [icon] Status icon indicating that the analyzer is warming-up. [icon] Status icon indicating that the analyzer is in control mode. [icon] Status icon indicating that the analyzer is in alarm mode. [icon] Status icon indicating that the analyzer is disconnected from the network. [icon] Status icon indicating that the analyzer is in maintenance mode. [icon] Status icon indicating that the analyzer is in stand-by mode. [icon] Status icon indicating that the analyzer is waiting for start. [icon] Status icon indicating that the analyzer is ready.
VOC72e 18:02:47	Information area indicating model and current time of the analyzer.
Warm-up	Status icon viewing the warm-up progress.

	Stop button of the current warm-up cycle.
	Indicates the hierarchical level of the password input in the analyzer, and displays the input pop-up to change this password (see below). 
	Displays the cycle start buttons: switches to READY mode, switches to START mode, launches a calibration cycle.
	Displays the contextual help.
	Displays analyzer information panel.
	Gives access to the advanced analyzer functionalities.

The user touches / clicks on to display the access page to the advanced analyzer functions. The allowed-to-user functions are white framed, they depend on his hierarchical password level:

The user displays each function screen by touching / clicking on the appropriate button, which switches from blue (e.g.) to green (e.g.), while a message explaining the function is displayed at screen top and is highlighted to. Then, the user touches / clicks on again the green function button (e.g.), or touches /clicks on.

See the example below « *General configuration (Address, Protocol, Measurement channels…)* »:



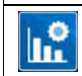
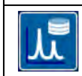
NOTE : For memory, as explained in section 3.1.4, access to the advanced analyzer functions depends on the hierarchical password level assigned to the user. There are three hierarchical levels: User, Advanced, Expert.

The **factory passwords** available in the analyzer on delivery are the following, symbolized by the icons:

Password level	Login	Icon
User	12345	1
Advanced	78300	2
Expert	00007	3

On the initial starting-on, it is advised to change the factory passwords. To do this, activate in the advanced functions home page shown here-above to display the password management pop-up. Enter the new passwords in the corresponding fields, activate to validate the entry and close the pop-up.

The button list giving access to each advanced function, as well as their definition, is given below:

	Restores factory settings. It is recommended to backup before executing this operation
	Passwords management
	General configuration (Address, Protocol, Measurement channels...)
	Automatic cycles configuration
	Language selection
	Finds and displays recorded averages
	Deletes all recorded averages (Warning ! this operation can't be cancelled)
	List of connected clients
	Diagnostic functions (Alarm, input / output, mux...)
	Sets the analyzer in stand-by mode
	Configuration and software backup on USB key
	Restores software and configuration from USB key (System will restart on operation completion)
	Records instantaneous measurement on USB key
	Gives the characteristics of the USB key (total memory and available memory) when connected to the analyzer
	Advanced analyzer configuration
	Real time chromatogram
	Last chromatogram
	Sets the analyzer in maintenance mode
	Returns to the standard functions home page

The bottom browsing bar has the same functions as described for the standard functions screen (see section 3.3.).

By touching / clicking on [home icon], the user returns to the standard function screen:

3.4 ANALYZER FUNCTION DESCRIPTION

3.4.1 STANDARD FUNCTIONS

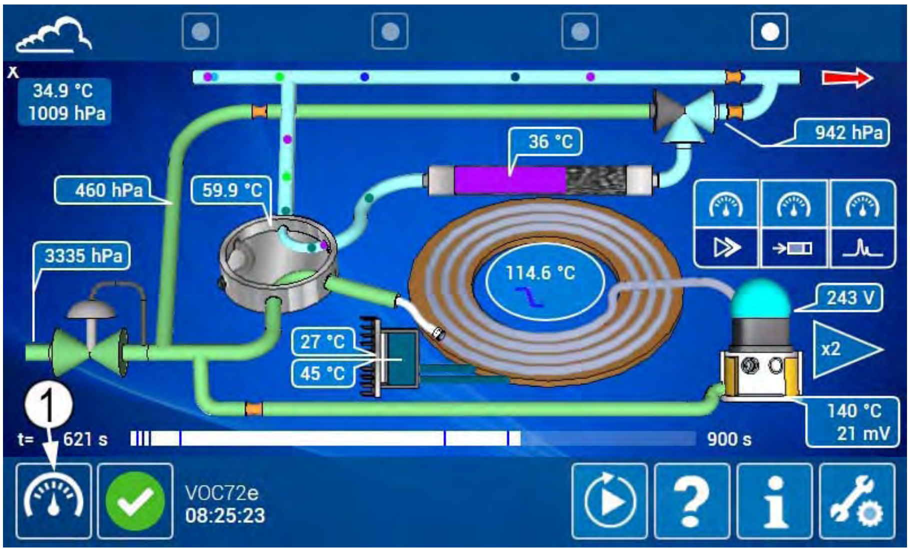
Before reading this paragraph, it is recommended to know the analyzer synoptic diagram detailed in paragraph 3.4.1.7.

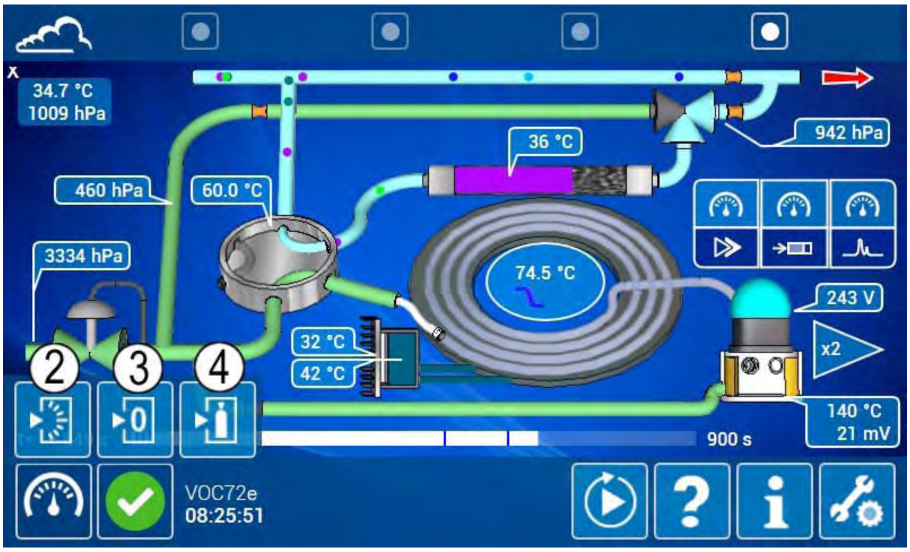
3.4.1.1 Fluid inlet selection

As described previously, the fluid inlet selection button is located at the left bottom side of the screen (1), and its icon represents the selected fluid inlet for the current sampling cycle. This button selects the fluid inlet for the next sampling cycle.

NOTE : As the analyzer operation is cyclic, the fluid inlet change can only occur when passing to the next cycle.

By touching/clicking on the inlet selector (1), the user displays the three available inlets: sample (2), zero (3), span (4).



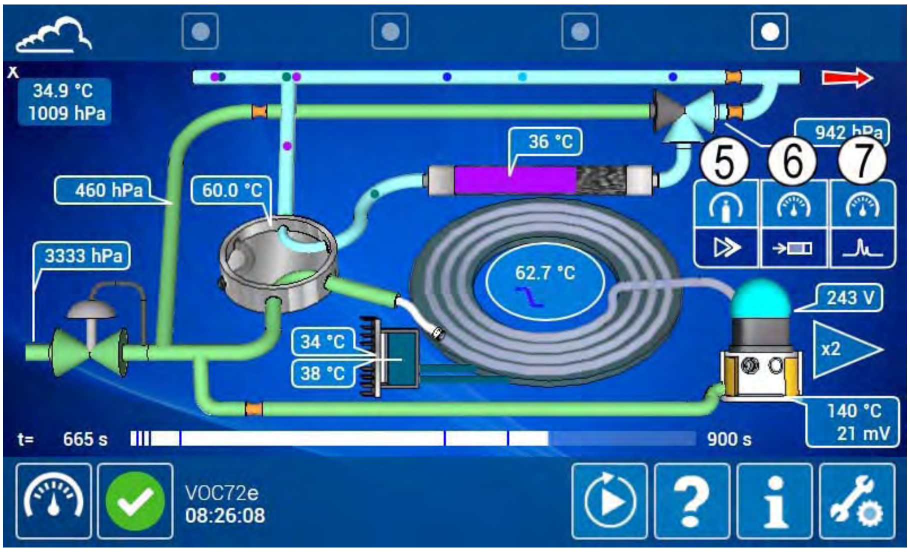


Example: span cycle description.

When the user touches/clicks on the span inlet (4, in screen above), the available fluid inlets disappear and the span icon (5) is displayed in the frame symbolizing the next sampling.

The sample icon remains displayed in the frame symbolizing the current sampling (6), showing that the current sampling cycle proceeds on the sample inlet.

In the same way, the sample icon remains displayed in the frame symbolizing the current analysis cycle (7) showing that the current analysis cycle still proceeds on the sample inlet.



At the next cycle and without action on the inlet selector, the inlet selector icon switches from sample to span (10).

The span icon is displayed in the current sampling frame (9), showing that the current sampling cycle switched to the span inlet.

The span icon remains displayed in the next sampling frame (11) showing that the cycle of the next sampling cycle remains on the span inlet.

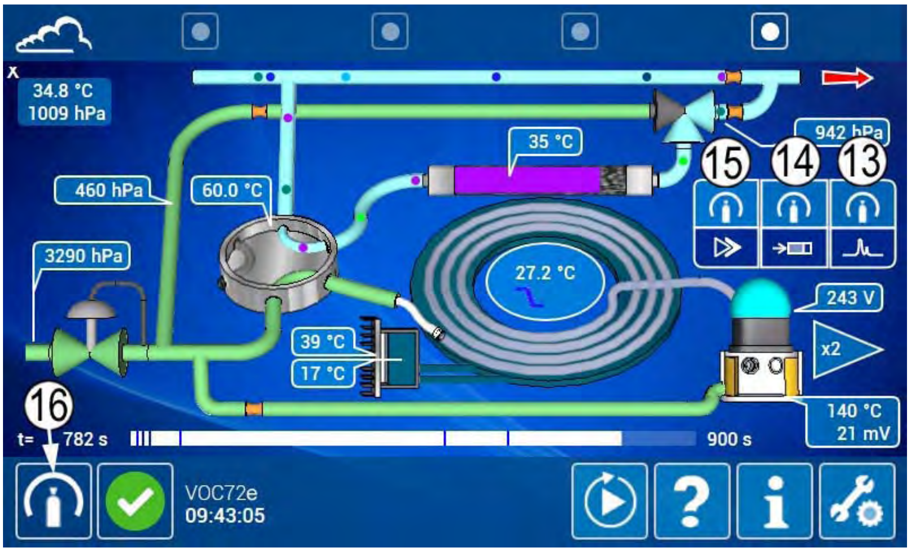
The sample icon remains displayed in the current analysis cycle frame (12) showing that the current analysis cycle continues on the sample inlet.

At the next cycle and without action on the inlet selector, the inlet selector icon remains in span position (16).

The span icon is displayed in the current analysis cycle frame (13), showing that the current analysis cycle switched from sample to span.

The span icon remains displayed in the current sampling frame (14), showing that the current sampling cycle is performed on the span inlet.

The span icon remains displayed in the next sampling frame (15), showing that the next sampling cycle will take place on the span inlet.



3.4.1.2 Cycle controls

Various cycle controls are available according to the VOC72e status. As previously described, the user touches / clicks on at screen bottom to display the available cycle controls for the considered analyzer status.

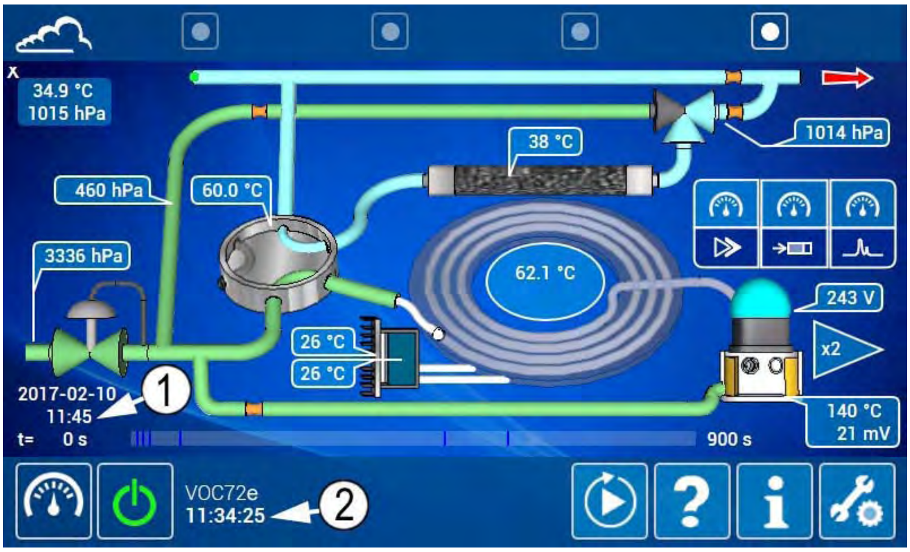
The control is available when the analyzer is in START mode (normal operation), WAITING FOR START mode, or STAND-BY mode, as described in the table below:

Available control	Analyzer status	Use/Operation
	START Normal operation	If this control is activated during the analysis cycle (normal operation), it stops the current cycle and switches the analyzer to READY mode, symbolized by the icon displayed instead of .
	WAITING FOR START	If this control is activated when the analyzer is WAITING FOR START, it switches the analyzer in READY mode, symbolized by the icon which is displayed instead of .

Available control	Analyzer status	Use/Operation
	STAND-BY	If this control is activated when the analyzer is in STAND-BY mode, it activates the hydrogen pressure control (the hydrogen circuit changes from white to green on the synoptic screen) and then it switches on the detector PID lamp (the PID lamp dome lights up in the synoptic screen). If the hydrogen pressure and lamp voltage parameters are correct, the analyzer switches to the READY mode symbolized by the icon which is displayed instead of .

The control is available when the analyzer is in STAND-BY or READY mode as described in the table below table:

Available control	Analyzer status	Use/Operation
Cycle start	STAND-BY READY	If this control is activated when the analyzer is in STANBY mode, it switches the analyzer to READY mode, symbolized by the icon which is then displayed instead of . Then, this control action depends on the Departure field setting of the "Advanced Analyzer Configuration" screen  : – If the departure field is set to Immediate, this control launches the first analysis cycle, and the icon is displayed instead of . – If the departure field is set to Delayed, this control activates the start synchronization, the icon is displayed instead of , and the start time (1) blinks. When the analyzer clock (2) reaches the start time, the first analysis cycle is launched and the icon is displayed instead of .



Above screen legend: (1) analysis cycle start time, (2) analyzer clock time.

The control is only available if the analyzer is switched to stand-by mode off when the column temperature is higher than 50°C, as described in the table below:

Available control	Analyzer status	Use/Operation
	START/ Normal operation READY	If the VOC72e is switched to stand-by mode when the column temperature is above 50°C, a safety device maintains the hydrogen pressure at 460 hPa, Column temperature did not drop below 50 ° C, to protect the column. Since the column cooling can only be done by natural dissipation, it may last up to 30 minutes, which prevents any restart during this time. To shorten this delay, activating puts the analyzer into READY mode, symbolized by the icon that then appears instead of . Once the analyzer reaches the READY conditions, the control will be available instead of and its activation will restart an analysis cycle. The icon will then be displayed instead of .

The screens below show in detail the step sequence:

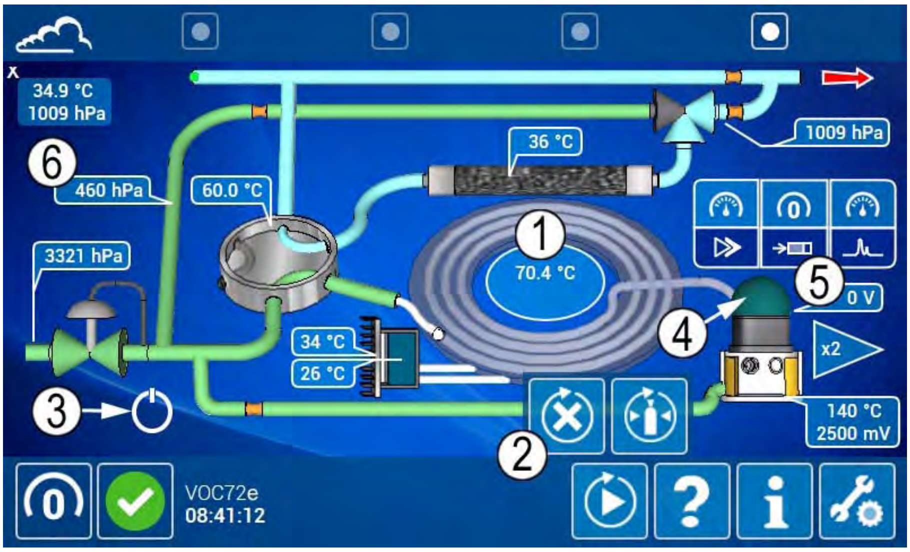
Screen 1: The analyzer is put in stand-by mode while the column temperature (1) is higher than 50°C. Simultaneously:

– Control (2)  becomes available,

– Indicator (3) is displayed and blinks indicating that the unit attempts to pass to STAND-BY mode,

– PID lamp supply is switched off: PID lamp dome (4) is off and the PID lamp voltage (5) is zero,

– Hydrogen pressure (6) is maintained in the column because its temperature is higher than 50°C.

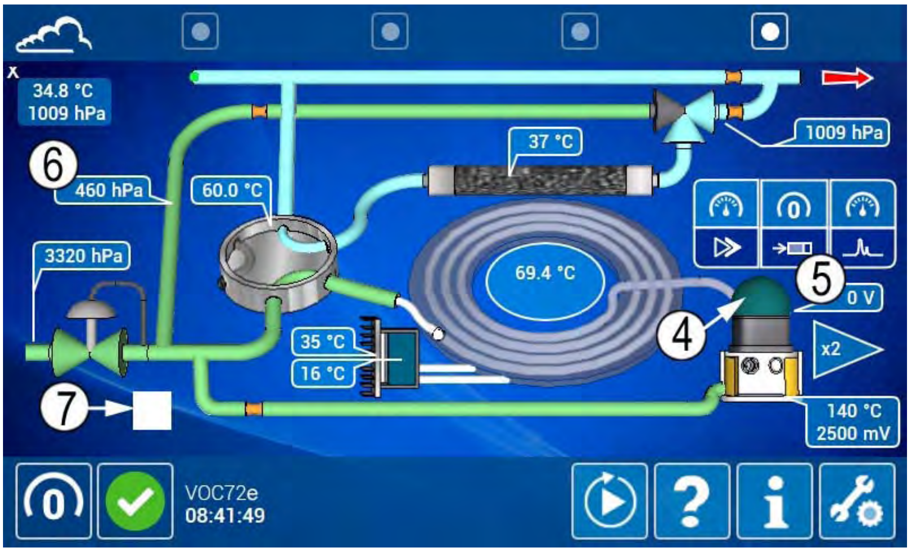


Screen 2: Touching/clicking on , the user allows the analyzer to pass in READY mode. The screen below is displayed, showing that:

– Indicator (7) is displayed and blinks indicating that the analyzer now attempts to pass to READY mode,

– PID lamp dome (4) is off and its voltage (5) is zero,

– Hydrogen pressure in the column is correct (6). Then, the analyzer again switches on the PID lamp to effectively pass to READY mode (screen 3 below).



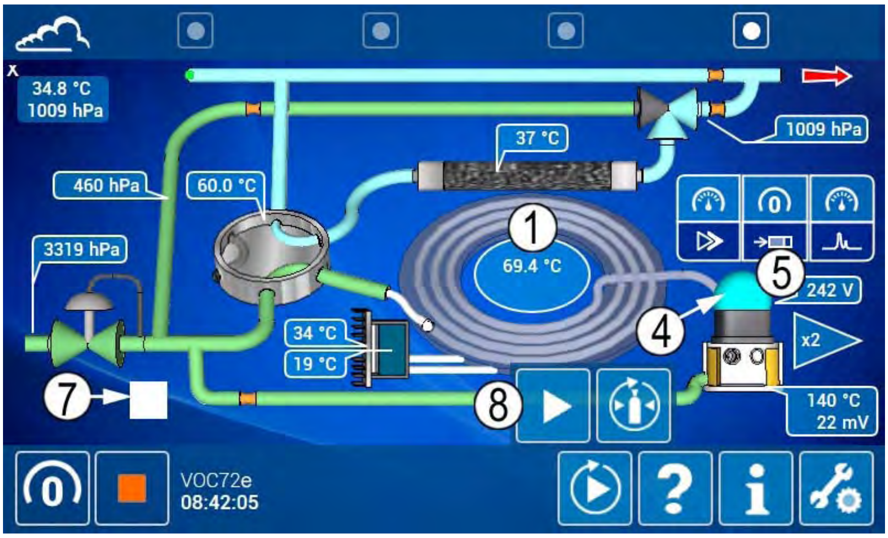
<u>Screen 3</u>: screen below shows that the unit is READY:

– Indicator (7) no more blinks (it is fixed), and the icon  is displayed instead of ,

– PID lamp dome (4) is on, and its voltage (5) is correct,

–  (8) is again available and its activation will re-start an analysis cycle.

While passing to READY mode, the column temperature (1) decreased only by 1 degree.

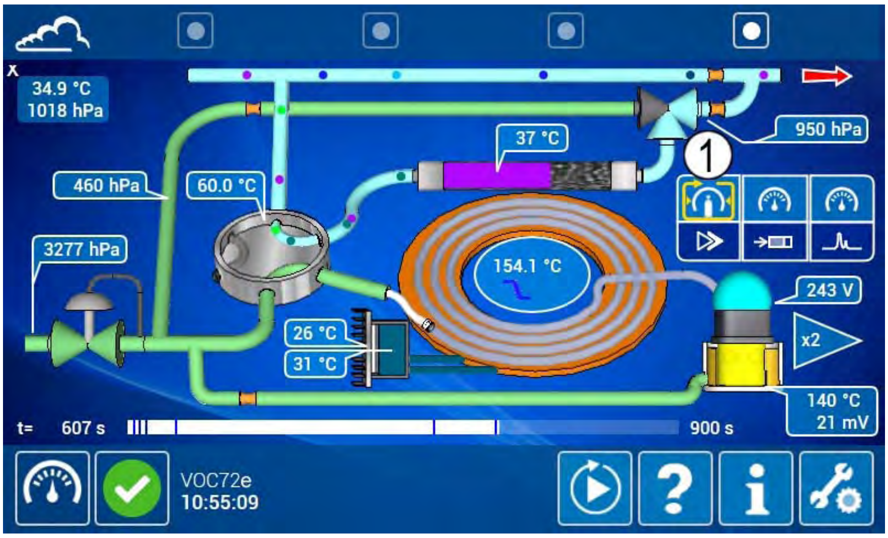


<u>Common legend to screens 1, 2 and 3</u> : (1) column temperature, (2) control, (3) passing-to-STAND-BY indicator, (4) PID lamp dome, (5) PID lamp voltage , (6) hydrogen pressure in the column, (7) passing-to-READY indicator, (8) control

NOTE : Without activating , the user should have waited for a precious time, more than 10 minutes in the above example, to reach the STAND-BY status and restart a cycle START by activating .

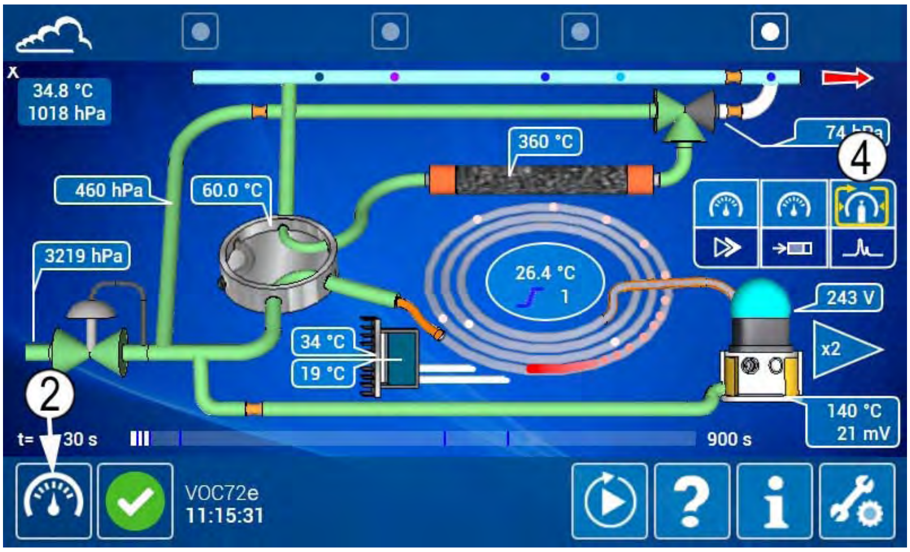
The start calibration cycle command  is always available, whatever the analyzer status. When this control is activated, it sets up a calibration cycle as the next sampling cycle, as shown by the calibration cycle icon (1) displayed in the frame symbolizing the next sampling cycle.

See screen below:



At the next cycle, the fluid inlet selection icon passes to calibration position (2), while the cycle calibration icon moves to the frame symbolizing the current sampling (3). See screen below:

At the next cycle, the fluid inlet selection icon (2) returns to its initial status (sample, in the below example), while the cycle calibration icon moves to the frame symbolizing the current analysis cycle (4).

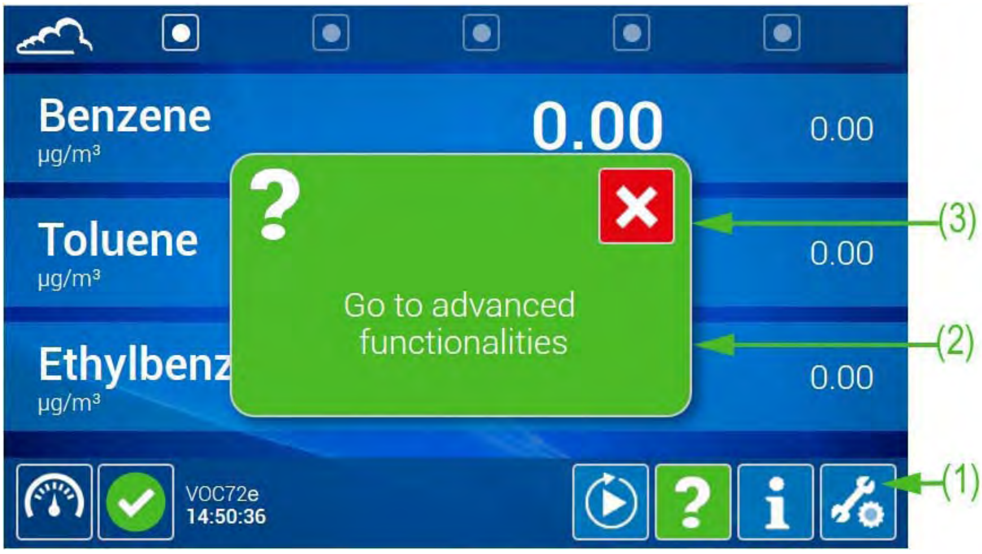


At the end of the calibration cycle, the span chromatogram is generated. Then, depending on the calibration type, the calibration coefficients and the retention times of the compounds are updated.

3.4.1.3 Contextual help

The user activates the contextual help by touching / clicking on the button  that will become green . Then, the user touches / clicks on the button, screen part, configuration field or icon he wants to know the meaning, use or operation way. A pop-up giving the information is displayed. The user closes the pop-up clicking on .

See the example below:

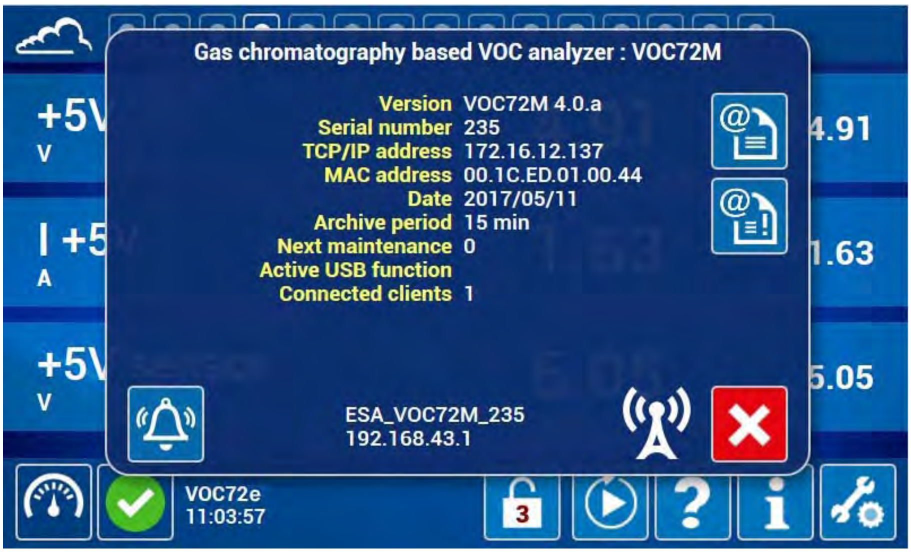


(1) Activated button (highlighted), (2) pop-up message giving the desired information, (3) icon to be used to close the pop-up.

3.4.1.4 Information panel

The user displays the analyzer information panel by touching / clicking on the button .

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



Specific icon and button definition to the information panel

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

3.4.1.5 Measurement channel selection and display

By default, the first standard function page displays the measurement channels for Benzene, Toluene, and Ethylbenzene; the second page displays the measurement channels of MP-Xylene, O-Xylene and 1,3-Butadiene.

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

<u>Button definitions specific to this section:</u>

	Opens the pop-up to add a measurement channel.
	Moves upwards the selected measurement channel to change display order in the standard function screen.
	Moves downwards the selected measurement channel.
	Deletes the selected measurement channel.

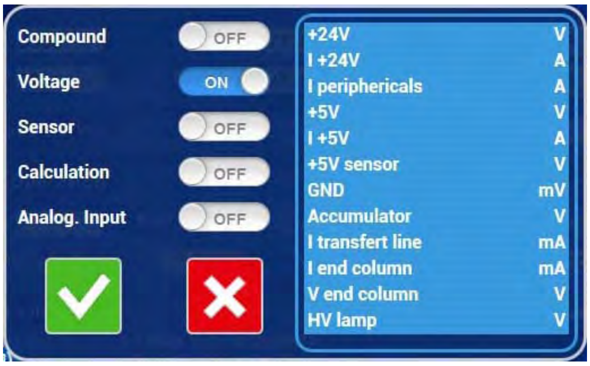
To select additional channels, touch/click on to open the selection pop-up. There are five channel families: Compounds, Voltage, Sensor, Calculation, Analog inputs.

By default, the Compound field is set to ON, and the remaining parameters to be selected are indicated in the right frame, see Styrene in the example below.

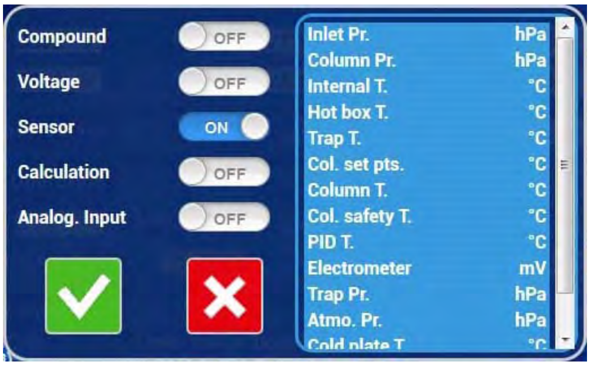
Then, activate  to  in order to display the corresponding element family, touch/click on the elements to be selected : they are sky-blue highlighted. Activate  of the pop-up to validate this selection and close the pop-up. The key  closes the pop-up without validating.

Do the same with the other channel families: it is possible to select the whole available channels as shown below.

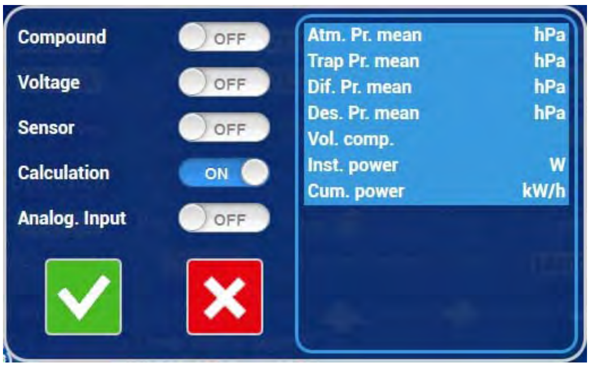
Voltage channel selection:



Sensor channel selection:



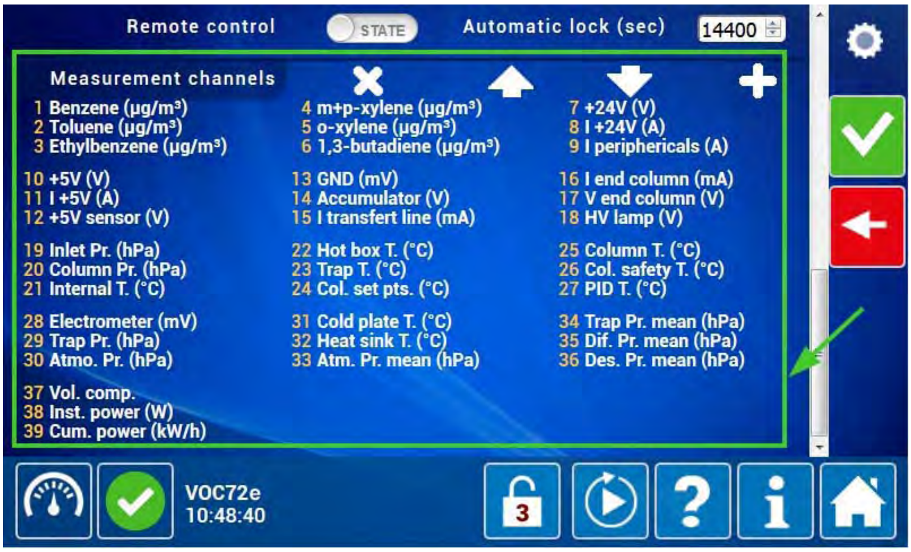
Calculation channel selection:



Once they are selected, the channels no longer appear in the pop-up list. It avoids selecting the same channel twice.

The selected measurement channels are placed in the numbered fields of the Measurement channels section (see frame with arrow in the screen below). Touch / click on in the right side of the screen to definitively validate the whole selection.

NOTE : It is not possible to select more than 40 measurement channels.



Touch / click on to view the measurement channels in the standard function screen. The standard function pages display no more than three measurement channels at a time. Consequently, to view all the selected channels, the graphic interface generates as many pages as necessary.

These additional pages are symbolized by the buttons and present at screen top (outlined frame with arrow in the screen below). The button indicates that the corresponding page is being displayed.

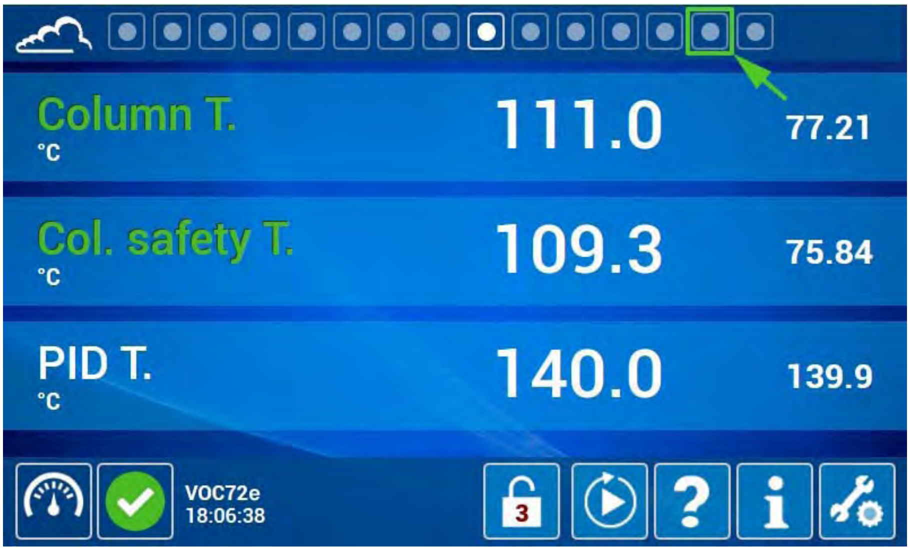
The user displays the desired pages by touching / clicking on these buttons. He can also drag the pages by touching them with his finger or clicking on with the mouse to view them successively.

3.4.1.6 Real time graph

The page to display the measurement channel curve is the next-to-last page (see arrow in the outlighted frame below). When no measurement channel was previously selected, the below page is displayed by default:

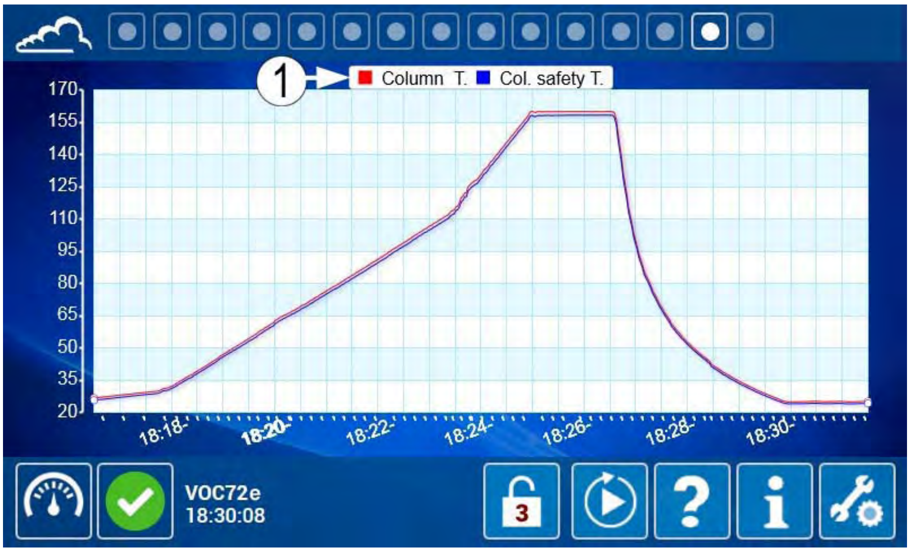
To select measurement channel(s), the user touches / clicks on the channel name(s) he wants to display the curve(s). The channel name changes color from white to green.

Then touch / click on the next-to-last button (indicated below by the arrow) to display the selected channel graphs.

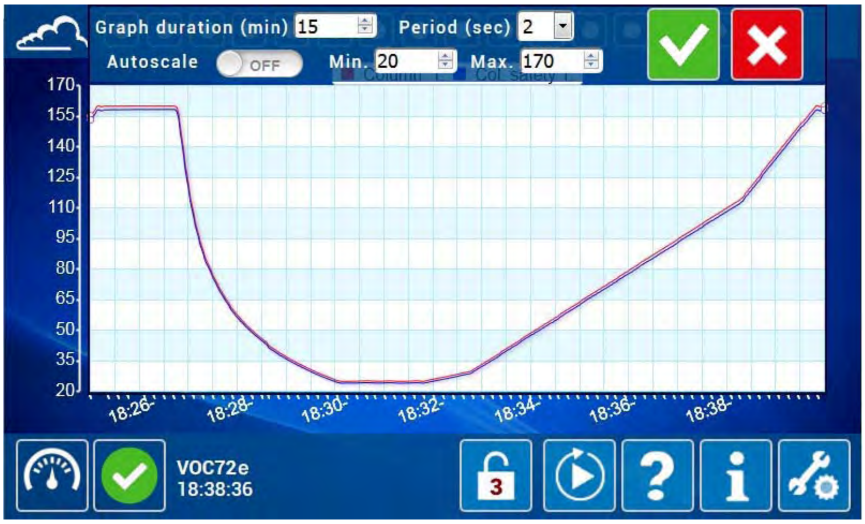


No more than six curves can be displayed at the same time.

The measurement channel name and their color plotting in the screen are indicated above the graph (1). By default, the Y-scale setting is automatic, and thus is adjusted in real time to allow each selected channel curve to be displayed inside the screen.



To configure the Y-axis, the user touches / clicks in the current graph: the modifiable parameters are displayed at the screen top. Then he switches the Autoscale field to OFF, sets the minimum and maximum values of the Y-axis scale (20 and 170 in the example below) and validates the modifications with .



To activate the zoom function, the user delimits the zone he wants to zoom by touching it, or using the mouse pointer. The selected area appears grayed out. Then he validates the selection by touching / clicking on .

The graph zoom is displayed.

The user exits the zoom to return to the previous scale by clicking again in the screen.

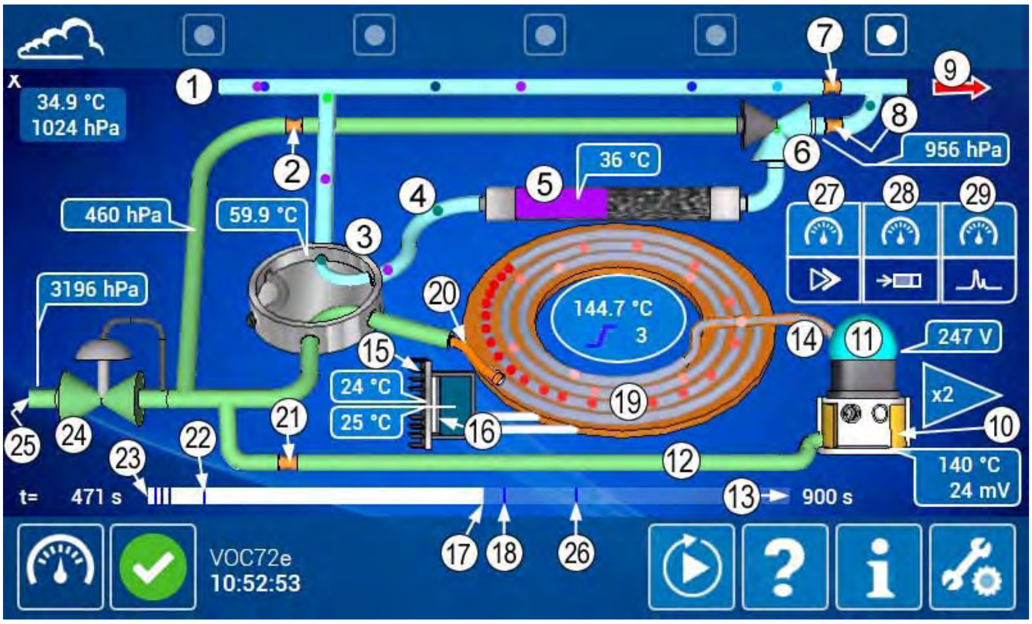
3.4.1.7 Synoptic diagram of the analyzer

The user views the synoptic diagram of the analyzer by touching / clicking on the last button of the navigation bar at the top right of the screen.

This screen displays the whole fluid circuit and the significant values of the operating parameters.

For easy reading, the same synoptic screen is described in detail in the two pages after.

Mark	Description	Displayed status
1	Sample inlet	
2	Purge restrictor	
3	6-way injection valve	Rest position
4	Transfer line	Heating cut off
5	Trap	Heating cut off
6	Purge valve	Rest position (sampling)
7	Sample bypass restrictor	
8	Sample trapping restrictor	
9	Vacuum pump	
10	Photo-ionization detector (PID)	
11	UV lamp	Active
12	PID hydrogen scavenging circuit	
13	Cycle end mark	
14	Column end (detector side)	Heating
15	Cooler heat sink	
16	Cold plate of cooler	Inactive
17	Progress bar	
18	Calculation mark	
19	Chromatographic column	Heating
20	Column end (injection side)	Heating
21	PID scavenging restrictor	
22	Trap sampling mark	
23	Cycle starting mark	
24	Proportional valve	Active
25	Hydrogen inlet	
26	Column cooling mark	
27	Fluid inlet for the next sampling cycle. symbolizes trap inlet on next cycle.	Sample inlet
28	Fluid inlet for the current sampling cycle. symbolizes current inlet in trap.	Sample inlet
29	Fluid inlet for the current analysis cycle. symbolizes chromatogram (current measurement).	Sample inlet



Mark	Description	Units
2	Hour	HH :MM :SS
3	Trap temperature	Celsius degree
4	Atmospheric pressure (absolute)	hectoPascal
5	Trap pressure (absolute)	hectoPascal
6	Photo-ionization (PID) detector temperature	Celsius degree
7	Internal temperature	Celsius degree
8	Photo-ionization (PID) detector signal	Millivolt
9	Photo-ionization (PID) detector gain	Without unit
10	Temperature of cooler heat sink	Celsius degree
11	Cycle duration	Second
12	Cold plate temperature of cooler	Celsius degree
13	Chromatographic column temperature	Celsius degree
16	Hot box temperature	Celsius degree
18	Cycle clock	Second
19	Vector gas pressure (relative)	hectoPascal
20	Hydrogen inlet pressure (relative)	hectoPascal
21	PID lamp voltage	Volt
22	Thermal programming (ramp)	Without unit
23	Ramp number (third)	Without unit

3.4.2 ADVANCED FUNCTIONALITIES

As seen in paragraph 3.3, the user accesses the advanced functions home page by touching / clicking on in any standard functions screen.

For memory, the advanced functionalities are only accessible to users with passwords. There are three different password levels to allow selective access: User level, Advanced level, Expert level. The whole advanced functionalities available to Expert users are described below.

3.4.2.1 Password management

Only the Expert user can activate this function by touching / double-clicking on to display the management pop-up of passwords.

The passwords indicated in the screenshot below are the **factory passwords** present in the analyzer on delivery. During the first starting on, **it is recommended to modify these factory passwords** (see section 3.1.4).

To carry out the necessary modifications, the user fills in the corresponding fields, then touches / clicks on to validate modifications and close the window. By touching/clicking on , the user closes the window without validating the modifications.

3.4.2.2 General configuration

The user accesses this screen by touching / clicking on . The icon of this button is reminded at the top right side of the screen.

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

: This icon is displayed at the top left side of the screen when the analyzer is connected to a PC or a tablet. By clicking on it, the user updates the date and hour of the analyzer with the current date and hour of the PC or the tablet.

DATE and TIME fields: they indicate the current date and time of the analyzer and allow the Expert user to modify them. The date and time cannot be modified in START mode.

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

COM1 section: its fields are used to configure the serial link. The address, speed, format and communication protocol are configurable:

– Analyzer address: programmable on 4 characters. The analyzer name, written with 4 characters, is used by default : V72M

– Communication speed of the serial link stated in Bauds: 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200.

– Format: 8,n,1 ; 8,o,1 ; 8,e,1 ; 8,n,2 ; 8,o,2 ; 8,e,2.

– Communication protocol: Mode4, PRN, JBUS, BAYERN.

NETWORK field: it activates automatic network configuration.

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

When DHCP field is OFF, the ADDRESS, MASK and GATEWAY fields are displayed to allow the expert user to define the TCP / IP address, gateway and mask necessary for connection.

WIFI/WPA key field: it indicates the WPA encryption key of Wi-Fi. It is modifiable by the Expert user only (8 to 63 characters, 0-9 and A-F authorized).

UDP SERVER section: it is used to configure port numbers, addresses, and communication protocol for the User Datagram Protocol (UDP) server:

– Available A and B port numbers: programmable from 1000 to 9999.

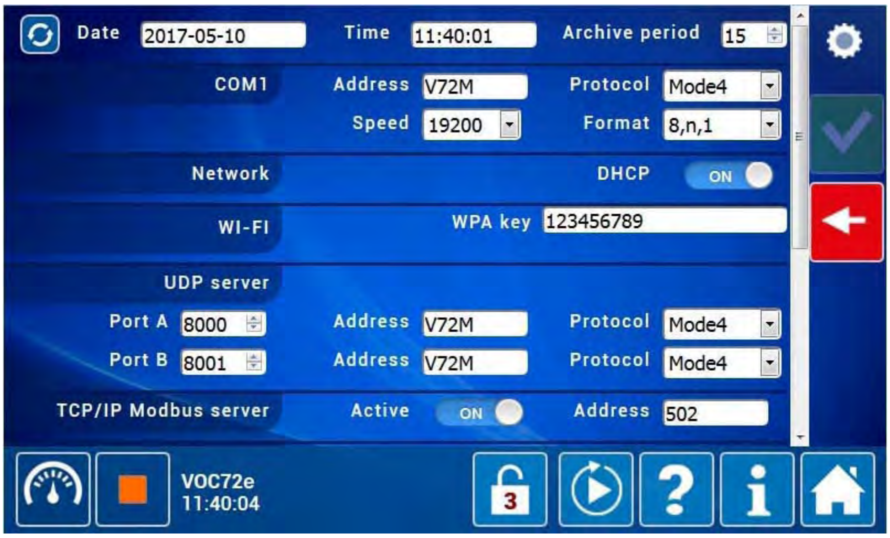
– Analyzer address for communication is used only for Mode4 (4 alphanumeric characters) and JBUS (number from 0000 to 0255). By default: the analyzer name written on 4 characters: V72M

– Communication protocol: Mode4, JBUS, BAYERN, PRN.

TCP/IP MODBUS SERVER field: it is used to configure the TCP MODBUS communication.

– Active ON indicates that its communication mode is activated,

– Address 502 is the standard address of the communication port in TCPIP MODBUS.



OPERATION section:

- CUSTOM IDENT. field: it is used to enter the customer-specific identifier.
- NEG. VALUES field ON/OFF indicates if negative values are authorized or not.
- ALARM field ON/OFF enables or disables the alarm management.
- AUTOMATIC LOCK (SEC) field: it enables to set the duration in seconds between two password entries.

MEASUREMENT CHANNELS section:

This section displays the selected measurement channels.

For the selection, display and deletion of measurement channels, refer to paragraph 3.4.1.5.

3.4.2.3 Automatic cycle configuration

The user accesses this screen by touching / clicking on . The icon of this button is reminded on the top right side of the screen.

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

INLET field: it selects the inlet used for the cycle (Zero, Span, and Sample).

PROGRAMMED INLET field: It is only applied to the calibration cycle. When ON, the analyzer uses the inlet programmed in the INLET field. When OFF, the analyzer uses the active inlet.

REMOTE CONTROL field: it allows (ON) or not (OFF) the cycle triggering on a remote control inlet (ESTEL board option).

CYCLIC field: it enables (ON) or disables (OFF) the cycle periodic triggering.

PERIOD field: it allows fixing the automatic triggering periodicity.

START HOUR field: it sets the start time for automatic cycle triggering. If several cycles are declared at the same start hour, they will be triggered in the following order: Calibration, Zero, and Span.

3.4.2.4 Language selection

The available languages are English and French.

The user touches/double-clicks on  to display the language selection pop-up.

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

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

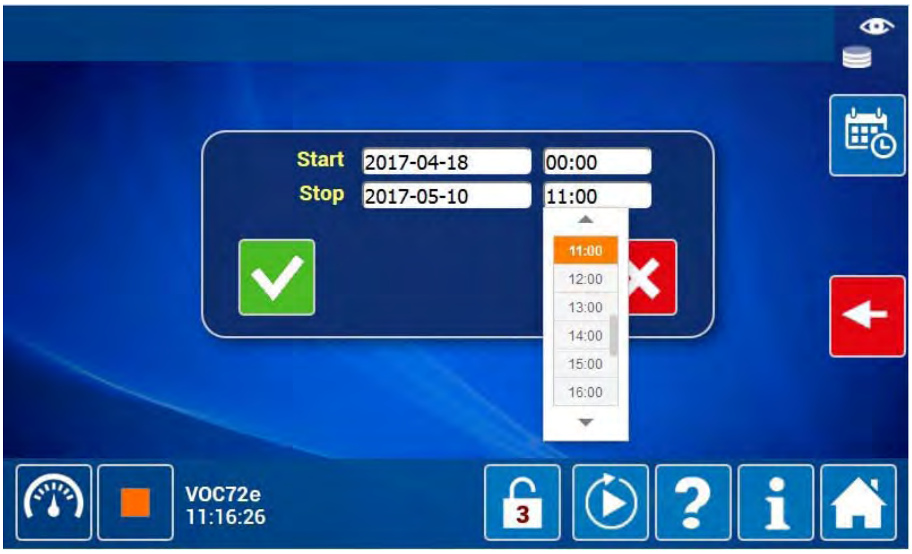
3.4.2.5 Find and display recorded averages

The user accesses this screen by touching / clicking on . The icon of this button is reminded on the top right side of the screen.

It is used to set the data period the user wants to view and to display these data for all the previously selected measurement channels.

To do this, the user touches/clicks on the Start and Stop fields to select the dates and times of the desired period, then he touches / clicks on  to validate the selection, close the pop-up and display the data viewing screen.

Note:  closes the pop-up without validating the selection.

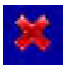


The user touches/ clicks on  to display the next measurement channel data, and on  to display the previous measurement channel data.

Button definition specific to this screen:

	It opens the popup to select another period. 
	It exports the displayed data to a TXT file.

Display icon meaning

	It indicates an average stored with an alarm status. Alarm details are displayed by touching / clicking on this icon.
	This icon indicates an average stored with a control status. Control details are displayed by touching this icon.
	This icon indicates an average stored with a calibration status. Calibration details are displayed by touching / clicking on this icon (zero, span).

3.4.2.6 Delete all recorded averages

The user touches / clicks on the button  to delete all the recorded averages.

WARNING! This operation is irreversible.

3.4.2.7 List of the connected clients

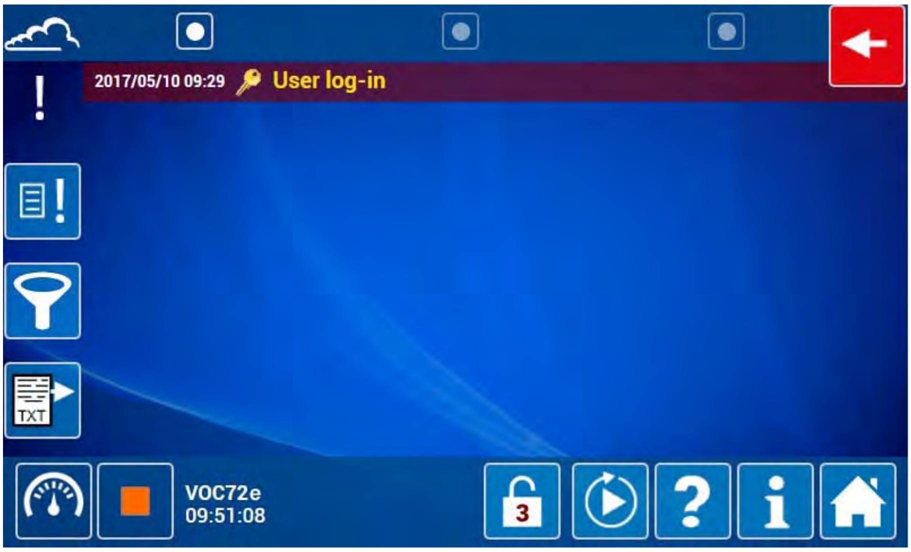
The user touches/double-clicks on  to display the pop-up giving the IP addresses and inactivity duration of the currently connected clients. He touches/clicks on  to close the pop-up.

3.4.2.8 Diagnostic functions (alarm, input/output, mux…)

The user accesses this screen by touching / clicking on . The icon of this button is reminded on the top right side of the screen.

The pages of this screen are displayed by touching / clicking on the white points in the screen top browsing bar.

The first page lists the current alarms and significant events on the analyzer.



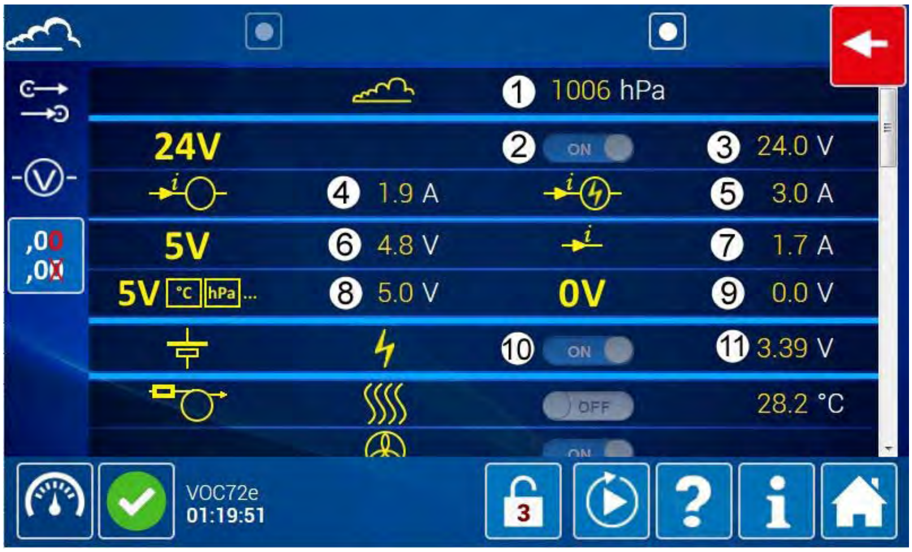
Button definition specific to this screen:

It displays or hides all the archived events.

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

It exports the displayed data in a TXT file.

The second page displays the analyzer signal values.



(1) Atmospheric pressure, (2) 24V control (ON), (3) 24V voltage, (4) Peripheral current, (5) Power current, (6) 5V power supply voltage, (7) 5V power supply current 5V, (8) 5V-sensors supply voltage, (9) 0V potential, (10) Desorber supply relay (ON), (11) Battery voltage of the desorber.

(1) Trap heating (OFF), (2) Trap temperature, (3) Trap vent (ON), (4) Transfer line heating (OFF), (5) Transfer line heating current, (6) Hot box heating (ON), (7) Hot box temperature, (8) Pilot solenoid valve of injection (OFF).

(1) Column heating (ON), (2) Column temperature, (3) Column safety temperature, (4) Vector gas inlet pressure, (5) Pressure regulation (ON), (6) Regulated column pressure, (7) Column end heating (ON), (8) Column end current, (9) Heating voltage of end column, (10) Detector heating (ON), (11) Detector temperature, (12) Detector power supply (ON), (13) PID lamp voltage, (14) Detector signal.

(1) Peltier cooler control (OFF), (2) Cold plate temperature, (3) Radiator fan (ON), (4) Radiator temperature, (5) Cooling pump (OFF).

The command column (9) is grayed out in all operation modes (except stand-by) and the controls cannot be accessed by the screen.

(1) Purge solenoid valve (OFF), (2) Sample pump (ON), (3) Trap pressure, (4) Stirring fan (ON), (5) Cooling fan (ON), (6) Internal temperature, (7) Zero solenoid valve (OFF), (8) Solenoid valve (OFF)

In standby mode (1), the control column (2) is highlighted and the controls get available by the screen.

3.4.2.9 Set the analyzer in stand-by mode

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

PAY ATTENTION: Depending on the column temperature, the stand-by time may be longer or shorter.

When the analyzer is switched to stand-by mode, the status icon on the information area (bottom left side of the screen) changes to indicate stand-by status . However, the alarm or control indication has priority.

Consequently, if the analyzer is switched to stand-by mode while in alarm is still active in this status, the alarm icon or control icon will remain displayed and the stand-by icon will not be displayed.

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

3.4.2.10 Advanced analyzer configuration

The user accesses this screen by touching / clicking on . The icon of this button is reminded on the top right side of the screen.

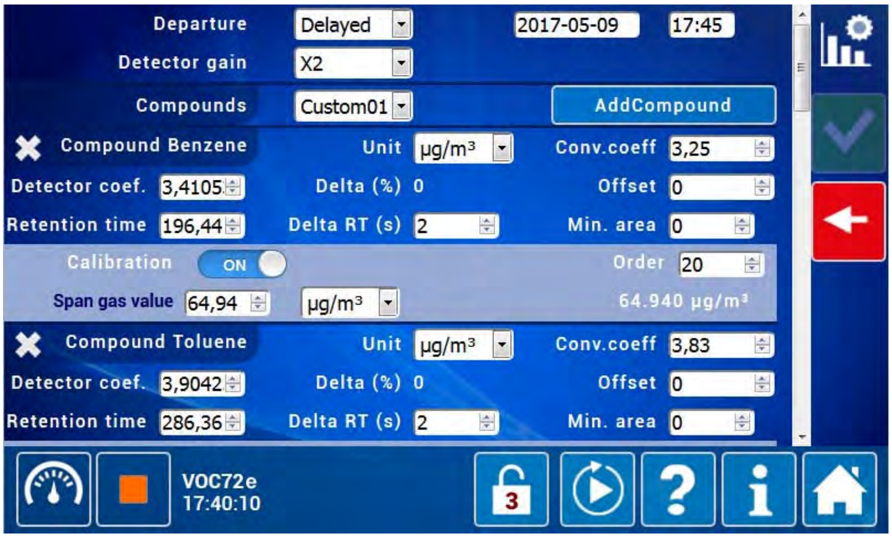
This screen allows the advanced analyzer configuration.

DEPARTURE field: it is used to select the START type of the first measurement cycle. Two choices are available: immediate or delayed.

– Immediate: the first measurement cycle starts as soon as the analyzer is READY (icon).
– Delayed: the analyzer switches to READY (icon) mode, then to WAITING FOR START mode (icon) until the date and time of the analyzer clock reaches the date and time of cycle start.

DETECTOR GAIN field: it is used to define the multiplicative factor to amplify the output detector signal.

COMPOUND fields: it indicates the available compound list. To add a compound, the user selects it from the drop-down list and then presses the "AddCompound" button. This compound and its measurement configuration fields are displayed in the corresponding section at screen bottom. To delete a compound from the screen, the user touches / clicks on at left side of the compound name.



COMPOUND section: by default, the screen contains the 6 compounds sections corresponding to the standard tests carried out in factory: Benzene, Toluene, Ethylbenzene, MP-Xylene, O-Xylene, 1,3-Butadiene.

– UNIT field: it indicates the unit in which the measurement is stated. Two units are available µg/m^3, and ppb.

– CONV. COEFF field: it is the conversion coefficient of the compound measurement from ppb to µg/m^3. In the screen below, 1 ppb of benzene is equivalent to 3.25 µg/m^3 of benzene. The conversion coefficient is specific to each compound. The user must therefore verify that this coefficient values is correct before entering it in this field.

– OFFSET field: this field is used to program the offset, i.e. the value added to the measurement values.

– DETECTOR COEF. field: it indicates the response coefficient of the detector (calibration coefficient of the compound). It can be entered manually, or calculated automatically during automatic calibration. In this case, it is modified each time the analyzer is calibrated

– RETENTION TIME field: it is the programmed retention time. It corresponds to the central value of the compound detection window. It can be entered manually (see § Manual calibration of retention times) or calculated automatically (see § Automatic Calibration of RT and Concentration).

– DELTA RT (s) field: it defines the detection window width. For example, if the delta RT is set to 2 seconds (as in the screen below), when the retention time of a chromatographic peak is in the detection window of a compound (+/- 2 seconds), the peak is identified as corresponding to this compound. For example, for benzene, the detection window will be defined from 194.44 to 198.44 seconds.

– MIN. AREA field: it indicates the minimum peak surface beyond which the peak is taken into account for a possible concentration calculation. Below this surface, zero is assigned to the compound measurement, allowing to pass over small peaks.

  When this field is equal to zero, any peak is taken into account whatever its surface.

– CALIBRATION field:

  If ON, the compound is taken into account in the automatic analyzer calibration. The Span gas value field is used to enter this compound concentration in the calibration mixture. This concentration can be expressed in ppb or µg/m^3.

  If OFF, the compound is not taken into account in the automatic analyzer calibration.

– ORDER field: this field is used for the « R.T. and Conc. » calibration. It allows to fix the peak elution order.


Compound Benzene
Unit µg/m³
Conv.coeff 3,25
Detector coef. 3,4105
Delta (%) 0
Offset 0
Retention time 196,44
Delta RT (s) 2
Min. area 0
Calibration ON
Order 20
Span gas value 64,94 µg/m³
64.940 µg/m³
Compound Toluene
Unit µg/m³
Conv.coeff 3,83
Detector coef. 3,9042
Delta (%) 0
Offset 0
Retention time 286,36
Delta RT (s) 2
Min. area 0
Calibration ON
Order 40
Span gas value 76,82 µg/m³
76.820 µg/m³
Compound Ethylbenzene
Unit µg/m³
Conv.coeff 4,42
VOC72e
17:46:14
3

TEMPERATURE SETTING section: it is used to define the set points for the fixed temperature control.

- INTERNAL T° OFFSET field: this field is not applicable to the VOC72e, it must always remain to zero.
- AMBIANT T° REG. field: it refers to the internal analyzer temperature, and is set to 35°C by default.
- TRAP T° REG. field: it refers to the trap desorption temperature which is set to 380°C by default.

CALIBRATION section:

- CALIBRATION MODE field: two automatic calibration modes are available: “Standard” and “T.R. and Conc.”. The standard calibration adjusts only the detector response coefficient for each compound. The T.R. and Conc. adjusts both the detector response coefficient and the retention time for each compound.
- FIRST CALIBRATION field : this field acts as a safety in case of too important variations of the detector coefficient after an automatic calibration:
  - When this field is OFF: it invalidates the calibration if the detector coefficient varies by more than 50% from its initial value. In this case, the calibration is not taken into account (the previous coefficients are maintained) and a Calibration alarm is triggered.
  - When this field is ON: it allows a detector coefficient variation by more than 50%.

FLOW RATE section: it is used to calculate the flow rate from the trap pressure measurement. The flow rate corresponds to the equation: Y = A X + B, with:

- Y: Flow rate, in milliliter per minute,
- A: Slope,
- X: Absolute trap pressure, in hPa,
- B: Origin.

The calculated flow rate value is displayed at right side of the field B.

The flow calculation has a direct effect on the compound measurement: a 10% decrease in the calculated flow corresponds to the same decrease in the trapped volume (as the sampling time is constant) and then results in a 10% increase of the concentrations displayed for the measured compounds. It is recommended to re-calibrate the compounds after flow rate calibrating.

VOLUMIC COMP. field: it must remain ON, to avoid the concentration measurements varying with the sample pressure.

3.4.2.11 Real time chromatogram

The user accesses this screen by touching / clicking on . The icon of this button is reminded on the top right side of the screen.

It allows to view the analysis cycle chromatogram during acquisition.

The chromatogram acquisition starts at t = 11 seconds of the analysis cycle (at the thermal trap desorption) (see Chapter 2, Figure 2-4). It ends at t = 501 seconds of the analysis cycle when the progress bar of the synoptic screen reaches the calculation mark (see Chapter 2, Figure 2-10). At this point, the column reaches the hot step (160 ° C.).

The time scale (X) of the instantaneous chromatogram is thus equal to 501 s - 11 s, i.e. 490 seconds. The height axis (Y) of the chromatograms can be adjusted according to three different scales: 0-2.5 V, 0-0.5 V, 0-0.1 V. At any time, the user can switch from one scale to another by activating one of the three corresponding buttons shown below:

Activated button : 0.1

Scale : 0-0.1 V

Activated button : 0.5

Scale : 0-0.5 V

Activated button : 

Scale : 0-2.5 V

3.4.2.12 Last chromatogram

The user accesses this screen by touching / clicking on . The icon of this button is reminded on the top right side of the screen.

It displays the last complete chromatogram recorded in the analyzer. This display is scaled automatically. Compounds peaks whose retention time is configured in the software are identified using yellow bubbles.

The dates and times indicated in the upper banner correspond to the sampling cycle. In the example below, the sampling cycle occurred between 17h and 17h15, the analysis cycle occurred between 17h15 and 17h30 (i.e. 900 seconds).

The last chromatogram display remains available until the next chromatogram acquision is complete.

The red points indicate the chromatographic peaks, the yellow bubbles indicate the compound peaks.

The user displays the following screen by clicking on a yellow bubble.

This screen contains the specific chromatogram of this peak in the right frame, and the corresponding analysis information in the left frame.

PEAK field: it indicates the peak exit order on the chromatogram.

START field: it indicates the peak start abscissa in seconds (3).

END field: it indicates the peak end abscissa in seconds (4).

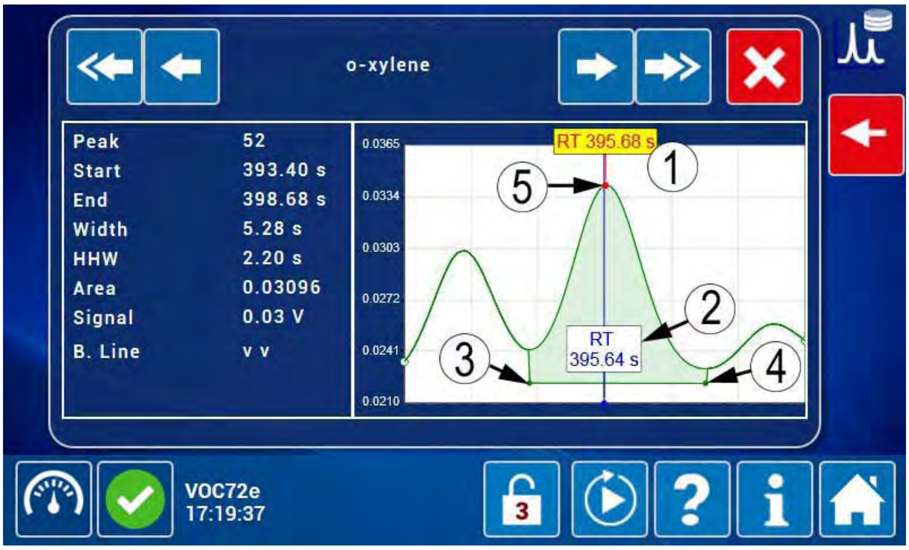
WIDTH field: it gives the difference between the peak end time (END) and peak start time (START)

HHW: it indicates the half height width of the peak. This value characterizes the peak thickness.

AREA field: it is the peak surface (in green). It is stated in volt.seconds.

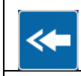
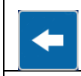
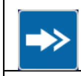
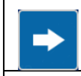
SIGNAL field: it is the peak top ordinate represented by the red point (5).

B. LINE field: it characterizes baseline type, which can be vv (i.e. valley-valley), vb (i.e. valley-base), bb (i.e. base-base), bv (i.e. base-valley).



(1) effective retention time (RT) of the peak, (2) programmed retention time (RT) in the software, (3) peak start, (4) peak end, (5) peak top.

Button definition specific to this screen:

	It displays the previous compound peak whose name is displayed in the top banner.
	It displays the previous peak.
	It displays the next compound peak whose name is displayed in the top banner.
	It displays the next peak.
	It closes this screen to return to the previous screen.

3.4.2.13 Set the analyzer in maintenance mode

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

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

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

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

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

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

3.5 CALIBRATION

3.5.1 GENERAL

To ensure quality of the measurements performed using the VOC72e, it is necessary to regularly carry out checking, calibration and adjustment operation according to the quality assurance plan of the user.

A check point check every two weeks is recommended.

The VOC72e requires a dual calibration for each compound:

– Retention time (RT).

– Response factor (K).

A flow calibration is also required for the volume compensation of the sample.

3.5.2 ZERO AIR SOURCES

The possible sources are:

– A synthetic air cylinder. The cylinder is filled with a mixture of nitrogen and oxygen free of hydrocarbon.

– A zero air generator. In this type of generator, the ambient air is compressed, dried and passes a catalytic oven where hydrocarbons are oxidized.

Alternate zero source for the VOC72e:

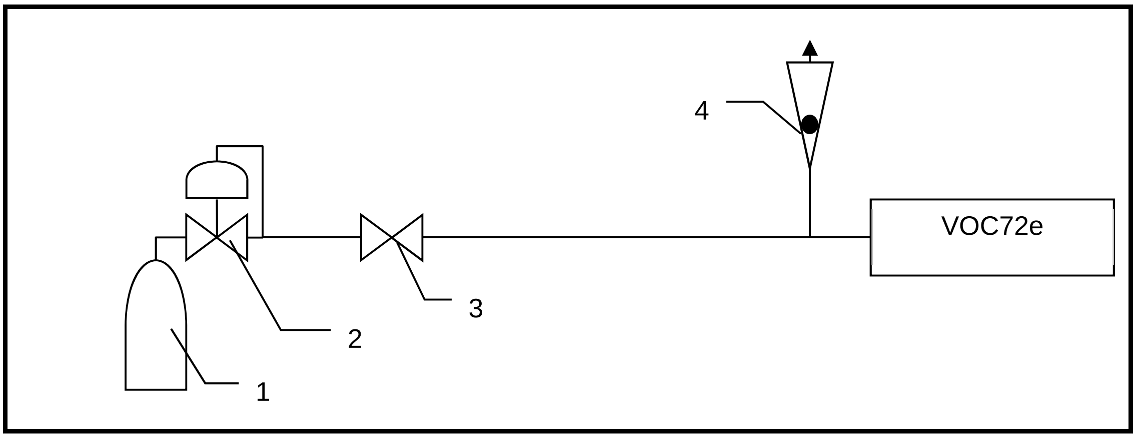
– A charcoal filter is a good choice as zero filter for benzene.

3.5.3 SPAN GAS SOURCE

The recommended span gas concentration of benzene per EN14662-3 standard is 50µg/m^3 (approx. 15ppb) in zero air.

The possible sources are: a diluted span gas cylinder, a gas dilutor, a permeation bench.

3.5.3.1 Diluted span gas cylinder



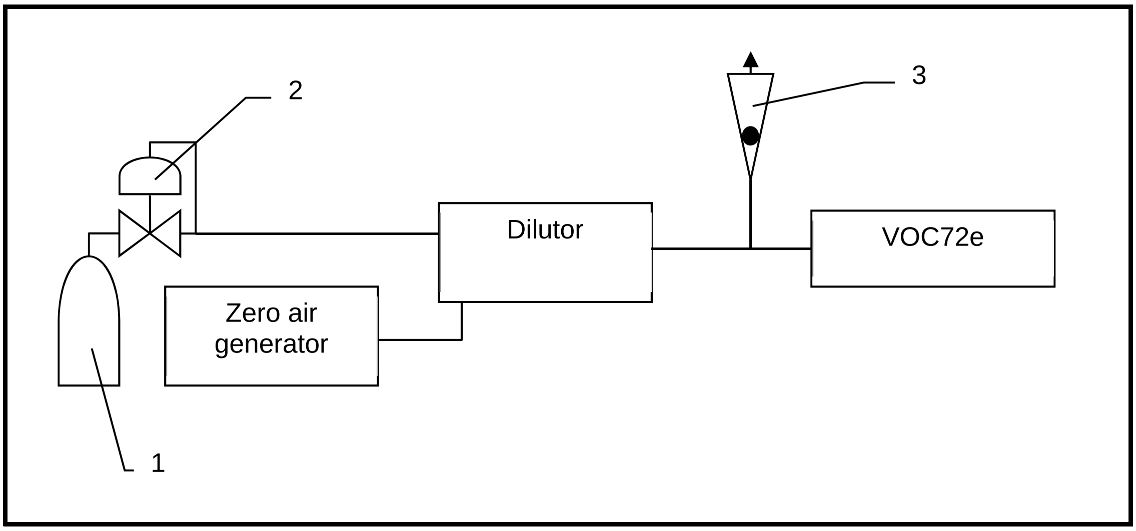
(1) Span gas cylinder, (2) Pressure reducer, (3) Needle valve, (4) Excess flow meter

+ Minimum parts, easy to move and to install.

– Span concentration in the low ppb range difficult to achieve and to maintain along the time.

– Limited volume of available span gas.

3.5.3.2 Gas dilutor



(1) Span gas cylinder, (2) Pressure reducer, (3) Excess flow meter

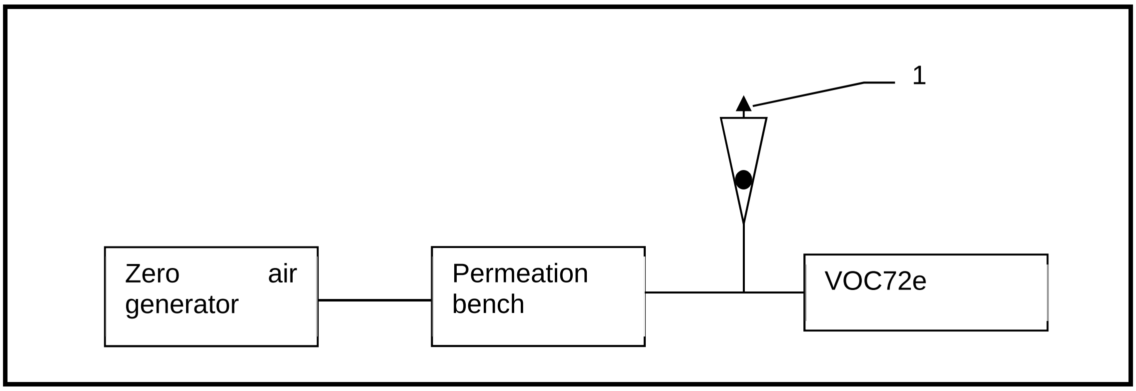
+ Cylinder span gas concentration in the ppm range (easiest to do and to warranty in time, reasonable price).

+ Large volume of available span gas (typically x100 versus direct cylinder).

+ Possibility to generate several concentrations including the zero.

- Requirement of an air zero source and a gas dilutor (initial cost, electricity, warm-up time, metrological check of gas dilutor…).

3.5.3.3 Permeation bench



(1) Excess flow-meter,

+ Very large span gas volume available.
+ Avoid to use high pressure cylinders.

– Requires a permanent purge flow.
– One permeation tube required per compound (=> limited number of compound according to the size of the oven).
– Long warm-up time required to obtain stable concentration.

3.5.4 SCALE POINT CHECK

- Connect the span gas source to the sample inlet at the beginning of the analysis cycle (the trap sampling starts 80 seconds after the cycle start).

NOTE : Always install an excess Tee before the analyzer inlet in order to avoid any overpressure.

- Verify the result at the end of the next cycle:
    - Compounds concentration within the acceptable limits.
    - Retention times centered within the detection window (less than 0.5 second drift).
    - No extra significant peak in the GC chromatogram.

3.5.5 THE MANUAL CALIBRATION

The manual calibration is applied to the retention time (RT), response factor (K factor) or both these parameters at the same time.

3.5.5.1 Manual Retention Time (RT) Calibration

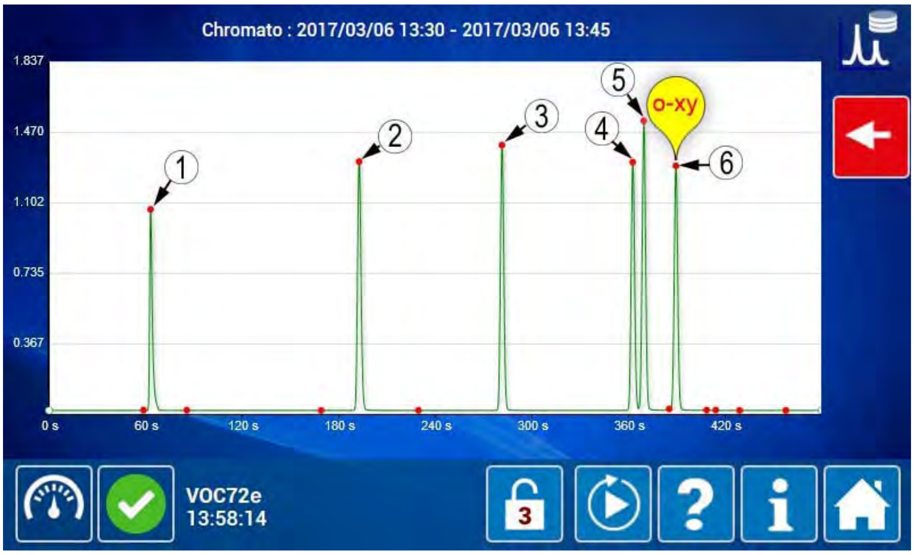
For each compound measured, the manual RT calibration consists of entering in the *« Advanced analyzer configuration »* screen the effective retention time found in the span mixture chromatogram.

When the user injects a span mixture composed of the following compounds: benzene, toluene, Ethylbenzene, m-xylene (or p-xylene), o-Xylene, 1,3-butadiene, he obtains after the analysis cycle a 6-peak chromatogram whose order corresponds to the increasing boiling temperatures:

Rank	**Compound**	**Boiling temperature**
1	1,3-Butadiene	- 4.4°C
2	Benzene	80.1°C
3	Toluene	110.6°C
4	Ethylbenzene	136.2°C
5	m-Xylene and p-Xylene	343.9°C and 343.1°C
6	O-Xylene	357.2°C

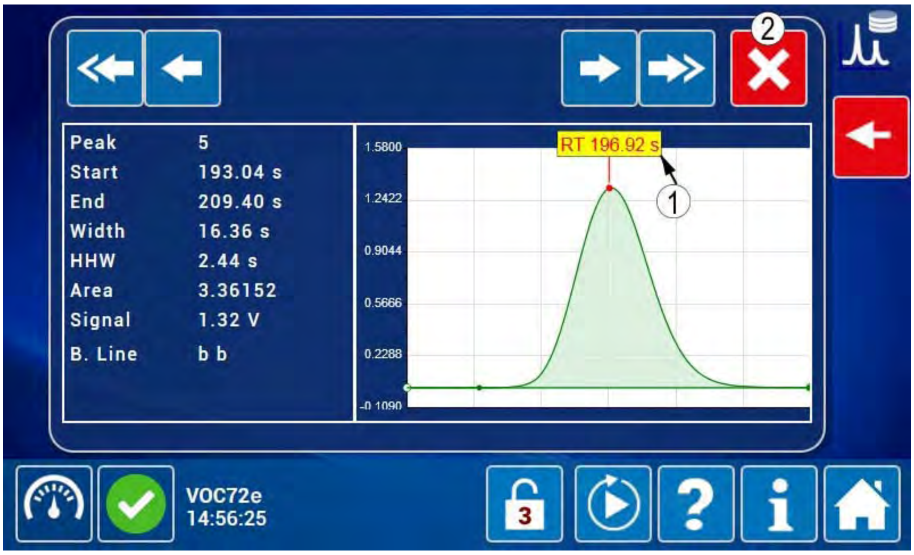
NOTE : For retention time calibration, the exact compound concentration is not important. However, it is necessary that the compound concentration be sensibly higher than the impurity amount in order to avoid confusing them.

The span chromatogram below shows 6 peaks. The peaks of 1,3-Butadiene (1), Benzene (2), Toluene (3), Ethylbenzene (4) and m + p-Xylene (5) have no label, meaning that they are not identified by the software. Only the o-Xylene peak (6) has a label, and therefore seems to be identified by the software.

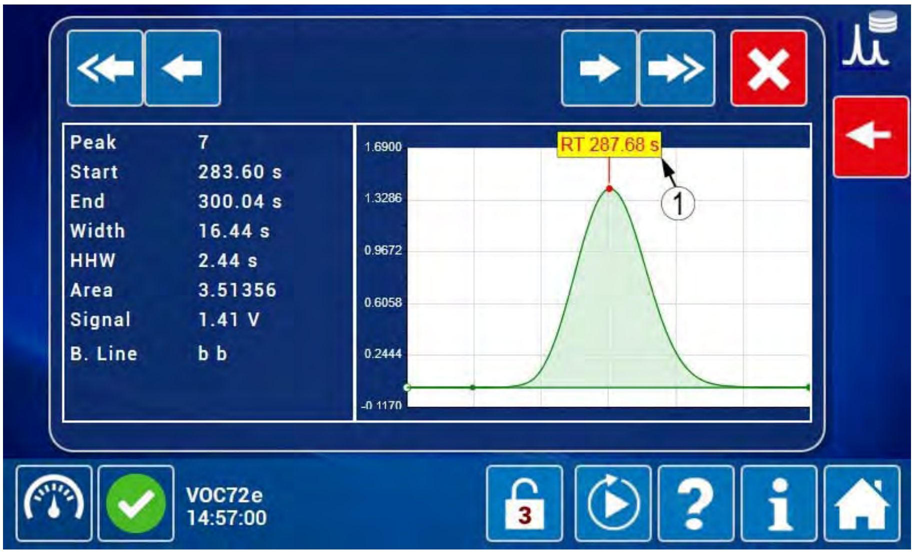


By clicking on the Benzene peak (2), the user displays the following screen shown below. This screen shows that the effective retention time of the peak identified as Benzene is 196.92 seconds (1).

Click on (2) in the screen below to return to the chromatogram above, and click on the peak (3) to display the peak identified as Toluene.



The screen below shows that the effective retention time of the peak identified as toluene is 287.68 seconds (1).



Go to the « *Advanced analyzer configuration* » screen and note that the initially programmed retention times are:

– Benzene (1) Retention time (RT) = 200 seconds, i.e. a + 3.08 seconds deviation compared to the effective RT.

– Toluene (2) Retention time (RT) = 300 seconds, i.e. a + 12.32 seconds deviation compared to the effective RT.

In both cases, the deviation is greater than 2 seconds of the Delta TR (3), thus explaining the identification absence.

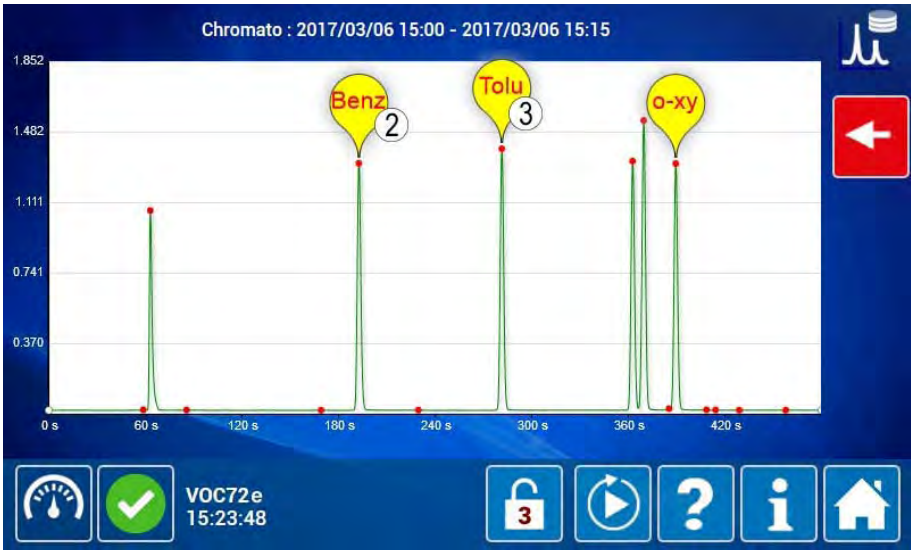
In the « *Advanced analyzer configuration* », use the keyboard to enter the retention times found above:

– 196.92 seconds for Benzene (1),

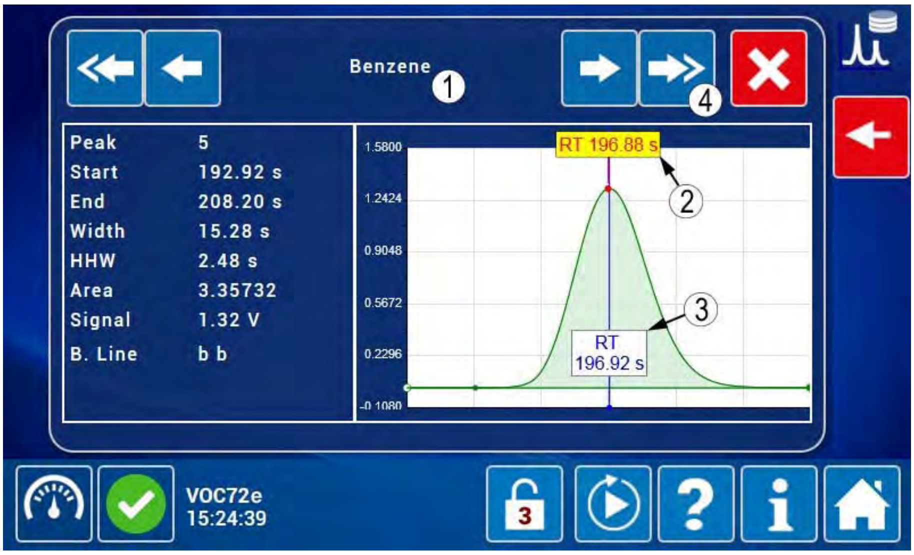
– 287.68 seconds for Toluene (2).

Valid with the button (3).

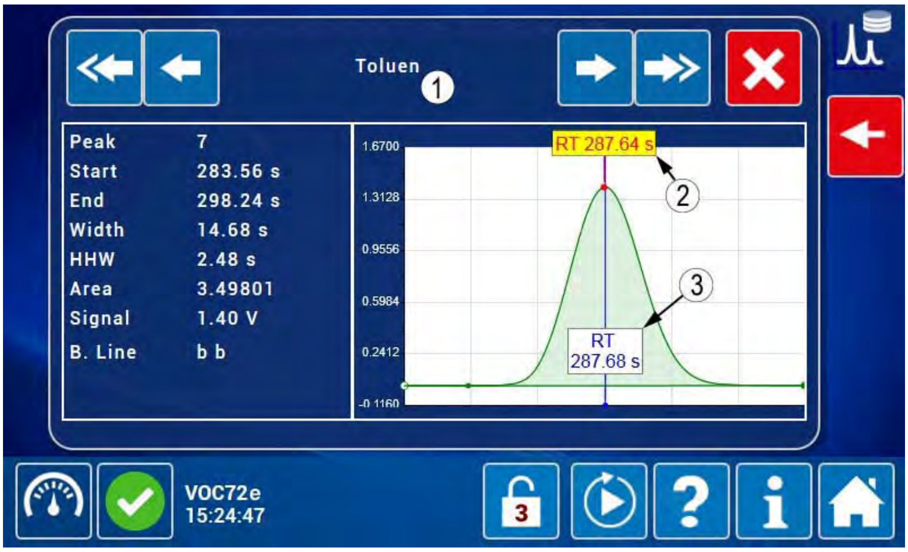
At the next cycle, VOC72e now identifies Benzene and Toluene, as indicated by labels (2) and (3) on the peaks.



The following screen is obtained by clicking on the label (2): the effective retention time (2) of the peak is very close to the programmed retention time (3) for Benzene, consequently it is identified as the Benzene peak (1).



The user activates the button (4) of the above screen to display the next compound peak shown in the screen below. This peak has an effective retention time (2) very close to the programmed Toluene retention time (3), consequently, it is identified as the Toluene peak (1).



The manual retention time calibration of Benzene and Toluene is finished.

This procedure of manual retention time calibration must be applied identically to the other compounds.

At this calibration end, the deviation between the effective retention time and the programmed retention time must be very low in order to position the compound peak in the center of the detection window.

NOTE : This deviation must remain less than one second to ensure reliable detection over time.

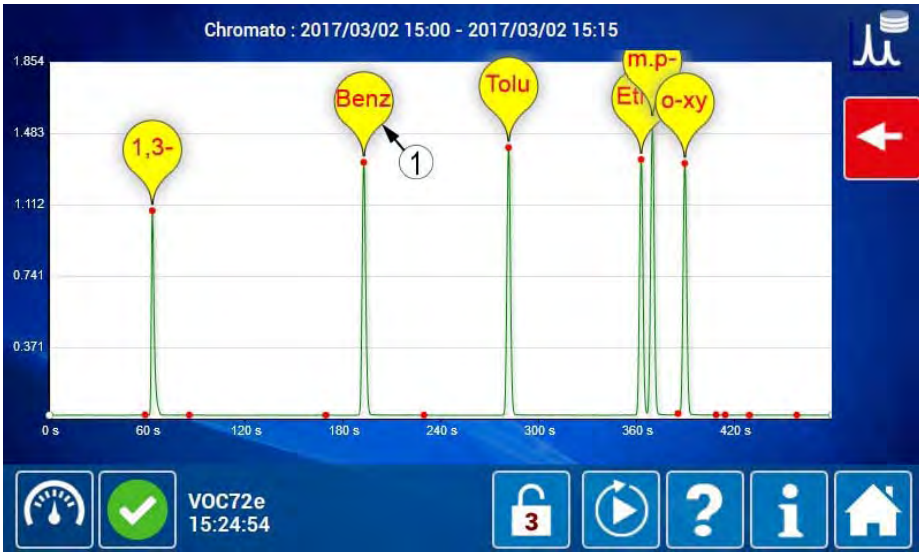
3.5.5.2 Manual K detector coefficient calibration

This calibration can only be carried out with a valid retention time (TR) calibration. The compound calibration is considered as valid when the absolute deviation between the programmed retention time and the effective retention time is less than 1 second. **If the deviation exceeds 1 second, the programmed retention time must be adjusted.**

NOTE : The maximum allowed deviation corresponds to the Delta TR parameter set to 2 seconds. Beyond this value, the compound peak is no longer detected and a close peak may be detected instead of it.

The retention time calibration can be checked quickly by viewing the compound peaks displayed in the last chromatogram.

The chromatogram shown below is a span mixture chromatogram. The label presence (1) indicates that the compound peak is within the detection window at less than 2 seconds of the programmed retention time.



By clicking on the yellow bubble (1) of the above screen, the user displays the Benzene peak (shown below screen) in which two information about the retention time are indicated:

– Effective retention time, red on yellow background (2), with a red arrow ended by a red point at peak summit.

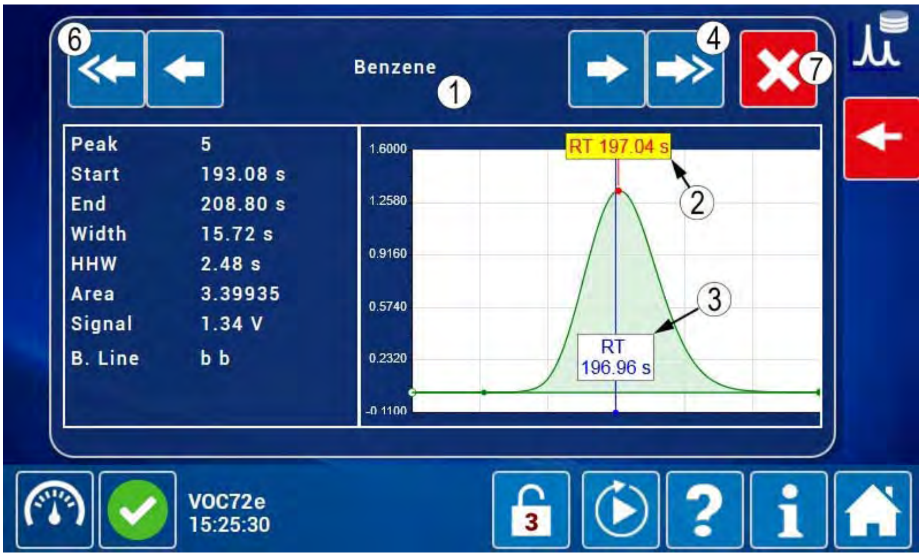
– Programmed benzene retention time, blue in white background (3), with a blue vertical line materializing this position.

These data values indicated in the screen show that the variation between the effective retention time and the programmed retention time for benzene is:

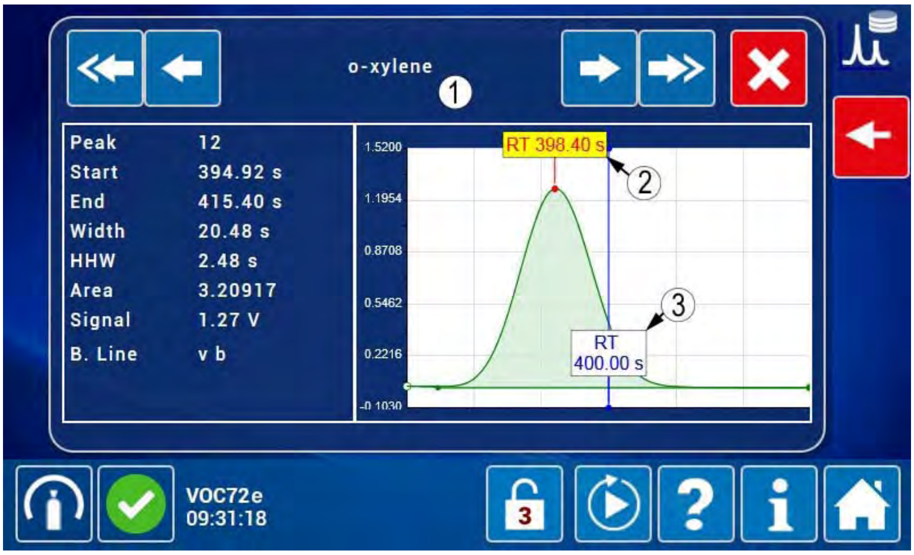
197.04 – 196.96 = 0.08 seconds.

This time is less than 1 second, so the retention time calibration is considered as valid for Benzene and does not require adjustment.

In the below screen, click on (4) to go to the next compound, on (6) to go to the previous compound, and on (7) to return to the last chromatogram.



In the example below showing the O-Xylene peak (1), the effective retention time is 398.40 seconds (2) while the programmed retention time is 400 seconds (3). The 1.6 second deviation separating the effective retention time and the programmed retention time is less than 2 seconds, thus allowing the compound detection. But since this deviation is greater than 1 second, it is invalid. Consequently, the user must adjust the programmed retention time to 398.4 seconds (see procedure described in the previous paragraph).



To simplify in the following example, only Benzene and Toluene are considered. After the span mixture analysis, the VOC72e displays the following concentrations before calibration:

(1) Cb1 = 114.7 µg/m³ of Benzene ➔ for Cbi = 64.94 µg/m³ of Benzene injected.

(2) Ct1 = 119.9 µg/m³ of Toluene ➔ for Cti = 76.82 µg/m³ of Toluene injected.

With:

- Cb1 = Benzene concentration before calibration,
- Cbi = Benzene concentration injected
- Ct1 = Toluene concentration before calibration,
- Cti = Toluene concentration injected.

In the « *Advanced analyzer configuration* » screen, the user finds:

(1) programmed Benzene retention time (as seen above)

(2) Benzene detector coefficient before calibration, Kb1 = 6.

(3) Toluene detector coefficient before calibration, Kt1 =6.

After calibration, the new Benzene detector coefficient, Kb2, is calculated as follows:

Kb2 = Kb1 x Cbi / Cb1.

With the values given in the example above:

Kb1 = 6, Cbi = 64.94 µg/m, Cb1 = 114.7 µg/m^3.

It is obtained by calculation: Kb2 = 6 x 64.94 / 114.7 = 3.397.

After calibration, the new Toluene detector coefficient, Kt2, is calculated as follows:

Kt2 = Kt1 x Cti / Ct1.

With the values given in the example above:

Kb1 = 6, Cti = 76.82 µg/m^3, Ct1 = 119.39 µg/m^3.

It is obtained by calculation: Kt2 = 6 x 76.82 / 119.9 = 3.844.

The detector coefficients before calibration must then be replaced, in the *« Advanced analyzer configuration »* screen, by these new detector coefficients after calibration, obtained by the above calculation:

(1) Kb2 Coefficient for Benzene.

(2) Kt2 Coefficient for Toluene.

Then, click on (3) to validate.

NOTE : Without validation, the coefficients keep the old value. But, the user can only realize it in displaying the *« Advanced analyzer configuration »* screen.

After carrying out the adjustments, the user displays the measurement channel home page to note that:

– the measured benzene concentration (1) is now very close to the injected span mixture concentration Cbi = 64.94 µg/m³.

– the measured toluene concentration (2) is now very close to the injected span mixture concentration Cti = 76.82 µg/m³.

The manual calibration of benzene and toluene detector coefficients is finished.

This procedure of manual detector coefficient calibration must be applied identically to the other compounds.

3.5.6 THE AUTOMATIC CALIBRATION

3.5.6.1 Automatic standard calibration of concentration

This calibration consists in performing, for each selected compound, an automatic adjustment of the detector response coefficient (K).

The five necessary conditions to carry out the standard calibration are:

- Valid retention time calibration for all compounds,
- Span gas sampling cycle without alarm, followed by an analysis cycle without alarm,
- No saturated compound peak (i.e. amplitude close to 2500 mV),
- Calculated detector coefficient comprised between 0.1 and 50.
- Calculated detector coefficient different from the current coefficient by less than 50%. This condition can be ignored if the First Calibration parameter is set to ON in the *« Advanced analyzer configuration »* screen.

If one of the above conditions is not fulfilled, the detector coefficients are not modified and the VOC72e generates a calibration alarm.

Step 1: Checking the span gas input configuration

In the *« Automatic cycle configuration »* screen, check that:

- The Inlet/Calibration field is configured to Span (1) for the span gas inlet when the analyzer is equipped with the Span option or the Pressure span option.
- The Programmed inlet field is configured to ON (2), in order to switch the sampling to the span inlet for the sampling cycle used for calibration.

NOTE : If the VOC72e is not equipped with the Span option or the Pressure Span option, the input port setting is not important, but it is necessary to switch manually the sample inlet to the span gas source before starting the sampling cycle of the automatic calibration, and then reconnect the sample source at the beginning of the next cycle.

Step 2: Checking the retention time accuracy

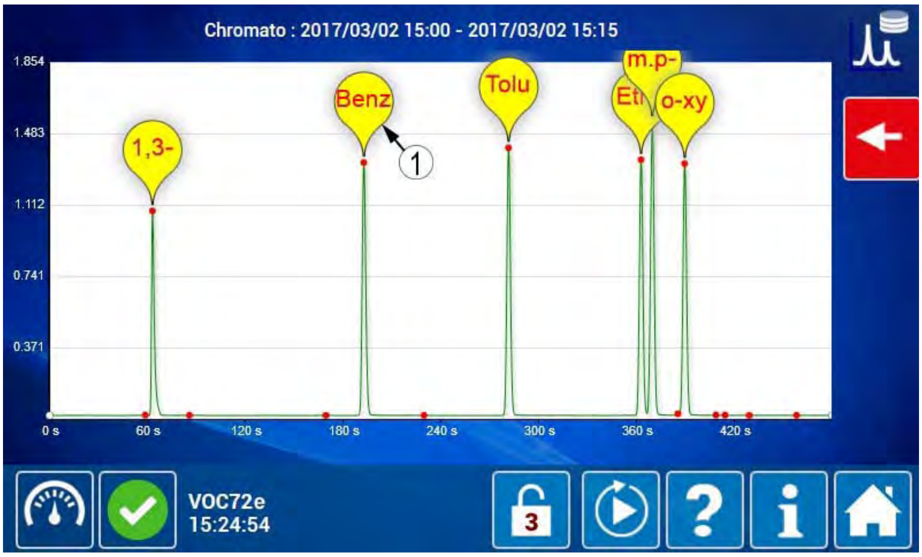
This checking ensures the peak detection reliability. It is carried out by examining the chromatogram obtained with a span mixture including mainly the compounds to be checked.

Reminder: a peak is detected when the deviation between its effective retention time and its retention time programmed in the software is less than 2 seconds (delta TR value set by default in the software). A red label on yellow background placed on the red point at peak summit allows its identification. See the benzene peak (1) in the chromatogram below. This deviation of less than 2 seconds allows the compound detection, but if it exceeds 1 second, it must be adjusted.

The chromatogram shown below is a span mixture chromatogram. The label presence on the red point at each of the six peak summit indicates that the six compounds are detected.

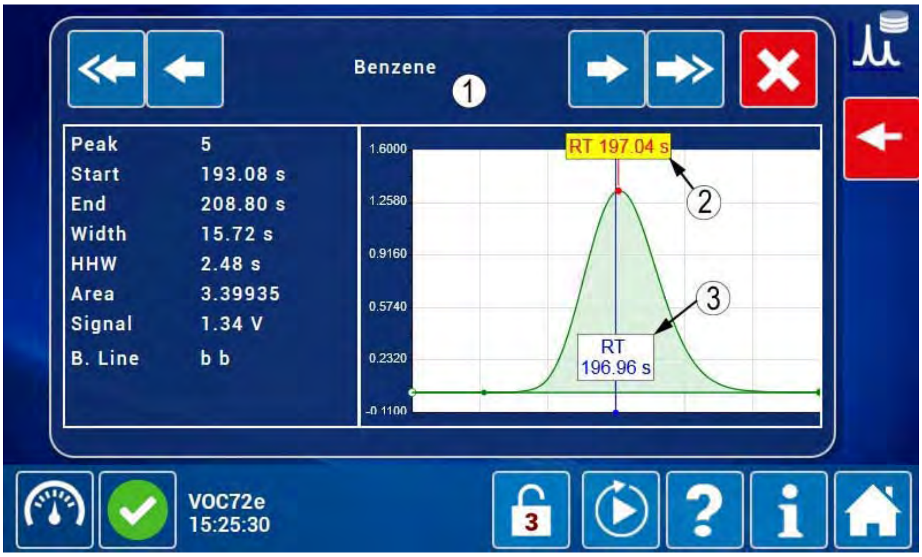
It is now necessary to make sure that this detection is valid by checking, for each compound, that the deviation between the effective retention time and the programmed retention time is less than 1 second.

For example, to check this deviation for benzene, click on the corresponding label (1).



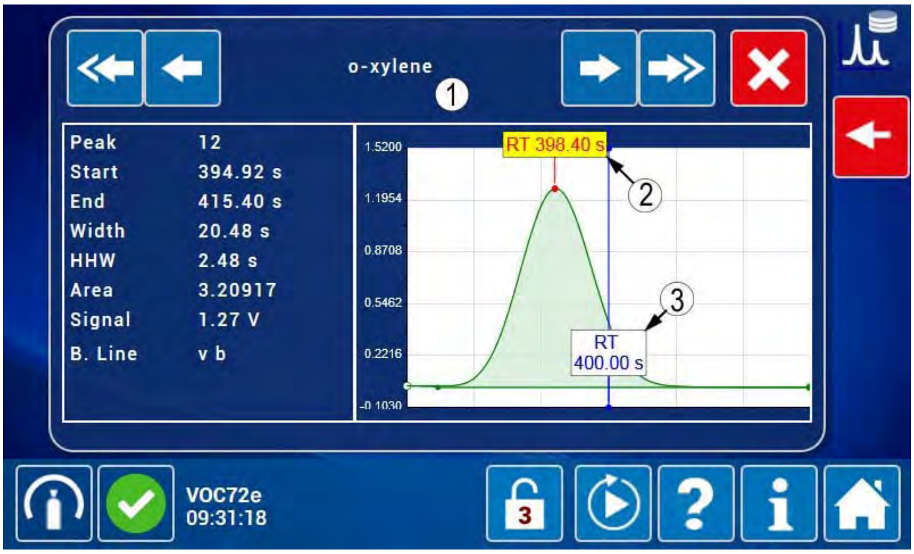
The Benzene peak (1) is displayed in the detection window.

The deviation between the effective retention time (2) TR = 197.04 sec and the programmed retention time (3) TR = 196.96 sec. is 0.08 seconds. This deviation is therefore less than 1 second, consequently the programmed retention time for benzene is valid.



Similarly, to check this deviation for O-Xylene, click on the O-Xy chromatogram label: the O-Xylene peak is displayed in the detection window.

Here, the deviation between the effective retention time (2) TR = 398.40 sec and the programmed retention time (3) TR = 400.00 sec. is 1.6 seconds. This deviation is greater than 1 second, therefore the programmed retention time for O-Xylene is not valid and must be adjusted to 398.40 seconds.



Step 3: Setting the « Advanced analyzer configuration »

For each compound to be calibrated, it is necessary to specify in this screen:

– Display unit (µg/m³ or ppb) (1).

– Conversion coefficient (in the below screen, 1 ppb benzene = 3.25 µg/m³) (2).

– Valid retention time (3).

– Calibration field ON (4).

– Span gas concentration (5).

– Span gas concentration unit (6).

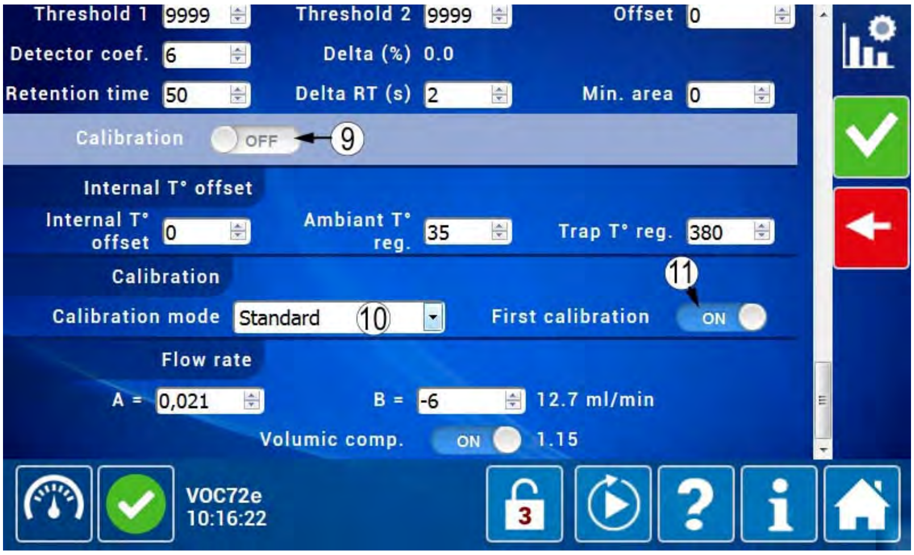
NOTE : Delta RT (7) is set to 2 seconds by default (Do not change it). The order (8) is not important for this calibration.

– Calibration parameter (9) must be OFF for the compounds not present in the mixture.

– Calibration mode field is set to Standard (10).

– First Calibration field is ON (11) to allow a detector coefficient variation greater than 50%. After calibration, this parameter automatically switches back to OFF.

Top part of the Advanced analyzer configuration screen

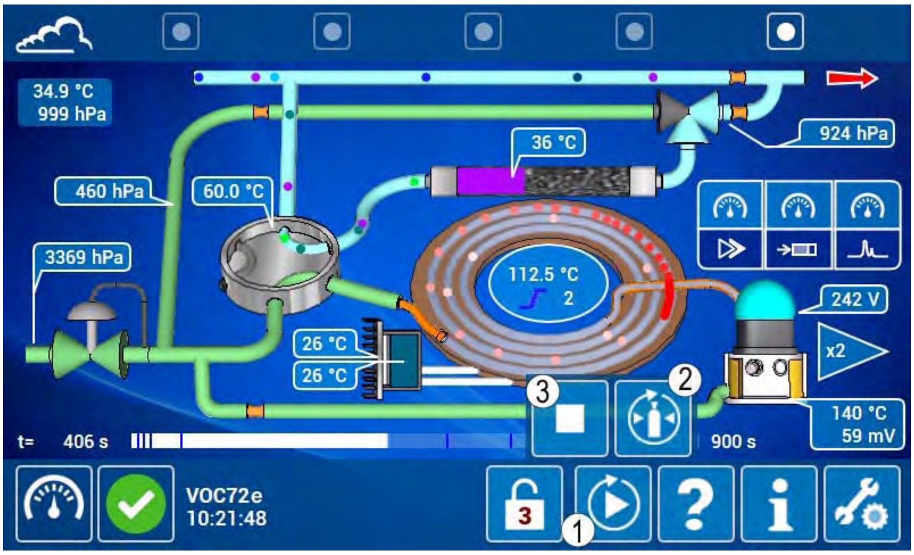


Bottom part of the Advanced analyzer configuration screen

Step 4: Launching and performing the automatic calibration

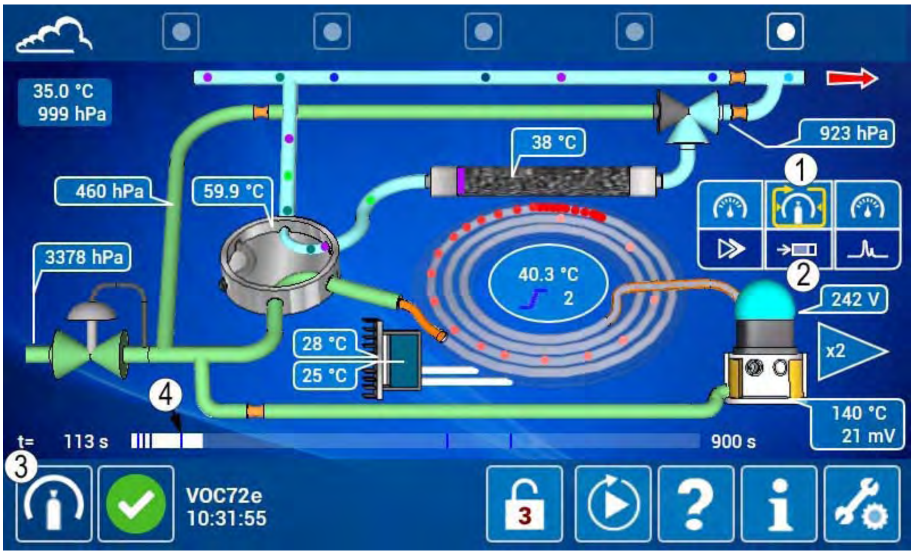
Activate the control (1) to display the calibration control and activate it (2).

DO NOT TOUCH the pause control (3).

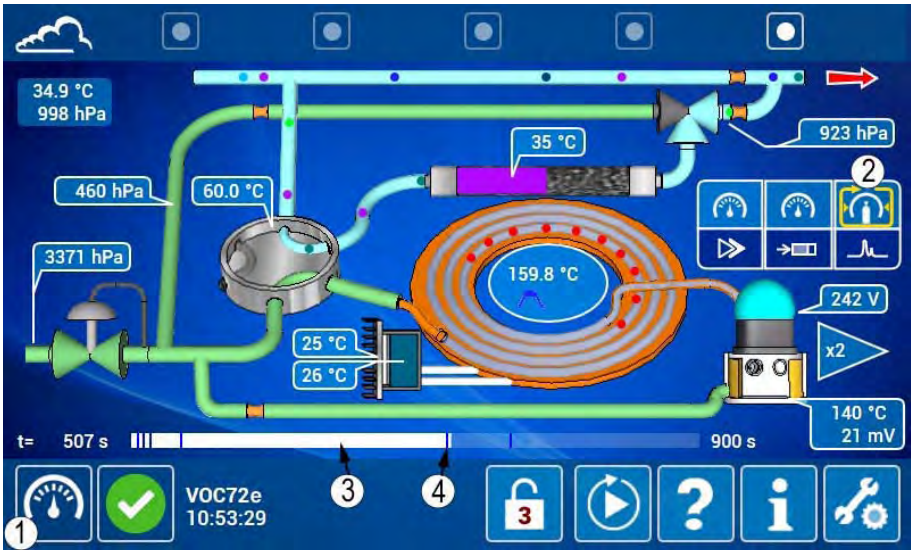


A calibration cycle is then positioned as the next cycle (1) while the analyzer continues the current cycle.

At the next cycle, the calibration icon (1) moves in the sampling cycle (2), the analyzer inlet switches to the span position (3), and from the sampling mark (4), the trap starts the span mixture sampling.



At the next cycle, the analyzer inlet automatically switches to sample position (1) and the column analyzes the span mixture (2). When the progress bar (3) reaches the calculation mark (4) the span chromatogram acquisition is finished and the automatic calibration starts.



The result is displayed in the *« Advanced analyzer configuration »* screen, where for each selected compound for calibration, the detector coefficient is automatically adjusted (1) (2).

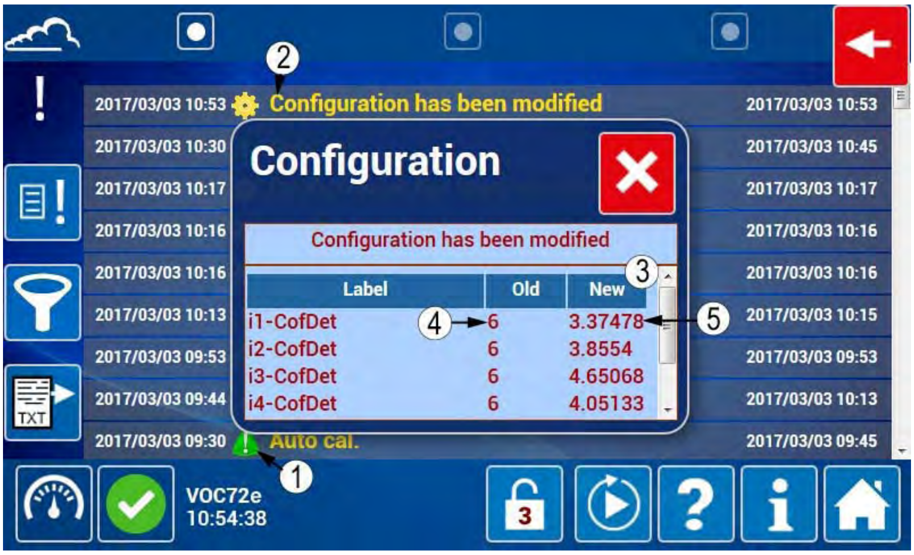
The measured compounds concentration (1) displayed in the measurement channels page corresponds exactly to the concentration values indicated for the span mixture in the *« Analyzer advanced configuration »* screen.

In the *« Diagnostic functions (alarm, input/output, mux…) »* screen, a message indicates that a calibration cycle was performed (1) and a second message indicates that the configuration was modified (2). By clicking on this last message, a pop-up is displayed and gives the modification details carried out (3) corresponding to the detector coefficient adjustment for each compound:

– Old detector coefficient for Benzene (4).

– New detector coefficient for Benzene (5).

The automatic concentration calibration in concentration is finished.



Then, it is then possible to start a new automatic calibration cycle using the cycle control without repeating the settings seen above.

3.5.6.2 Automatic Calibration of Retention Time RT and Concentration

For each compound selected, this calibration consists in performing at the same time:

- Automatic retention time adjustment (TR).
- Automatic adjustment of the detector response coefficient.

The seven conditions necessary to carry out a retention time TR and concentration calibration are:

- A span gas sampling cycle without alarm, followed by an analysis cycle without alarm.
- A peak number detected in the span chromatogram greater or equal to the declared compound number.
- No saturated peak (amplitude close to 2500 mV) in the span chromatogram.
- Chromatographic compound peaks having surface of the same magnitude order: the surface ratio between two peaks must not be greater than 3/1. In practice, the largest peak height must not be three times greater than the smallest peak height.
- Chromatographic compound peaks having a much larger surface than the impurity peak surface: the surface ratio between peaks must be at least 5/1. In practice, the smallest compound peak height must be at least five times greater than the largest impurity peak height.
- The calculated detector coefficient must be between 0.1 and 50.
- The calculated detector coefficient must be different from the current coefficient (before calibration) by less than 50%. This condition can be ignored if the First Calibration field is set to ON in the *« Advanced analyzer configuration »* screen.

If one of the above conditions is not fulfilled, the coefficients are not modified and a calibration alarm is generated

Step 1: Checking the span gas inlet configuration.

In the screen *« Automatic cycle configuration »*, check that:

– Inlet/Calibration field is configured to Span (1) for the span gas inlet when the analyzer is equipped with the Span or the Pressure span option.

– Programmed inlet field is set to ON (2), in order to switch the sample to the span inlet for the calibration sampling cycle.

NOTE : If the VOC72e is not equipped with the Span option or the Pressure Span option, the input port setting is not important, but it is necessary to switch manually the sample inlet to the span gas source before starting the sampling cycle of the automatic calibration, and then reconnect the sample source at the beginning of the next cycle.

Step 2: « Advanced analyzer configuration » screen setting:

For each compound to be calibrated, it is necessary to specify in this screen:

- Display unit (µg/m^3 or ppb) (1).
- Conversion coefficient (in the below screen, 1ppb benzene = 3.25 µg/m^3) (2).
- Calibration field ON (3).
- Span gas concentration value (4).
- Span gas concentration unit (5).
- Elution order (6)

NOTE : Delta RT (7) is set to 2 seconds by default (do not modify it).

Elution order:

The elution order is used to identify the span chromatogram peaks.

If a span mixture composed of the six following compounds is injected: Benzene, Toluene, Ethylbenzene, m-Xylene (or p-Xylene), o-Xylene, 1,3-Butadiene, these six compounds will elute in the following order.

Elution rank	Compound	Elution order
1	1,3-Butadiene	10
2	Benzene	20
3	Toluene	40
4	Ethylbenzene	60
5	m-Xylene and p-Xylene	80
6	O-Xylene	100

It is possible to use the above elution rank as an elution order, but in this case, if an additional compound is inserted between two existing compounds, the elution rank of the next compounds will be incremented.

In the above example, the iso-octane addition, which elutes between Benzene and Toluene, would result in the following table

Elution rank	Compound	Elution order
1	1,3-Butadiene	10
2	Benzene	20
3	Iso-octane	30
3 → 4	Toluene	40
4 → 5	Ethylbenzene	60
5 → 6	m-Xylene et p-Xylene	80
6 → 7	o-Xylene	100

By assigning the elution order 30 to Iso-octane, it ranks third without having to modify the elution order of the other compounds and nine other compounds can also be inserted between Benzene and Iso-octane.

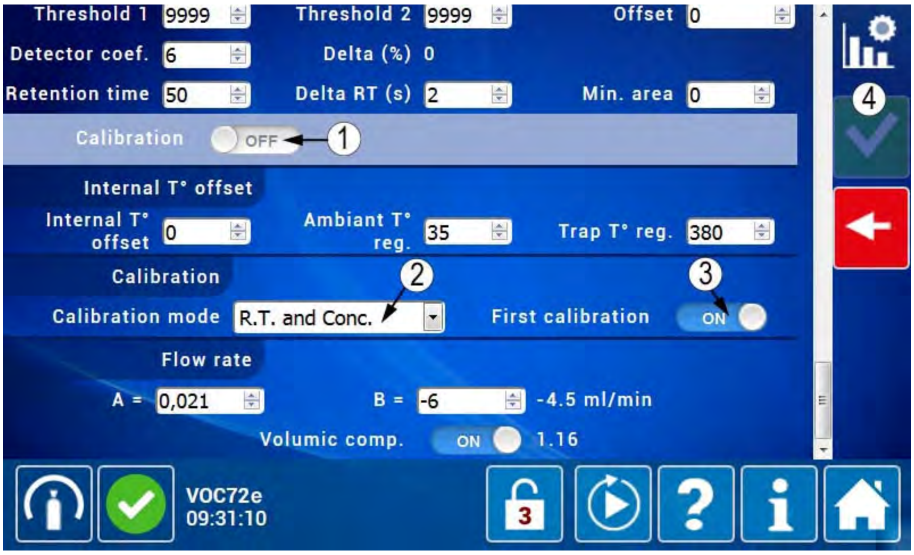
By moving down the « *Advanced analyzer configuration* » screen lift, the user accesses the calibration mode to be set as follows:

– Calibration field (1) must be OFF for the compounds not present in the mixture.

– Calibration mode field is set to « R.T. and Conc. » (2).

– First calibration field is set to ON (3) to allow a detector coefficient variation greater than 50%. After calibration, this parameter automatically switches back to OFF.

Validate settings by touching / clicking on (4).

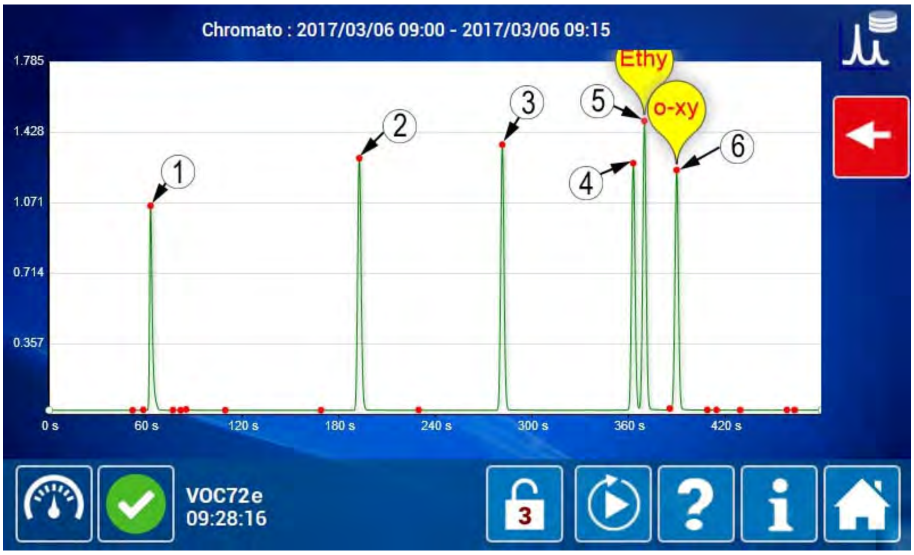


The screen below shows the span chromatogram corresponding to the default configuration before automatic calibration. It is composed of six peaks, only two of them have a label:

- 1,3-Butadiene (1), Benzene (2), Toluene (3) and Ethylbenzene (4) peaks have no label because these compounds are not detected right now due to an effective retention time differing by more than two seconds from the programmed retention time.
- m + p-Xylene peak (5) is detected as Ethylbenzene.
- only o-Xylene peak (6) is detected correctly.

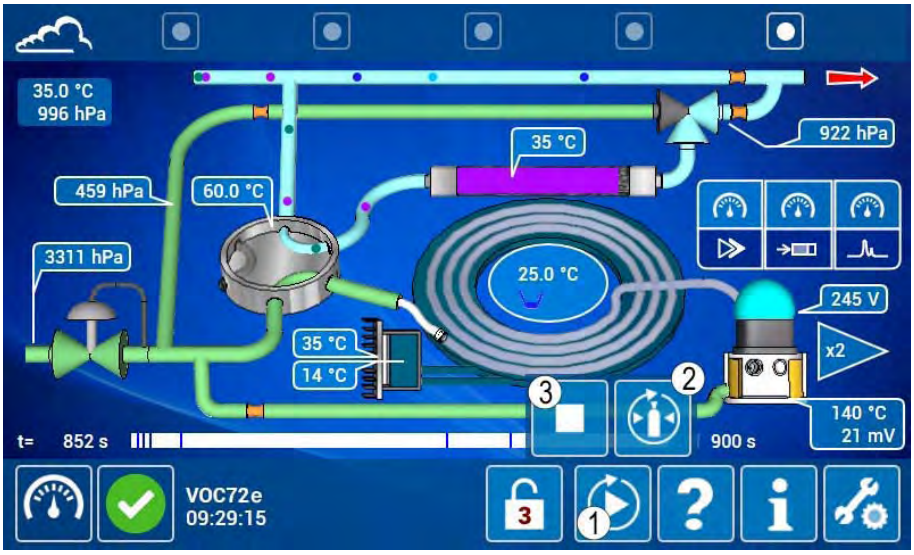
Nevertheless, this chromatogram meets the automatic calibration conditions of retention time TR and concentration:

- the six main peaks (i.e. major) correspond to the six compounds to be calibrated.
- there is no saturated peak. Indeed, the largest peak (5) amplitude is 1.5 volts (and therefore lower than 2.5 volts).
- the smallest major peak is the 1,3 Butadiene (1) peak and its amplitude is about 1 volt. Under these conditions, the ratio between the largest and the smallest peak is 1.5 / 1 (and therefore lower than 3/1).
- the smallest major peak amplitude (1 volt for 1,3-butadiene (1)) ranks the maximum impurity peak level at 1/5 = 0.2 volts. The impurities represented by the red points close to the baseline have an amplitude much smaller than 0.2 V.

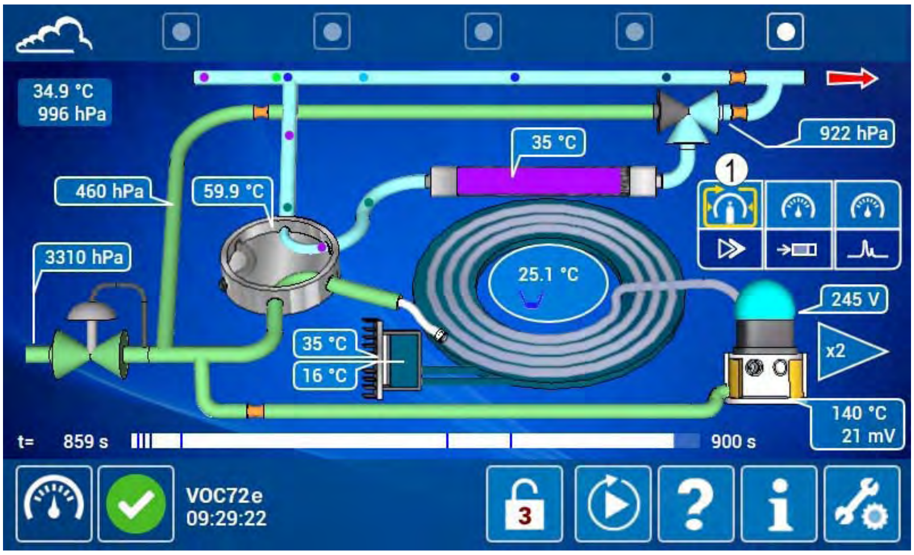


<u>Step 3: Launching and performing the automatic calibration</u>

Click on the control (1) to display the calibration control (2). DO NOT TOUCH the pause control (3). Click on the calibration control (2) to launch the automatic calibration.

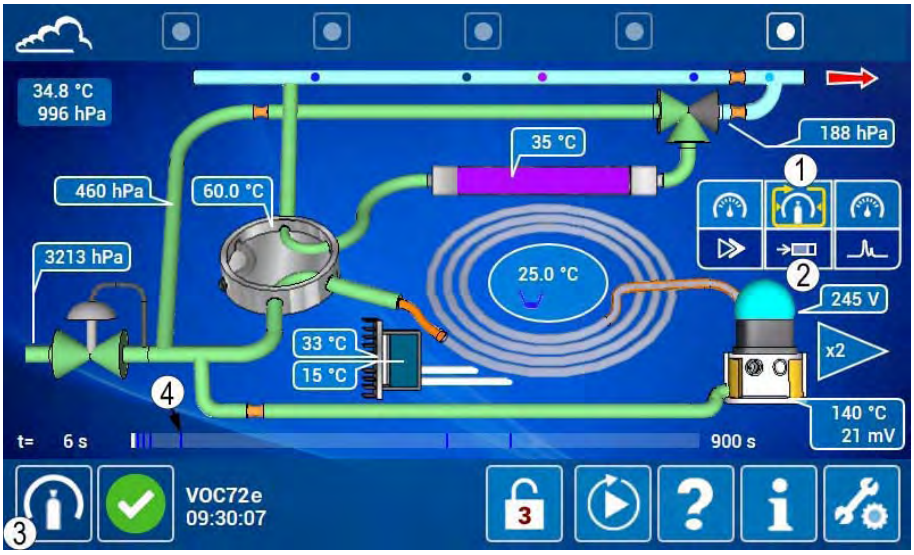


A calibration cycle is then positioned as next cycle (1) while the analyzer continues the current cycle.

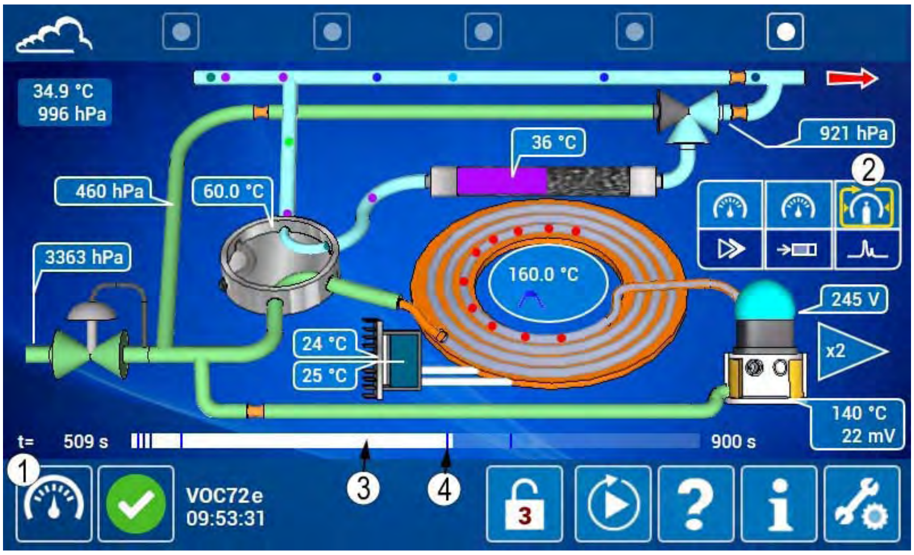


On the next cycle, the calibration icon (1) moves in the sampling cycle (2), the analyzer inlet switches to the span position (3) and from the sampling mark (4), the trap starts the span mixture sampling.

NOTE : If the calibration option is not available, manually switch the sample inlet to the span gas source before the progress bar reaches the sampling mark (4).



On the next cycle, the analyzer inlet is automatically switched again to the sample position (1) and the column performs the span mixture analysis (2). When the progress bar (3) reaches the calculation mark (4), the span chromatogram acquisition is finished and the automatic calibration process starts.



For each selected compound (1) for automatic calibration (2), the retention time (3) and the detector coefficient (4) are automatically adjusted.

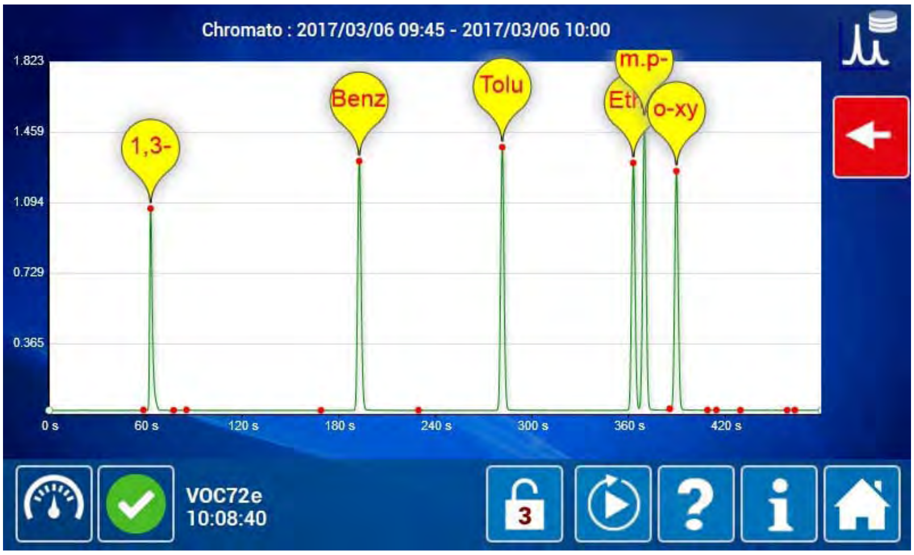
At the calibration end, the analyzer displays the span mixture concentrations in the measurement channel home page.

On the « *Diagnostic functions (alarm, input / output, mux…)* » screen, a message indicates that the configuration was modified. By touching / clicking on it, a pop-up is displayed giving the modification details of the calibration parameters carried out:

– old benzene retention time (compound n°1) (1),
– new benzene retention time (2),
– old benzene response coefficient (3),
– new benzene response coefficient (4),
– old toluene retention time (compound n°2) (5),
– new toluene retention time (6),
– old toluene response coefficient (7),
– new toluene response coefficient (8),

Move the lift (9) downwards to display the other parameters modified by the calibration:

By displaying the « *Last chromatogram* » screen, the user views that the peak identification is now correct.



The automatic calibration of retention time RT and concentration is finished. On the next cycle, the VOC72e will use the new parameters to analyze the chromatogram.

3.5.6.3 Error messages when automatic calibration fails

Message	Cause	Possible action
Calib.: Invalid cycle → 0001	One alarm at least occurred during the automatic calibration cycle leading to an invalid cycle.	Go to the «*Alarms historic*» screen, look for the invalid cycle origin and fix the problem.
Calib.: Peak < compounds → 0002	Less peaks found in the calibration chromatogram than compounds to calibrate for the "RT and Conc." automatic calibration.	Check the span chromatogram: it must include as many significant (= major) peaks as compounds to calibrate. Remove the missing gases of the span mix from the list of compounds selected for the auto-calibration.
Calib.: Saturated peak → 0004	There is a saturated peak in the chromatogram for the "RT and Conc." automatic calibration. At least one of the compounds peak is saturated in the chromatogram for the "Standard" automatic calibration.	Check the span chromatogram and display the greatest peak: its "Signal" must be less than 2490 mV (see the peak screen page 3-60). Reduce the detector gain or the span gas concentration to avoid the peak saturation. A peak saturation occurs when the PID signal is higher than 2490mV).
Calib.: Ratio major peaks → 0008	The surface ratio (≈ the height ratio) between the compounds peaks is greater than 3/1 in the chromatogram for the "RT and Conc." automatic calibration.	Check the span chromatogram: it must include as many significant (= major) peaks as compounds to calibrate and the ratio between the highest major peak and the lowest major peak must be less than 3. Check the span gas source composition (in ppb). The ratio between the highest concentration and the lowest concentration must be less than 3.
Calib.: Peaks > Compounds → 0016	There are more peaks of similar amplitude in the span chromatogram than compounds selected for the "RT and Conc." automatic calibration.	Check the span chromatogram: it must include as many significant (= major) peaks as compounds to calibrate and the residual (= minor) peaks amplitude must be less than 20% of any major peak amplitude. – An extra major peak may result from: – An extra compound in the span cylinder not selected in the auto-calibration selection. – A foreign compound resulting from a pollution. – A foreign compound resulting from a leak. – A mistake in the inlet selection for the auto-calibration: the VOC72e tries to calibrate on air instead of span gas.

Message	Cause	Possible action
Calib.: K span overrange → 0032	The automatic calibration gives a K factor outside the [0.1-50] range.	– Check that the calibration chromatogram looks like a span gas chromatogram: it must include as many significant (= major) peaks as compounds to calibrate. Typically, the “Calib.: K span overrange” comes with a “flat” chromatogram or an ambient air chromatogram instead of a span gas chromatogram. – Check that the declared concentrations for the calibration correspond to the span mixture composition.
Calib.: K span variation → 0064	The automatic calibration gives a K factor which differs more than 50% from the old K factor	– Analyze the origin of the sensitivity change. – If the old K factor is not significant, switch the “First calibration” field to ON in the advanced analyser configuration and restart an automatic calibration.

A Calib. message means that:

– The auto-calibration process has been cancelled.

– The K factor and RT are not adjusted: the VOC72e keeps the “old” K factors and retention times for the future analysis cycles.

– The icon is replaced by a icon which corresponds to a calibration control for the future analysis cycles.

There are two solutions to clear the …icon resulting from an auto-calibration failure.

1) - Find the cause of the auto-calibration failure, fix it and run a new auto-calibration. A successful auto-calibration clears the icon.

2) - If the old K factors and/or retention times are still valid and you have no time (or no span gas available) to run a new auto-calibration, go to the advanced analyzer configuration and change a retention time or a K-factor of any compound, then press the .key: the icon is cleared. Then you can restore the original value and press the key.

CHAPTER 4

PREVENTIVE MAINTENANCE

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4. PREVENTIVE MAINTENANCE

4.1 SAFETY INSTRUCTIONS

The personnel must observe all safety instructions at all times.

When operations need to be carried out on the analyzer, cut off the power supply sources whenever possible.

Take the necessary precautions for the handling of dangerous products such as gases under high pressure (put the cylinders in a rack in a ventilated room).

Frequently check that there are no leaks in the pipes.

Competent personnel only are allowed to carry out operations on the analyzer.

Concerning safety, the manufacturer disclaims his responsibility in case of:

– unqualified personnel using the analyzer,

– use of the analyzer under other conditions than those specified in this document,

– modification of the analyzer by the user,

– lack of maintenance on the analyzer.

A systematic and periodical inspection visit is essential.

4.2 MAINTENANCE CALENDAR

Due to its design, the VOC72e requires simplified maintenance only.

However, to guarantee its described characteristics in continuous operation, maintenance should be carried out frequently on the analyzer.

The maintenance frequencies are given as indication, and they could vary according to the operation conditions of the analyzer.

Nature of operations	Frequency	Sheet n°
Check-up of the cylinder pressure	15 days	4.3.1
Check-up of the PTV parameters	15 days	4.3.2
Calibration check-up	15 days	4.3.3
Sample filter replacement	2 months	4.3.4
Internal filter replacement	2 months	4.3.5
Check-up and / or cleaning of the heat sink	2 months	4.3.6

4.3 MAINTENANCE OPERATION SHEET

MAINTENANCE SHEET

ANALYZER serial N :	OPERATION SHEET : 4.3.1	
Subject : Check-up of the cylinder pressure	PAGE : 1/1	Frequency : 15 days

Read the pressure on the cylinder

- Identify the cylinder manometer (generally graduated from 0 to 300 bar) and read the pressure indicated by its pointer (1). Hydrogen cylinder pressure = 70 bar.

Write down the value (to within 5 bar) in the monitoring sheet here-below :

Week	0	2	4	6	8
Pressures					
Atmospheric pressure					
Trap					
Limit vacuum of pump					
Hydrogen inlet					
Cylinder	70				

Write down the value (to within 5 bar) in the cylinder monitoring table (see next page.).

This table is used to graphically monitor the Hydrogen pressure whose decreasing must be about parallel to the theoric decreasing curve indicated by cylinder type (from B5 to B50).

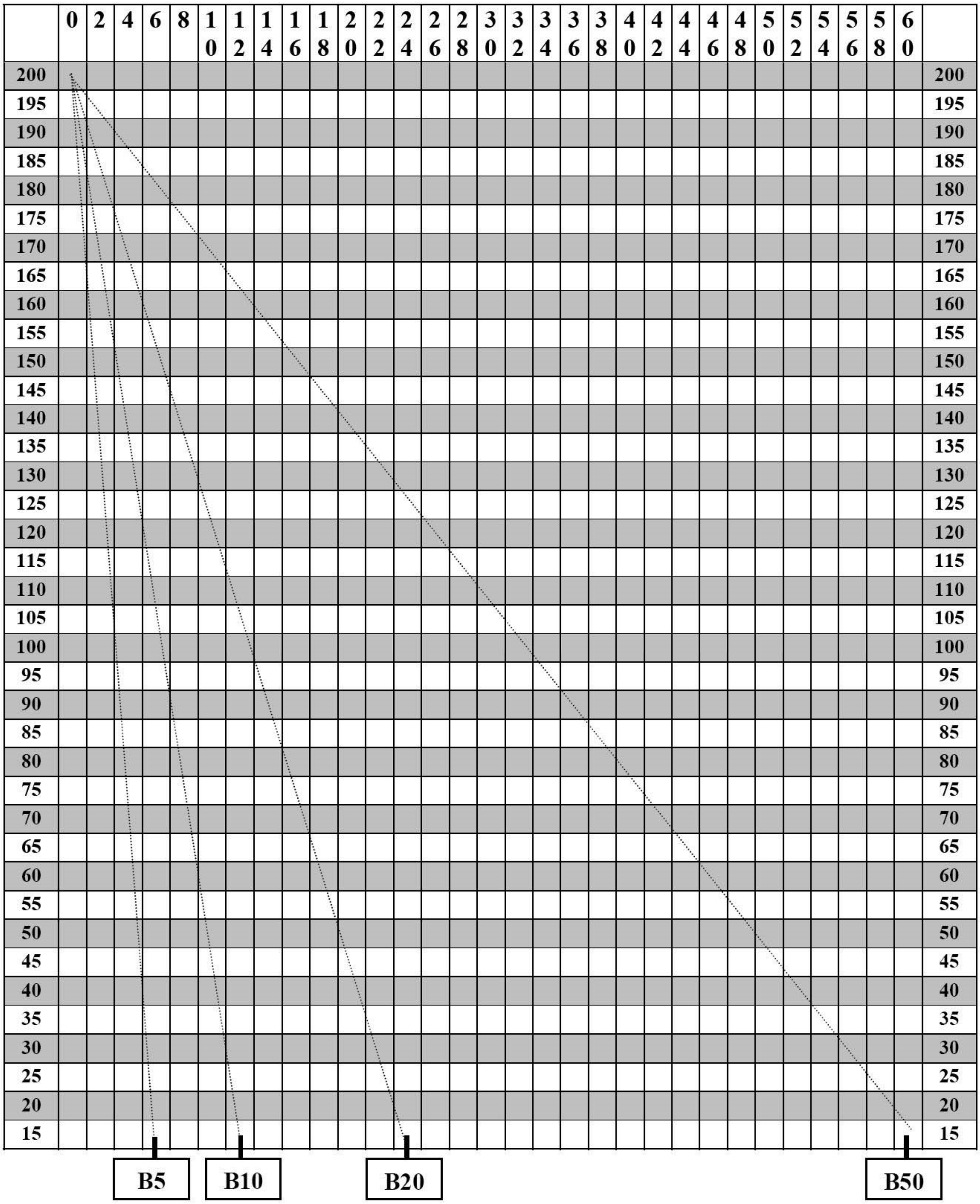
In case of quickest decreasing, look for a leak.

By extrapolation of pressure decreasing, it is possible to determine the best possible date to replace the cylinder (typically at 10% of the filling pressure, that is to say 20 bar for a 200 bar filling).

– **Tool required**

- None

Table 4–1 – Monitoring of the pressure inside the cylinder

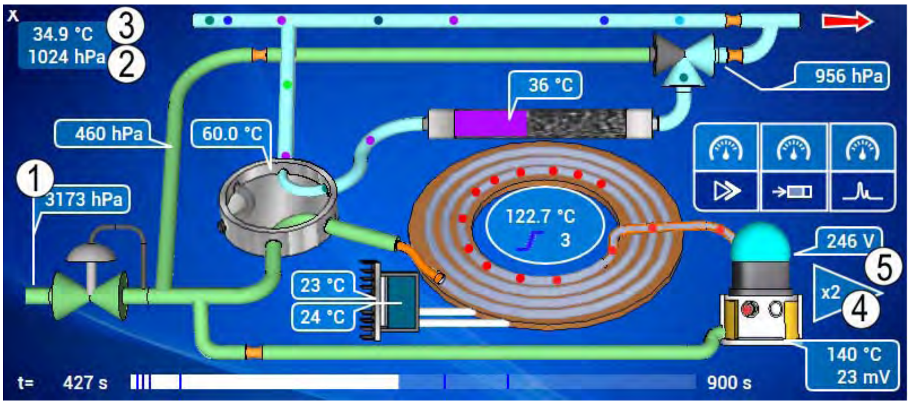


MAINTENANCE SHEET

ANALYZER serial N :	OPERATION SHEET 4.3.2	
Subject : Check-up of the PTV parameters	PAGE : 1/4	Frequency : 15 days

	Date
The check-up of the PTV parameters (pressure, temperature, voltage) is monitored in the « *Synoptic* » screen during the analysis cycle, with the cover closed and the analyzer installed into its analysis enclosure.	

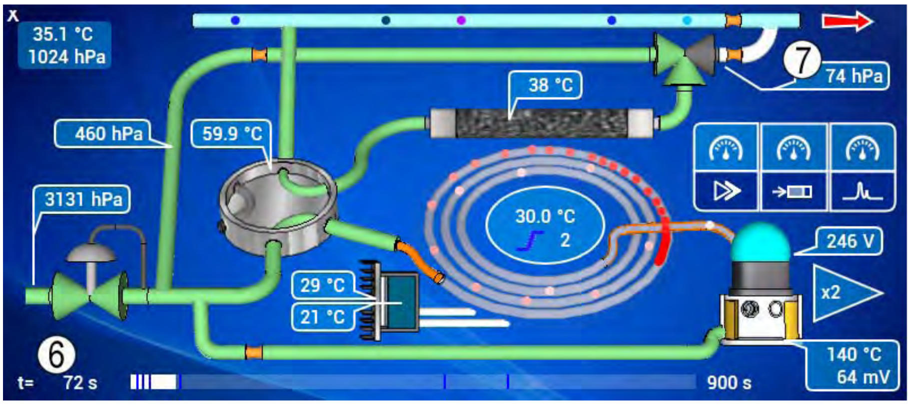
1) **Read the permanent parameters that can be recorded at any cycle phase**



At any time of the measurement cycle, it is possible to write down in the table:

- The supply Hydrogen pressure (1) **Pressure /of Hydrogen inlet** = 3173 hPa.
- The atmospheric pressure (2) **Pressure / atmospheric pressure** = 1024 hPa.
- The internal temperature of the analyzer (3) **Temperature / Internal temperature** = 34.9°C.
- The detector gain (4) **Detector / Gain = 2**.
- The PID lamp voltage (5) = 246 V

2) **Read the limit vacuum of the pump during the trap cooling phase.**



The limit vacuum of the pump is equal to the trap pressure (7) during the trap cooling phase between 60 and 80 seconds (6). **Pressures / Pump limit vacuum** = 74 hPa.

– **Tool required**

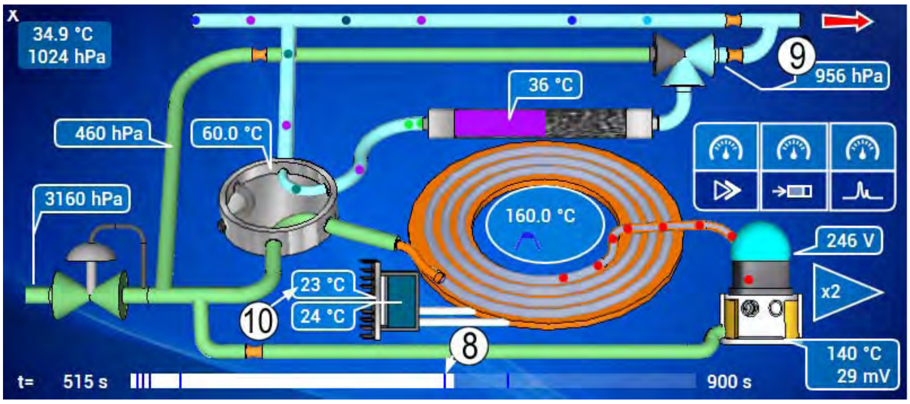
- None

MAINTENANCE SHEET

ANALYZER serial N :	**OPERATION SHEET : 4.3.2**	
Subject : Check-up of the PTV parameters	**PAGE : 2/4**	**Frequency : 15 days**

Date

3) Read the minimum temperature of the heat sink and the trap pressure.

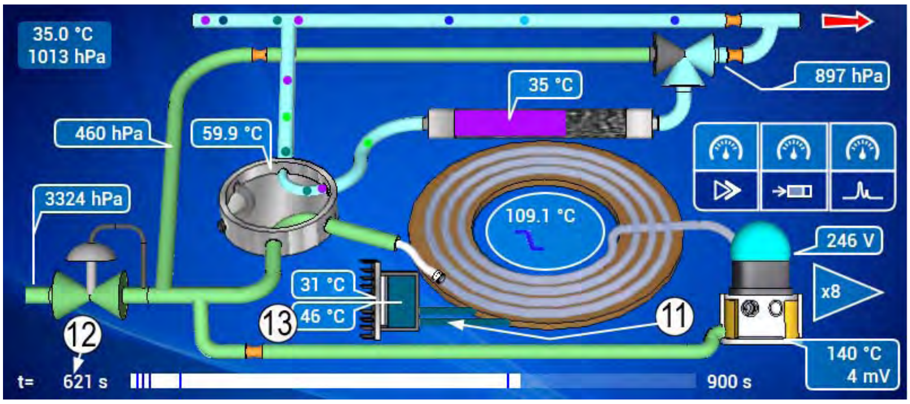


The minimum temperature of the heat sink is equal to the heat sink temperature (10) during the hot step of the column (160°C) which is reached when the calculation mark (8) is stepped over.

Temperatures / Mini heat sink = 23°C. This temperature corresponds approximately to the available temperature on the rear panel of the analyzer which must remain within the interval 0-30°C.

During all the sampling cycle, the trap pressure (9) remains stable.
Pressures / Trap = 956 hPa.

4) Read the maximum temperature of the cold plate.



From 600 seconds (12) the column cooling is indicated by the link (11) with the cooler. The column cooling involves the cold plate heating (13) which passes by a maximum (within 620 and 640 seconds) before to decrease because of the cooler effect.

Temperature / Max cold plate (CP) =46°C.

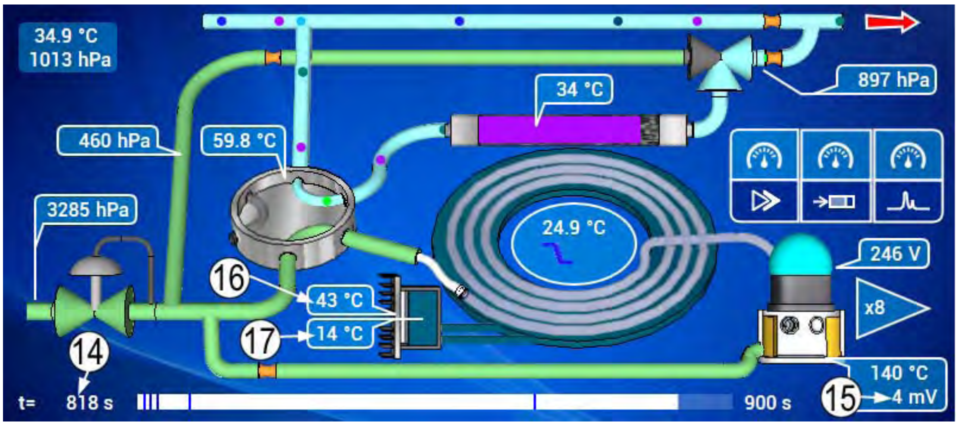
– **Tool required**

- None

MAINTENANCE SHEET

ANALYZER serial N :	OPERATION SHEET : 4.3.2	
Subject : Check-up of the PTV parameters	**PAGE : 3/4**	**Frequency : 15 days**

5) Read the maximum temperature of the heat sink and the detector offset. — Date



Near to 800 seconds (14) the cold plate (17) reaches, for the first time, the threshold of 14°C and the heat sink radiator passes by a maximum (16).

Temperatures / Max heat sink = 43°C.

During all the phase of column cooling, the PID detector does not receive compounds anymore and its signal (15) corresponds to the offset signal.
Detector / Offset signal = 4 mV.

– **Tool required**

- None

MAINTENANCE SHEET

ANALYZER serial N :	**OPERATION SHEET : 4.3.2**	
Subject : Check-up of the PTV parameters	**PAGE : 4/4**	**Frequency : 15 days**

Date

6) Write down the new values of K and RT in the monitoring table.

Week	0	2	4	6
Pressures (hPa)				
Atmospheric pressure	1024			
Trap	956			
Pump limit vacuum (60-80 sec)	74			
H2 Inlet pressure	3173			
Cylinder pressure				
Detector				
Offset signal	4			
Gain	2			
Lamp voltage				
Temperatures (°C)				
Internal temperature	34.9			
mini heat sink (temperature)	23			
Max heat sink (temperature)	43			
Max cold plate (temperature)	46			
K factor				
K of benzene				
K of toluene				
K of ethylbenzene				
K of m+p xyl				
K of o xylene				
K of 1,3but				
Retention Time				
RT of benzene				
RT of toluene				
RT of ethylbenzene				
RT of m+p xyl				
RT of o xylene				
RT of 1,3but				

– **Tool required**

- None

MAINTENANCE SHEET

ANALYZER serial N :	OPERATION SHEET : 4.3.3	
Subject : Calibration check-up	**PAGE : 1/4**	**Frequency : 15 days**

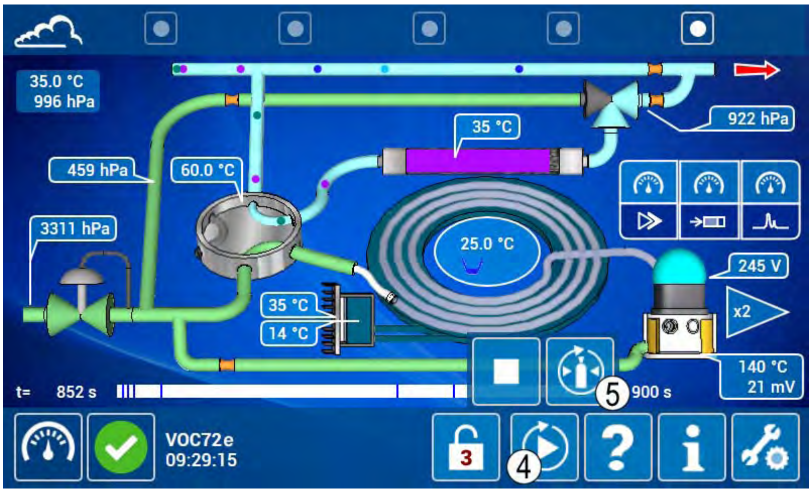
Date

1) **Check-up that the span concentrations used correspond to the concentrations declared into the « *Advanced analyzer configuration* » screen:**

- (1) The available compounds into the span must be declared « ON ».
- (2) The elution rank must be in conformity with the outlet order of the compounds in the chromatogram.
- (3) The compounds concentration must correspond to the span concentration.

2) **Connect the span source to the sample inlet and launch the calibration from the « Synoptic » screen.**

To do that, press down successively (4) then (5).



– **Tool required**

- BTEX gas source at 20 ppb in air

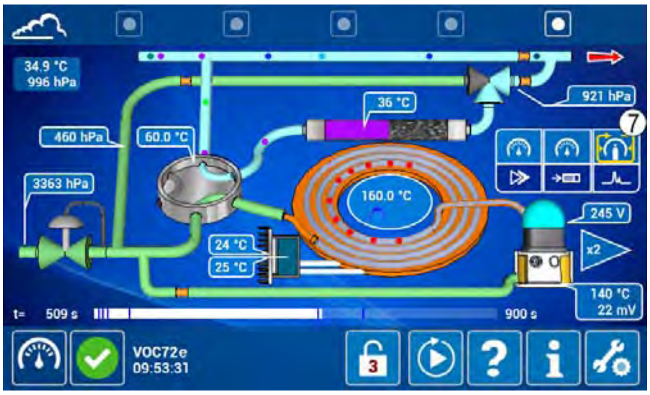
MAINTENANCE SHEET

ANALYZER serial N :	OPERATION SHEET : 4.3.3	
Subject : Calibration check-up	PAGE : 2/4	Frequency : 15 days

Date

3) The auto-calibration

(6) The « Auto-calibration » flag is displayed in sampling.



(7) The « Auto-calibration » flag moves to analysis.

At the end of the calibration cycle, the measured concentrations correspond to the declared span concentrations.

– **Tool required**

- BTEX gas source at 20 ppb in air

MAINTENANCE SHEET

ANALYZER serial N :	**OPERATION SHEET : 4.3.3**	
Subject : Calibration check-up	**PAGE : 3/4**	**Frequency : 15 days**

Date

4) <u>Read the RT and K-factor (response factor).</u>

At the end of the Auto-calibration cycle, go to the *« Advanced analyzer configuration »* screen.

The retention times RT are displayed.

(1) RT benzene = 197.04 seconds, (2) RT toluene = 287.8 seconds, and so on…

As well as the associated detector response coefficients:

(3) K benzene = 3.3604, (4) K Toluen = 3.8296, and so on...

– <u>Tool required</u>

- BTEX gas source at 20 ppb in air

MAINTENANCE SHEET

ANALYZER serial N :	OPERATION SHEET : 4.3.3	
Subject : Calibration check-up	PAGE : 4/4	Frequency : 15 days

Date

5) **Write down the new values of K and RT in the monitoring table.**

Week	0	2	4	6
Pressures				
Atmospheric pressure				
Trap				
Pump limit vacuum (60-80 sec)				
H2 Inlet pressure				
Cylinder pressure				
Detector				
Offset signal				
Gain				
Lamp voltage				
Temperatures				
Internal temperature				
mini heat sink (temperature)				
Max heat sink (temperature)				
Max cold plate (temperature)				
K factor				
K of benzene	3.3604			
K of toluene	3.8296			
K of ethylbenzene				
K of m+p xyl				
K of o xylene				
K of 1.3but				
Retention Time				
RT of benzene	197.04			
RT of toluene	287.8			
RT of ethylbenzene				
RT of m+p xyl				
RT of o xylene				
RT of 1.3but				

– **Tool required**

- BTEX gas source at 20 ppb in air

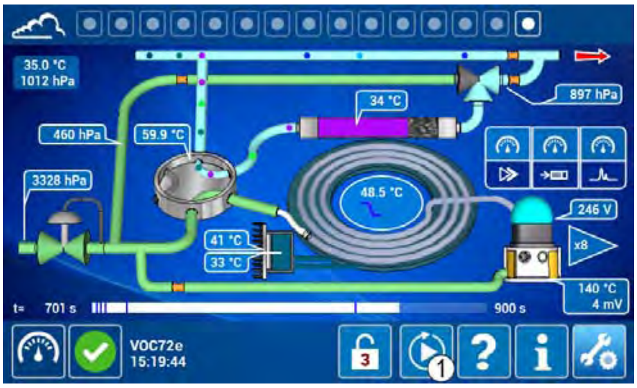
MAINTENANCE SHEET

ANALYZER serial N :	OPERATION SHEET 4.3.4	
Subject : Sample filter replacement	**PAGE : 1/3**	**Frequency : 2 months**

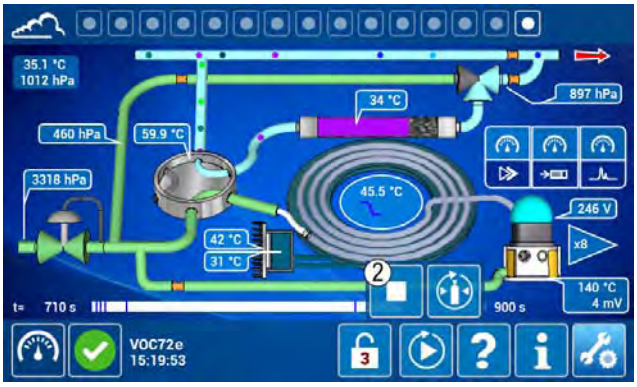
Date

1) Stop the analysis cycle from the synoptic screen

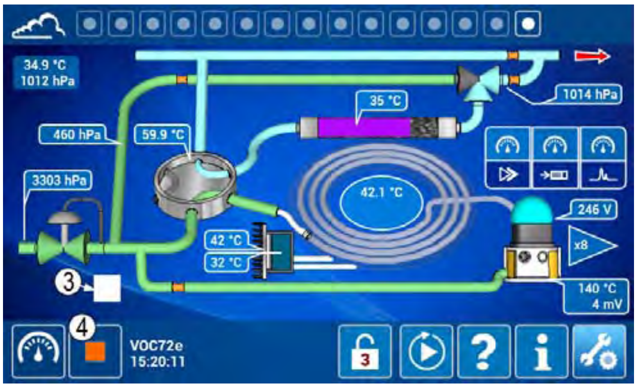
To do that, press down the cycle start key (1) in the synoptic screen :



Then, press down the key (2) pause :



The pause indicator (3) flashes and then remains fixed. The pause icon (4) is displayed:



– **Tool required**

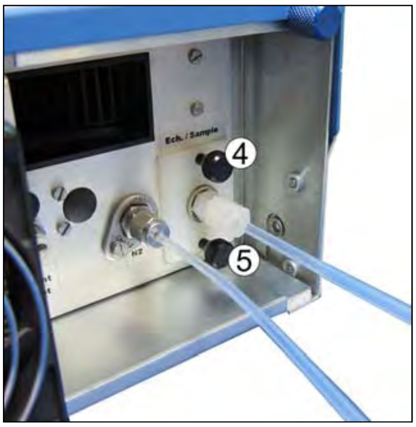
- 1 filter ref. F05-0226-A

MAINTENANCE SHEET

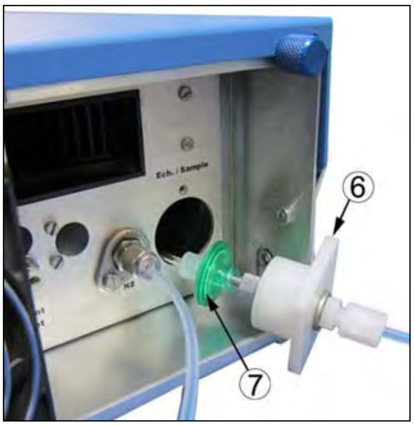
ANALYZER serial N :	OPERATION SHEET : 4.3.4	
Subject : Sample filter replacement	**PAGE : 2/3**	**Frequency : 2 months**

Date

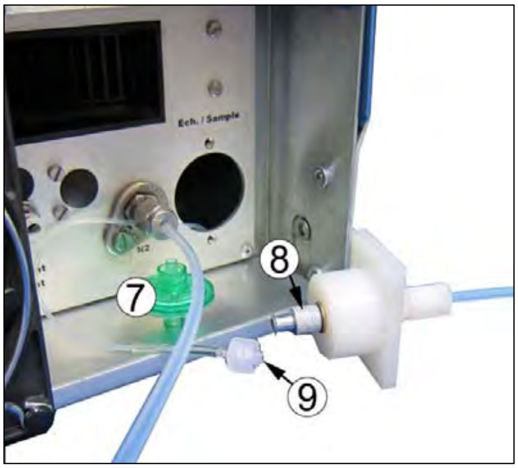
2) Replace the filter



Unscrew both the (4) and (5) knurled screws keeping in place the sample inlet block.



Delicately remove the sample inlet block (6) on which the sample filter (7) is fixed.



Remove the worn filter (7) from the sample tube (9) and the fitting (8) of the sample inlet block.

Put in place a new filter.

Put the block back in place.

Attach the sample inlet block with both the knurled screws (4) and (5).

– Tool required

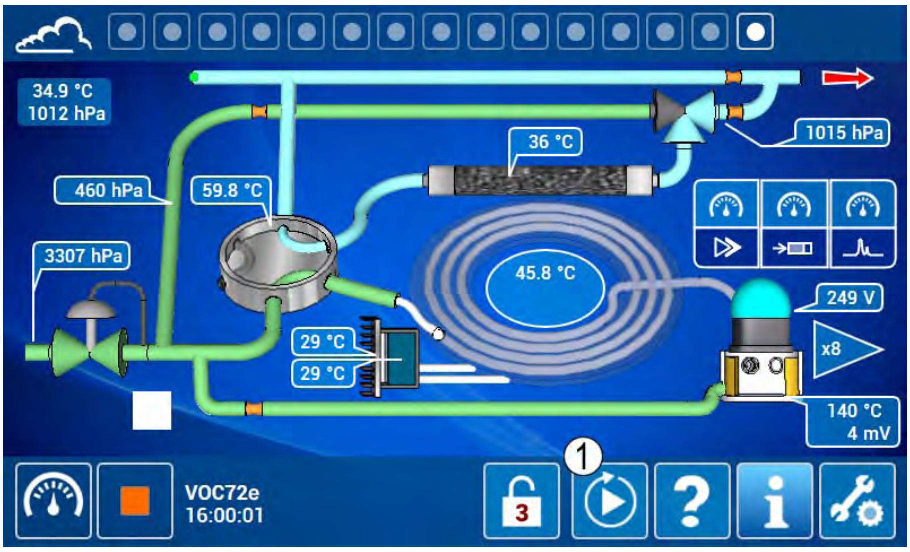
- 1 filter ref. F05-0226-A

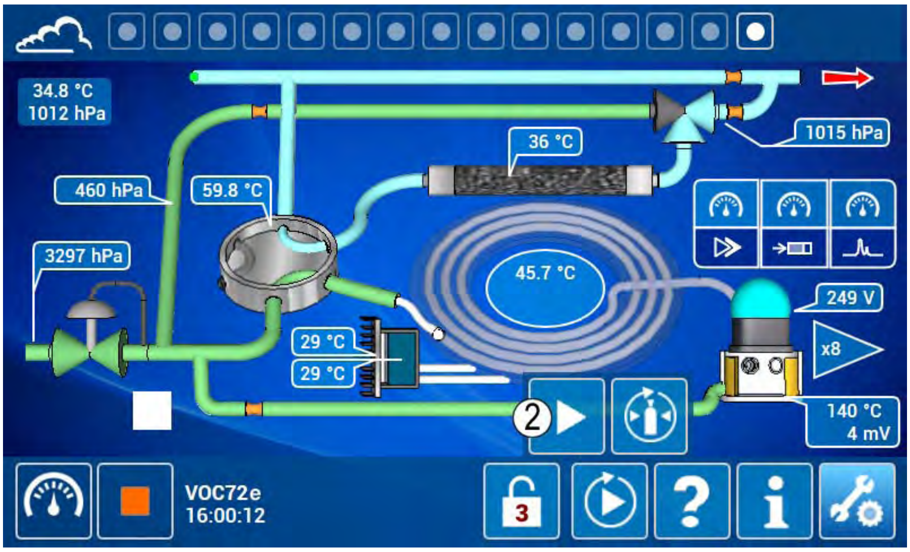
MAINTENANCE SHEET

ANALYZER serial N :	OPERATION SHEET : 4.3.4	
Subject : Sample filter replacement	PAGE : 3/3	Frequency : 2 months

3) <u>Re-start the analyzer</u>

Press down the start cycle key (1), then the key (2).





Depending on the start configuration, the analyzer starts immediately, or after a 1/4 hour synchronization.

Date

– **<u>Tool required</u>**

- 1 filter ref. F05-0226-A

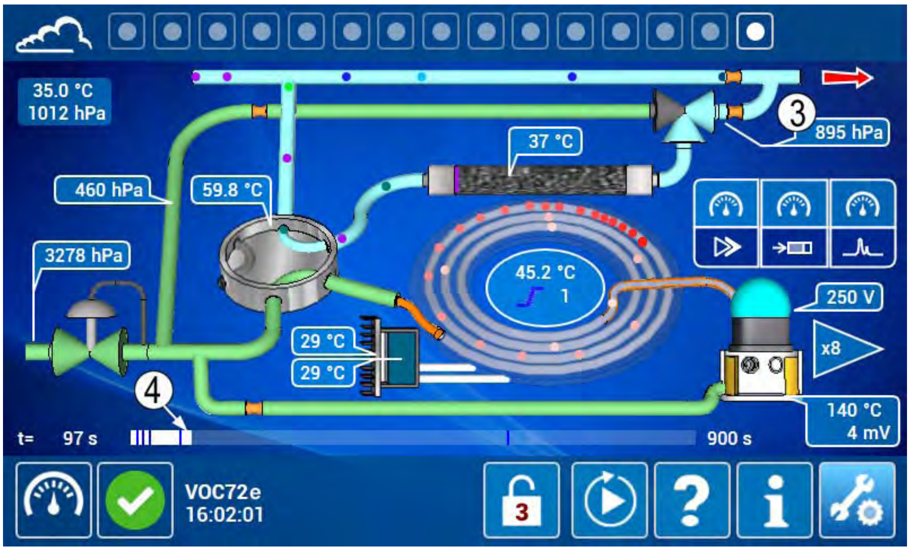
MAINTENANCE SHEET

ANALYZER serial N :	OPERATION SHEET : 4.3.4	
Subject : Sample filter replacement	**PAGE : 4/4**	**Frequency : 2 months**

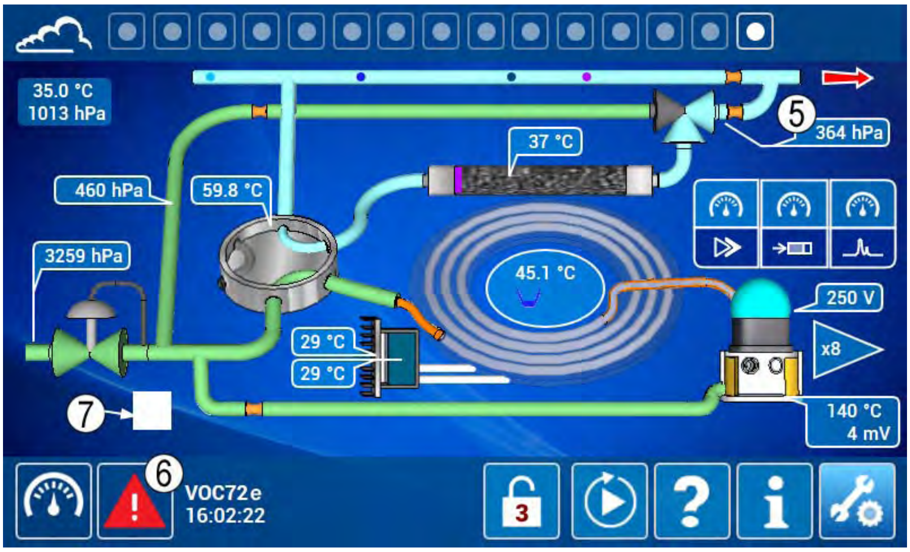
Date

4) **Carry out a leak test**

Wait for the trap to pass into sampling (4) and for the trap pressure increasing (3), then plug the sample inlet with a stopper.



The trap pressure must quickly decrease below 400 hPa (5) and a trap pressure alarm is displayed (6), while the analyzer passes to pause (7), then to stand-by.



Remove the plug and connect the sample inlet to the sampling system. Then, restart the cycle (as explained in §3)

– **Tool required**

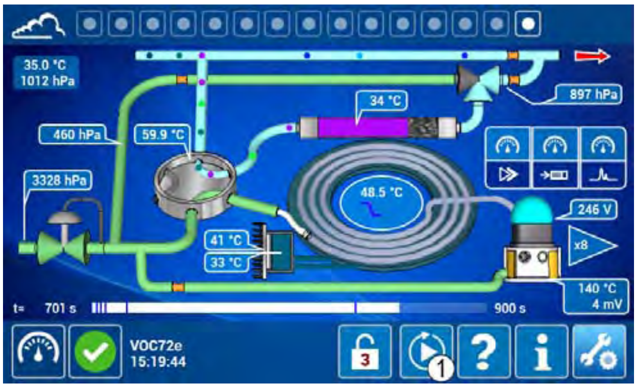
- Flat screwdriver
- 1 filter ref. V04-PA-002

MAINTENANCE SHEET

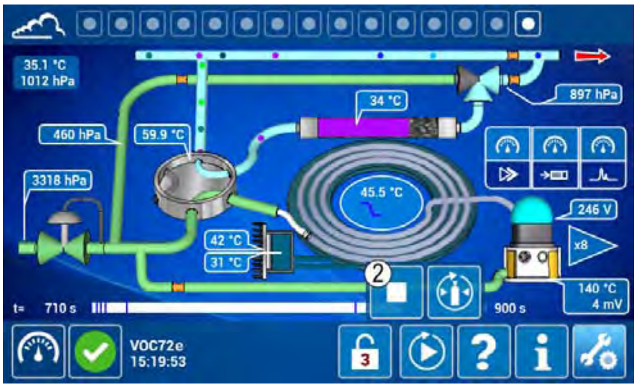
ANALYZER serial N :	OPERATION SHEET : 4.3.5	
Subject : Internal filter replacement	**PAGE : 1/4**	**Frequency : 2 months**

1) Stop the analysis cycle in the « *Synoptic* » screen. — **Date**

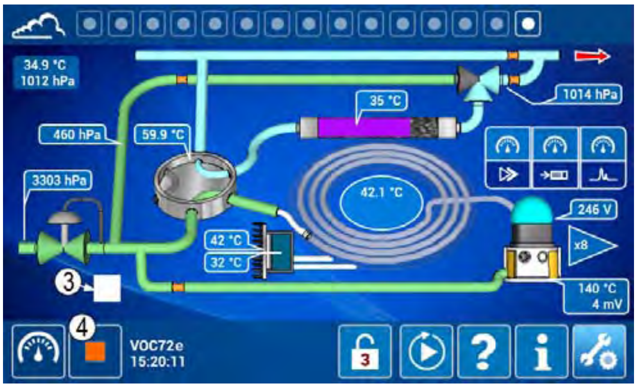
Preferably wait for the cycle end when the column temperature decreases below 50°C.
Then, press down the start cycle key (1) in the « *Synoptic* » screen.



Then press down the pause key (2) :



The pause indicator (3) flashes and then remains fixed. The pause icon (4) is displayed:



– **Tool required**

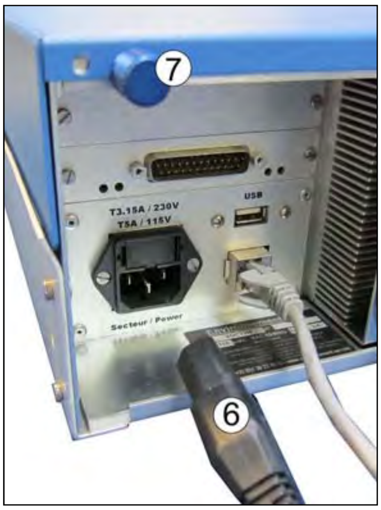
- Flat screwdriver
- 1 filter ref. V04-PA-002

MAINTENANCE SHEET

ANALYZER serial N :	OPERATION SHEET : 4.3.5	
Subject : Internal filter replacement	**PAGE : 2/4**	**Frequency : 2 months**

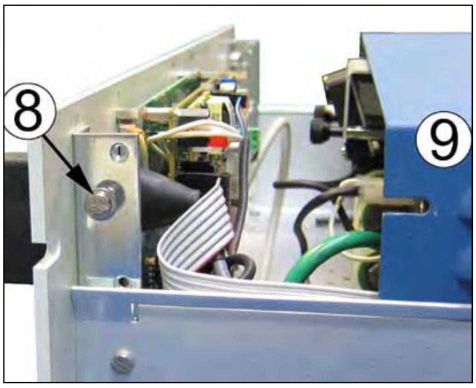
	Date
2) Stop and open the analyzer	

Put the analyzer OFF using its switch (1) located on the front face.



Disconnect the mains cable (6) from its socket located on the rear panel of the analyzer.

Unscrew both the knurled nuts (7) fixing the cover located at the rear panel of the analyzer.



Slightly unscrew the front locking screws (8) of the cover and glide along the cover rearwards (9) or remove it.

– **Tool required**

- Flat screwdriver
- 1 filter ref. V04-PA-002

MAINTENANCE SHEET

ANALYZER serial N :	OPERATION SHEET : 4.3.5	
Subject : Internal filter replacement	PAGE : 3/4	Frequency : 2 months

3) Replace the filter — Date

Look for the mixing fan (10) at the front right side of the analyzer.

Remove the plastic grid (11) from the mixing fan.

– **Tool required**

- Flat screwdriver
- 1 filter ref. V04-PA-002

MAINTENANCE SHEET

ANALYZER serial N :	OPERATION SHEET : 4.3.5	
Subject : Internal filter replacement	PAGE : 4/4	Frequency : 2 months

Date

Replace the dust filter (12) or clean it.

4) <u>Install the new filter and re-start the analyzer.</u>

Fit the plastic grid (11) equipped with the filter (12) on the fan (10).

Put again the cover in place and fix it using the two lateral screws (8) and the two rear knurled screws (7).

Re-connect the mains power supply cord (6). Switch on the front panel switch to re-start the analyzer.

At the end of warm-up (less than 15 minutes), the analyzer passes into « Ready » mode.

Press down the [Start] key to re-start the analysis cycle.

– **<u>Tool required</u>**
- Flat screwdriver
- 1 filter ref. V04-PA-002

MAINTENANCE SHEET

ANALYZER serial N :	OPERATION SHEET : 4.3.6	
Subject : Check-up and / or cleaning of the heat sink	**PAGE : 1/3**	**Frequency : 2 months**

1) Check-up the heat sink status on the rear panel of the analyzer

Date

(it is possible to carry out this checking-up when the analyzer is working).

The heat sink is clean

The heat sink is dirty

– Tool required

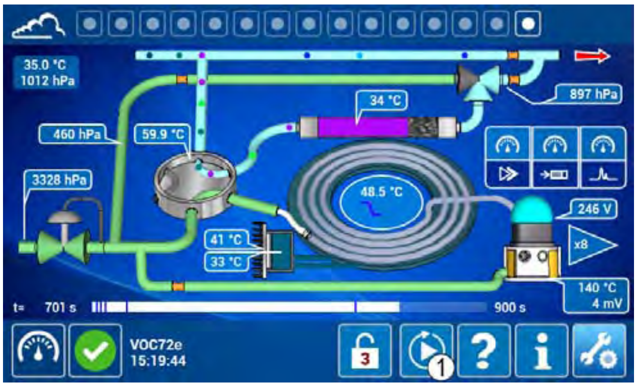
- Compressed air gun
- Vacuum cleaner

MAINTENANCE SHEET

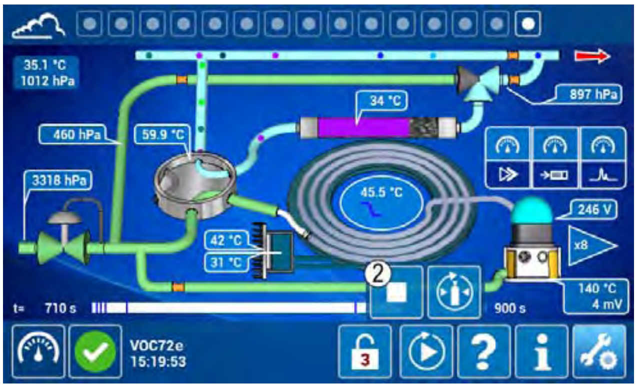
ANALYZER serial N :	OPERATION SHEET : 4.3.6	
Subject : Check-up and cleaning of the heat sink	PAGE : 2/3	Frequency : 2 months

2) <u>If cleaning is required, stop the analysis cycle from the synoptic screen.</u> — **Date**

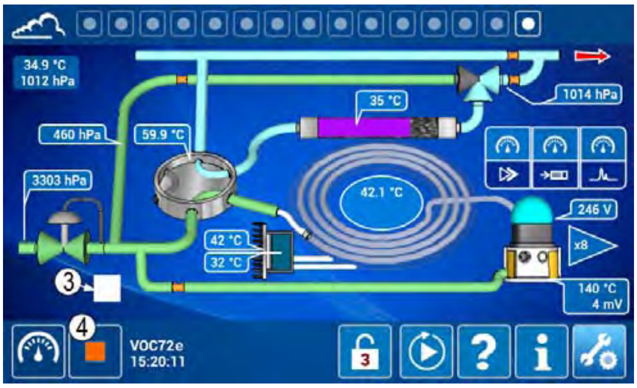
Preferably, wait for the end of cycle when the column temperature decreases below 50°C.
Press down the start cycle key (1) into the synoptic screen.



Press down the pause key (2):



The pause indicator (3) flashes and then remains fixed. The pause icon (4) is displayed:



– **<u>Tool required</u>**

- Compressed air gun
- Vacuum cleaner

MAINTENANCE SHEET

ANALYZER serial N :	OPERATION SHEET : 4.3.6	
Subject : Check-up and cleaning of the heat sink	**PAGE : 3/3**	**Frequency : 2 months**

Date

3) Stop the analyzer

Stop the analyzer using its switch (1) located on the front face.

Disconnect the mains cable (6) from its socket located on the rear panel of the analyzer

4) Cleaning.

Clean the heat sink with compressed air. In case of great amount of dirt, it is advised to carry out this operation outside, or to use a vacuum cleaner at the same time.

Complete the operation in dusting off the electric panel and the fluid panel located on both sides of the heat sink.

WARNING : Avoid dust to enter the fluid panel fittings if they were put down for this cleaning operation.

5) Re-Start

Reconnect the mains power supply cord (6). Press down the switch on the front face to start the analyzer.

At the end of warm-up, (less than 15 minutes), the analyzer passes into « *Ready* » mode.

Press down the [Start] key into the « *Synoptic* » screen to start the analysis cycle.

– Tool required

- Compressed air gun
- Vacuum cleaner

4.4 MAINTENANCE KIT AND RECOMMENDED SPARE PARTS

Maintenance kit for 1 year: VOC72e-K

This kit is composed of:

N°	Designation	Reference	Quantity
1	5µm syringe filter 25mm dia	F05-0226-A	6
2	Kit for KNF Pump	V04-0005-A	1
3	Fan filter	F05-5060-A	2
4	Set trap	P10-2128-A-SAV	1
5	Maintenance and upgrade kit for cooling	SAV-K-000199-B	1

Recommended spare parts:

This set of recommended spare parts is composed of:

N°	Designation 1	Reference	Quantity
1	Purge solenoid valve, wired	F01-0118-C	1
2	Proportional solenoid valve 2/2	F01-0018-C	1
3	solenoid valve 3/2 NF	F01-EV-0016-A	1
4	Pressure sensor board column	C06-C1-0402-B	1
5	Direct action 3/2 NF solenoid valve, type 6012	C06-C2-0402-C	1
4	Column pressure sensor board	C06-C1-0402-C	1
5	Supply pressure sensor board	C06-C2-0402-C	1
6	Trap pressure sensor board	C06-0402-C	1
7	PID lamp	D01-0772-A	1
8	Peltier and mixing fan, wired	V03-0012-C	1
9	Cooling fan, wired	V03-0013-C	1
10	Trap fan, wired	V03-0015-C	1
11	M3 fixation of PT1000, wired	T05-0012-D	2
12	Time-delay fuse, D1TD/3.15A o5x20	S01-TT03_15-A	2
13	Delay fuse, 8A 250VAC	S01-FT08_000-B	1
14	Delay fuse, 2,5A 250 VAC	S01-FT02_500-C	1
15	Delay fuse, 3,15A 250VAC	S01-FT03_150-B	1
16	O-ring, oint.:2 cord:1.6	G06-002_0-1_6-V	12
17	O-ring, oint.:2.90 cord	G06-002_9-1_7-V	6
18	O-ring, o Int:6.0 cord 1.0 Viton	G06-006_0-1_0-V	7
19	Stainless steel joint / FKM for RS 1/8" connector	F03-S-2-RS-2V	2
20	PFA Tube dia 1/16 x 1/32	F04-PFA-1/16-1/32-A	2
21	PFA Tube dia 1/8 x 1/16	F04-PFA-1/8-1/16-A	1
22	Pipe ref.:3814-7	F04-CLI-3814-7	0.25
23	ISOVERSINIC tube o3Xo5 (Viton)	F04-IS-003-005	1
24	Part of column Ø0.53mm Lg 10mm	P01-1711-A	8
25	Part of column Ø0.53mm Lg 20mm	P01-1712-A	8
26	By-Pass restrictor	P10-2095-A-SAV	0.25
27	PID restrictor	P10-2096-A-SAV	1
28	Trap restrictor	P10-2097-A-SAV	1
29	Purge restrictor	P10-2098-A-SAV	1
30	Nitrogen filter	P10-2099-A-SAV	1

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CHAPTER 5.

CORRECTIVE MAINTENANCE

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5. CORRECTIVE MAINTENANCE

Maintenance must be carried out by qualified personnel to intervene on the analyzer using the information provided in this technical manual.

5.1 THE 3-LEVEL PROTECTION PRINCIPLE

The VOC72e carries out a permanent automatic control of its main functions and indicates all the detected faults by a 3-level warning system: « CONTROL – ALARM – SECURITY ».

5.1.1 LEVEL 1: « CONTROL »

In case of minor operation fault, the « CONTROL » icon  is displayed in the lower browsing bar common to all the screens, while the analysis cycle is going on.

The « CONTROL » icon  message is intended for the user to be aware that one or many parameters are at the limit (very near) to produce an alarm which will interrupt the measurement.

5.1.2 LEVEL 2: « ALARM »

In case of some more important fault which corrupts the metrology, the « ALARM » icon  is displayed in the lower browsing bar common to all the screens, while the analysis cycle is interrupted and the analyzer switches to « STAND-BY mode » in most cases.

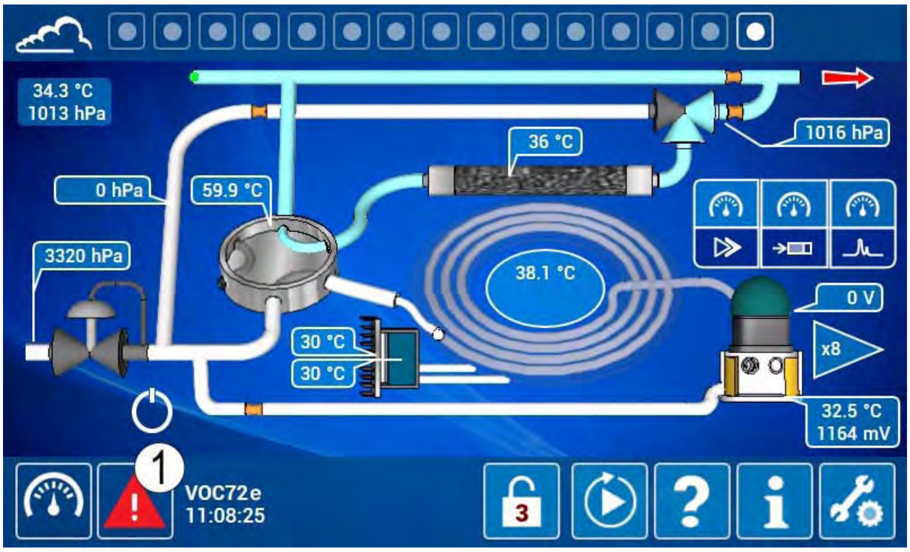
5.1.3 LEVEL 3: « SECURITY »

In case of major fault that could damage the analyzer, the « SECURITY » icon  is displayed in the lower browsing bar common to all the screens while the 24V supply of the power units (desorber, transfer line, column, Peltier, PID heating, hot box heating) is interrupted in order to prevent any overheating.

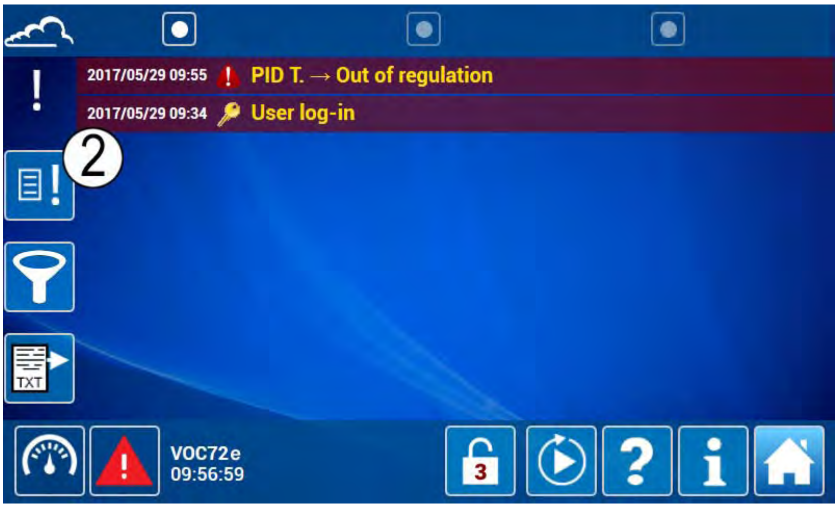
5.1.4 LOOKING FOR THE FAULT ORIGIN

To view and find the operation fault origin, touch / double-click on [icon] to display the *« Diagnostic functions (alarm, input / output, mux…) »* screen.

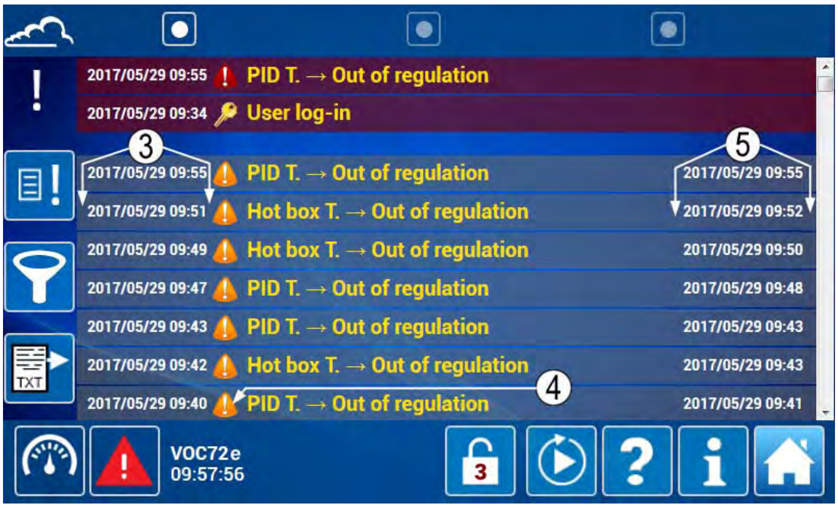
When the fault is in progress on the analyzer, one of the « CONTROL » [icon], « ALARM » [icon], or « SECURITY » [icon] icon is displayed in the lower browsing bar common to all the screens. In this case, the user accesses the *« Diagnostic functions (alarm, input / output, mux…) »* screen by touching / clicking on this icon, for example in (1) of the below screen.



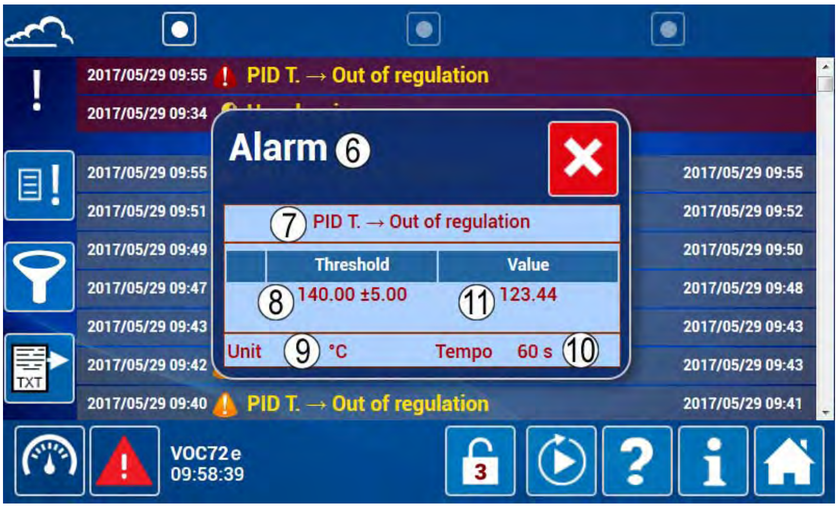
The page 1 of the *« Diagnostic functions (alarm, input / output, mux…) »* screen indicates the faults and messages ongoing on the analyzer.



By touching / clicking on (2) in the above screen, the user displays / hides the faults and events historic. This historic display informs about the date and time of fault occurrence (3), the fault level (control, alarm, security) (4), the date and time of eventual fault vanishing (5).



By touching / clicking on the fault icon (see (4) in the screen above), the user opens a pop-up window which indicates the fault level (6), the fault message description (7), the fault threshold (8), the unit (9), the alarm temporization (10), the monitored parameter value after the alarm temporization (11).

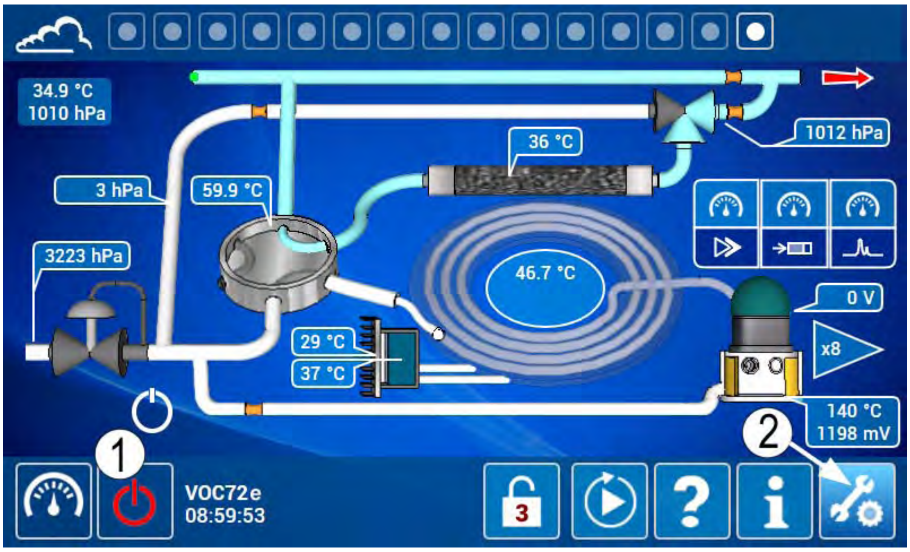


NOTE : The alarm occurs only if the monitored parameter exceeds permanently the alarm threshold during a period equal or greater than the alarm temporization.

5.1.4.1 Automatic stand-by switching without apparent fault

The fault switches the analyzer to stand-by mode, which results in fault vanishing.

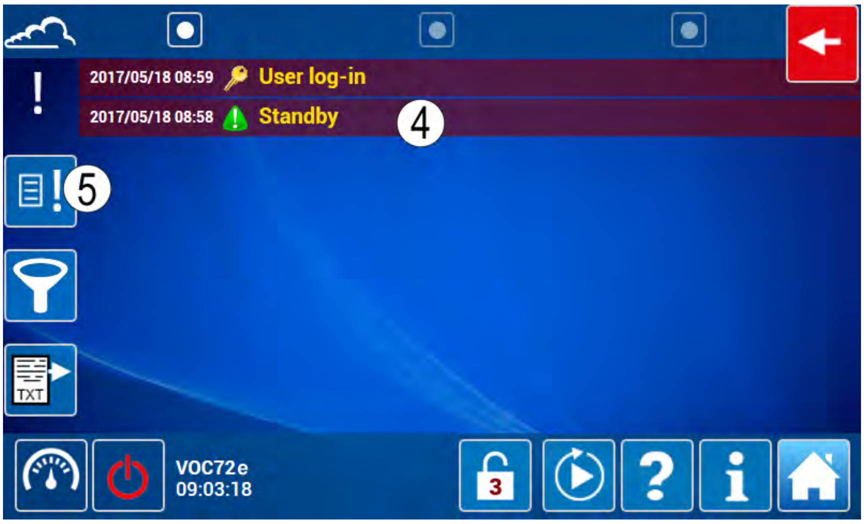
In the example below, the analyzer is found in stand-by mode, as indicated by the icon (1), without any action on the screen to stop the analysis cycles, and there is no alarm in progress.



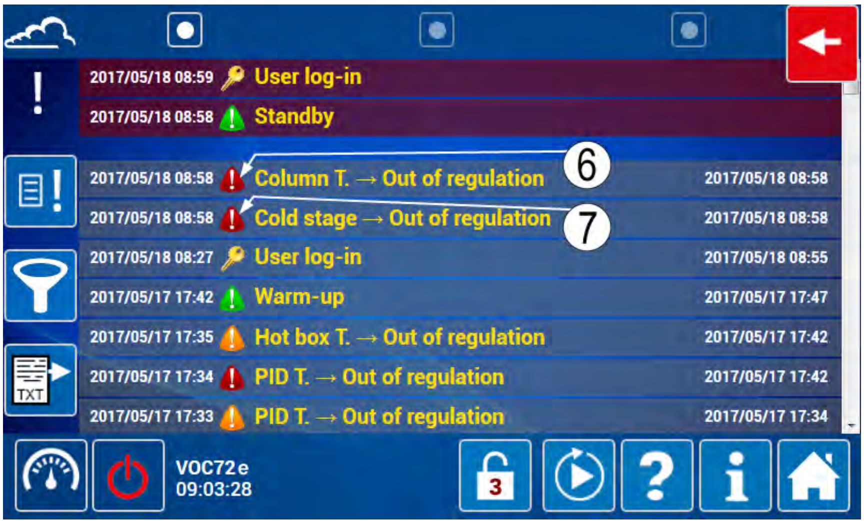
By touching / clicking (2) on the above screen, the user accesses the advanced functionalities, where the icon and button (1) indicates that the device is in stand-by mode.

As explained above, the user displays the *« Diagnostic functions (alarms, inputs / outputs, mux…) »* screen by touching/ clicking on (3) in the screen below.

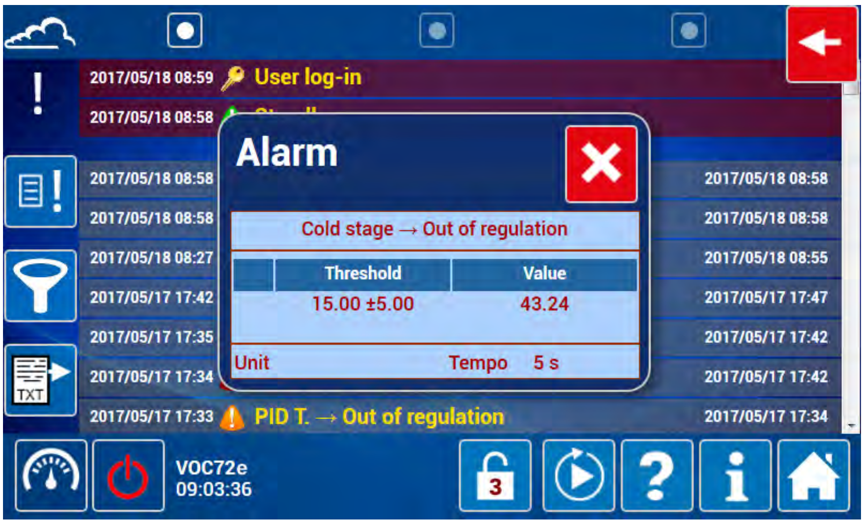
The « *Diagnostic functions (alarms, inputs / outputs, mux…)* » screen confirms the stand-by status (4). The user touches / clicks on (5) to display the fault and event historic.



This historic indicates two simultaneous alarms (6) and (7) occurred just before the stand-by and disappeared almost at the same time (at 8:58).

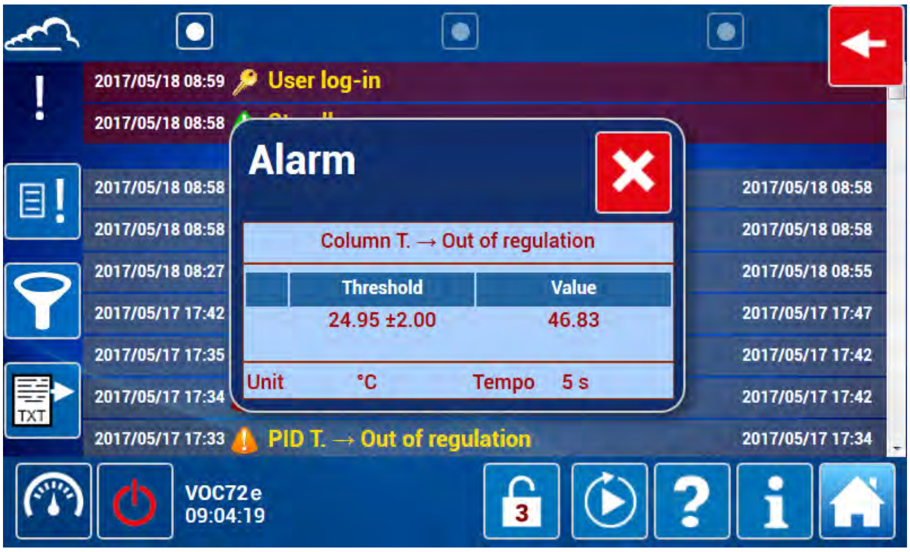


In this situation, the oldest alarm must always be considered as the alarm that triggers the stand-by. By clicking on its icon (7), the operator views its description:



The cold stage (cooler cold plate) temperature remained at more than 43°C (probable cause: Peltier element out-of-order), instead of reaching its set temperature of 15°C, which triggered the stand-by.

This cooling fault caused also a cooling column fault. By clicking on its icon (6), the user views its description:



Without cooler at 15°C., the column temperature remained at more than 46°C., instead of reaching its set temperature of 25°C., which triggered a second alarm.

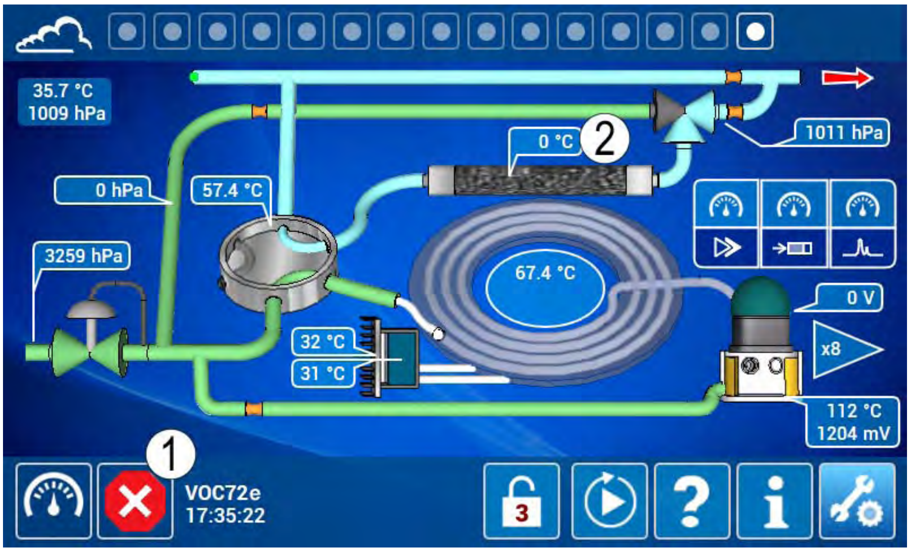
However, the stand-by triggered by the cold stage alarm removes the temperature monitoring on the column and the cooler, and consequently the temperature alarms of cold stage and column.

<u>Conclusion</u>: In case of automatic stand-by switching, the user must look for the alarm in the historic.

5.1.4.2 Case of security switching

In case of serious fault that could damage the analyzer, the security switching disconnects physically the 24V power supply, which results in other successive alarms as in the following example.

The icon (1) indicates a security analyzer switching. The trap temperature (2) is 0°C, which is impossible with an internal temperature of 35.7°C.

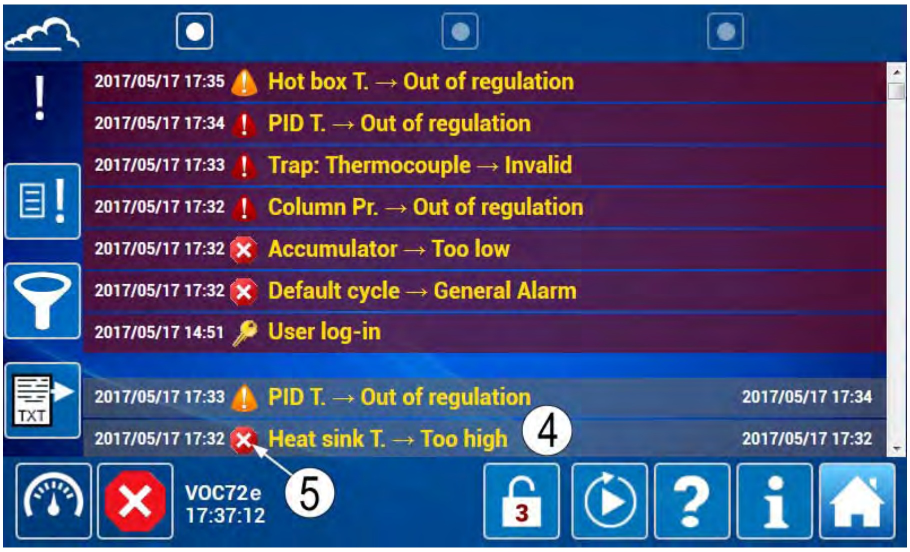


By clicking on the above screen icon (1), the user directly accesses the diagnostic function screen. The alarms in progress are numerous but they all result from the 24V power cut.

For example, without 24V power, the PID detector is no longer heated which triggers the PID temperature alarm. In the same way, without 24V power, the desorber board is switched to security mode which isolates its battery, and it is the reason why the battery voltage and the trap temperature are zero.

In this case, it is required to display the historic by touching / clicking on (3).

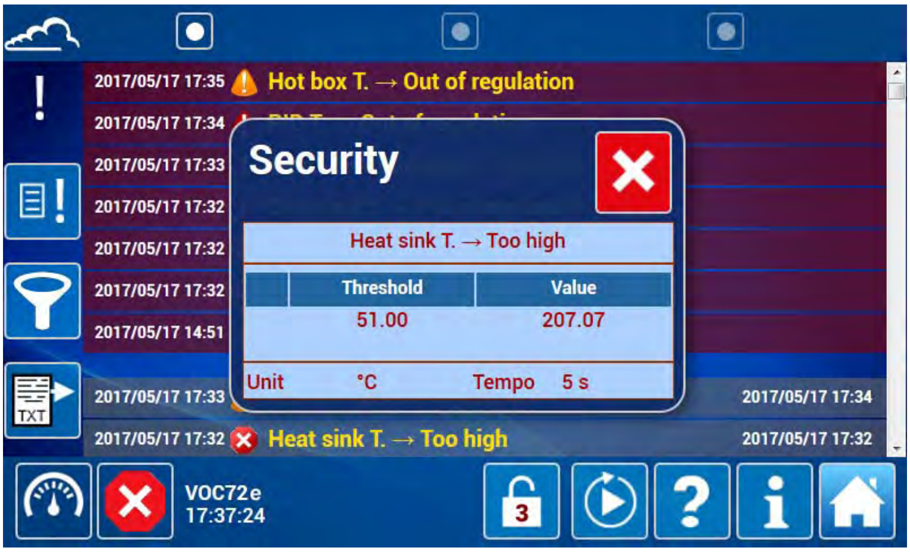
The historic allows to go back to the triggering event of the security switching which is always located earlier in the time, therefore down in the historic. In the example above, the heat sink temperature (4) is concerned.



By touching / clicking on this fault icon (5), the user views the critical value which triggered the security switching.

Then, he observes that the safety origin is a temperature higher than 200 ° C.

In fact, this temperature may result from a faulty temperature probe or false contact that lasted more than 5 seconds before vanishing.



Conclusion : In case of safety switching, DO NOT take into account the alarms in progress, but look for the initial safety switching, including the historic, to deal with the actual cause of the incident.

5.2 LIST OF FAULT AND CORRECTIVE ACTIONS

Table 5–1 – List of faults and corrective actions

: Control, : Alarm, : Security.

Messages **Min./Max. values**	**Possible cause(s)**	**Possible action(s)**
+ 24V → Too low **+ 24V → Too high** Min = 23.0 V Max = 24.5 V	The voltage of the 24V power supply is out of the interval : [23.0 V – 24.5 V] Then, the alarm triggers the Stand-by mode.	– Check the 24V voltage in the *« Diagnostic functions (alarm, input / output, mux…) »*, screen 2.
	The voltage of the 24V power supply is near to zero : V ≈ 0V	The analyzer is not in Stand-by mode, but in safety mode : – In the *« Diagnostic functions (alarm, input / output, mux…)»*, screen 1, then press down , look for the cause of the safety mode triggering (activating the Security flag), and correct it. Then, switch OFF/ON the analyzer. – If the fault is still present, check the F2 fuse (Power Fuse) on the interconnection board, and the 24V power supply.
	The voltage of the 24V power supply is higher than 24,5V	Adjust to 24 V the output voltage of the 24V power supply.
	The voltage of the 24V power supply is near to V ≈ 24V	In the *« Diagnostic functions (alarm, input / output, mux…)»*, screen 2, press down and to launch again an analysis cycle: – If the voltage falls down during the analysis cycle, replace the 24V power supply.
+ 5V → Too low **+ 5V → Too high** Min = 4.8 V Max = 5.2 V	The voltage of the 5V power supply is out of the interval : [4.8 V – 5.2 V] Then, the alarm triggers the Stand-by mode.	– Check the 5V voltage in the *« Diagnostic functions (alarm, input / output, mux…) »*, screen 2, Power supplies section. – Replace the Module board.

Messages Min./Max. values	Possible cause(s)	Possible action(s)
+5V sensor → Too low **+5V sensor → Too high** Min = 4.8 V Max = 5.2 V	The power supply voltage of the sensors is out of the interval : [4.8 V – 5.2 V] Then, the alarm triggers the Stand-by mode.	– Check the 5V sensor voltage in the *« Diagnostic functions (alarm, input / output, mux…) »,* screen 2, Power supplies section. – Replace the Module board.
Inlet Pr. → Too low **Inlet Pr. → Too high** Min = 2900 hPa Max = 3700 hPa	The hydrogen inlet pressure is out of the interval : [2900 hPa – 3700 hPa]	– Check the hydrogen inlet pressure in the *« Synoptic »* screen. – On the pressure reducing valve of the cylinder, adjust the hydrogen pressure to 3200 hPa. – In case of random fault, it is essential to use a double-stage pressure reducing valve.
Inlet Pr. → Too low **Inlet Pr. → Too high** Min = 2800 hPa Max = 3800 hPa	The hydrogen inlet pressure is out of the interval : [2800 hPa – 3800 hPa] Then, the alarm triggers the Stand-by mode	– Check the hydrogen inlet pressure in the *« Synoptic » screen*.
	Hydrogen inlet pressure > 3800 hPa	– Adjust the pressure on the pressure reducing valve of the cylinder
	Hydrogen inlet pressure < 2800 hPa	– Adjust the pressure on the pressure reducing valve of the cylinder. – Check the cylinder pressure, the opening of the cylinder valve and the connection to the analyzer.
	Hydrogen inlet pressure ≠ Pressure of the reducing valve 2800 hPa < Hydrogen inlet pressure < 3800 hPa	– In case of difference between the pressure value indicated in the *« Synoptic »* screen and the value read on the manometer of the pressure reducing valve, check the connection of the inlet pressure sensor on J22 of the interconnection board, or replace the inlet pressure sensor. – The Stand-by mode occurs on a fugitive fault : • Move the cable of the inlet pressure sensor to look for a possible false contact. • Replace the inlet pressure sensor, see (11) of figure 1-4.

Messages Min./Max. values	Possible cause(s)	Possible action(s)
Column Pr. → Out of regulation Min = Setting – 5 hPa Max = Setting + 5 hPa	The hydrogen pressure inside the column is different of more than 5 hPa against the setting	– Watch the column pressure on the « *Synoptic* » screen during the analysis cycle. See (19), page 3-45.
	The pressure falls down at the beginning of the hot purge	– Look for leak at the column connection on the injection valve, and remedy to it.
	The pressure is permanently low	– Measure the voltage at the proportional valve terminals : • If the voltage is higher than 22V: ⇨ there is a leak downstream the proportional valve. • If the voltage is lower than 15V: ⇨ replace the Module board.
Column Pr. → Out of regulation Min = Setting – 10 hPa Max = Setting + 10 hPa	The hydrogen (carrier gas) pressure in the column is out of the interval : [450 hPa – 470 hPa] Then, the alarm triggers the stand-by mode.	– Watch the value of the carrier gas pressure of the column in the « *Synoptic* » screen with the analyzer in Ready mode. See (19), page 3-45.
	The hydrogen pressure in the column is higher than 50 hPa, with the analyzer in Stand-by mode.	– Check the column pressure sensor and replace it if necessary. See (10) of figure 1-4.
	The hydrogen pressure in the column is lower than 50 hPa, with the analyzer in Stand-by mode.	– Switch to « Ready » mode and watch the carrier gas pressure of the column in the « *Synoptic* » screen. See (19), page 3-45.
	The hydrogen pressure in the column is lower than 450 hPa, with the analyzer in « Ready » mode.	– Check the control led of the proportional valve, in (29) of the interconnection board (see Figure 5–5): • The led is lit up: look for an important leak downstream the proportional valve, • The led is off: replace the Module board.
	The hydrogen pressure in the column is higher than 470 hPa, with the analyzer in « Ready » mode.	– Check the control led of the proportional valve, in (29) of the interconnection board (see Figure 5–5): • The led is lit up: replace the Module board. • The led is off: replace the proportional valve.

Messages Min./Max. values	Possible cause(s)	Possible action(s)
Hot box T. → Out of regulation Min = Setting – 2°C Max = Setting + 2°C	The hot box temperature is different of more than 2°C against the setting temperature (60°C by default).	– Check the hot box temperature in the « *Synoptic* » screen. See (16) page 3-45.
	The hot box temperature is within the interval : [50°C - 58°C]	– Check that the ambient temperature is higher than 0°C., and that the internal temperature of the analyzer in the « *Synoptic* » screen is higher than 15°C. See (7) page 3-45.
Hot box T. → Out of regulation Min = Setting – 10°C Max = Setting + 10°C	The hot box temperature is different of more than 10°C against the setting temperature (60°C by default), Then, the alarm triggers the Stand-by mode.	– Watch the hot box temperature value in the « *Synoptic* » screen. See (16), page 3-45.
	The hot box temperature is over 200°C.	– Check the temperature sensor of the hot box on J33 (13) of the interconnection board. • If the sensor is cut, replace the sensor. • If the sensor is disconnected, re-connect the sensor.
	The hot box temperature is near the internal temperature of the analyzer.	– Check the status of the heating led of the hot box on (14) of the interconnection board, near the J10 connector : • If the led is lit up, check the heating resistor on J10 (25Ω) (15) of the interconnection board. Replace the heating foil if the resistor is cut. • If the led is off, replace the Module board.
PID T. → Out of regulation Min = Setting – 2°C Max = Setting + 2°C	The PID detector temperature is different of more than 2°C against the setting temperature (140°C by default).	– Watch the PID detector temperature value in the « *Synoptic* » screen. See (6), page 3-45.
	The PID detector temperature is within the interval: [135°C - 138°C]	– Check that the ambient temperature is higher than 0°C, and that the internal temperature of the analyzer is higher than 15°C in the « *Synoptic* » screen. See (7) page 3-45. – If the fault occurs after PID detector de-assembling, check the presence of the insulating disk made of glass felt in the lower panel of the PID detector.

Messages Min./Max. values	Possible cause(s)	Possible action(s)
PID T. → Out of regulation Min = Setting – 5°C Max = Setting + 5°C	The PID detector temperature is different from more than 5°C against the setting temperature (140°C by default) Then, the alarm triggers the Stand-by mode.	– Watch the value of the PID detector temperature in the « *Synoptic* » screen. See (6), page 3-45.
	The PID detector temperature is near the internal temperature of the analyzer.	– Check the status of the heating led of the PID detector in (39) of the interconnection board, near the J6 connector : • If the led is lit up, check the heating resistor on J10 (40Ω) (15) of the interconnection board. • If the led is off, replace the Module board.
PID T → Out of regulation Max = Setting + 10°C	The PID temperature is over 200°C and triggers the safety.	– Check the PID temperature sensor on J39 (37) of the interconnection board. • If the sensor is cut, replace the sensor. • If the sensor is disconnected, re-connect it.
Internal T° → Too high Max = 43°C	The internal temperature of the analyzer exceeds 43°C.	– Make sure that the ambient temperature does not exceed 30°C. WARNING: if the analyzer is integrated into a cabinet, the ambient temperature is the temperature inside the enclosure. – In the « *Synoptic* » screen, compare the trap temperature value (3) with the internal temperature of the analyzer (7). See page 3-45.
	If the difference between the internal temperature of the analyzer and the trap temperature is lower than 3 °C : T°C (internal) – T°C (trap) < 3°C	– Check the cooling fan working, (15) of figure 1-4. This fan must work at maximum speed as soon as the internal temperature exceeds 37°C.
	If the difference between the internal temperature of the analyzer and the trap temperature is higher than 3 °C : T°C (internal) – T°C (trap) > 3°C	– Check the mixing fan working (27) and the status of its filter (29) of figure 1-4.

Messages Min./Max. values	Possible cause(s)	Possible action(s)
Internal T. → Too high Max = 45°C	The internal temperature of the analyzer exceeds 45°C. Then, the alarm triggers the Stand-by mode.	– Watch the value of the internal temperature of the analyzer in the screen « *Synoptic* ». See (7), page 3-45.
	A numeric value higher than 45 °C is displayed.	– Re-start the analyzer and remedy the internal overheating as described for the **Internal T. → Too high** message.
Internal T. → Too high Max = 47°C	The internal temperature is over 150°C and triggers the safety.	– Check the temperature sensor connection on J32 at (7) of the interconnection board. In case of cut, replace the sensor.
Heat sink T. → Too high Max = 48°C	The temperature of the external heat sink exceeds 48°C.	– Make sure that the ambient temperature does not exceed 30°C. – Check the working of the two cooling fans on the heat sink in (8) of figure 1-3, the free space between these grids and the wall (10 cm minimum) and the dirt amount of the heat sink.
Heat sink T. → Too high° Max = 50°C	The temperature of the external heat sink exceeds 49°C Then, the alarm triggers the Stand-by mode.	– Re-start the analysis cycle and remedy the over heating of the heat sink as described for the **Heat sink T. → Too high°** message.
Heat sink T. → Too high Max = 51°C	The temperature of the external heat sink exceeds 51°C. Then, the alarm triggers the safety mode.	– Watch the heat sink temperature value in the « *Synoptic* » screen. See (10), page 3-45. – Usually, the safety mode cut the power supply of the power-consuming elements: the temperature must decrease to the ambient temperature value.
	Trad > 150°C	– Check the status and the connection of the heat sink temperature sensor on J44 of the interconnection board (48) in Figure 5–5. In case of cut, replace the sensor.
	Trad < 51°C	– Check the heat sink temperature in the pop-up of alarm historic. If this temperature is higher than 150°C, replace the temperature sensor of the heat sink.

Messages Min./Max. values	Possible cause(s)	Possible action(s)
Cold stage → Out of regulation Max = Setting + 3°C	The cold plate temperature during the cold step of the column is higher than 3°C at least against its setting temperature (15°C).	– Watch the temperature value of the cold plate in the « *Synoptic* » screen. See (12) page 3-45.
Cold stage → Out of regulation Max = Setting + 5°C	The cold plate temperature during the cold step of the column is higher than 5°C at least against its setting temperature (15°C). Then, the alarm triggers the Stand-by mode.	– Re-start the analysis cycle by pressing down and . – Check the Peltier element connection on J7 of the interconnection board. See (50) page 5–38. – Go to the « *Diagnostic functions (alarm, input / output, mux…)* », screen 2, Power supplies section and check that the « *I power* » current is higher than 5 A during the column cooling. On the contrary case : • If the Peltier led on (49) of the interconnection board lights up during the column cooling, replace the Peltier element located in the thermo cooler assembly on (16) of the figure 1-4. • If the Peltier led is lit off during the column cooling, replace the Module board
Cold plate T. → Too high Max = 55°C	The cold plate temperature exceeds 55°C.	– Check the temperature value of the cold plate in the « *Synoptic* » screen. See (12) page 3-45. – Usually, a safety stops the cooling pump (See (18) of figure 1-4) when the cold plate temperature reaches 51°C. – A temperature higher than 51°C indicates that the Peltier cooler is faulty, or inverted.
Cold plate T. → Too high Max = 58°C	The cold plate temperature exceeds 58°C. Then, the alarm triggers the Stand-by mode. The cold plate temperature decreases slowly, which cancels the alarm.	– Re-start the analysis cycle by pressing down and , and check the temperature value of the cold plate in the « *Synoptic* » screen. See (12) page 3-45. – Remedy the overheating of the cold plate as described for the **Cold plate T. → Too high** message.

Messages Min./Max. values	Possible cause(s)	Possible action(s)
Cold plate T. → Too high Max = 60°C	The temperature of the cold plate exceeds 60°C. Then, the alarm triggers the safety mode. The cold plate temperature decreases slowly, which cancels the alarm.	– Check the temperature value of the cold plate in the « *Synoptic* » screen. See (12) page 3-45.
	The cold plate temperature is over 200°C, in the synoptic screen or the pop-up of alarm historic.	– Check the temperature sensor connection on J37 of the interconnection board (51). In case of cut, replace the sensor.
	The cold plate temperature is less than 60°C and decreases slowly.	– Switch OFF/ON the analyzer and re-start the analysis cycle by pressing down and . Then, remedy the overheating of the cold plate as described for the **Cold plate T. → Too high** message.
Icing cold plate T. → Out of regulation Min = Setting – 3°C	The temperature of the cold plate is lower than 3°C at least against its setting temperature (15°C).	– Check the value of the cold plate temperature and the internal temperature of the analyzer on the « *Synoptic* » screen. See (12) and (7) page 3-45. – Check that the ambient temperature is higher than 0°C and that the internal temperature of the analyzer is higher than 15°C.
Icing cold plate T. → Out of regulation Min = Setting – 4°C	The temperature of the cold plate is lower than 4°C at least against its setting temperature (15°C) Then, the alarm triggers the Stand-by mode.	– Check the value of the cold plate temperature and the internal temperature of the analyzer in the « *Synoptic* » screen. See (12) and (7) page 3-45. – Check that the ambient temperature is higher than 0°C and that the internal temperature of the analyzer is higher than 15°C. – Re-start the analysis cycle by pressing down and .
Icing cold plate T. → Out of regulation Min = Setting – 6°C	The cold plate temperature is lower than 6°C at least against its setting temperature (15°C). Then, the alarm triggers the safety mode.	– Check the value of the cold plate temperature and the internal temperature of the analyzer in the « *Synoptic* » screen. See (12) and (7) page 3-45. – Check that the ambient temperature is higher than 0°C and that the internal temperature is higher than 15°C. – Re-start the analyzer by pressing the OFF/ON button.

Messages Min./Max. values	Possible cause(s)	Possible action(s)
Trap Pr. (clog) → Out of regulation Min = PA – 300 hPa Max = PA + 200 hPa *When the analyzer is in Sampling mode* *See § 2-7 in page 2-9.*	The trap pressure in sampling is too far compared to the atmospheric pressure.	– Check the value of the trap pressure and the atmospheric pressure in the « *Synoptic* » screen. See (5) and (4) page 3-45.
	Trap pressure is lower than atmospheric pressure – 300 hPa	– Check the status of the sample inlet filter, See (11) figure 1-5, and (2) figure 3-2.
	Trop pressure is higher than atmospheric pressure + 200 hPa	– Check the pressure at the sampling point.
Trap Pr. → Out of regulation Min = PA – 40 hPa Max = PA + 40 hPa *When the analyzer is in Stand-by mode or Ready mode*	The analyzer is in Stand-by mode or Ready mode, and the trap pressure is more than 40 hPa higher or lower than the atmospheric pressure.	– Disconnect the sample inlet and check, in the « *Synoptic* » screen, the pressure difference between the trap pressure and the atmospheric pressure. – If the fault is still present and the atmospheric pressure is correct, replace the trap pressure sensor. See (6) of figure 1-5. – If the fault disappears, look for the cause of the difference between the sample pressure and the atmospheric pressure (for example, an excess Tee is missing).
Trap Pr. (clog.) → Out of regulation Min = PA – 400 hPa Max = PA + 400 hPa *When the analyzer is in Sampling mode* *See § 2-7 of page 2-9*	The trap pressure, during the trap sampling is more than 400 hPa higher or lower than the atmospheric pressure. Then, the alarm triggers the Stand-by mode.	– If the alarm disappears in Stand-by mode, press down the [button] and [button], and check, in the « *Synoptic* » screen, the trap pressure and the atmospheric pressure when the sampling cycle begins.
	If the trap pressure is lower than the atmospheric pressure. - 400 hPa :	– Check that the sample pressure at the sampling point is near the atmospheric pressure. – Check that the sampling line is not clogged. – Replace the sample inlet filter. See (11) figure 1-5, and (2) figure 3-2. – Lastly, replace the trap, see (6) of figure 1-4.
	If the trap pressure is higher than the atmospheric pressure + 400 hPa :	– The sample line is under pressure. Fit up a restrictor and an excess Tee upstream the sample inlet.

Messages Min./Max. values	Possible cause(s)	Possible action(s)
Trap Pr. → Out of regulation Min = PA – 80 hPa Max = PA + 80 hPa *When the analyzer is in Stand-by mode or ready mode*	The analyzer is into « Stand-by mode » or « Ready » mode, and the trap pressure is more than 80 hPa higher or lower than the atmospheric pressure.	– Disconnect the sample inlet and check the pressure difference between the trap pressure and the atmospheric pressure in the *« Synoptic »* screen. – If the fault is still present and the atmospheric pressure is correct, replace the trap pressure sensor. See (6) of figure 1-5. – If the fault disappears, look for the cause of the pressure difference between the sample pressure and the atmospheric pressure (for example, an excess Tee is missing).
Trap T. → Out of regulation Min = 360°C Max = 400°C	The trap temperature during its heating is more than 20°C different against the heating setting (380°C by default).	– Check the trap temperature at the beginning of the analysis cycle in the *« Synoptic »* screen. See (3) page 3-45. – Tighten again the knurled nuts of the trap on the desorber board (see 4 of figure 1-4). – Replace the trap. See (6) of figure 1-4. – Replace the desorber board. See (4) of figure 1-4.
Trap T. → Out of regulation Min = 350°C Max = 410 °C	The trap temperature during its heating is more than 30°C different against the heating setting (380°C by default). The alarm interrupts the heating and triggers the Stand-by mode.	– Restart the analysis cycle by pressing down and , then check-up in the *« Synoptic »* screen the trap temperature at the beginning of the analysis cycle and remedy the temperature problem in the same way as for the here-above **Trap T. → Out of regulation** message.
Accumulator →Too low **Accumulator →Too high** Min = 3.1 V Max = 3.5 V	The desorber battery voltage is not within the interval [3.1V – 3.5V] anymore.	– Go to the *« Diagnostic functions (alarm, input / output, mux…) »*, screen 2, to display the desorber battery voltage in the trap section.
	The desorber battery voltage is lower than 3.1 V.	– Check that the led indicator of battery charging is lit up, on (7) of the desorber board (see Figure 5–1) and that charging is ON, on the *« Diagnostic functions (alarms, inputs / outputs, mux…» screen 2*.
	The desorber battery voltage is higher than 3.5V.	– Check that the led indicator of battery charging is lit off, on (7) of the desorber board (see Figure 5–1).

Messages Min./Max. values	**Possible cause(s)**	**Possible action(s)**
Accumulator →Too low **Accumulator →Too high** Min = 3.0 V Max = 3.6 V	The desorber battery voltage is not within the interval [3.0 – 3.6 V] anymore. Then, the alarm triggers the Stand-by mode.	– Restart the analysis cycle by pressing down and , then check-up in the *« Diagnostic »* screen 2 the accumulator voltage at the beginning of the analysis cycle and remedy the accumulator voltage problem in the same way as for the here-above **Accumulator →Too low** and **Accumulator →Too high** messages.
Accumulator →Too low **Accumulator →Too high** Min = 2.7 V Max = 3.7	The desorber battery voltage is outside the interval [2.7 – 3.7V]. Then the alarm triggers the “safety” mode and the battery voltage drops to zero volt.	– Go to the alarm historic in the *« Diagnostic »* screen 1 and check the battery voltage (value) that triggered the “safety” mode.
	The value is zero volt.	– Look for another safety event that occurred before the Accumulator safety event.
	The value is close to 2.7 volt or close to 3.7 volt.	– Replace the desorber board (charger issue).
I transfer line → Too low **I transfer line → Too high** Min = 2500 mA Max = 4000 mA	The heating intensity of the transfer line is lower than 2500 mA when the heating control of the transfer line is activated.	– Go to the *« Diagnostic functions (alarm, input / output, mux…) »* screen 2, Trap section/ I Transfer line, and check the intensity of the transfer line at the beginning of the analysis cycle. This intensity must be within 2800 mA and 3800 mA.
		– Check that the transfer line is correctly connected to the trap. See (28) of figure 1-4.

Messages Min./Max. values	Possible cause(s)	Possible action(s)
I transfer line → Too low **I transfer line → Too high** Min = 2000 mA Max = 4500 mA	The heating intensity of the transfer line is lower than 2000 mA, but the analyzer is still working.	Go to the « *Diagnostic functions (alarm, input / output, mux…)* » screen 2, Trap section, and check the transfer line intensity.
	The transfer line heating intensity is near to zero: I ≈ 0 mA	– Check that the electric connector of the transfer line is correctly plugged on (3) of the desorber board (see Figure 5–1). See Figure 5–1 page 5–34. – Check that the light indicator of the transfer line heating located on (2) of the desorber board, lights up at the beginning of the cycle. – Go to the « *Diagnostic functions (alarm, input / output, mux…)* » trap section/ Transfer line set, and check that the transfer line setting is correctly adjusted to 30%.
Vacuum pump → Too high Max = 200 hPa	The trap pressure displayed in the « *Synoptic* » screen during the trap operation phases other than sampling is higher than 200 hPa. See (5) page 3-45.	– Check the trap pressure at the beginning of the analysis cycle in the « *Synoptic* » screen to confirm the fault. – Connect a vacuometer at pump inlet : Usual value : ≤ 150 hPa (abs). – If the limit vacuum is correct, look for a leak in the vacuum circuit of the analyzer. – If the vacuum limit is too weak (over 150 hPa), replace the membrane and valves of the pump.
Vacuum pump → Too high Max = 250 hPa	The trap pressure displayed in the « *Synoptic* » screen during the trap operation phases other than sampling is higher than 250 hPa. See (5) page 3-45. Then, the alarm triggers the Stand-by mode which clears the alarm.	– Press down the and keys in the « *Synoptic* » screen to re-start the analysis cycle and confirm the fault. If the fault is confirmed, apply the procedure described here-above for the **Vacuum pump → Too high.**

Messages Min./Max. values	Possible cause(s)	Possible action(s)
I end column → Too low **I end column → Too high** Min = 700 mA Max = 2000 mA	The heating intensity of the column end is outside the interval [700 – 2000 mA] and inside the interval [400 – 2500 mA].	– Go to the Diagnostic screen 1 and click on the control icon to display the corresponding pop-up window and notice the intensity value that triggered the control. – Go to the Diagnostic screen 2 section “column” and check the voltage and intensity of the end column heating when the heating is ON.
	End Column: ON V end column ≈ 4 V 400 < I end column < 700 mA	– Check the column electrical connection at the contact blade of the PID detector. – Disconnect J9 rep 35 of Figure 5–5 on the interconnection board and measure the resistor between the frame and the contact blade: R ≈ 4Ω.
	End Column: ON V end column < 3V I end column > 2000 mA	– Check the electrical insulation of the contact blade on the PID detector.
	End Column: ON V end column > 6V I end column > 2000 mA	– Check that the End col set point is 15. If yes, replace the Module board.

Messages Min./Max. values	**Possible cause(s)**	**Possible action(s)**
I end column → Too low **I end column → Too high** Min = 400 mA Max = 2500 mA	The heating intensity of the column end is outside the interval [400 - 2500 mA]. Then the alarm triggers the Stand-by mode which clears the alarm	– Go to the alarm historic, click on the alarm icon to display the corresponding pop-up window and notice the intensity value that triggered the alarm. – Go to the Diagnostic screen 2 section “column”, restart the analysis cycle by pressing and and check the voltage and intensity of the end column heating when the heating is ON.
	End Column: ON V end column ≈ 4 V I end column < 400 mA	– Check the column electrical connection at the contact blade of the PID detector. – Check the J9 connection (see rep 35 of Figure 5–5 on the interconnection board). – Disconnect J9 rep 35 of Figure 5–5 on the interconnection board and measure the resistor between the frame and the contact blade: R ≈ 4Ω.
	End Column: ON V end column < 3V I end column > 2500 mA	– Check the electrical insulation of the contact blade on the PID detector.
	End Column: ON V end column > 6V I end column > 2500 mA	– Check that the End col set point is 15. – If yes, replace the Module board.

Messages Min./Max. values	Possible cause(s)	Possible action(s)
Column T. → Out of regulation Min = Setting – 1°C Max = Setting + 1°C	The column temperature during the analysis is more than 1°C different against its set point.	– Go to the *« Diagnostic functions (alarms, inputs / ouputs, mux…»* screen 2, column section, and check the variation between the Column T. and the Col. set pts.
	The column temperature is more than 1°C different against its set point: Column T. > Col. Set pts + 1°C. A cooling fault is detected at the beginning of the second cycle.	– Check the cooling fluid level (17) and the cooling pump operation (18) of figure 1-4: • If the cooling fluid level is correct, and the cooling fault proved, replace the cooling pump. **Note**: on end-of-life, the pump motor can generate a random cooling fault which triggers the Stand-by mode.
	The column temperature is lower than its set point minus 1°C : Column T. < Col. Set pts - 1°C A heating fault is detected during the cycle.	– Check the status of the heating column led during heating, on (17) of the interconnection board : • The led is lit-off : replace the Module board • The led is lit-up: check the resistor (≈ 7Ω) on the heating column connector J4, on (18) of the interconnection board. If the resistor is cut, replace the column.
Column T. → Out of regulation Min = Setting – 2°C Max = Setting + 2°C	The column temperature during the analysis is more than 2°C different against its set point Then, the alarm triggers the Stand-by mode.	– Press down the [restart] and [play] keys in the *« Synoptic »* screen to re-start the analysis cycle and generate again the alarm.
	The column temperature is more than 2°C different against its set point : Column T. > Col. Set pts + 2°C. A cooling fault is detected at the beginning of the second cycle.	– Check the cooling fluid level (17) and the cooling pump operation (18) of figure 1-4 : • If the cooling fluid level is correct, and the cooling fault proved, replace the cooling pump. **Note**: on end-of-life, the pump motor can generate a random cooling fault which triggers the Stand-by mode.
	The column temperature is lower than its set point minus 2°C : Column T. < Col. Set pts - 2°C A heating fault is detected during the cycle.	– Check the status of the heating column led during heating, on (17) of the interconnection board : • The led is lit-off : replace the Module board • The led is lit-up: check the resistor (≈ 7Ω) on the heating column connector J4, on (18) of the interconnection board. If the resistor is cut, replace the column.

Messages **Min./Max. values**	Possible cause(s)	Possible action(s)
Incoh. Column T. → Out of regulation ΔTmax = 10°C	The column temperature safety sensor gives a different value of more than 10°C against the column temperature indicated in the *« Synoptic »* screen. Then, the alarm triggers the Stand-by mode.	– Go to the *« Diagnostic functions (alarms, inputs / ouputs, mux…»* screen 2, column section, and compare the Column T. when cold, with Col. safety T. temperature. If the fault is confirmed, check the connector J30 (16) on the interconnection board, or replace the column.
Column T. → Too high Max = 170°C	The column temperature exceeds 170°C. Then, the alarm triggers the safety mode.	– Check, when cold, the column temperature indicated in the *« Synoptic »* screen. • If the column temperature is higher than 170°C, check the connector J30 on (16) of the interconnection board Figure 5–5. • If the column temperature is near the internal temperature of the analyzer, switch OFF/ON the analyzer to re-start, then press down the and .keys in the *« Synoptic »* screen to re-start the analysis cycle. Then check the column temperature and the status of the column heating led, on (17) of the interconnection board : if the led is permanently ON and the temperature increases up, replace the Module board
HV lamp → Too low **HV lamp → Too high** Min = 155 V Max = 350 V	The PID lamp voltage is outside the interval [155-350V] and inside the interval [150-400V]. The analyzer cannot switch from “stand-by” mode to “ready” mode.	– Check the PID lamp voltage on the *« Synoptic »* screen see (21) page 3-45. – Replace the PID lamp.

Messages Min./Max. values	Possible causes (s)	Possible action(s)
HV lamp → Too low **HV lamp → Too high** Min = 150 V Max = 400 V	The PID lamp voltage is lower than 150V or higher than 400V. Then the alarm triggers the "stand-by" mode which clears the alarm.	– Go to the alarm historic, click on the alarm icon and check the voltage that triggered the "stand-by" mode. – For confirmation, launch the "ready" mode by pressing and .Then check the PID lamp voltage see (21) page 3-45.
	The PID lamp voltage is higher than 1000 V.	– Replace the PID lamp or check its electrical connection.
	The PID lamp voltage is close to zero volt.	– Check the 5V supply led on the PID supply board. See (1) Figure 5–3. – The led is lit-up (amber): replace the PID supply board. – The led is lit-off: replace the Module board.
	The PID lamp voltage is close to 150 V.	– Replace the PID lamp.

Messages Min./Max. values	Possible cause(s)	Possible action(s)
Module link → No activity	The communication between the Module board and the ARM20 board does not work anymore then the alarm triggers the safety mode.	– Check the connections of the link cable between the ARM20 board and the interconnection board. – Switch OFF/ON the analyzer to reset it.
Init. Module board → Too high	The Module board is not programmed.	– Contact the Customer Service.
Inv. C.: Atmo .Pr → 0001	The averaged atmospheric pressure recorded for this cycle is outside the [600 hPa-1100 hPa] range.	– Go to the «*Synoptic*» screen and compare the atmospheric pressure (see (4) page 3-45) with a reference barometer. – If the difference exceeds 50 hPa, replace the Module board.
Inv. C.: Pr. Dif. → 0002	The averaged trap pressure during the sampling cycle is different of more than 300 hPa against the atmospheric pressure.	– Go to the «*Synoptic*» screen and compare the atmospheric pressure (see (4) page 3-45) with the trap pressure (see (5) page 3-45) during the trap sampling (see § 2.7 page 2-9): in normal condition, the trap pressure is 100 hPa below the atmospheric pressure. – See also the action for Trap Pr. (clog) → Out of regulation
Inv. C.: Trap Pr. → 0004	The averaged trap pressure during the sampling cycle is outside the [500 hPa-1500 hPa] range.	– Go to the «*Synoptic*» screen and check the trap pressure (see (5) page 3-45) during the trap sampling (see 2.7 page 2-9): in normal condition, the trap pressure is 100 hPa below the atmospheric pressure. – See also the action for Trap Pr. (clog) → Out of regulation
Inv. C.: Desor. Pr. → 0008	The averaged desorption pressure i-e the trap pressure during the desorption cycle is greater than 250 hPa	– Go to the «*Synoptic*» screen and check the trap pressure (see (5) page 3-45) during the trap cooling (see 2.6 page 2-8): in normal condition, the trap pressure is less than 150 hPa – See also the action for **Vacuum pump → Too high**

Messages Min./Max. values	Possible cause(s)	Possible action(s)
Inv. C.: MB, stack full → 0016	The intermediate storage stack of the chromatogram is saturated which may result in a disturbed chromatogram.	– Consult the chromatogram with Winchrom2 to confirm the problem. – Contact the customer service.
Inv. C.: MB, pts to 0 → 0032	Some missing points in the chromatogram have been replaced by null points to keep the retention time integrity.	– Consult the chromatogram with Winchrom2 to confirm the problem. – Contact the customer service.
Analog. out of range	One of the input channels of the optional ESTEL board is saturated.	– Go to the « Advanced functionalities » then « Optional interface configuration » then [icon] to check input configuration of ESTEL board.
	The input channel setting of ESTEL board is lower than the signal to be measured.	– Set the « range » parameter in the input configuration of ESTEL board.
	The saturation corresponds to a measurement at 9999 (µg / m3 or ppb) following a saturated peak on the chromatogram.	– Reduce the detector gain to remove saturation. – Set the « range » parameter of ESTEL board to 10000 in order to take into account the peak saturation.

Error messages when automatic calibration fails:

Messages	Possible cause(s)	Possible action(s)
Calib.: Invalid cycle → 0001	One alarm at least occurred during the automatic calibration cycle leading to an invalid cycle.	– Go to the «*Alarms historic*» screen, look for the invalid cycle origin and fix the problem.
Calib.: Peak < compounds → 0002	Less peaks found in the calibration chromatogram than compounds to calibrate for the "RT and Conc." automatic calibration.	– Check the span chromatogram: it must include as many significant (= major) peaks as compounds to calibrate. – Remove the missing gases of the span mix from the list of compounds selected for the auto-calibration.
Calib.: Saturated peak → 0004	There is a saturated peak in the chromatogram for the "RT and Conc." automatic calibration. At least one of the compounds peak is saturated in the chromatogram for the "Standard" automatic calibration.	– Check the span chromatogram and display the greatest peak: its "Signal" must be less than 2490 mV (see the peak screen page 3-60). – Reduce the detector gain or the span gas concentration to avoid the peak saturation. A peak saturation occurs when the PID signal is higher than 2490mV).
Calib.: Ratio major peaks → 0008	The surface ratio (≈ the height ratio) between the compounds peaks is greater than 3/1 in the chromatogram for the "RT and Conc." automatic calibration.	– Check the span chromatogram: it must include as many significant (= major) peaks as compounds to calibrate and the ratio between the highest major peak and the lowest major peak must be less than 3. – Check the span gas source composition (in ppb). The ratio between the highest concentration and the lowest concentration must be less than 3.
Calib.: Peaks > compounds → 0016	There are more peaks of similar amplitude in the span chromatogram than compounds selected for the "RT and Conc." automatic calibration.	– Check the span chromatogram: it must include as many significant (= major) peaks as compounds to calibrate and the residual (= minor) peaks amplitude must be less than 20% of any major peak amplitude. – An extra major peak may result from: – An extra compound in the span cylinder not selected in the auto-calibration. – A foreign compound resulting from a pollution. – A foreign compound resulting from a leak. – A mistake in the inlet selection for the auto-calibration: the VOC72e tries to calibrate on air instead of span gas.

Messages	Possible cause(s)	Possible action(s)
Calib.: K span overrange → 0032	Analyze the origin of the sensitivity change. If the old K factor is not significant, switch the “First calibration” field to ON in the advanced analyser configuration and restart an automatic calibration.	– Check that the calibration chromatogram looks like a span gas chromatogram: it must include as many significant (= major) peaks as compounds to calibrate. Typically, the “Calib.: K span over range” comes with a “flat” chromatogram or an ambient air chromatogram instead of a span gas chromatogram. – Check that the declared concentrations for the calibration correspond to the span mixture composition.
Calib.: K span variation → 0064	The automatic calibration gives a K factor which differs more than 50% from the old K factor	– Analyze the origin of the sensitivity change. – If the old K factor is not significant, switch the “First calibration” field to ON in the advanced analyzer configuration and restart an automatic calibration.

The fast alarm messages:

The trap heating of the VOC72e is a very fast process. It is protected by a set of four alarms implemented directly on the Module board of the VOC72e which controls the trap heating. So the reaction to the alarm situation can be fast because it is not affected by the data flow between the Module board and the Arm20 board.

Messages Min./Max. values	Possible cause(s)	Possible action(s)
Trap: Battery → Invalid	The instant voltage of the desorber battery drops under 2.2 volt. Then the Module board halts the trap heating and sends the alarm to the Arm20 board which triggers the "Stand-by" mode.	– Restart the analysis cycle to confirm the alarm. – Replace the desorber board.
Trap: Rise time → Invalid	The instant trap temperature after the first second of heating is less than 150°C. Then the Module board halts the trap heating and sends the alarm to the Arm20 board which triggers the "Stand-by" mode.	– Restart the analysis cycle to confirm the alarm. – Tighten again the knurled nuts of the trap on the desorber board (wrong electrical contact). See (4) of figure 1-4. – Replace the trap. See (6) of figure 1-4. – Replace the desorber board.
Trap: Gas vector → Invalid	The instant column pressure during the trap heating is less than 400 hPa. Then the Module board halts the trap heating and sends the alarm to the Arm20 board which triggers the "Stand-by" mode.	– Restart the analysis cycle to confirm the alarm. – Replace the proportional valve. See (12) of figure 1-4. – See also the actions for **Column Pr → Out of regulation**
Trap: Thermocouple → Invalid	The instant trap temperature just before heating is outside the [5°C – 50°C] range. Then the Module board does not heat the trap and sends the alarm to the Arm20 board which triggers the "Stand-by" mode.	– Go to the «*Synoptic*» screen and check the trap temperature. See (3) page 3-45. In normal conditions without heating, the trap temperature is close to the internal temperature. – Replace the trap (dead thermocouple). – Replace the desorber board (dead thermocouple amplifier).

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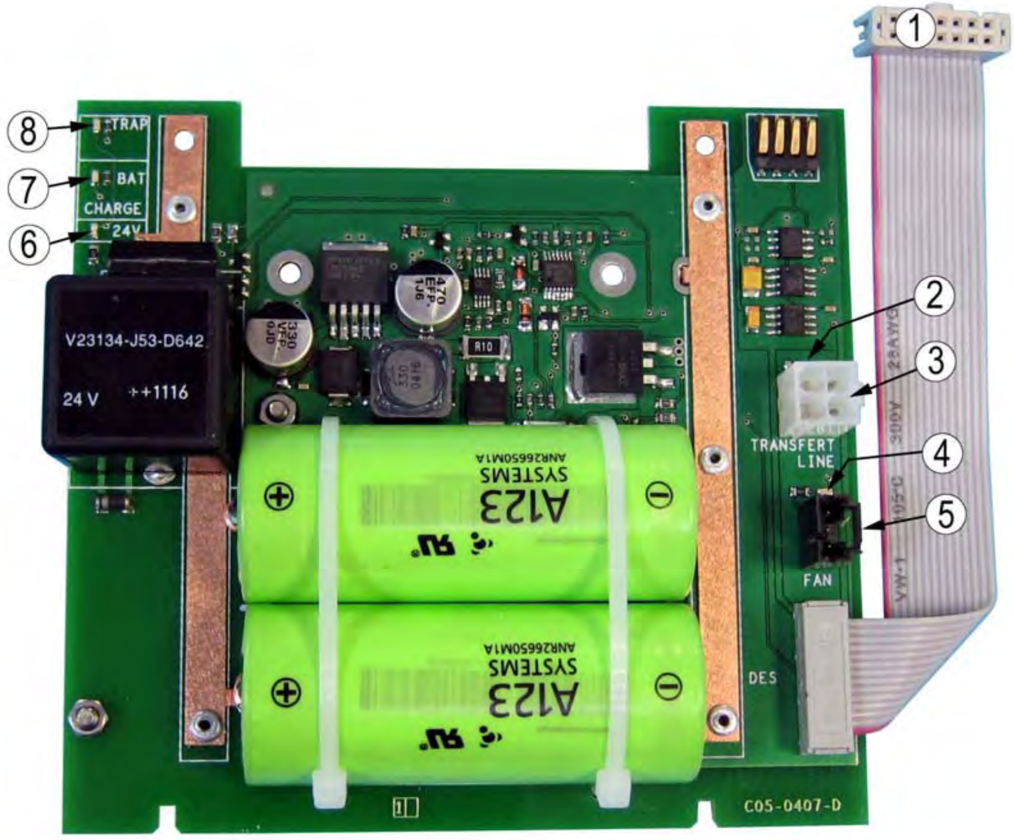

Figure 5–1 – Desorber board

Table 5–2 – Description of the desorber board

Mark	Function	Description
1	Supply connector	He10 14 pts
2	Transfer line heating led indicator	Yellow
3	Transfer line connector	4 pts
4	Trap fan led indicator	Yellow
5	Trap fan connector	2 pts
6	24V supply led indicator	Green
7	Charging led indicator	Yellow
8	Trap heating led indicator	Yellow

WARNING : The power accumulator of the desorber board can deliver 120 A. in continuous and much more in short circuit condition. Take precautions to avoid short circuits: considerable heat will occur through the shorting conductor. The resultant high temperature can cause severe injuries or initiate a fire if flammable materials are present.

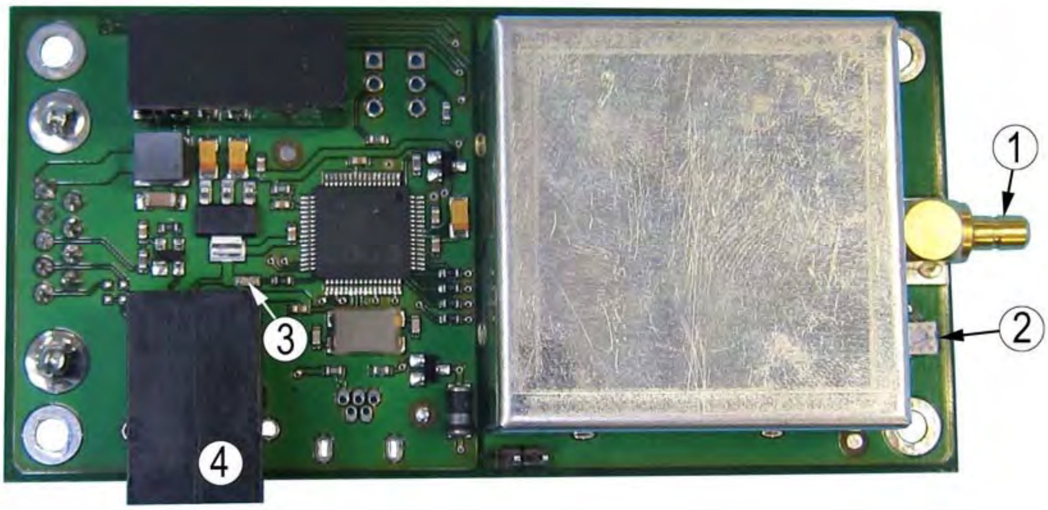

Figure 5–2 – Electrometer board

Table 5–3 – Description of the Electrometer

Mark	Function	Description
1	Signal coaxial connector	
2	Offset adjustment potentiometer	
3	Microcontroller activity led indicator	Blinking red
4	Programming connector	

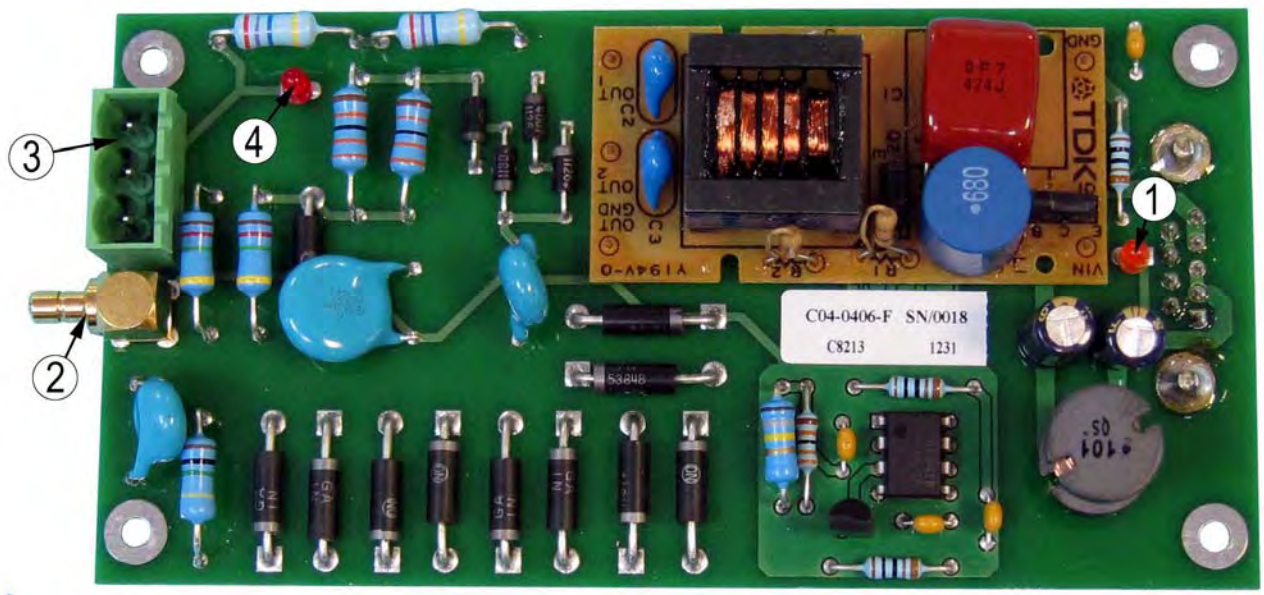

Figure 5–3 – PID supply board

Table 5–4 – Description of the PID supply board

Mark	Function	Description
1	5V supply led indicator	Orange
2	Polarization coaxial connector	
3	PID lamp supply connector	
4	Lamp firing led indicator	Red

WARNING : Presence of high voltage **(2000 Volts)** on the board.

Do not make it work without its transparent protection cover.

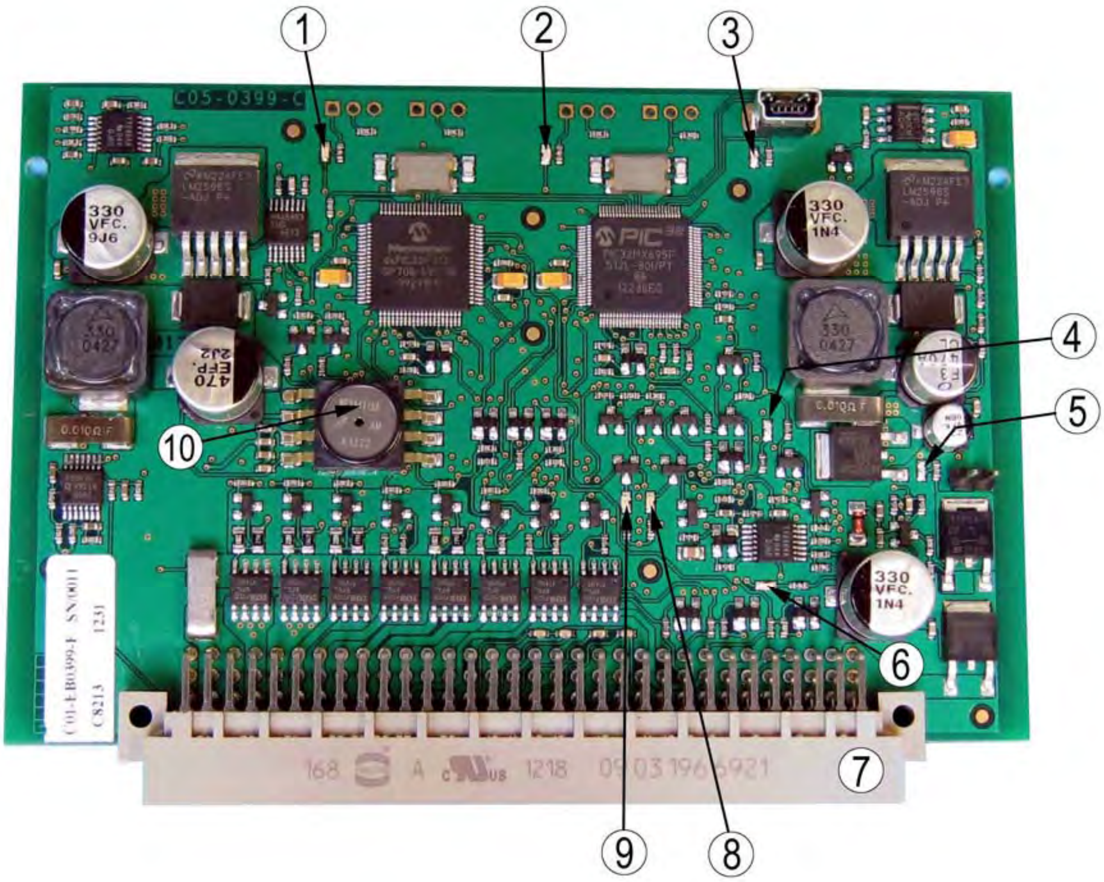

Figure 5–4 – Module board

Table 5–5 – Description of the Module board

Mark	Function	Description
1	PIC33 activity led indicator	Orange
2	PIC32 activity led indicator	Orange
3	USB led indicator	
4	3.3V power supply led indicator	Green
5	24V power supply led indicator	Green
6	Safety relay led indicator	Green
7	96-pin connector	
8	RS232 TX activity led indicator	Red
9	RS232 RX activity led indicator	Green
10	Atmospheric pressure sensor	

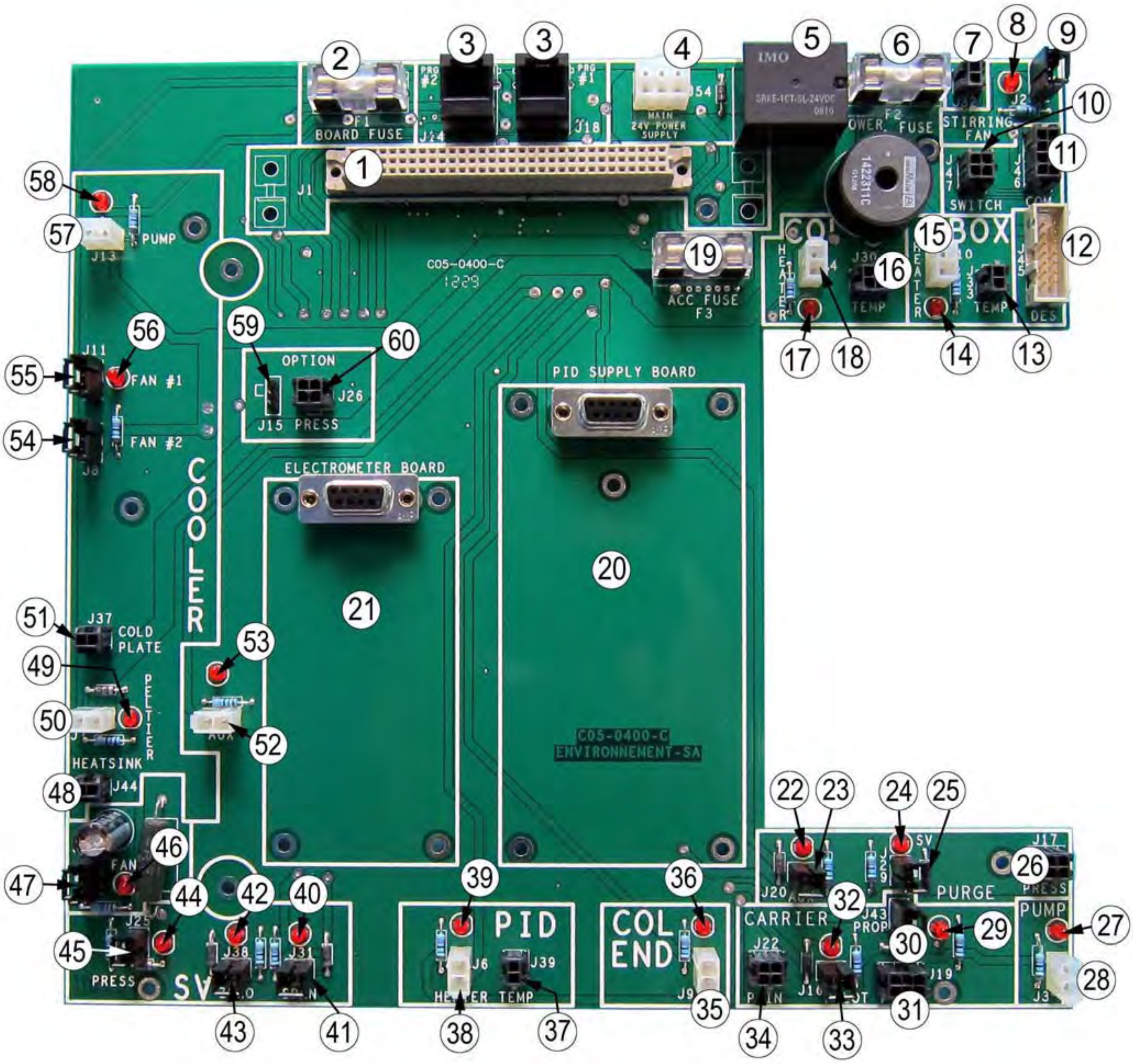

Figure 5–5 – Interconnection board

Table 5–6 – Description of the interconnection board

Mark	Function	Description
1	Module board slot	J1
2	Module board fuse	F1
3	Programming connectors	J14 & J18
4	24V power supply connector	J54
5	Safety relay	
6	Power fuse	F2
7	Internal temperature connector	J32
8	Stirring fan led indicator	Red
9	Stirring fan connector	J2
10	Front switch connector	J47
11	ARM20 COM connector	J46
12	Desorber board connector	J45
13	Hot box temperature sensor connector	J33
14	Hot box heating led indicator	Red
15	Hot box heating connector	J10
16	GC column temperature sensor connector	J30
17	GC column heating led indicator	Red
18	GC column heating connector	J4
19	Accessory fuse	F3
20	PID supply board location	
21	Electrometer board location	
22	AUX valve led indicator	Red
23	AUX valve connector	J20
24	Purge valve led indicator	Red
25	Purge valve connector	J29
26	Trap pressure sensor connector	J17
27	Vacuum pump led indicator	Red
28	Vacuum pump connector	J3
29	Proportional valve led indicator	Red
30	Proportional valve connector	J43
31	GC column pressure sensor connector	J19
32	Pilot valve led indicator	Red
33	Pilot valve connector	J16
34	Hydrogen supply pressure sensor connector	J22
35	GC column end heating connector	J9
36	GC column end heating led indicator	Red
37	PID detector temperature sensor connector	J39
38	PID detector heating connector	J6
39	PID detector heating led indicator	Red
40	Span valve led indicator	Red
41	Span valve connector	J31
42	Zero valve led indicator	Red
43	Zero valve connector	J38
44	Pressure span valve led indicator	Red
45	Pressure span valve connector	J25
46	Cooling fan led indicator	Red
47	Cooling fan connector	J5
48	Heat sink temperature sensor connector	J44
49	Peltier cooler led indicator	Red
50	Peltier cooler connector	J7
51	Cold plate temperature sensor connector	J37
52	AUX power connector	
53	AUX led indicator	Red
54	Peltier Fan #2 connector	J8
55	Peltier Fan #1 connector	J11
56	Peltier Fan led indicator	Red
57	Cooling pump connector	J13
58	Cooling pump led indicator	Red
59	Pressure sensor voltage selection	J15
60	Auxiliary pressure sensor connector	J19

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