TÜV RHEINLAND
ENERGIE UND UMWELT GMBH

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D-PL-11120-02-00

Report on performance testing of the VOC72M ambient air monitoring system manufactured by Environnement S.A. for the component benzene

TÜV-Report No.: 936/21217807/A
Cologne, 16 August 2012

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The department of Environmental Protection of TÜV Rheinland Energie und Umwelt GmbH
is accredited for the following work areas:

- Determination of air quality and emissions of air pollution and odour substances;
- Inspection of correct installation, function and calibration of continuously running emission measuring devices including systems for data evaluation and remote monitoring of emissions;
- Performance testing of measuring systems for continuous monitoring of emissions and ambient air, and of electronic systems for data evaluation and remote monitoring of emissions

according to EN ISO/IEC 17025.

The accreditation is valid up to 31-01-2013. DAkkS-register number: D-PL-11120-02-00.

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Report on performance testing of the VOC72M ambient air monitoring system manufactured by Environnement S.A. for the component benzene

Instrument tested: VOC72M

Manufacturer:

Environnement S.A.
111 Bd. Robespierre
78300 Poissy
France

Test period: October 2011 to August 2012

Date of report: 16 August 2012

Report number: 936/21217807/A

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1. Overview and certification proposal

1.1 Overview

Environnement S.A. have commissioned TÜV Rheinland Energie und Umwelt GmbH to carry out a type approval test of the VOC72M measuring system for component benzene.

The test was performed under consideration of the following Guidelines and Standards:

- VDI 4202, Part 1: Performance criteria for performance tests of automated ambient air measuring systems; Point-related measurement methods for gaseous and particulate air pollutants. September 2010
- VDI 4203, Part 3: Testing of automated measuring systems; Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants. September 2010
- EN 14662-3: Ambient air quality – Standard method for the measurement of benzene concentrations – Part 3: Automated pumped sampling with in situ gas chromatography. May 2005
- prEN 14662-3: Ambient air quality – Standard method for the measurement of benzene concentrations – Part 3: Automated pumped sampling with in situ gas chromatography. November 2011

The measuring system operates according to the standard reference method of gas chromatography for in-situ determination of benzene. The tests were performed in the laboratory and during a three-month field test in Cologne. The tested measuring range was 0 – 50 µg/m³.

The minimum requirements were fulfilled during type approval testing.

TÜV Rheinland Energie und Umwelt GmbH therefore suggests approval as a suitability-tested measuring system for continuous monitoring of benzene concentrations in ambient air.

1.2 Certification proposal

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

Device designation:

VOC72M for Benzene

Manufacturer:

Environnement S.A., Poissy, France

Field of application:

Continuous in-situ determination of benzene concentrations in ambient air

Measuring ranges during performance testing:

Component	Certification range	Unit
Benzene	0 – 50	µg/m³

Software version:

3.0.9

Restrictions:

The permitted ambient temperature range at the installation site of the measuring system is 5 °C to 35 °C.

Notes:

1. Depending on the process, the measuring system might not have a living zero point.
2. The measuring system must be operated within a closable measuring container.
3. The test report is available on the website www.qal1.de.

Test report:

TÜV Rheinland Energie und Umwelt GmbH, Cologne
Report No.: 936/21217807/A of 16 August 2012

1.3 Summary of test results

Performance criterion	Minimum requirement	Test result	Fulfilled	Page
4 Requirements on the instrument design				
4.1 General requirements				
4.1.1 Measured value display	The measuring system shall be equipped with a measured value display.	The measuring system is equipped with a measured value display.	yes	30
4.1.2 Easy maintenance	Maintenance should be possible without larger effort, if possible from outside.	The maintenance works can be performed from the outside with conventional tools in a reasonable time.	yes	31
4.1.3 Functional check	Particular instruments used for this purpose shall be considered as part of the measuring system and be applied in the corresponding sub-tests and included in the assessment.	The tested instrument does not have provisions for performing functional checks.	N/A	32
4.1.4 Set-up times and warm-up times	These shall be specified in the instruction manual.	The set-up and warm-up times were determined.	yes	33
4.1.5 Instrument design	The instruction manual shall include the appropriate specifications.	The instrument design specifications of the instruction manual are complete and correct.	yes	34
4.1.6 Unintended adjustment	It shall be possible to secure the adjustment of the measuring system.	The measuring system itself does not have provisions against unintended or unauthorised adjustment of the instrument parameters. The measuring system shall be locked inside a measurement container.	yes	35
4.1.7 Data output	The output signals shall be provided digitally and/or as analogue signals.	The measured signals can be output as analogue signals (0-1 or 5 V) or digitally (via Ethernet, RS 232, USB).	yes	36

Performance criterion	Minimum requirement	Test result	Fulfilled	Page
5. Performance requirements				
5.1 General	The manufacturer's specifications in the instruction manual shall be by no means better than the results of the performance test.	No specifications in the instruction manual which deviate from the product configuration were observed.	yes	38
5.2 General requirements				
5.2.1 Certification range	Certification ranges shall meet the requirements stated in Table 1 of VDI 4202 Part 1.	On the grounds of the tests performed, the measuring system can be certified within the relevant limit values.	yes	39
5.2.2 Measuring range	The upper limit of measurement shall be greater or equal to the upper limit of the certification range.	By default, a measuring range of 0 – 50 µg/m³ is set. Other measuring ranges of up to 0 – 1.000 µg/m³ can be adjusted. The upper limit of measurement of the AMS is greater than the upper limit of the certification range.	yes	40
5.2.3 Negative output signals	Negative output signals may not be suppressed (life zero).	Due to its principle of operation, the AMS cannot output negative measured signals.	N/A	41
5.2.4 Failure in the mains voltage	Uncontrolled emission of operation and calibration gas shall be avoided; the 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.	After power returns, the AMS resumes operation smoothly and starts the measurement automatically.	yes	42
5.2.5 Operating states	The measuring system shall allow the control of operating states by telemetrically transmitted status signals.	The measuring system can be monitored and operated via modem or router from an external PC.	yes	43
5.2.6 Switch-over	Switch-over between measurement and functional check and/or calibration shall be possible telemetrically.	In principle, all works to be performed in order to check the functionality of the AMS can be monitored and controlled directly on the instrument or telemetrically via remote control.	yes	44
5.2.7 Maintenance interval	Maintenance interval should be three months, if possible, but at least two weeks.	The maintenance interval depends on the amount of necessary maintenance works and has been set to 4 weeks.	yes	45

Performance criterion	Minimum requirement	Test result	Fulfilled	Page
5.2.8 Availability	Availability shall be at least 95 %.	The availability of both instruments amounts to 98.4 %, including the period in which maintenance works required for testing were performed.	yes	46
5.2.9 Instrument software	The version of the instrument software shall be displayed during switch-on. The test institute shall be informed on changes in the instrument software, which have influence on the performance of the measuring system.	The instrument software version is displayed on the AMS. The test institute will be informed in the event of changes to the instrument software.	yes	47
5.3 Test procedures for measuring systems for gaseous air pollutants				
5.3.1 General	Minimum requirements according to VDI 4202 Part 1.	Testing and evaluation was carried out in accordance with the minimum requirements of Guideline VDI 4202 Part 1 (September 2010).	yes	48
5.3.2 Repeatability standard deviation at zero point	The repeatability standard deviation at zero point shall not exceed the requirements of Table 2 of VDI 4202 Part 1 (September 2010) in the certification range according to Table 1 of VDI 4202 Part 1 (September 2010).	The repeatability standard deviation at zero point at 1/10 of the limit value amounts to 0.02 µg/m³ for system 1 (SN 0006) and 0.01 µg/m³ for system 2 (SN 0006).	yes	49
5.3.3 Repeatability standard deviation at reference point	The repeatability standard deviation at reference point shall not exceed the requirements of Table 2 of VDI 4202 Part 1 (September 2010) in the certification range according to Table 1 of VDI 4202 Part 1 (September 2010)..	The repeatability standard deviation at span point amounts to 0.02 µg/m³ for system 1 (SN 0006) and 0.01 µg/m³ for system 2 (SN 0006).	yes	51

Performance criterion	Minimum requirement	Test result	Fulfilled	Page
5.3.4 Linearity (lack of fit)	The analytical function describing the relationship between the output signal and the value of the air quality characteristic shall be linear.	The maximum deviation from the linear regression function is 1.7 % for system 1 (SN: 0005) and 2.1 % for system 2 (SN: 0006).	yes	53
5.3.5 Sensitivity coefficient of sample gas pressure	The sensitivity coefficient of sample gas pressure at reference point shall not exceed the requirements of Table 2 of VDI 4202 Part 1 (September 2010).	The drift check data result in a sensitivity coefficient of surrounding pressure of -0.045 for system 1 (SN 005) and -0.010 for system 2 (SN 006).	N/A	59
5.3.6 Sensitivity coefficient of sample gas temperature	The sensitivity coefficient of sample gas temperature at reference point shall not exceed the requirements of Table 2 of VDI 4202 Part 1 (September 2010).	The sensitivity coefficient of sample gas temperature amounts to 0.012 µg/m³ for system 1 (SN 005) and 0.006 µg/m³ for system 2 (SN 006).	yes	61
5.3.7 Sensitivity coefficient of surrounding temperature	The sensitivity coefficient of surrounding temperature at zero and reference point shall not exceed the requirements of Table 2 of VDI 4202 Part 1 (September 2010).	The permissible surrounding temperature range according to the manufacturer's specifications is 5°C – 35°C. In consideration of the measured values, a maximum sensitivity coefficient of surrounding temperature of -0.0009 µg/m³/K was determined for the zero point and 0.0041 µg/m³/K for the span point.	yes	63

Performance criterion	Minimum requirement	Test result	Fulfilled	Page
5.3.8 Sensitivity coefficient of supply voltage	The sensitivity coefficient of supply voltage shall not exceed the requirements of Table 2 of VDI 4202 Part 1 (September 2010).	In consideration of the measured values, a maximum sensitivity coefficient of supply voltage of -0.0003 µg/m³/V was determined for the zero point and 0.0007 µg/m³/V for the span point.	yes	68
5.3.9 Cross-sensitivity	The change in the measured value caused by interfering components in the sample gas shall not exceed the requirements of Table 2 of VDI 4202 Part 1 (September 2010) at zero and reference point.	An assessment of the cross-sensitivity tests according to the requirements of VDI 4202 Part 1 for ambient air components could not be carried out. This was due to the fact that for benzene measuring systems, tests to be performed at zero point are not carried out at zero but at approx. 1/10 of the limit value. The cross-sensitivity tests were assessed in accordance with Standard EN 14662-3. The results are presented in Section 7.1 8.5.9 Interference.	yes	70
5.3.10 Averaging effect	For gaseous components the measuring system shall allow the formation of hourly averages. The averaging effect shall not exceed the requirements of Table 2 of VDI 4202 Part 1 (September 2010).	Due to the principle of measurement of the AMS tested, this performance criterion is not applicable.	N/A	72
5.3.11 Standard deviation from paired measurements	The standard deviation from paired measurements shall be determined with two identical measuring systems in the field test. It shall not exceed the requirements of Table 2 of VDI 4202 Part 1 (September 2010).	The relative standard deviation from paired measurements under field conditions for component benzene amounts to 0.025 µg/m³.	yes	73

Performance criterion	Minimum requirement	Test result	Fulfilled	Page
5.3.12 Long-term drift	The long-term drift at zero point and reference point shall not exceed the requirements of Table 2 of VDI 4202 Part 1 (September 2010).	The maximum long-term drift amounts to 0.05 µg/m³ at zero point and 2.48 % of the certification range at the span point.	yes	76
5.3.13 Short-term drift	The short-term drift at zero point and reference point shall not exceed the requirements of Table 2 of VDI 4202 Part 1 (September 2010) within 12 h (for benzene 24 h) in the laboratory test and within 24 h in the field test.	The maximum short-term drift amounts to 0.01 µg/m³ at zero point and -0.05 µg/m³ at span point.	yes	79
5.3.14 Response time	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.	See Section 7.1 8.5.10 Carry-over (memory effect).	N/A	82

Performance criterion	Minimum requirement	Test result	Fulfilled	Page
5.3.15 Difference between sample and calibration port	The difference between the measured values obtained by feeding gas at the sample and calibration port shall not exceed the requirements of Table 2 of VDI 4202 Part 1 (September 2010).	N/A	N/A	83
5.3.16 Converter efficiency	In case of measuring systems with a converter, the converter efficiency shall be at least 98 %.	N/A	N/A	84
5.3.17 Increase of NO2 concentration due to residence in the measuring system	In case of NO_X measuring systems the increase of NO_2 concentration due to residence in the measuring system shall not exceed the requirements of Table 2 of VDI 4202 Part 1 (September 2010).	N/A	N/A	85
5.3.18 Overall uncertainty	The expanded uncertainty of the measuring system shall be determined. The value determined shall not exceed the corresponding data quality objectives in the applicable EU Directives on air quality listed in Annex A, Table A1 of VDI 4202 Part 1 (September 2010).	The uncertainty calculation was carried out according to EN 14662-3 (2005) and is presented in Section 7.1 8.7 Total uncertainty calculation according to Section 8.7 of EN 14662-3.	N/A	86
5.4	Requirements on measuring systems for particulate air pollutants			
8.5.3 Lack of fit	The calculation of the linear regression function and residuals shall be performed according to Annex A of EN 14662-3. The largest relative residual from the linear regression function shall meet the following criterion: ± 5 %.	The maximum deviation from the linear regression function amounts to 1.0 % for system 1 and 0.7 % for system 2. The following values were used for the calculation of the total uncertainty: 0.028 for system 1 and 0.020 for system 2.	yes	87

Performance criterion	Minimum requirement	Test result	Fulfilled	Page
8.5.4 Short-term drift	The short-term drift (24 h) shall comply with the following performance criterion: max. 5 % of the applied benzene concentration.	The short-term drift d24h amounts to 0.08 % for system 1 and 0.06 % for system 2. The standard uncertainty due to short-term drift is 0.0079 µg/m³ for system 1 and 0.0065 µg/m³ for system 2.	yes	92
8.5.5 Repeatability	Repeatability shall comply with the performance criterion both at zero (0.3 µg/m³) and at the test concentration limit value (± 5 %).	The repeatability (ri) at 1/10 of the limit value amounts to 0.03 µg/m³ for system 1 and 0.03 µg/m³ for system 2. For repeatability at the limit value the following results were obtained: 0.04 µg/m³ for system 1 and 0.03 µg/m³ for system 2. The values obtained at 1/10 of the limit value which are used as contribution for the total uncertainty calculation are the following: 0.02 µg/m³ for system 1 and 0.01 µg/m³ for system 2. The contributions to the total uncertainty obtained at the limit value amount to 0.02 µg/m³ for system 1 and 0.01 µg/m³ for system 2.	yes	94
8.5.6 Dependence on sample gas pressure	The dependence of sample gas pressure shall not exceed ± 1 %/kPa.	The drift check data result in a sensitivity coefficient of surrounding pressure of 0.045 for system 1 (SN 005) and 0.010 for system 2 (SN 006) For the calculation of the total uncertainty, a value up of 0.038 µg/m³ is used for system 1 (SN 005) and 0.008 µg/m³ for system 2 (SN 006).	yes	97

Performance criterion	Minimum requirement	Test result	Fulfilled	Page
8.5.7 Dependence on surrounding air temperature	The dependence on surrounding air temperature shall not exceed ± 0.2 %/K.	The dependence on surrounding air temperature (bTs) at 1/10 of the limit value amounts to 0.0001 µg/m³ for system 1 and 0.0002 µg/m³ for system 2. At 70 % of the certification range, the dependence on surrounding air temperature amounts to 0.0010 µg/m³ for system 1 and 0.0016 µg/m³ for system 2. The following values obtained at 1/10 of the limit value are used as contribution for the total uncertainty calculation: 0.0010 µg/m³ for system 1 and 0.0019 µg/m³ for system 2. The contributions obtained at 70 % of the certification range amount to 0.0087 µg/m³ for system 1 and 0.0135 µg/m³ for system 2.	yes	99
8.5.8 Dependence on voltage	The dependence on voltage shall not exceed ± 0.2 %/V.	The dependence on voltage (bv) at 1/10 of the limit value amounts to 0.0003µg/m³ for system 1 and 0.0001 µg/m³ for system 2. At 70 % of the certification range, the dependence on voltage amounts to 0.0017 µg/m³ for system 1 and 0.0006 µg/m³ for system 2. The following values obtained at 1/10 of the limit value are used as contribution for the total uncertainty calculation: 0.0029 µg/m³ for system 1 and 0.0014 µg/m³ for system 2. The contributions obtained at 70 % of the certification range amount to 0.0172 µg/m³ for system 1 and 0.0058 µg/m³ for system 2.	yes	104
8.5.9 Interference	The influence of the interferences shall comply with the following performance criteria: Ozone: <± 5 %, relative humidity: <± 4 %, sum of possible interfering organic compounds at span value: <± 5 %.	The following interferences (u) were determined at 1/10 of the limit value: For component ozone, interference amounts to 0,00 µg/m³ for system 1 and 0,00 µg/m³ for system 2. For humidity, interference totals 0,00 µg/m³ for system 1 and 0,00 µg/m³ for system 2. For organic substances, interference was found to be 0,01 µg/m³ for system 1 and 0,001 µg/m³ for system 2. The following interferences (u) were determined at a concentration of 70% of certification range: For component ozone, interference amounts to 0,00 µg/m³ for system 1 and 0,00 µg/m³ for system 2. For humidity, interference totals 0,00 µg/m³ for system 1 and 0,01 µg/m³ for system 2. For organic substances, interference was found to be -0,22 µg/m³ for system 1 and -0,16 µg/m³ for system 2. For the calculation of the total uncertainty, the following	yes	107

		contributions were determined at 70 % of the certification range: For humidity: 0.006 µg/m³ for system 1 and 0.014 µg/m³ for system 2.		

Performance criterion	Minimum requirement	Test result	Fulfilled	Page
8.5.10 Carry-over (memory effect)	The second analysis of zero air immediately following analysis of the highest concentration of benzene shall not exceed a measured benzene concentration of 0.5 µg/m³ (10 % of limit value).	The minimum requirement was fulfilled. The VOC72M measuring system outputs a value close to 10 % of the limit value even during the first zero analysis after the change in sample gas.	yes	115
8.6.5 Long-term drift	The long-term drift at span value shall not exceed 10 %.	The maximum long-term drift d14d amounts to 2.35 % for system 1 and 2.53 % for system 2. The associated uncertainty ud calculation resulted in a maximum value of 0.23 µg/m³ for system 1 and 0.25 µg/m³ for system 2.	yes	117
8.6.6 Maintenance interval	The maintenance interval shall be at least two weeks.	The maintenance interval depends on the amount of necessary maintenance works and has been set to 4 weeks.	yes	120
8.6.7 Availability	The availability shall be greater than 90 %.	The availability of both instruments amounts to 100 %, excluding the period in which maintenance works required for testing were performed.	yes	121
8.6.8 Reproducibility standard deviation under field conditions	The reproducibility standard deviation under field conditions shall not exceed ± 0.25 µg/m³.	The standard uncertainty corresponding to the reproducibility in the field amounts to 0.025 µg/m³ for component benzene.	yes	123

2. Task Definition

2.1 Nature of Test

Environnement S.A. have commissioned TÜV Rheinland Energie und Umwelt GmbH to carry out a complete type approval test of the VOC72M measuring system.

2.2 Objective

The measuring system shall be capable of determining the benzene content in ambient air within a concentration range of 0 - 50 µg/m³.

The test was carried out applying the current legislation for performance testing and under consideration of the latest developments.

Testing was conducted in compliance with the following Standards and Directives:

- VDI 4202, Part 1: Performance criteria for performance tests of automated ambient air measuring systems; Point-related measurement methods for gaseous and particulate air pollutants. September 2010
- VDI 4203, Part 3: Testing of automated measuring systems; Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants. September 2010
- EN 14662-3: Ambient air quality – Standard method for the measurement of benzene concentrations – Part 3: Automated pumped sampling with in situ gas chromatography. May 2005
- *prEN 14662-3: Ambient air quality – Standard method for the measurement of benzene concentrations – Part 3: Automated pumped sampling with in situ gas chromatography. July 2012

* The requirements and assessment procedures of the current Standard were compared to those of the new draft. In case of inconsistency, both assessment procedures were used. The calculation of the overall uncertainty was carried out with the data assessed according to the Standard version in use at the time of preparation of this report.

3. Description of the AMS tested

3.1 Measuring principle

The VOC72M ambient air measuring system is an analyser of volatile organic compounds. The functional principle of this system is based on gas chromatography for the separation of the measured compounds coupled with photo-ionisation detection.

Figure 1: Illustration of the VOC72M measuring system

The sampling is achieved with a gas trap filled with a specific sorbent. 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.

At the end of the sampling cycle, the trap is connected to the gas chromatography column and quickly heated (35 to 380°C within 2 seconds). 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) for flushing all the 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 a small electric signal. This signal is amplified and digitised in the electrometer board available in 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 the compound. The peak area is corrected with a volume calculation 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.

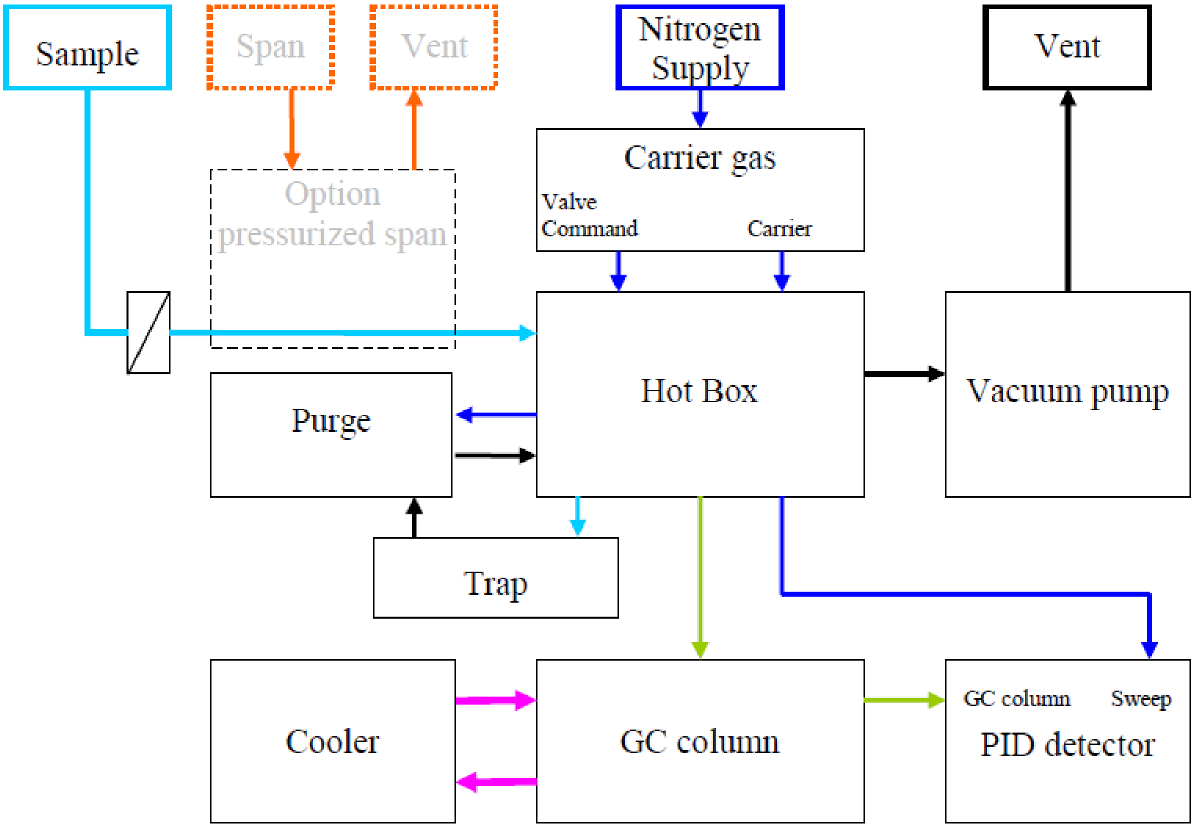


Figure 2: Flow chart of VOC72M

3.2 AMS scope and set-up

The VOC72M ambient air measuring system consists of only a compact enclosure. The system is operated through a display on the front panel of the instrument. The user can recall measurement data and device information, change parameters as well as carry out tests for controlling the functionality of the measuring system.

(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) Column pressure sensor, (11) Nitrogen input pressure sensor, (12) Proportionnal solenoid valve, (13) Pilot solenoid valve, (14) Photo-ionization detector (PID), (15) Internal cooling fan, (16) Thermo cooler, (17) Expansion tank, (18) Cooling pump, (19) USB socket, (20) Ethernet socket, (21) Power 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) ARM7 data board, (31) purge assembly, (32) heat sink.

Figure 3: Internal view of VOC72M

Table 1 contains a list of important technical characteristics of the VOC72M measuring system.

Table 1: Technical characteristics of VOC72M (manufacturer's specifications)

Measuring range	Maximum 1000 µg/m³ (programmable)
Units	ppb or µg/m³ (programmable)
Measured compounds	Benzene (tested), additionally: toluene, ethene benzene, m+p-xylene, o-xylene (not tested for suitability)
Cycle duration	15 min during performance testing, further intervals are programmable
Sample flow	50 ml/minute
Trap flow; trap volume	12 ml/minute; 165 ml/cycle
Flow control	Integrated vacuum pump + heated micro capillary tube
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 Detector temperature	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 inputs 0 – 2.5 V
Ethernet port	RJ45 socket, UDP protocol
Mains voltage	100 – 240 V + ground; 50 – 60 Hz
Power demand	Average 130 VA, peak 200 VA
Gas supply	Nitrogen 6.0; 3.2 ± 0.2 bar; 15 ml/minute
Dimensions (L x I x H) / Weight	606 x 483 x 133 mm / 12.5 kg

4. Test program

4.1 General

Type approval testing was carried out with two identical instruments with serial numbers

SN: 0005 and **SN: 0006**.

Software version 3.0.9 was installed on the instruments at the time of testing.

The test consisted of a laboratory test for determining the performance characteristics and a field test carried out over several months.

Under the title corresponding to each performance criterion in this report, the minimum requirement is provided with number and wording according to the applicable directives [1, 2, 3, 4].

4.1 Laboratory test

The laboratory test was carried out with two identical devices of the type VOC72M with serial numbers SN 0005 and SN 0006. In conformity with Directives [2, 3], the following performance criteria were tested in the laboratory:

- Description of the AMS tested
- General requirements
- Lack of fit
- Short-term drift
- Repeatability
- Dependence on sample gas pressure
- Dependence on surrounding air temperature
- Dependence on voltage
- Interference
- Carry-over (memory effect)

The measured values were recorded with an external data logger.

Section 6 describes the results of the laboratory test.

4.3 Field test

The field test was carried out with two identical measuring systems. These were:

System 1:	SN 005
System 2:	SN 006

The following performance criteria were tested in the field:

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

5. Reference measuring method

For type approval tests of gas chromatographs it must be ensured that the employed test gases can be traced back to a reference standard.

During the test, benzene test gas was generated with help of a permeation oven manufactured by MCZ. In order to validate the generated benzene concentration and to determine the permeation rate of the permeation tube used in the oven, the change of mass of the permeation tube located in the oven under constant temperature and purge air conditions was determined at regular time intervals.

This gravimetric determination of the permeation rate was carried out before and during the type approval test.

Date	Time		Weight [g]	Difference [g]	Minutes	Perm.-rate [g/min]	**Perm.-rate [ng/min]**
04.07.2011	16:05	04.07.2011 16:05	21,03092				
02.08.2011	16:24	02.08.2011 16:24	21,00341	0,02751	41779	6,58465E-07	**658,464779**
02.08.2011	16:24	02.08.2011 16:24	21,00341				
02.09.2011	12:15	02.09.2011 12:15	20,97289	0,03052	44391	6,87527E-07	**687,526751**
02.09.2011	12:15	02.09.2011 12:15	20,97289				
04.10.2011	17:23	04.10.2011 17:23	20,94256	0,03033	46388	6,53833E-07	**653,832888**
04.10.2011	13:20	04.10.2011 13:20	20,94256				
03.11.2011	08:32	03.11.2011 08:32	20,91411	0,02845	42912	6,62985E-07	**662,984713**
03.11.2011	08:32	03.11.2011 08:32	20,91411				
05.12.2011	09:37	05.12.2011 09:37	20,88189	0,03222	46145	6,98234E-07	**698,233828**
05.12.2011	09:37	05.12.2011 09:37	20,88189				
09.01.2012	17:16	09.01.2012 17:16	20,84878	0,03311	50859	6,51016E-07	**651,015553**
09.01.2012	17:16	09.01.2012 17:16	20,84878				
02.02.2012	14:15	02.02.2012 14:15	20,82575	0,02303	34379	6,69886E-07	**669,885686**
02.02.2012	14:15	02.02.2012 14:15	20,82575				
05.03.2012	15:25	05.03.2012 15:25	20,79556	0,03019	46150	6,54171E-07	**654,171181**
05.03.2012	15:25	05.03.2012 15:25	20,79556				
05.04.2012	09:30	05.04.2012 09:30	20,76653	0,02903	44285	6,55527E-07	**655,526702**
05.04.2012	09:30	05.04.2012 09:30	20,76653				
02.05.2012	12:15	02.05.2012 12:15	20,74112	0,02541	39045	6,50788E-07	**650,787553**

Average Permeation-rate: **664,24296** [ng/min]

Standard deviation 16,3507 [ng/min]

Standard deviation in % 2,46

Table 2: Uncertainty of the employed benzene test gas

6. Test results corresponding to the requirements of VDI 4203 Part 3

6.1 4.1.1 Measured value display

The measuring system shall be fitted with a measured value display.

6.2 Equipment

No additional equipment is required.

6.3 Method

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

6.4 Evaluation

The measuring system is equipped with a measured value display.

6.5 Assessment

The measuring system is equipped with a measured value display.

Minimum requirement fulfilled? yes

6.6 Detailed presentation of test results

Figure 1 on page 24 shows the measuring system including its display.

6.1 4.1.2 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 Method

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

6.4 Evaluation

The following maintenance works shall be carried out by the user:

1. Examination of the operating status of the instrument
   The operating status of the instrument can be visually monitored and controlled on the display of the measuring system.
2. Regular checks of the nitrogen nominal pressure
3. Zero and span point checks (once a month)

6.5 Assessment

The maintenance works can be performed from the outside with conventional tools in a reasonable time.

Minimum requirement fulfilled? yes

6.6 Detailed presentation of test results

Maintenance was performed during the test in accordance with the tasks and procedures specified in the instruction manuals. No complications were observed during performance of maintenance works in compliance with the instructions. All tasks were carried out smoothly with conventional tools.

6.1 4.1.3 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.
Test gas units included in the measuring system shall indicate their operational readiness to the measuring system by a status signal and shall provide direct as well as remote control via the measuring system.

6.2 Equipment

The instruction manual was used to test this performance criterion.

6.3 Method

The tested instrument does not have provisions for performing functional checks. The operating status of the instrument is continuously being monitored and malfunctions are displayed by means of a series of status signals.

A functional check of the instrument was performed with help of external test gas feedings.

6.4 Evaluation

The current operating status of the instrument is continuously being monitored and malfunctions are displayed by means of a series of status signals.

An external zero and span point check is possible by using test gases.

6.5 Assessment

The tested instrument does not have provisions for performing functional checks.

Minimum requirement fulfilled? N/A

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 4.1.4 Set-up times and warm-up times

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

6.2 Equipment

A clock was used to test this performance criterion.

6.3 Method

The measuring systems were put into operation in accordance with the manufacturer's descriptions. The set-up times and warm-up times needed were measured separately.

Required constructional measures carried out prior to the installation, e.g. the set-up of an aperture on the container ceiling, were not assessed.

6.4 Evaluation

The instruction manual does not contain specifications regarding set-up times. They depend on the situation at the installation site as well as on the on-site power supply. Since the VOC72M measuring system is a compact analyser, the set-up times consist mainly of:

- The establishment of power supply
- The piping (nitrogen, sampling, venting)
- The establishment of nitrogen supply (N_2, purity: 6.0, nominal pressure: 3.2 bar)

A set-up time of 1.5 h was determined during various changes of location (installation and dismounting at the climatic chamber) as well as during installation at the field test site.

A warm-up time of 15 min is specified in the instruction manual. This time is necessary for warming up the "Hot Box" and the detector, as was observed during the test. When switched on from a cold state, the instrument requires approx. 4-10 measurement cycles (approx. 1 – 2h) until the reading has stabilised.

The measuring system shall be installed in conditions that avoid its being affected by the weather, e.g. in an air-conditioned measurement container.

6.5 Assessment

The set-up and warm-up times were determined.

The measuring system can be used at different measurement sites with manageable effort. The set-up time is approx. 1.5 h and the warm-up time, 1.5 – 2.5 h, depending on the stabilisation time needed.

Minimum requirement fulfilled? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 4.1.5 Instrument design

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

6.2 Equipment

A measuring system for the determination of the power consumption and a balance were used to test this performance criterion.

6.3 Method

The set-up of the devices provided was compared with the description in the instruction manuals. The power consumption specified was determined over 24 h during normal operation in the field test.

6.4 Evaluation

The measuring system shall be installed horizontally (e.g. on a bench or a rack), in conditions that avoid its being affected by the weather. The temperature at the installation site shall lie within the temperature range 5°C – 35°C.

The dimensions and weight of the measuring system coincide with the description of the instruction manual.

The manufacturer has specified a maximum power consumption of approx. 120 W (peaks in energy demand of up to 200 W). The total power consumption of the measuring system was determined over a 24-hour-test. The specified values were not exceeded at any point.

6.5 Assessment

The instrument design specifications of the instruction manual are complete and correct.

Minimum requirement fulfilled? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 4.1.6 Unintended adjustment

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

6.2 Equipment

No additional equipment is required.

6.3 Method

The measuring system is operated through the display on the front panel or via the RS232 / Ethernet interface of an external PC, which is connected directly to the instrument.

The instrument does not have internal provisions against unintended or unauthorised adjustment (password protection). However, a change of parameters or adjustment of the sensors is only possible by entering a series of key sequences and confirming the changes. An unintended adjustment is therefore not possible.

Since the measuring system cannot be installed outdoors, protection against unauthorised adjustment is ensured by installing the instrument at sites with restricted access to prevent unauthorised people entering (e.g. a locked measurement container).

6.4 Evaluation

Instrument parameters which have an influence on the measurement characteristics can only be changed by entering elaborate key sequences by hand (up/down menu) and confirming the changes. An unintended adjustment is therefore not possible.

In order to ensure protection from unauthorised adjustment, the instrument shall be installed at a site with restricted access (measurement container / measurement cabinet).

6.5 Assessment

The measuring system itself does not have provisions against unintended or unauthorised adjustment of the instrument parameters. The measuring system shall be locked inside a measurement container.

Minimum requirement fulfilled? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 4.1.7 Data output

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

6.2 Equipment

A PC with the software “CemVoc” was used to test this performance criterion.

6.3 Method

The test was carried out using a PC with the software “CemVoc” (via Ethernet).

The measuring system was connected via Ethernet to a PC, to which the data were downloaded. At the same time, the data were saved on a USB-stick via USB interface (as is customary during the test). The test consisted of a comparison between both data records.

In addition, the measuring system offers the possibility of outputting data as analogue signals (max. 4 analogue outputs) or as measured signals / communication via serial interface RS232 or RS422.

6.4 Evaluation

The measured signals are transmitted through the following ports on the rear panel:

Analogue:	0 / 4 to 20 mA or 0 to 1 /10 V	selectable concentration range
Digital:	RS 232 / RS 422 interface	
	USB	

The measured values transmitted via Ethernet equal those downloaded via USB interface.

6.5 Assessment

The measured signals can be output as analogue signals (0-1 or 5 V) or digitally (via Ethernet, RS 232, USB).

It is possible to connect additional measuring and peripheral devices through the respective ports (e.g. analogue inputs).

Minimum requirement fulfilled? yes

6.6 Detailed presentation of test results

Figure 4 shows the rear panel containing the respective data outputs.

(1) Empty slot for the optional Estel, Sorel, or RS4I boards, (2) mains fuse, (3) cooling fan exhaust, (4) Input filter assembly screw, (5) sample port for 4mm OD (overall diameter) tube, (6) nitrogen port for 1/8" OD tube, (7) vent port for 4mm OD tube, (8) heat sink cooling fan, (9) USB socket, (10) Ethernet socket, (11) identification plate, (12) power socket.

Figure 4: View of rear panel of VOC72M

6.1 5.1 General

The manufacturer's specifications in the instruction manual shall be by no means better than the results of the performance test.

6.2 Equipment

No additional equipment is required.

6.3 Method

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

6.4 Evaluation

Specifications included in the first draft of the instruction manual that deviate from the actual product configuration were corrected.

6.5 Assessment

No specifications in the instruction manual which deviate from the product configuration were observed.

Minimum requirement fulfilled? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 5.2.1 Certification range

The certification range intended for testing shall be determined.

6.2 Equipment

No additional equipment is required.

6.3 Method

The certification range intended for testing was determined.

6.4 Evaluation

Guideline VDI 4202 Part 1 and Standard EN 14662 Part 3 specify the following minimum requirements on certification ranges for continuous ambient air monitoring systems for component benzene:

Table 3: Certification ranges according to VDI 4202-1

Measured component	Lower limit of CR	Upper limit of CR	Limit value	Assessment period
	in µg/m³	in µg/m³	in µg/m³	
Benzene	0	50	5	Calendar year

Table 4: Certification ranges according to EN 14662-3

Measured component	Lower limit of CR	Upper limit of CR	Limit value	Assessment period
	in µg/m³	in µg/m³	in µg/m³	
Benzene	0.5	50	5	Calendar year

Due to its principle of operation, the measuring system cannot display values that are smaller than zero. Therefore, all tests have been carried out according to the requirements of EN 14662-3, which specify a test gas nominal value of 0.5 µg/m³. This allows for determining negative drifts of the measured signals at zero point.

6.5 Assessment

On the grounds of the tests performed, the measuring system can be certified within the relevant limit values.

Minimum requirement fulfilled? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 5.2.2 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

No additional equipment is required.

6.3 Method

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

6.4 Evaluation

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

Max. possible measuring range:	1000 µg/m³
Upper limit of certification range:	50 µg/m³

6.5 Assessment

By default, a measuring range of 0 – 50 µg/m³ is set. Other measuring ranges of up to 0 – 1.000 µg/m³ can be adjusted.

The upper limit of measurement of the AMS is greater than the upper limit of the certification range.

Minimum requirement fulfilled? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 5.2.3 Negative output signals

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

6.2 Equipment

No additional equipment is required.

6.3 Method

It was checked both in the laboratory and in the field whether the measuring system indicates negative measured values.

6.4 Evaluation

Due to its principle of operation, the measuring system cannot display values that are smaller than zero. Therefore, all tests have been carried out according to the requirements the current Standards, which specify a test gas concentration of 0.5 µg/m³. This allows for determining negative influences on the measured signals.

6.5 Assessment

Due to its principle of operation, the AMS cannot output negative measured signals.

Minimum requirement fulfilled? N/A

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 5.2.4 Failure in the mains voltage

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

6.2 Equipment

No additional equipment is required.

6.3 Method

It was checked by simulating a failure in the mains voltage, whether the instrument stays undamaged and is ready to measure after power returns.

6.4 Evaluation

In the event of a power outage, the measuring system enters the warm-up phase after power returns. The warm-up times depend on the ambient conditions at the site of installation as well as on the thermic state of the instrument upon switch-on. After warm-up, the instrument switches to the operating mode that was active before the outage.

An uncontrolled emission of operating materials (in this case N_2 carrier gas) was not observed.

6.5 Assessment

After power returns, the AMS resumes operation smoothly and starts the measurement automatically.

Minimum requirement fulfilled? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 5.2.5 Operating states

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

6.2 Equipment

A PC was used for recording data.

6.3 Method

The measuring system was connected via Ethernet to a PC. It was checked whether the data, including the status signals, are transferred correctly.

Remote monitoring and operation is possible via router or modem.

6.4 Evaluation

It is possible to perform a comprehensive control and operation of the measuring system telemetrically using a variety of connections (Ethernet, RS232).

6.5 Assessment

The measuring system can be monitored and operated via modem or router from an external PC.

Minimum requirement fulfilled? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 5.2.6 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

No additional equipment is required.

6.3 Method

The measuring system can be monitored and operated manually on the instrument itself or telemetrically via remote control.

6.4 Evaluation

All operation procedures that do not require a manual input can be monitored and controlled by the personnel directly on the instrument or telemetrically via remote control.

6.5 Assessment

In principle, all works to be performed in order to check the functionality of the AMS can be monitored and controlled directly on the instrument or telemetrically via remote control.

Minimum requirement fulfilled? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 5.2.7 Maintenance interval

The maintenance 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

No additional equipment is required.

6.3 Method

This test consisted of determining the maintenance work and the corresponding time intervals necessary for a correct functioning of the measuring system. Furthermore, the results on the determination of zero and span point drift described in Section 6.1 5.3.12 Long-term drift were considered in the evaluation of this performance criterion.

6.4 Evaluation

All drifts observed during the field test lay within the permissible limits. Therefore, the maintenance interval depends solely on the tasks to be performed during maintenance.

During operating time, maintenance can be limited to contamination checks, plausibility checks and possible status/error messages.

6.5 Assessment

The maintenance interval depends on the amount of necessary maintenance works and has been set to 4 weeks.

Minimum requirement fulfilled? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 5.2.8 Availability

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

6.2 Equipment

No additional equipment is required.

6.3 Method

The start and end times of the availability tests correspond to the start and end of the field test at the four field test sites. All interruptions of testing, e.g. malfunctions or maintenance, were documented.

6.4 Evaluation

The field test was carried out from 13 January 2012 to 27 April 2012. This amounts to a total measurement time of 104 days. Table 5 presents a summary of the operating, maintenance, and outage times.

No malfunctions were observed.

6.5 Assessment

The availability of both instruments amounts to 98.4 %, including the period in which maintenance works required for testing were performed.

Minimum requirement fulfilled? yes

6.6 Detailed presentation of test results

Table 5: Determination of the availability

		System 1 (SN 0005)	System 2 (SN 0006)
Total operating time	h	2520	2520
Outage time	h	0	0
Maintenance	h	39	39
Actual operation	h	2481	2481
Availability	%	98.4	98.4

6.1 5.2.9 Instrument software

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

6.2 Equipment

No additional equipment is required.

6.3 Method

It was checked, whether the instrument software is displayed on the measuring system. The manufacturer was made aware that any change to the instrument software has to be informed to the test institute.

6.4 Evaluation

The current software is displayed on the measuring system during switch-on. Moreover, it can be reviewed any time on the configuration menu.

The test was carried out with the software version 3.0.9 (status of 2012).

6.5 Assessment

The instrument software version is displayed on the AMS. The test institute will be informed in the event of changes to the instrument software.

Minimum requirement fulfilled? yes

6.6 Detailed presentation of test results

Figure 5: Display of software version (3.0.9) on the start menu

6.1 5.3.1 General

The tests are carried out in accordance with the requirements of Guideline VDI 4202 Part 1 (September 2010).

6.2 Equipment

No additional equipment is required.

6.3 Method

The test was carried out in accordance with the requirements of Guideline VDI 4202 Part 1 (September 2010).

6.4 Evaluation

After a comprehensive revision, Guidelines VDI 4202 Part 1 and VDI 4203 Part 3 were reissued in September 2010. The minimum requirements listed in Table 2 a/b of the above mentioned Directive serve as basis for the evaluation of these tests.

6.5 Assessment

Testing and evaluation was carried out in accordance with the minimum requirements of Guideline VDI 4202 Part 1 (September 2010).

Minimum requirement fulfilled? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 5.3.2 Repeatability standard deviation at zero point

The repeatability standard deviation at zero point shall not exceed the requirements of Table 2 of Guideline VDI 4202 Part 1 (September 2010) in the certification range according to Table 1 of Guideline VDI 4202 Part 1 (September 2010).

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

Note: For benzene the performance criterion is related to the repeatability r.

The repeatability standard deviation shall not exceed 0.3 µg/m³.

6.2 Equipment

Zero and test gases of suitable concentrations were used for testing this performance criterion.

6.3 Method

Zero and test gas were fed alternately for testing purposes. For benzene, 10 repetitions were required.

Since the benzene analyser VOC72M cannot display negative values, this test was carried out with a test gas concentration of approx. 1/10 of the limit value = 0.5 µg/m³, as specified in Standard EN 14662-3.

6.4 Evaluation

The repeatability standard deviation at zero point was calculated according to the following equation:

$$s_{r,zp} = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \bar{y})^2}{n-1}}$$

where:

$s_{r,zp}$ = repeatability standard deviation in µg/m³ or nmol/mol

y_i = *i*th output signal in µg/m³ or nmol/mol

$\bar{y}$ = average of the output signals

n = number of measurements

6.5 Assessment

The repeatability standard deviation at zero point at 1/10 of the limit value amounts to 0.02 µg/m³ for system 1 (SN 0006) and 0.01 µg/m³ for system 2 (SN 0006).

Minimum requirement fulfilled? yes

6.6 Detailed presentation of test results

Table 6: Repeatability standard deviation at zero point for component benzene at 1/10 of the limit value

Laboratory		**Zero point**	
Date	**Time**	**System 1 (0005)**	**System 2 (0006)**
		[µg/m³]	**[µg/m³]**
05 NOV 2011	07:37 - 08:37	0.52	0.48
05 NOV 2011	09:37 - 10:37	0.54	0.49
05 NOV 2011	11:37 - 12:37	0.54	0.50
05 NOV 2011	13:37 - 14:37	0.54	0.50
05 NOV 2011	15:37 - 16:37	0.56	0.48
05 NOV 2011	17:37 - 18:37	0.51	0.48
05 NOV 2011	19:37 - 20:37	0.52	0.48
05 NOV 2011	21:37 - 22:37	0.52	0.50
05 NOV 2011	23:37 - 00:37	0.52	0.50
06 NOV 2011	01:37 - 02:37	0.54	0.51
Number of measurements (n)		10	10
Average		0.53	0.49
Standard deviation (sr)		**0.02**	**0.01**
Requirement of VDI 4202-1		0.30	0.30
Requirement fulfilled?		yes	yes

6.1 5.3.3 Repeatability standard deviation at reference point

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

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

The repeatability standard deviation shall not exceed 5 % in relation to the span value (limit value = 5.0 µg/m³). This equals a maximum repeatability standard deviation of 0.25 µg/m³.

6.2 Equipment

Zero and test gases of suitable concentrations were used for testing this performance criterion.

6.3 Method

Zero and test gas were fed alternately for testing purposes. For benzene, 10 repetitions were required.

The test was carried out with a test gas concentration c_t at the limit value = 5.0 µg/m³.

6.4 Evaluation

The repeatability standard deviation at span point was calculated according to the following equation:

$$s_{r,rp} = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \bar{y})^2}{n-1}}$$

where:

$s_{r,rp}$ = repeatability standard deviation in µg/m³ or nmol/mol

y_i = *i*th output signal in µg/m³ or nmol/mol

$\bar{y}$ = average of the output signals

n = number of measurements

6.5 Assessment

The repeatability standard deviation at span point amounts to 0.02 µg/m³ for system 1 (SN 0006) and 0.01 µg/m³ for system 2 (SN 0006).

Minimum requirement fulfilled? yes

6.6 Detailed presentation of test results

Table 7: Repeatability standard deviation at the limit value for component benzene

Laboratory		**Span point**	
Date	**Time**	**System 1 (0005)**	**System 2 (0006)**
		[µg/m³]	**[µg/m³]**
05 NOV 2011	08:38 - 09:37	5.06	5.01
05 NOV 2011	10:37 - 11:37	5.08	5.02
05 NOV 2011	12:37 - 13:37	5.04	5.01
05 NOV 2011	14:37 - 15:37	5.08	5.00
05 NOV 2011	16:37 - 17:37	5.04	5.02
05 NOV 2011	18:37 - 19:37	5.05	5.04
05 NOV 2011	20:37 - 21:37	5.05	5.02
05 NOV 2011	22:37 - 23:37	5.06	5.02
06 NOV 2011	00:37 - 01:37	5.04	5.04
06 NOV 2011	02:37 - 03:37	5.02	5.02
Number of measurements (n)		10	10
Average		5.05	5.02
Standard deviation (sr)		**0.02**	**0.01**
Requirement of VDI 4202-1		0.25	0.25
Requirement fulfilled?		yes	yes

6.1 5.3.4 Linearity (lack of fit)

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

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

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

6.2 Equipment

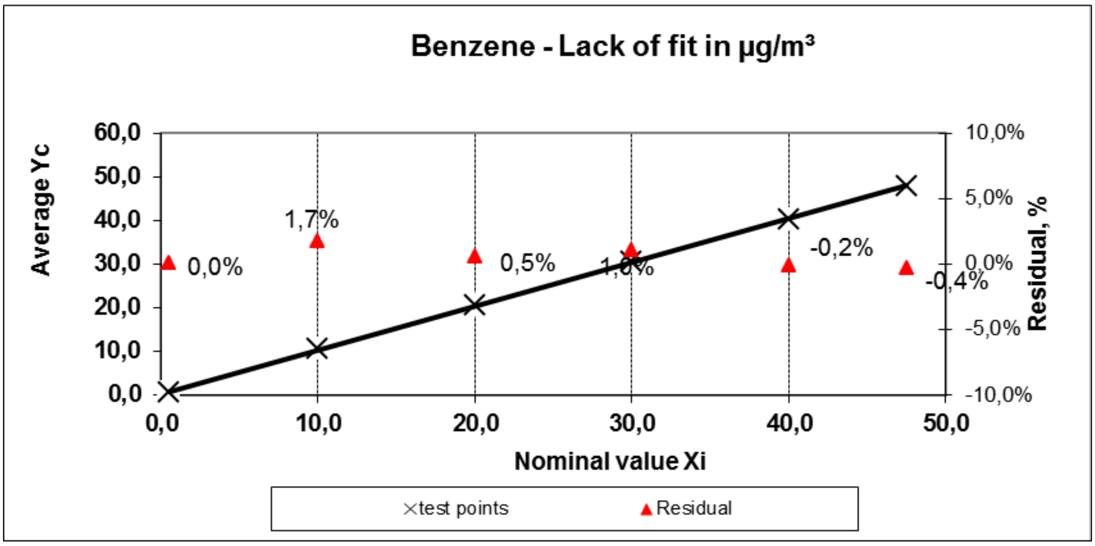
Zero and test gases of suitable concentrations as well as a gas mixing unit were used to test this performance criterion.

6.3 Method

The test was performed in the range 0 % – 95 % of the maximum of the certification range with at least six concentrations, including zero point (here: 0.5 µg/m³). At least five independent readings were obtained at each concentration.

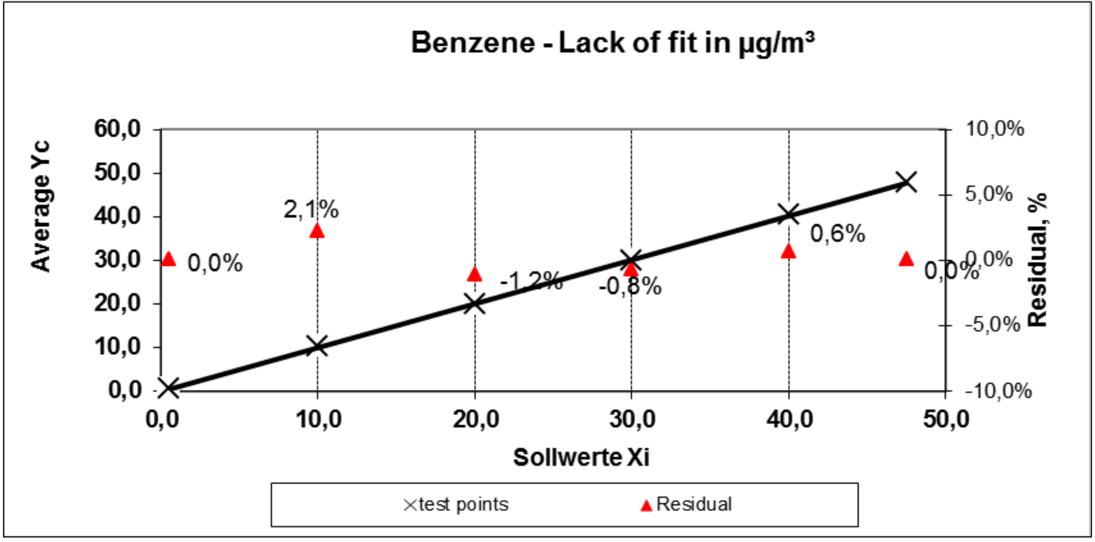
The concentrations were applied in the following sequence: 80 %, 40 %, 0 %, 60 %, 20 % and 95 %.

6.4 Evaluation



The permissible deviation range of the residuals dcrel is ± 5 % in relation to the measured value.

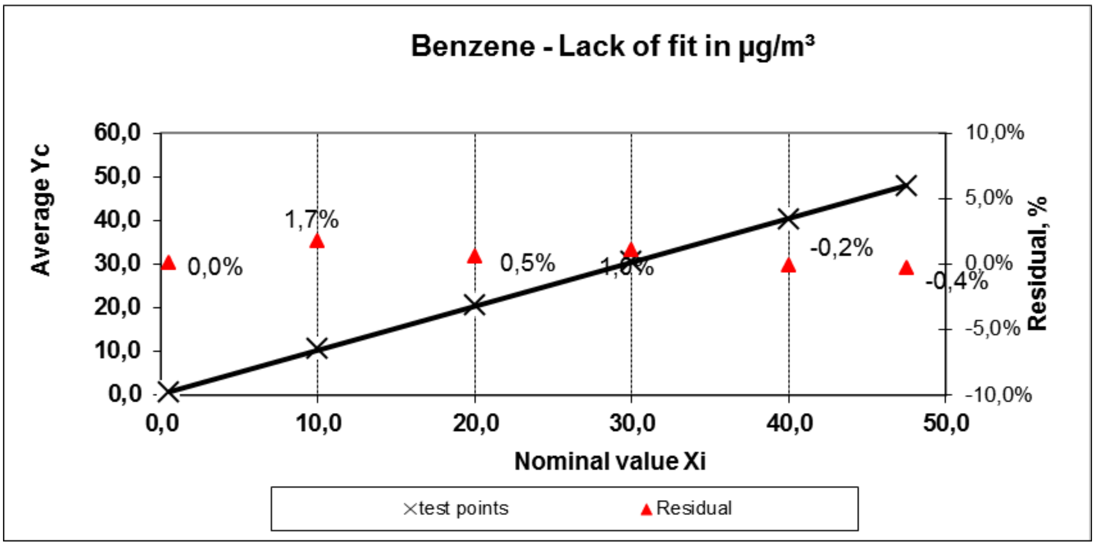
Figure 6 and



The **permissible deviation range of the residuals dcrel is ± 5 % in relation to the measured value.**

Figure 7 present the deviations from the linear regression function in graphic and tabular form.

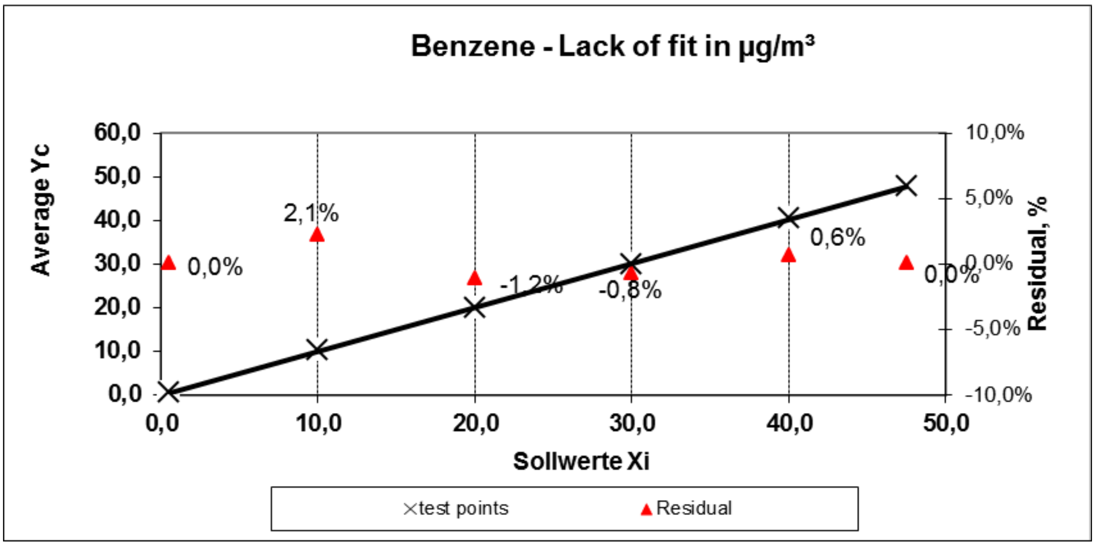
Linearity test	**Measuring range**		**50**	**µg/m³**	**Benzene**		
Concentrations	**Benzene**	**80%**	**40%**	**0%**	**60%**	**20%**	**95%**
Nominal value	µg/m³	40.000	20.000	0.501	30.000	10.000	47.500
Reading Yi 1	µg/m³	40.335	20.522	0.515	30.673	10.516	47.589
Reading Yi 2	µg/m³	40.338	20.564	0.518	30.655	10.497	47.704
Reading Yi 3	µg/m³	40.311	20.124	0.526	30.669	10.512	47.721
Reading Yi 4	µg/m³	40.308	20.698	0.521	30.664	10.495	47.763
Reading Yi 5	µg/m³	40.330	20.349	0.514	30.666	10.467	47.772
Average Yc	µg/m³	40.324	20.451	0.519	30.665	10.497	47.710
Residuals dc	µg/m³	-0.07	0.10	-0.29	0.29	0.17	-0.20
Residuals (d$_{r)c}$	%	**-0.2%**	**0.5%**	**0.0%**	**1.0%**	**1.7%**	**-0.4%**



The permissible deviation range of the residuals dc$_{rel}$ is ± 5 % in relation to the measured value.

Figure 6: Deviation from the linear regression function, system 1

Linearity test	**Measuring range**		**50**	**µg/m³**	**Benzene**		
Concentrations	**Benzene**	**80%**	**40%**	**0%**	**60%**	**20%**	**95%**
Nominal value	µg/m³	40.000	20.000	0.500	30.000	10.000	47.500
Reading Yi 1	µg/m³	40.465	19.958	0.498	29.909	10.251	47.781
Reading Yi 2	µg/m³	40.438	19.856	0.483	29.931	10.248	47.759
Reading Yi 3	µg/m³	40.505	19.639	0.507	29.924	10.250	47.794
Reading Yi 4	µg/m³	40.444	19.876	0.509	29.931	10.254	47.767
Reading Yi 5	µg/m³	40.481	19.963	0.499	29.944	10.258	47.786
Average Yc	µg/m³	40.467	19.858	0.499	29.928	10.252	47.777
Residuals dc	µg/m³	0.24	-0.24	0.01	-0.23	0.21	0.01
Residuals $(d_r)_c$	%	**0.6%**	**-1.2%**	**0.0%**	**-0.8%**	**2.1%**	**0.0%**



The permissible deviation range of the residuals dc_{rel} is ± 5 % in relation to the measured value.

Figure 7: Deviation from the linear regression function, system 2

6.5 Assessment

The maximum deviation from the linear regression function is 1.7 % for system 1 (SN: 0005) and 2.1 % for system 2 (SN: 0006).

Minimum requirement fulfilled? yes

6.6 Detailed presentation of test results

The individual results of this test are presented in Table 8 and Table 9.

Table 8: Individual results of lack of fit test, system 1

Concentration	Date	Time	Reading [µg/m³]	Nominal value [µg/m³]	Deviation [µg/m³]
80%	10 NOV 2011	11:22	40.335	40.000	0.335
80%	10 NOV 2011	11:37	40.338	40.000	0.338
80%	10 NOV 2011	11:52	40.311	40.000	0.311
80%	10 NOV 2011	12:07	40.308	40.000	0.308
80%	10 NOV 2011	12:22	40.330	40.000	0.330
40%	10 NOV 2011	13:37	20.522	20.000	0.522
40%	10 NOV 2011	13:52	20.564	20.000	0.564
40%	10 NOV 2011	14:07	20.124	20.000	0.124
40%	10 NOV 2011	14:22	20.698	20.000	0.698
40%	10 NOV 2011	14:37	20.349	20.000	0.349
0%	10 NOV 2011	15:52	0.515	0.500	0.015
0%	10 NOV 2011	16:07	0.518	0.500	0.018
0%	10 NOV 2011	16:22	0.526	0.500	0.026
0%	10 NOV 2011	16:37	0.521	0.500	0.021
0%	10 NOV 2011	16:52	0.514	0.500	0.014
60%	11 NOV 2011	07:07	30.673	30.000	0.673
60%	11 NOV 2011	07:22	30.655	30.000	0.655
60%	11 NOV 2011	07:37	30.669	30.000	0.669
60%	11 NOV 2011	07:52	30.664	30.000	0.664
60%	11 NOV 2011	08:07	30.666	30.000	0.666
20%	11 NOV 2011	09:22	10.516	10.000	0.516
20%	11 NOV 2011	09:37	10.497	10.000	0.497
20%	11 NOV 2011	09:52	10.512	10.000	0.512
20%	11 NOV 2011	10:07	10.495	10.000	0.495
20%	11 NOV 2011	10:22	10.467	10.000	0.467
95%	11 NOV 2011	11:22	47.589	47.500	0.089
95%	11 NOV 2011	11:37	47.704	47.500	0.204
95%	11 NOV 2011	11:52	47.721	47.500	0.221
95%	11 NOV 2011	12:07	47.763	47.500	0.263
95%	11 NOV 2011	12:22	47.772	47.500	0.272

Table 9: Individual results of lack of fit test, system 2

Concentration	Date	Time	Reading [µg/m³]	Nominal value [µg/m³]	Deviation [µg/m³]
80%	10 NOV 2011	11:22	40.465	40.000	0.465
80%	10 NOV 2011	11:37	40.438	40.000	0.438
80%	10 NOV 2011	11:52	40.505	40.000	0.505
80%	10 NOV 2011	12:07	40.444	40.000	0.444
80%	10 NOV 2011	12:22	40.481	40.000	0.481
40%	10 NOV 2011	13:37	19.958	20.000	-0.042
40%	10 NOV 2011	13:52	19.856	20.000	-0.144
40%	10 NOV 2011	14:07	19.639	20.000	-0.361
40%	10 NOV 2011	14:22	19.876	20.000	-0.124
40%	10 NOV 2011	14:37	19.963	20.000	-0.037
0%	10 NOV 2011	15:52	0.498	0.500	-0.002
0%	10 NOV 2011	16:07	0.483	0.500	-0.017
0%	10 NOV 2011	16:22	0.507	0.500	0.007
0%	10 NOV 2011	16:37	0.509	0.500	0.009
0%	10 NOV 2011	16:52	0.499	0.500	-0.001
60%	11 NOV 2011	07:07	29.909	30.000	-0.091
60%	11 NOV 2011	07:22	29.931	30.000	-0.069
60%	11 NOV 2011	07:37	29.924	30.000	-0.076
60%	11 NOV 2011	07:52	29.931	30.000	-0.069
60%	11 NOV 2011	08:07	29.944	30.000	-0.056
20%	11 NOV 2011	09:22	10.251	10.000	0.251
20%	11 NOV 2011	09:37	10.248	10.000	0.248
20%	11 NOV 2011	09:52	10.250	10.000	0.250
20%	11 NOV 2011	10:07	10.254	10.000	0.254
20%	11 NOV 2011	10:22	10.258	10.000	0.258
95%	11 NOV 2011	11:22	47.781	47.500	0.281
95%	11 NOV 2011	11:37	47.759	47.500	0.259
95%	11 NOV 2011	11:52	47.794	47.500	0.294
95%	11 NOV 2011	12:07	47.767	47.500	0.267
95%	11 NOV 2011	12:22	47.786	47.500	0.286

6.1 5.3.5 Sensitivity coefficient of sample gas pressure

The sensitivity coefficient of sample gas pressure at reference point shall not exceed the requirements of Table 2 of Guideline VDI 4202 Part 1 (September 2010). 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

Zero and test gases of suitable concentrations were used for testing this performance criterion.

6.3 Method

The benzene analyser VOC72M measures the content of benzene in ambient air. It is equipped with a pump, with which it absorbs the ambient air to be analysed (approx. 0.05 l/min total flow). This pump works against surrounding conditions, i.e. the pressure at the sample gas inlet is the same as the pressure at the sample gas outlet. A forced induction of overpressure or underpressure in the system could damage the analyser.

The VOC72M is equipped with internal pressure measurement provisions which measure the atmospheric pressure. The output signals always compensate the pressure.

During the three-month field test, surrounding pressures of 100.7 kPa (4 April 2012) and 103.6 kPa (06 February 2012) were measured on the days on which the drift checks were carried out. No particular behaviours of the analysers with respect to changes on the surrounding air pressure and, by extension, to the pressure conditions of the sampled test gases could be observed during this period.

6.4 Evaluation

Due to the structure of the measuring system, the sample gas pressure could not be repeatedly adjusted as to deviate from the surrounding pressure, for this could damage the system. All measurement results are pressure-compensated by internal provisions for measuring surrounding pressure. The measured surrounding pressure is shown on the display.

The influence of sample gas pressure was calculated according to the following equation:

$$e_{gp} = \frac{(y_2 - y_1)}{(p_2 - p_1)}$$

where:

e_{gp} = sensitivity coefficient of sample gas pressure
y_1 = average of measurements at sample gas pressure p_1
y_2 = average of measurements at sample gas pressure p_2
p_1 = minimum value of sample gas pressure in kPa
p_2 = maximum value of sample gas pressure in kPa

The minimum value of surrounding pressure = 100.7 kPa was recorded during the field test on 4 April 2012. On this day the drift checks at span resulted in values of 34.33 µg/m³ for system 1 and 34.18 µg/m³ for system 2.

The highest value of surrounding pressure = 103.6 kPa was recorded on 6 February 2012. On this day the drift checks at span resulted in values of 34.20 µg/m³ for system 1 and 34.15 µg/m³ for system 2.

6.5 Assessment

The drift check data result in a sensitivity coefficient of surrounding pressure of -0.045 for system 1 (SN 005) and -0.010 for system 2 (SN 006).

Minimum requirement fulfilled? N/A

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 5.3.6 Sensitivity coefficient of sample gas temperature

The sensitivity coefficient of sample gas temperature at reference point shall not exceed the requirements of Table 2 of Directive 4202 Part 1 (September 2010). A value c_t at 70 % to 80 % of the upper limit of the certification range shall be used as reference point.

Table 2 of Directive 4202 Part 1 does not specify a minimum requirement for sensitivity coefficient of sample gas temperature.

6.2 Equipment

A climatic chamber with a temperature range of 0°C – +35°C as well as zero and test gases of suitable concentrations were used to test this performance criterion.

6.3 Method

For the determination of the dependence of sample gas temperature, measurements were performed at sample gas temperatures of $T_{gt,1}$ = 273 K (0 °C) and $T_{gt,2}$ = 303 K (30 °C). The temperature dependence was determined at the span point. At each temperature three individual readings were obtained.

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

For this test, the test gas was generated within the climatic chamber, while the analysers were placed outside. The test was performed first at 0°C and then at 30 °C.

6.4 Evaluation

The influence of sample gas temperature was calculated according to the following equation:

$$e_{gt} = \frac{(y_2 - y_1)}{(T_{gt,2} - T_{gt,1})}$$

where:

e_{gt} = sensitivity coefficient of sample gas temperature
y_1 = average of measurements at sample gas temperature T_1
y_2 = average of measurements at sample gas temperature T_2
$T_{gt,1}$ = minimum absolute sample gas temperature in K
$T_{gt,2}$ = maximum absolute sample gas temperature in K

6.5 Assessment

The sensitivity coefficient of sample gas temperature amounts to 0.012 µg/m³ for system 1 (SN 005) and 0.006 µg/m³ for system 2 (SN 006).

Minimum requirement fulfilled? yes

6.6 Detailed presentation of test results

The individual results are presented in Table 10.

Table 10: Individual results of the determination of sensitivity coefficient of sample gas temperature

Date	Span point			
	Time	Temperature [°K]	System 1 (005) [µg/m³]	System 2 (006) [µg/m³]
12 DEC 2011	08:10 - 08:25	**273**	40.025	40.498
12 DEC 2011	08:25 - 08:40	**273**	40.218	40.785
12 DEC 2011	08:40 - 08:55	**273**	40.169	40.621
	Average		**40.137**	**40.635**
12 DEC 2011	15:25 - 15:40	**303**	40.425	40.856
12 DEC 2011	15:40 - 15:55	**303**	40.529	40.784
12 DEC 2011	15:55 - 16:10	**303**	40.506	40.799
	Average		**40.487**	**40.813**
Sensitivity coefficient (e_{gt})			**0.012**	**0.006**

6.1 5.3.7 Sensitivity coefficient of surrounding temperature

The sensitivity coefficient of surrounding temperature at zero and reference point shall not exceed the requirements of Table 2 of Directive 4202 Part 1 (September 2010). A value c_t at 70 % to 80 % of the upper limit of the certification range shall be used as reference point.

The influence of surrounding temperature at zero and reference point shall not exceed 0.2%/K for every change of surrounding temperature.

6.2 Equipment

A climatic chamber with a temperature range of 0°C – +35°C as well as zero and test gases of suitable concentrations were used to test this performance criterion.

6.3 Method

The permissible surrounding temperature range according to the manufacturer's specifications is 5°C – 35°C. Accordingly, the test was limited to this temperature range.

In order to determine the temperature dependence of the zero point and the measured values, the complete measuring systems were operated inside the climatic chamber.

6.4 Evaluation

The sensitivity coefficient of surrounding temperature was calculated according to the following equation:

$$e_{st} = \frac{y_T - \frac{y_1 + y_2}{2}}{(T_{st} - T_{st,0})}$$

where:

e_{st} = sensitivity coefficient of surrounding temperature

y_T = average of measurements at $T_{st,min}$ or $T_{st,max}$

y_1 = first average of measurements at $T_{st,0}$

y_2 = second average of measurements at $T_{st,0}$

$T_{st,0}$ = starting temperature in K

T_{st} = temperature $T_{st,min}$ or $T_{st,max}$ in K

Table 11: Sensitivity coefficient of surrounding temperature at zero point

1^{st} run					
Zero point	**T** **[° K]**	**Average System 005 [µg/m³]**	**Determined e_{st} [µg/m³/K]**	**Average System 006 [µg/m³]**	**Determined e_{st} [µg/m³/K]**
T_1	293	0.53		0.50	
T_{min}	278	0.51	**0.0011**	0.48	**0.0007**
T_1	293	0.53		0.49	
T_1	293	0.53		0.49	
T_{max}	308	0.51	**-0.0009**	0.50	**0.0002**
T_1	293	0.51		0.50	
2^{nd} run					
Zero point	**T** **[° K]**	**Average System 005 [µg/m³]**	**Determined e_{st} [µg/m³/K]**	**Average System 006 [µg/m³]**	**Determined e_{st} [µg/m³/K]**
T_1	293	0.51		0.50	
T_{min}	278	0.51	**0.0002**	0.49	**0.0007**
T_1	293	0.52		0.50	
T_1	293	0.52		0.50	
T_{max}	308	0.51	**-0.0006**	0.48	**-0.0009**
T_1	293	0.52		0.50	
3^{rd} run					
Zero point	**T** **[° K]**	**Average System 005 [µg/m³]**	**Determined e_{st} [µg/m³/K]**	**Average System 006 [µg/m³]**	**Determined e_{st} [µg/m³/K]**
T_1	293	0.52		0.50	
T_{min}	278	0.51	**0.0002**	0.51	**-0.0009**
T_1	293	0.51		0.49	
T_1	293	0.51		0.49	
T_{max}	308	0.52	**0.0002**	0.50	**0.0003**
T_1	293	0.52		0.51	
Sensitivity coefficient (e_{gt})			**-0.0009**		**-0.0009**

Table 12: Sensitivity coefficient of surrounding temperature at span point

1^{st} run	

Span point	**T [° K]**	**Average System 005 [µg/m³]**	**Determined e_{st} [µg/m³/K]**	**Average System 006 [µg/m³]**	**Determined e_{st} [µg/m³/K]**
T_1	293	35.62		35.55	
T_{min}	278	35.63	**-0.0007**	35.52	**0.0010**
T_1	293	35.61		35.52	
T_1	293	35.61		35.52	
T_{max}	308	35.65	**0.0022**	35.51	**-0.0008**
T_1	293	35.62		35.53	
2nd run					
Span point	**T [° K]**	**Average System 005 [µg/m³]**	**Determined e_{st} [µg/m³/K]**	**Average System 006 [µg/m³]**	**Determined e_{st} [µg/m³/K]**
T_1	293	35.62		35.53	
T_{min}	278	35.65	**-0.0013**	35.53	**-0.0001**
T_1	293	35.63		35.52	
T_1	293	35.63		35.52	
T_{max}	308	35.68	**0.0037**	35.57	**0.0041**
T_1	293	35.61		35.50	
3rd run					
Span point	**T [° K]**	**Average System 005 [µg/m³]**	**Determined e_{st} [µg/m³/K]**	**Average System 006 [µg/m³]**	**Determined e_{st} [µg/m³/K]**
T_1	293	35.61		35.50	
T_{min}	278	35.63	**-0.0006**	35.52	**0.0000**
T_1	293	35.63		35.55	
T_1	293	35.63		35.55	
T_{max}	308	35.66	**0.0026**	35.53	**-0.0019**
T_1	293	35.61		35.57	
Sensitivity coefficient (e_{gt})			**0.0037**		**0.0041**

6.5 Assessment

The permissible surrounding temperature range according to the manufacturer’s specifications is 5°C – 35°C. In consideration of the measured values, a maximum sensitivity coefficient of surrounding temperature of -0.0009 µg/m³/K was determined for the zero point and 0.0041 µg/m³/K for the span point.

Minimum requirement fulfilled? yes

6.6 Detailed presentation of test results

Table 13: Individual results of the determination of sensitivity coefficient of surrounding temperature at zero point

Date	Zero point			
	Time	Temperature [°K]	Device 1 (0005) [µg/m^3]	Device 2 (0006) [µg/m^3]
05.12.2011	08:06 - 08:21	**293**	0,52	0,49
05.12.2011	09:06 - 09:21	**293**	0,54	0,50
05.12.2011	10:06 - 10:21	**293**	0,52	0,50
	Average		**0,53**	**0,50**
05.12.2011	17:06 - 17:21	**278**	0,51	0,48
05.12.2011	18:06 - 18:21	**278**	0,51	0,49
05.12.2011	19:06 - 19:21	**278**	0,51	0,48
	Average		**0,51**	**0,48**
06.12.2011	02:06 - 02:21	**293**	0,52	0,49
06.12.2011	03:06 - 03:21	**293**	0,54	0,50
06.12.2011	04:06 - 04:21	**293**	0,52	0,48
	Average		**0,53**	**0,49**
06.12.2011	11:06 - 11:21	**308**	0,51	0,50
06.12.2011	12:06 - 12:21	**308**	0,51	0,50
06.12.2011	12:06 - 13:21	**308**	0,50	0,50
	Average		**0,51**	**0,50**
06.12.2011	20:06 - 20:21	**293**	0,51	0,51
06.12.2011	21:06 - 21:21	**293**	0,51	0,50
06.12.2011	22:06 - 22:21	**293**	0,52	0,50
	Average		**0,51**	**0,50**
07.12.2011	05:06 - 05:21	**278**	0,52	0,49
07.12.2011	06:06 - 06:21	**278**	0,51	0,49
07.12.2011	07:06 - 07:21	**278**	0,51	0,49
	Average		**0,51**	**0,49**
07.12.2011	14:06 - 14:21	**293**	0,51	0,49
07.12.2011	15:06 - 15:21	**293**	0,53	0,50
07.12.2011	16:06 - 16:21	**293**	0,52	0,50
	Average		**0,52**	**0,50**
07.12.2011	23:06 - 23:21	**308**	0,52	0,48
08.12.2011	00:06 - 00:21	**308**	0,51	0,48
08.12.2011	01:06 - 01:21	**308**	0,51	0,49
	Average		**0,51**	**0,48**
08.12.2011	08:06 - 08:21	**293**	0,52	0,49
08.12.2011	09:06 - 09:21	**293**	0,53	0,50
08.12.2011	10:06 - 10:21	**293**	0,52	0,50
	Average		**0,52**	**0,50**
08.12.2011	17:06 - 17:21	**278**	0,51	0,51
08.12.2011	18:06 - 18:21	**278**	0,51	0,51
08.12.2011	19:06 - 19:21	**278**	0,52	0,50
	Average		**0,51**	**0,51**
09.12.2011	02:06 - 02:21	**293**	0,50	0,49
09.12.2011	03:06 - 03:21	**293**	0,51	0,49
09.12.2011	04:06 - 04:21	**293**	0,52	0,49
	Average		**0,51**	**0,49**
09.12.2011	11:06 - 11:21	**308**	0,51	0,51
09.12.2011	12:06 - 12:21	**308**	0,53	0,50
09.12.2011	12:06 - 13:21	**308**	0,52	0,50
	Average		**0,52**	**0,50**
09.12.2011	20:06 - 20:21	**293**	0,52	0,50
09.12.2011	21:06 - 21:21	**293**	0,54	0,51
09.12.2011	22:06 - 22:21	**293**	0,51	0,51
	Average		**0,52**	**0,51**

Table 14: Individual results of the determination of sensitivity coefficient of surrounding temperature at span point

Date	**Span point**			
	Time	**Temperature**	**Device 1 (0005)**	**Device 2 (0006)**
		[°K]	**[µg/m³]**	**[µg/m³]**
05.12.2011	08:36 - 08:51	**293**	35,61	35,54
05.12.2011	09:36 - 09:51	**293**	35,63	35,56
05.12.2011	10:36 - 10:51	**293**	35,63	35,56
	Average		**35,62**	**35,55**
05.12.2011	17:36 - 17:51	**278**	35,62	35,54
05.12.2011	18:36 - 18:51	**278**	35,64	35,51
05.12.2011	19:36 - 19:51	**278**	35,62	35,52
	Average		**35,63**	**35,52**
06.12.2011	02:36 - 02:51	**293**	35,61	35,54
06.12.2011	03:36 - 03:51	**293**	35,60	35,52
06.12.2011	04:36 - 04:51	**293**	35,62	35,51
	Average		**35,61**	**35,52**
06.12.2011	11:36 - 11:51	**308**	35,64	35,50
06.12.2011	12:36 - 12:51	**308**	35,64	35,50
06.12.2011	13:36 - 13:51	**308**	35,67	35,54
	Average		**35,65**	**35,51**
06.12.2011	20:36 - 20:51	**293**	35,62	35,54
06.12.2011	21:36 - 21:51	**293**	35,61	35,52
06.12.2011	22:36 - 22:51	**293**	35,64	35,52
	Average		**35,62**	**35,53**
07.12.2011	05:36 - 05:51	**278**	35,62	35,56
07.12.2011	06:36 - 06:51	**278**	35,64	35,51
07.12.2011	07:36 - 07:51	**278**	35,68	35,51
	Average		**35,65**	**35,53**
07.12.2011	14:36 - 14:51	**293**	35,64	35,54
07.12.2011	15:36 - 15:51	**293**	35,62	35,52
07.12.2011	16:36 - 16:51	**293**	35,63	35,51
	Average		**35,63**	**35,52**
07.12.2011	23:36 - 23:51	**308**	35,68	35,56
08.12.2011	00:36 - 00:51	**308**	35,67	35,58
08.12.2011	01:36 - 01:51	**308**	35,68	35,58
	Average		**35,68**	**35,57**
08.12.2011	08:36 - 08:51	**293**	35,62	35,51
08.12.2011	09:36 - 09:51	**293**	35,61	35,49
08.12.2011	10:36 - 10:51	**293**	35,61	35,50
	Average		**35,61**	**35,50**
08.12.2011	17:36 - 17:51	**278**	35,62	35,52
08.12.2011	18:36 - 18:51	**278**	35,63	35,51
08.12.2011	19:36 - 19:51	**278**	35,64	35,54
	Average		**35,63**	**35,52**
09.12.2011	02:36 - 02:51	**293**	35,62	35,54
09.12.2011	03:36 - 03:51	**293**	35,63	35,55
09.12.2011	04:36 - 04:51	**293**	35,64	35,55
	Average		**35,63**	**35,55**
09.12.2011	11:36 - 11:51	**308**	35,66	35,51
09.12.2011	12:36 - 12:51	**308**	35,66	35,56
09.12.2011	13:36 - 13:51	**308**	35,66	35,52
	Average		**35,66**	**35,53**
09.12.2011	20:36 - 20:51	**293**	35,62	35,58
09.12.2011	21:36 - 21:51	**293**	35,61	35,56
09.12.2011	22:36 - 22:51	**293**	35,61	35,57
	Average		**35,61**	**35,57**

6.1 5.3.8 Sensitivity coefficient of supply voltage

The sensitivity coefficient of supply voltage shall not exceed the requirements of Table 2 of Directive 4202 Part 1 (September 2010). 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

An isolating transformer as well as zero and test gases of suitable concentrations were used to test this performance criterion.

6.3 Method

In order to test the dependence of the measured signals on the supply voltage, the voltage was first reduced from 230 V to 210 V. Then, it was increased to 245 V with an intermediate step of 230 V.

6.4 Evaluation

The sensitivity coefficient of supply voltage was calculated according to the following equation:

$$e_v = \frac{(y_2 - y_1)}{(U_2 - U_1)}$$

where:

e_v	=	sensitivity coefficient of supply voltage
y_1	=	average of measurements at voltage U_1
y_2	=	average of measurements at voltage U_2
U_1	=	minimum supply voltage in V
U_2	=	maximum supply voltage in V

6.5 Assessment

In consideration of the measured values, a maximum sensitivity coefficient of supply voltage of -0.0003 µg/m³/V was determined for the zero point and 0.0007 µg/m³/V for the span point.

Minimum requirement fulfilled? yes

6.6 Detailed presentation of test results

Table 15 presents an overview of the test results.

Table 15: Sensitivity coefficient of supply voltage

Date	Time	Device 1 (0005)	Device 2 (0006)	Date	Time	Device 1 (0005)	Device 2 (0006)
		[µg/m³]	[µg/m³]			[µg/m³]	[µg/m³]
zero gas at 230 V				**span gas at 230 V**			
21.12.2011	07:05 - 08:05	0,52	0,54	21.12.2011	08:05 - 09:05	35,21	34,98
21.12.2011	09:05 - 10:05	0,54	0,54	21.12.2011	10:05 - 11:05	35,26	34,99
21.12.2011	11:05 - 12:05	0,51	0,56	21.12.2011	12:05 - 13:05	35,24	34,95
Average		**0,52**	**0,55**	**Average**		**35,24**	**34,97**
zero gas at 210 V				**span gas at 210 V**			
21.12.2011	13:05 - 14:05	0,51	0,54	21.12.2011	14:05 - 15:05	35,26	35,01
21.12.2011	15:05 - 16:05	0,52	0,55	21.12.2011	16:05 - 17:05	35,31	34,98
21.12.2011	17:05 - 18:05	0,52	0,55	21.12.2011	18:05 - 19:05	35,32	34,96
Average		**0,52**	**0,55**	**Average**		**35,30**	**34,98**
zero gas at 230 V				**span gas at 230 V**			
21.12.2011	07:05 - 08:05	0,52	0,55	21.12.2011	08:05 - 09:05	35,29	34,94
21.12.2011	09:05 - 10:05	0,51	0,53	21.12.2011	10:05 - 11:05	35,27	34,98
21.12.2011	11:05 - 12:05	0,53	0,55	21.12.2011	12:05 - 13:05	35,28	34,98
Average		**0,52**	**0,54**	**Average**		**35,28**	**34,97**
zero gas at 245 V				**span gas at 245 V**			
21.12.2011	13:05 - 14:05	0,51	0,54	21.12.2011	14:05 - 15:05	35,28	34,99
21.12.2011	15:05 - 16:05	0,51	0,54	21.12.2011	16:05 - 17:05	35,28	34,95
21.12.2011	17:05 - 18:05	0,51	0,53	21.12.2011	18:05 - 19:05	35,31	34,94
Average		**0,51**	**0,54**	**Average**		**35,29**	**34,96**
Sensitivitycoeffizient (e_{gt})		-0,0002	-0,0003			-0,0002	-0,0007

6.1 5.3.9 Cross-sensitivity

The change in the measured value caused by interfering components in the sample gas shall not exceed the requirements of Table 2 of Directive 4202 Part 1 (September 2010) at zero and reference point. For benzene a value c_t at 70 % to 80 % of the upper limit of the certification range shall be used as reference point.

For measuring principles deviating from EN standards the absolute values of the sum of the positive and the sum of the negative deviations caused by interfering components in the sample gas shall not exceed 3 % of the upper limit of the certification range. 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

Zero and test gases of suitable concentrations, a dilution system and various gas flow meters were used to test this performance criterion.

6.3 Method

The change in the measured signal of the AMS caused by interfering components in ambient air was determined. These interferents can cause a positive or a negative signal. The test was carried out with a zero concentration and a test gas concentration (c_t) which resembles the hourly limit value.

The concentration of the mixtures of the test gases with the interfering component shall have an uncertainty of less than 5 % and shall be traceable to national standards.

The interfering components to be tested and their corresponding concentrations are listed on Table 2 of Guideline VDI 4202 Part 1 (September 2010). For benzene, cross-sensitivity tests with components H_2O (19 mmol/mol), ozone (200 nmol/mol) and various organic substances according to Annex B of Guideline VDI 4202 (2010) are stipulated. The influence of each interferent was tested separately. A correction on the concentration of the measured component was made for the dilution effect due to addition of an interfering component (e.g. water vapour).

After adjustment of the measuring system at zero and span point, the AMS was fed with a mixture of zero gas and the interferent to be tested in the concentration prescribed in Table 2 of Guideline VDI 4202 Part 1 (September 2010). One independent measurement followed by two further individual measurements was carried out with this mixture. This procedure was repeated with a mixture of the measured component at concentration c_t and the interfering component to be investigated.

6.4 Evaluation

The deviations at zero and concentration c_t were calculated according to the following equations:

$$\Delta y_{i,zp,j} = y_{i,zp,j}$$

$$\Delta y_{i,rp,j} = y_{i,rp,j} - c_t$$

where:

$\Delta y_{i,rp,j}$ = deviation at span point due to interfering component j

$\Delta y_{i,zp,j}$ = deviation at zero point due to interfering component j

$y_{i,rp,j}$ = average of measurements with interfering component j at span point

$y_{i,zp,j}$ = average of measurements with interfering component j at zero point

c_t = test gas concentration at span point

The deviations produced by interfering components shall comply with the requirements stated in Table 2 of Guideline VDI 4202 (2010) both at zero and concentration c_t.

6.5 Assessment

An assessment of the cross-sensitivity tests according to the requirements of VDI 4202 Part 1 for ambient air components could not be carried out. This was due to the fact that for benzene measuring systems, tests to be performed at zero point are not carried out at zero but at approx. 1/10 of the limit value. The cross-sensitivity tests were assessed in accordance with Standard EN 14662-3. The results are presented in Section 7.1 8.5.9 Interference.

Minimum requirement fulfilled? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 5.3.10 Averaging effect

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

The averaging effect shall not exceed the requirements of Table 2 of Directive 4202 Part 1 (September 2010).

6.2 Equipment

N/A

6.3 Method

Due to the principle of measurement of the AMS tested, this performance criterion is not applicable.

The VOC72M measuring system is a chromatograph, whose principle of measurement causes it to operate cyclically. The instrument produces a reading every 15 minutes, for each of which the sampling time amounts to 13.5 minutes.

6.4 Evaluation

Due to the principle of measurement of the AMS tested, this performance criterion is not applicable.

6.5 Assessment

Due to the principle of measurement of the AMS tested, this performance criterion is not applicable.

Minimum requirement fulfilled? N/A

6.6 Detailed presentation of test results

Due to the principle of measurement of the AMS tested, this performance criterion is not applicable.

6.1 5.3.11 Standard deviation from paired measurements

The standard deviation from paired measurements under field conditions shall be determined with two identical measuring systems by paired measurements in the field test. It shall not exceed the requirements of Table 2 of Guideline VDI 4202 Part 1 (September 2010).

6.2 Equipment

A benzene mixture was used to enrich the benzene concentration for this performance criterion.

6.3 Method

The standard deviation from paired measurements was determined under field conditions during the three-month field test with two identical measuring systems by paired measurements at the same site.

Since the benzene content in ambient air at traffic congested sites in Germany is in general rather low, the sample air was sporadically enriched in benzene in order to demonstrate that the measuring system also operates correctly at higher concentrations.

Furthermore, the values measured during the two-week long-term drift checks at the span point were taken into account for the determination of the standard deviation from paired measurements.

6.4 Evaluation

The standard deviation from paired measurements was calculated according to the following equation:

$$s_{D,abs} = \sqrt{\sum_{i=1}^{n} \frac{(y_{1,i} - y_{2,1})^2}{2n}}$$

where:

$s_{D,abs}$ = standard deviation from paired measurements under field conditions

$y_{1,i}$ = *i*th reading of system 1

$y_{2,i}$ = *i*th reading of system 2

n = number of paired measurements

The relative standard deviation $s_{D,\ rel}$ from paired measurements under field conditions was related to the average of all readings obtained during the field test according to the following equation:

$$s_{D,rel} = \frac{s_{D,abs}}{\bar{y}}$$

6.5 Assessment

The relative standard deviation from paired measurements under field conditions for component benzene amounts to 0.025 µg/m³.

Minimum requirement fulfilled? yes

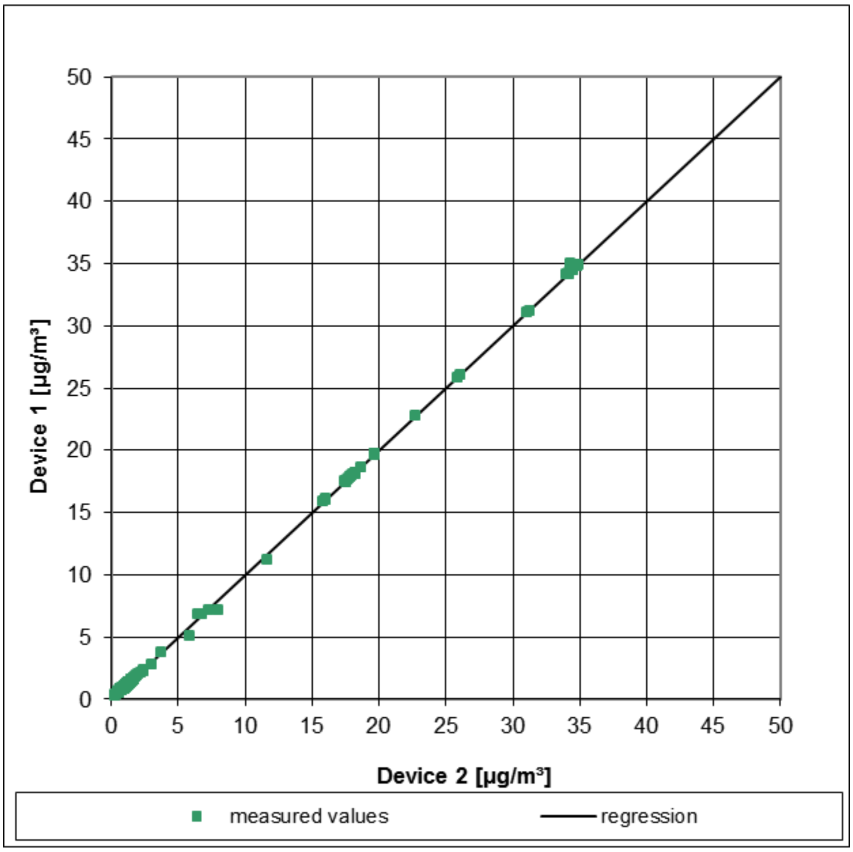
6.6 Detailed presentation of test results

The test results are presented in Table 16 and Figure 8.

Table 16: Standard deviation from paired measurements

Component:	Benzene			
AMS:	VOC72M			
Date of measurement:	23 JAN 2012 to 24 APR 2012			
Certification range	CR	=	0 - 50	µg/m³
Concentration range	System 1	=	0.3 - 34.9	µg/m³
Concentration range	System 2	=	0.3 - 35	µg/m³
Average	System 1	=	1.43	µg/m³
Average	System 2	=	1.40	µg/m³
y = b* x + c Slope	b	=	0.9998	
Axis intercept	c	=	-0.0217	µg/m³
Determination coefficient	r	=	0.9999	
No. of measurements	n	=	2146	
t-value	$t_{0,95,n}$	=	1.9611	
Standard deviation from paired measurements	$s_{D,abs}$	=	0.035	µg/m³
Relative standard deviation	$s_{D,rel}$	=	0.025	µg/m³
Limit		=	0.25	µg/m³

Figure 8: Graphic representation of the standard deviation from paired measurements



6.1 5.3.12 Long-term drift

The long-term drift at zero point and reference point shall not exceed the requirements of Table 2 of Guideline VDI 4202 Part 1 (September 2010) in the field test. 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

Zero and test gases of suitable concentrations were used to test this performance criterion.

6.3 Method

At the beginning of the drift test, the zero and span point were calibrated. 5 individual measurements with zero and test gas were carried out during the first 14 days. From then on, zero and span point checks were carried out on a bi-weekly basis.

6.4 Evaluation

The deviations of the measured values at zero and span point from the values obtained during calibration were calculated for all bi-weekly checks. The long-term drift at zero point was calculated according to the following equation:

$$D_{lt,zp} = y_{zp,2} - y_{zp,1}$$

where:

$D_{lt,zp}$ = long-term drift at zero point

$y_{zp,1}$ = average of measurements at zero point at the beginning of the drift test

$y_{zp,2}$ = average of measurements at zero point at the end of the maintenance interval

The long-term drift at span point and the relative long-term drift at span point were calculated according to the following equations:

$$D_{lt,rp} = (y_{rp,2} - y_{rp,1}) - D_{lt,zp}$$

$$D_{lt,rp,rel} = \frac{D_{lt,rp}}{y_{rp,l}} * 100\%$$

where:

$D_{lt,rp}$ = long-term drift at span point

$D_{lt,rp,rel}$ = relative long-term drift at span point in %

$y_{rp,1}$ = average of measurements at span point at the beginning of the drift test

$y_{rp,2}$ = average of measurements at span point at the end of the maintenance interval

Table 17 and Table 18 show the values obtained at the bi-weekly test gas feedings.

Table 17: Results of long-term drift check at zero point

	System 1 (005) [µg/m³]	System 2 (006) [µg/m³]
$C_{Z,1}$ Start	0.54	0.55
$C_{Z,2}$ 06 FEB 2012	0.56	0.55
$D_{L,Z}$ 06 FEB 2012	**0.02**	**0.00**
$C_{Z,2}$ 22 FEB 2012	0.57	0.53
$D_{L,Z}$ 22 FEB 2012	**0.03**	**-0.02**
$C_{Z,2}$ 06 MAR 2012	0.58	0.58
$D_{L,Z}$ 06 MAR 2012	**0.04**	**0.03**
$C_{Z,2}$ 21 MAR 2012	0.59	0.59
$D_{L,Z}$ 21 MAR 2012	**0.05**	**0.04**
$C_{Z,2}$ 04 APR 2012	0.51	0.52
$D_{L,Z}$ 04 APR 2012	**-0.03**	**-0.03**
$C_{Z,2}$ 16 APR 2012	0.54	0.57
$D_{L,Z}$ 16 APR 2012	**0.00**	**0.02**
$C_{Z,2}$ 27 APR 2012	0.53	0.56
$D_{L,Z}$ 27 APR 2012	**-0.01**	**0.01**

Table 18: Results of long-term drift check at span point

	System 1 (005) [µg/m³]	System 2 (006) [µg/m³]
$C_{S,1}$ Start	34.1	34.1
$C_{S,2}$ 06 FEB 2012	34.2	34.2
$D_{L,S}$ 06 FEB 2012	**0.33%**	**0.16%**
$C_{S,2}$ 22 FEB 2012	34.9	34.8
$D_{L,S}$ 22 FEB 2012	**2.21%**	**2.19%**
$C_{S,2}$ 06 MAR 2012	34.7	34.8
$D_{L,S}$ 06 MAR 2012	**1.86%**	**1.84%**
$C_{S,2}$ 21 MAR 2012	34.9	34.9
$D_{L,S}$ 21 MAR 2012	**2.27%**	**2.19%**
$C_{S,2}$ 04 APR 2012	34.2	34.2
$D_{L,S}$ 04 APR 2012	**0.54%**	**0.34%**
$C_{S,2}$ 16 APR 2012	34.3	35.0
$D_{L,S}$ 16 APR 2012	**0.69%**	**2.48%**
$C_{S,2}$ 27 APR 2012	34.3	34.5
$D_{L,S}$ 27 APR 2012	**0.66%**	**1.13%**

6.5 Assessment

The maximum long-term drift amounts to 0.05 µg/m^3 at zero point and 2.48 % of the certification range at the span point.

Minimum requirement fulfilled? yes

6.6 Detailed presentation of test results

The individual results of the long-term drift test are presented in Table 19.

Table 19: Individual results of long-term drift test

Date	Time	System 1 (005)	System 2 (006)	Time	System 1 (005)	System 2 (006)
	Zero point			Span point		
	[hh:mm]	[µg/m^3]	[µg/m^3]	[hh:mm]	[µg/m^3]	[µg/m^3]
23 JAN 2012	09:00	0.57	0.51	10:00	34.06	34.11
24 JAN 2012	07:00	0.50	0.54	08:00	34.09	34.12
25 JAN 2012	09:00	0.52	0.56	11:00	34.07	34.09
26 JAN 2012	10:00	0.56	0.58	11:00	34.08	34.11
27 JAN 2012	12:00	0.55	0.57	13:00	34.03	34.05
Average		**0.54**	**0.55**		**34.07**	**34.10**
06 FEB 2012	14:00	0.56	0.55	15:00	34.20	34.15
22 FEB 2012	13:00	0.57	0.53	14:00	34.85	34.82
06 MAR 2012	12:00	0.58	0.58	14:00	34.74	34.75
21 MAR 2012	14:00	0.59	0.59	15:00	34.89	34.88
04 APR 2012	11:00	0.51	0.52	13:00	34.22	34.18
16 APR.2012	09:00	0.54	0.57	10:00	34.30	34.96
27 APR 2012	11:00	0.53	0.56	12:00	34.28	34.49

6.1 5.3.13 Short-term drift

The short-term drift at zero point and reference point shall not exceed the requirements of Table 2 of Guideline VDI 4202 Part 1 (September 2010) within 12 h (for benzene 24 h) in the laboratory test and within 24 h in the field test. A value c_t at 70 % to 80 % of the upper limit of the certification range shall be used as reference point.

6.2 Equipment

Zero and test gases of suitable concentrations were used to test this performance criterion.

6.3 Method

The measuring system was adjusted at zero and span point. After that, 20 individual measurements were carried out first at zero and then at the test gas concentration at span point. From these 20 measurements the average is calculated for both zero and span point.

After a period of 24 h, 20 individual measurements were carried out first at zero and then at the test gas concentration at span point.

6.4 Evaluation

The short-term drift was calculated according to the following equation:

$$D_{st,zp} = y_{zp,2} - y_{zp,1}$$

where:

$D_{st,zp}$ = short-term drift at zero point

$y_{zp,1}$ = average of measurements at zero point at the beginning of the drift test

$y_{zp,2}$ = average of measurements at zero point at the end of the drift test

The short-term drift at span point was calculated according to the following equation:

$$D_{st,rp} = (y_{rp,2} - y_{rp,1}) - D_{st,zp}$$

where:

$D_{st,rp}$ = short-term drift at span point

$y_{rp,1}$ = average of measurements at span point at the beginning of the drift test

$y_{rp,2}$ = average of measurements at span point at the end of the drift test

Table 20 shows the values measured during the short-term drift test.

Table 20: Results of short-term drift test

	System 1 (005) [µg/m³]	System 2 (006) [µg/m³]
$y_{z,1}$	0.54	0.52
$y_{z,2}$	0.54	0.52
$D_{st,zp}$	**0.01**	**-0.01**
Requirement fulfilled?	**yes**	**yes**
$y_{s,1}$	35.60	35.68
$y_{s,2}$	35.57	35.62
$D_{st,rp}$	**-0.04**	**-0.05**
Requirement fulfilled?	**yes**	**yes**

6.5 Assessment

The maximum short-term drift amounts to 0.01 µg/m³ at zero point and -0.05 µg/m³ at span point.

Minimum requirement fulfilled? yes

6.6 Detailed presentation of test results

The individual results of the short-term drift test are presented in Table 21 and Table 22.

Table 21: Individual results of the determination of short-term drift, system 1 (0005)

Initial readings					**Readings after 24 h**			
Zero point		Span point			Zero point		Span point	
[Time]	[µg/m³]	[Time]	[µg/m³]		[Time]	[µg/m³]	[Time]	[µg/m³]
08:03	0.56	13:18	35.62		8:03	0.55	13:18	35.56
08:18	0.54	13:33	35.61		8:18	0.54	13:33	35.54
08:33	0.52	13:48	35.55		8:33	0.52	13:48	35.62
08:48	0.54	14:03	35.56		8:48	0.54	14:03	35.51
09:03	0.55	14:18	35.60		9:03	0.53	14:18	35.58
09:18	0.52	14:33	35.68		9:18	0.53	14:33	35.57
09:33	0.53	14:48	35.62		9:33	0.54	14:48	35.59
09:48	0.54	15:03	35.54		9:48	0.55	15:03	35.54
10:03	0.55	15:18	35.64		10:03	0.56	15:18	35.56
10:18	0.56	15:33	35.58		10:18	0.54	15:33	35.63
10:33	0.54	15:48	35.57		10:33	0.52	15:48	35.52
10:48	0.54	16:03	35.64		10:48	0.54	16:03	35.54
11:03	0.54	16:18	35.63		11:03	0.57	16:18	35.58
11:18	0.52	16:33	35.64		11:18	0.55	16:33	35.62
11:33	0.51	16:48	35.58		11:33	0.52	16:48	35.52
11:48	0.52	17:03	35.55		11:48	0.56	17:03	35.64
12:03	0.56	17:18	35.59		12:03	0.56	17:18	35.61
12:18	0.54	17:33	35.62		12:18	0.55	17:33	35.51
12:33	0.53	17:48	35.64		12:33	0.54	17:48	35.54
12:48	0.54	18:03	35.55		12:48	0.54	18:03	35.58
Average	**0.54**	**Average**	**35.60**		**Average**	**0.54**	**Average**	**35.57**

Table 22: Individual results of the determination of short-term drift, system 2 (0006)

Initial readings					Readings after 24 h			
Zero point		Span point			Zero point		Span point	
[Time]	[µg/m^3]	[Time]	[µg/m^3]		[Time]	[µg/m^3]	[Time]	[µg/m^3]
08:03	0.54	13:18	35.65		8:03	0.52	13:18	35.62
08:18	0.52	13:33	35.68		8:18	0.53	13:33	35.62
08:33	0.53	13:48	35.64		8:33	0.54	13:48	35.64
08:48	0.53	14:03	35.62		8:48	0.52	14:03	35.62
09:03	0.53	14:18	35.63		9:03	0.51	14:18	35.68
09:18	0.54	14:33	35.67		9:18	0.53	14:33	35.65
09:33	0.54	14:48	35.61		9:33	0.51	14:48	35.64
09:48	0.52	15:03	35.64		9:48	0.52	15:03	35.62
10:03	0.51	15:18	35.68		10:03	0.52	15:18	35.58
10:18	0.54	15:33	36.59		10:18	0.53	15:33	35.59
10:33	0.54	15:48	35.63		10:33	0.54	15:48	35.60
10:48	0.51	16:03	35.68		10:48	0.52	16:03	35.62
11:03	0.51	16:18	35.65		11:03	0.53	16:18	35.60
11:18	0.52	16:33	35.59		11:18	0.51	16:33	35.64
11:33	0.51	16:48	35.64		11:33	0.50	16:48	35.62
11:48	0.53	17:03	35.62		11:48	0.50	17:03	35.58
12:03	0.50	17:18	35.61		12:03	0.50	17:18	35.65
12:18	0.51	17:33	35.62		12:18	0.51	17:33	35.62
12:33	0.52	17:48	35.55		12:33	0.52	17:48	35.63
12:48	0.54	18:03	35.61		12:48	0.51	18:03	35.61
Average	**0.52**	**Average**	**35.68**		**Average**	**0.52**	**Average**	**35.62**

6.1 5.3.14 Response time

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

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

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

6.2 Equipment

N/A

6.3 Method

This performance criterion is not applicable to gas chromatographs. Due to its principle of measurement, the measurement cycle of the AMS is 15 minutes.

For benzene measuring systems, the influence of the memory effect is tested, which is caused by retention of benzene in the AMS as a consequence of unsuitable materials or too large a dead volume. The influence of memory-effect is assessed in Section 7.1 8.5.10 Carry-over (memory effect)

6.4 Evaluation

This performance criterion is not applicable to gas chromatographs.

6.5 Assessment

See Section 7.1 8.5.10 Carry-over (memory effect).

Minimum requirement fulfilled? N/A

6.6 Detailed presentation of test results

N/A

6.1 5.3.15 Difference between sample and calibration port

The difference between the measured values obtained by feeding gas at the sample and calibration port shall not exceed the requirements of Table 2 of Guideline VDI 4202 Part 1 (September 2010). 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

N/A

6.3 Method

N/A

6.4 Evaluation

The benzene measuring system tested only has one test gas inlet. This performance criterion is therefore not applicable.

6.5 Assessment

N/A

Minimum requirement fulfilled? N/A

A value of Dsc = 0 is used for the calculation of the total uncertainty.

6.6 Detailed presentation of test results

N/A

6.1 5.3.16 Converter efficiency

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

6.2 Equipment

N/A

6.3 Method

N/A

6.4 Evaluation

The benzene measuring system tested does not have a converter. This performance criterion is therefore not applicable.

6.5 Assessment

N/A

Minimum requirement fulfilled? N/A

6.6 Detailed presentation of test results

N/A

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

In case of NO_X measuring systems the increase of NO_2 concentration due to residence in the measuring system shall not exceed the requirements of Table 2 of Guideline VDI 4202 Part 1 (September 2010).

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

6.2 Equipment

N/A

6.3 Method

N/A

6.4 Evaluation

The AMS tested is not a NO_X measuring system. This performance criterion is therefore not applicable.

6.5 Assessment

N/A

Minimum requirement fulfilled? N/A

6.6 Detailed presentation of test results

N/A

6.1 5.3.18 Overall uncertainty

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

6.2 Equipment

The uncertainty calculation was carried out according to EN 14662-3 (2005) and is presented in Section 7.1 8.7 Total uncertainty calculation according to Section 8.7 of EN 14662-3.

6.3 Method

The uncertainty calculation was carried out according to EN 14662-3 (2005) and is presented in Section 7.1 8.7 Total uncertainty calculation according to Section 8.7 of EN 14662-3.

6.4 Evaluation

The uncertainty calculation was carried out according to EN 14662-3 (2005) and is presented in Section 7.1 8.7 Total uncertainty calculation according to Section 8.7 of EN 14662-3.

6.5 Assessment

The uncertainty calculation was carried out according to EN 14662-3 (2005) and is presented in Section 7.1 8.7 Total uncertainty calculation according to Section 8.7 of EN 14662-3.

Minimum requirement fulfilled? N/A

6.6 Detailed presentation of test results

The uncertainty calculation was carried out according to EN 14662-3 (2005) and is presented in Section 7.1 8.7 Total uncertainty calculation according to Section 8.7 of EN 14662-3.

7. Test results corresponding to the requirements of EN 14662-3

7.1 8.5.3 Lack of fit

The calculation of the linear regression function and residuals shall be performed according to Annex A of EN 14662-3. The largest relative residual from the linear regression function shall meet the following criterion: ± 5 %.

7.2 Equipment

Zero and test gases of suitable concentrations as well as a gas mixing unit were used to test this performance criterion.

7.3 Method

A linear regression function was determined from the responses of the analysers and the corresponding applied concentration levels. The residual at each concentration is equal to the difference between the average response measured, expressed as a concentration, and the concentration given by the linear regression function.

The linearity of the analyser was tested over the range between 0 % and 90 % of the maximum of the certification range, using at least six concentrations (including the zero point). The following concentrations were used: 0 µg/m³ (here approx. 0.5 µg/m³), 5 µg/m³ ± 10 %, 15 µg/m³ ± 10 %, 25 µg/m³ ± 10 %, 35 µg/m³ ± 10 % and 45 µg/m³ ± 10 %. The calibration function for the analyser was evaluated from the linearity test. At each concentration (including zero) at least 6 independent measurements were performed. The first measurement at each concentration level was excluded from the data analysis.

The largest relative residual from the linear regression function shall meet the criterion stated in Table 2 of EN 14662-3.

The greatest value of (d_r) is reported as X_{fit} and is included in the uncertainty calculation.

The standard uncertainty due to lack of fit at the limit value, $u_{fit,LV}$ is calculated according to the following equation:

$$u_{fit,LV} = \frac{\left(X_{fit}/100\right) * c_{LV}}{\sqrt{3}}$$

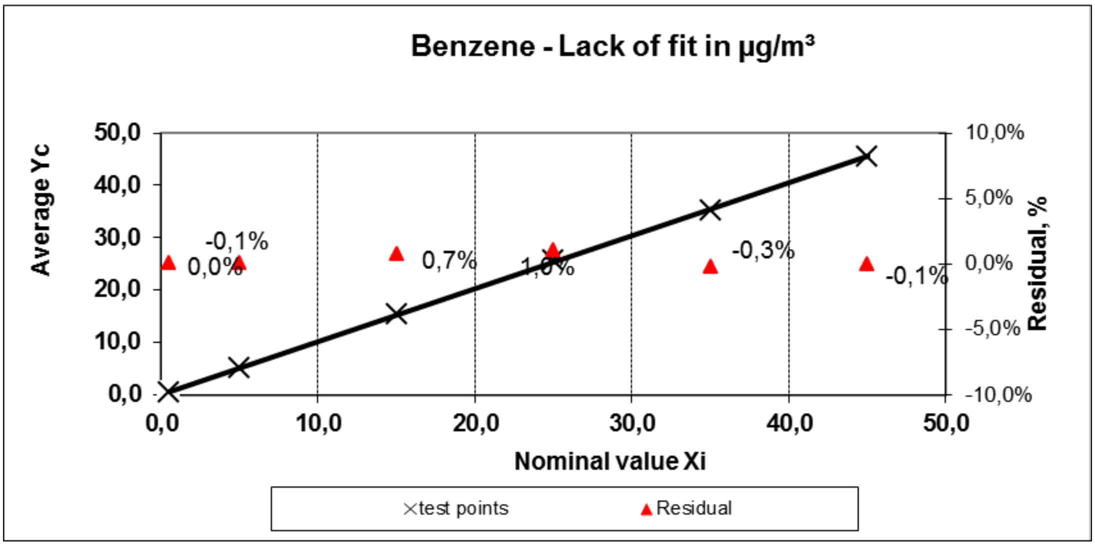
where:

$u_{fit,LV}$ = standard uncertainty due to lack of fit at the limit value
$X_{fit,LV}$ = calculated residual from a linear regression function at the limit value
c_{LV} = limit value

7.4 Evaluation

The following linear regressions were obtained. Figure 9 and Figure 10 present the deviations from the linear regression function in graphic and tabular form

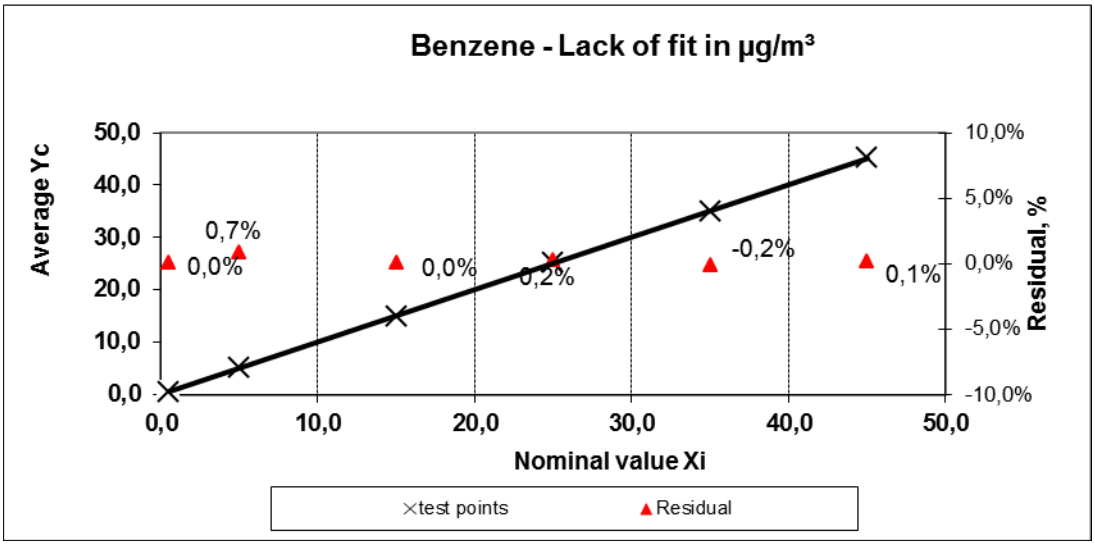
Linearity test	**Measuring range**		**50**	**µg/m³**	**Benzene**		
Concentrations	**Benzene**						
Nominal value	µg/m³	35.000	15.000	0.500	25.000	5.000	45.000
Reading Yi 1	µg/m³	35.369	15.469	0.512	25.742	5.234	45.665
Reading Yi 2	µg/m³	35.249	15.267	0.523	25.458	5.114	45.521
Reading Yi 3	µg/m³	35.397	15.463	0.515	25.635	5.234	45.415
Reading Yi 4	µg/m³	35.161	15.522	0.521	25.651	5.324	45.269
Reading Yi 5	µg/m³	35.282	15.234	0.523	25.471	5.231	45.241
Average Yc	µg/m³	35.292	15.391	0.519	25.591	5.227	45.422
Residuals dc	µg/m³	-0.11	0.10	-0.19	0.24	0.00	-0.04
Residuals $(d_r)_c$	%	**-0.3%**	**0.7%**	**0.0%**	**1.0%**	**-0.1%**	**-0.1%**



The permissible deviation range of the residuals dc_{rel} is ± 5 % in relation to the measured value.

Figure 9: Deviation from the linear regression function, system 1

Linearity test	**Measuring range**		**50**	**µg/m³**	**Benzene**		
Concentrations	**Benzene**						
Nominal value	µg/m³	35.000	15.000	0.500	25.000	5.000	45.000
Reading Yi 1	µg/m³	34.987	15.102	0.499	25.102	5.014	45.025
Reading Yi 2	µg/m³	35.026	15.032	0.501	25.236	5.069	45.018
Reading Yi 3	µg/m³	35.019	15.048	0.499	25.140	5.128	45.201
Reading Yi 4	µg/m³	34.968	15.147	0.497	25.039	5.111	45.186
Reading Yi 5	µg/m³	34.996	14.999	0.501	25.108	5.127	45.156
Average Yc	µg/m³	34.999	15.066	0.499	25.125	5.090	45.117
Residuals dc	µg/m³	-0.08	0.00	-0.05	0.06	0.04	0.03
Residuals $(d_r)_c$	%	**-0.2%**	**0.0%**	**0.0%**	**0.2%**	**0.7%**	**0.1%**



The permissible deviation range of the residuals dc_{rel} is ± 5 % in relation to the measured value.

Figure 10: Deviation from the linear regression function, system 2

7.5 Assessment

The maximum deviation from the linear regression function amounts to 1.0 % for system 1 and 0.7 % for system 2.

The following values were used for the calculation of the total uncertainty: 0.028 for system 1 and 0.020 for system 2.

Minimum requirement fulfilled? yes

7.6 Detailed presentation of test results

The individual test results are presented in Table 23 and Table 24.

Table 23: Individual results of lack of fit test, system 1

Concentration level	**Date**	**Time**	**Reading** [µg/m³]	**Nominal value** [µg/m³]	**Deviation** [µg/m³]
1	11 NOV 2011	14:37	35.369	35.000	0.369
1	11 NOV 2011	14:52	35.249	35.000	0.249
1	11 NOV 2011	15:07	35.397	35.000	0.397
1	11 NOV 2011	15:22	35.161	35.000	0.161
1	11 NOV 2011	15:37	35.282	35.000	0.282
2	11 NOV 2011	15:52	15.469	15.000	0.469
2	11 NOV 2011	16:07	15.267	15.000	0.267
2	11 NOV 2011	16:22	15.463	15.000	0.463
2	11 NOV 2011	16:37	15.522	15.000	0.522
2	11 NOV 2011	16:52	15.234	15.000	0.234
3	11 NOV 2011	17:07	0.512	0.500	0.012
3	11 NOV 2011	17:22	0.523	0.500	0.023
3	11 NOV 2011	17:37	0.515	0.500	0.015
3	11 NOV 2011	17:52	0.521	0.500	0.021
3	11 NOV 2011	18:07	0.523	0.500	0.023
4	11 NOV 2011	18:22	25.742	25.000	0.742
4	11 NOV 2011	18:37	25.458	25.000	0.458
4	11 NOV 2011	18:52	25.635	25.000	0.635
4	11 NOV 2011	19:07	25.651	25.000	0.651
4	11 NOV 2011	19:22	25.471	25.000	0.471
5	11 NOV 2011	19:37	5.234	5.000	0.234
5	11 NOV 2011	19:52	5.114	5.000	0.114
5	11 NOV 2011	20:07	5.234	5.000	0.234
5	11 NOV 2011	20:22	5.324	5.000	0.324
5	11 NOV 2011	20:37	5.231	5.000	0.231
6	11 NOV 2011	20:52	45.665	45.000	0.665
6	11 NOV 2011	21:07	45.521	45.000	0.521
6	11 NOV 2011	21:22	45.415	45.000	0.415
6	11 NOV 2011	21:37	45.269	45.000	0.269
6	11 NOV 2011	21:52	45.241	45.000	0.241

Table 24: Individual results of lack of fit test, system 2

Concentration level	Date	Time	Reading [µg/m³]	Nominal value [µg/m³]	Deviation [µg/m³]
1	11 NOV 2011	14:37	34.987	35.000	-0.013
1	11 NOV 2011	14:52	35.026	35.000	0.026
1	11 NOV 2011	15:07	35.019	35.000	0.019
1	11 NOV 2011	15:22	34.968	35.000	-0.032
1	11 NOV 2011	15:37	34.996	35.000	-0.004
2	11 NOV 2011	15:52	15.102	15.000	0.102
2	11 NOV 2011	16:07	15.032	15.000	0.032
2	11 NOV 2011	16:22	15.048	15.000	0.048
2	11 NOV 2011	16:37	15.147	15.000	0.147
2	11 NOV 2011	16:52	14.999	15.000	-0.001
3	11 NOV 2011	17:07	0.499	0.500	-0.001
3	11 NOV 2011	17:22	0.501	0.500	0.001
3	11 NOV 2011	17:37	0.499	0.500	-0.001
3	11 NOV 2011	17:52	0.497	0.500	-0.003
3	11 NOV 2011	18:07	0.501	0.500	0.001
4	11 NOV 2011	18:22	25.102	25.000	0.102
4	11 NOV 2011	18:37	25.236	25.000	0.236
4	11 NOV 2011	18:52	25.140	25.000	0.140
4	11 NOV 2011	19:07	25.039	25.000	0.039
4	11 NOV 2011	19:22	25.108	25.000	0.108
5	11 NOV 2011	19:37	5.014	5.000	0.014
5	11 NOV 2011	19:52	5.069	5.000	0.069
5	11 NOV 2011	20:07	5.128	5.000	0.128
5	11 NOV 2011	20:22	5.111	5.000	0.111
5	11 NOV 2011	20:37	5.127	5.000	0.127
6	11 NOV 2011	20:52	45.025	45.000	0.025
6	11 NOV 2011	21:07	45.018	45.000	0.018
6	11 NOV 2011	21:22	45.201	45.000	0.201
6	11 NOV 2011	21:37	45.186	45.000	0.186
6	11 NOV 2011	21:52	45.156	45.000	0.156

7.1 8.5.4 Short-term drift

The short-term drift (24 h) shall comply with the following performance criterion: max. 5 % of the applied benzene concentration.

7.2 Equipment

Zero and test gases of suitable concentrations as well as a gas mixing unit were used to test this performance criterion.

7.3 Method

The instrument was kept running under laboratory conditions whilst analysing span gas. From 4 successive measurements the mean value was calculated. After a period of 24 hours the measurements at span value were repeated.

The short-term drift at span level was calculated according to the following equation:

$$d_{24h} = \frac{\left|\overline{c}_n - \overline{c}_{n-1}\right|}{\overline{c}_n} * 100\%$$

where:

d_{24h} = drift at span concentration c_t as percentage

$\overline{c}_n$ = average of the 4 analyses at the beginning of the drift period

$\overline{c}_{n-1}$ = average of the 4 analyses at the end of the drift period (24 h)

The uncertainty u_s due to short-term drift was calculated as follows in accordance with ENV 13005:

$$d_{24h} = \frac{\overline{c}_n - \overline{c}_{n-1}}{2x\sqrt{3}}$$

where:

$\overline{c}_{n-1}$ = average of the 4 analyses at the beginning of the drift period

$\overline{c}_n$ = average of the 4 analyses at the end of the drift period (24 h)

The result of the short-term drift is not included in the uncertainty but is carried out to ensure that the contribution is not important.

7.4 Evaluation

The values obtained during the short-time drift are presented in Table 25.

Table 25: Results of short-term drift test

	System 1 (005) [µg/m³]	System 2 (006) [µg/m³]
c_n	35.59	35.65
c_{n-1}	35.56	35.63
d_{24h}	**0.08%**	**0.06%**
Requirement fulfilled?	**yes**	**yes**

7.5 Assessment

The short-term drift d_{24h} amounts to 0.08 % for system 1 and 0.06 % for system 2.

The standard uncertainty due to short-term drift is 0.0079 µg/m³ for system 1 and 0.0065 µg/m³ for system 2.

Minimum requirement fulfilled? yes

7.6 Detailed presentation of test results

The individual results of the short-term drift test are presented in Table 26 and Table 27.

Table 26: Individual results of short-term drift test, system 1

Initial reading			**End reading**	
Span point			Span point	
[Time]	[µg/m³]		[Time]	[µg/m³]
13:18	35.62		13:18	35.56
13:33	35.61		13:33	35.54
13:48	35.55		13:48	35.62
14:03	35.56		14:03	35.51
Average	**35.59**		**Average**	**35.56**

Table 27: Individual results of short-term drift test, system 2

Initial reading			**End reading**	
Span point			Span point	
[Time]	[µg/m³]		[Time]	[µg/m³]
13:18	35.65		13:18	35.62
13:33	35.68		13:33	35.62
13:48	35.64		13:48	35.64
14:03	35.62		14:03	35.62
Average	**35.65**		**Average**	**35.63**

7.1 8.5.5 Repeatability

The repeatability shall comply with the performance criterion both at zero (0.3 µg/m³) and at the test concentration limit value (± 5 %).

7.2 Equipment

Zero and test gases of suitable concentrations as well as a gas mixing unit were used to test this performance criterion.

7.3 Method

The standard deviations of 10 successive individual measurements at the limit value, and at approximately 1/10 of the limit value, were calculated according to the following equation:

$$s_r(c) = \sqrt{\frac{\sum (c_{test,i} - \bar{c}_{test})^2}{n-1}}$$

where:

$s_r(c)$	=	repeatability standard deviation at the measurand level c
$c_{test,i}$	=	*i*th individual measurement at measurand level c_{test}
$\bar{c}_{test}$	=	average of individual measurements at measurand level c_{test}
n	=	number of individual measurements

The repeatability (r_i) is calculated as follows:

$$r_i = t_{n-1;0,05} * s_i$$

where:

$t_{n-1;0,05}$	=	two-sided Student's t-factor at a confidence level of 0.05, with n-1 degrees of freedom (for n = 10, $t_{9;\,0,05}$ = 2.262)
s_i	=	repeatability standard deviation in µmol/mol

The repeatability standard uncertainty u_r is determined by:

$$u_r = s_r$$

7.4 Evaluation

Table 28 shows the results of the repeatability test at 1/10 of the limit value. Table 29 presents the test results at the limit value.

Table 28: Repeatability at 1/10 of the limit value

Laboratory		**Zero point**	
Date	**Time**	**System 1 (005)**	**System 2 (006)**
		[µg/m³]	**[µg/m³]**
05 NOV 2011	07:37 - 08:37	0.52	0.48
05 NOV 2011	09:37 - 10:37	0.54	0.49
05 NOV 2011	11:37 - 12:37	0.54	0.50
05 NOV 2011	13:37 - 14:37	0.54	0.50
05 NOV 2011	15:37 - 16:37	0.56	0.48
05 NOV 2011	17:37 - 18:37	0.51	0.48
05 NOV 2011	19:37 - 20:37	0.52	0.48
05 NOV 2011	21:37 - 22:37	0.52	0.50
05 NOV 2011	23:37 - 00:37	0.52	0.50
06 NOV 2011	01:37 - 02:37	0.54	0.51
Number of measurements (n)		10	10
Average		0.53	0.49
Standard deviation (s_r)		0.02	0.01
Repeatability (r_l)		**0.03**	**0.03**
Standard uncertainty (u_r)		0.02	0.01
Requirement of EN 14663-3		0.30	0.30
Requirement fulfilled?		yes	yes

Table 29: Repeatability at the limit value

Laboratory		Span point	
Date	Time	System 1 (005) [µg/m³]	System 2 (006) [µg/m³]
05 NOV 2011	08:38 - 09:37	5.06	5.01
05 NOV 2011	10:37 - 11:37	5.08	5.02
05 NOV 2011	12:37 - 13:37	5.04	5.01
05 NOV 2011	14:37 - 15:37	5.08	5.00
05 NOV 2011	16:37 - 17:37	5.04	5.02
05 NOV 2011	18:37 - 19:37	5.05	5.04
05 NOV 2011	20:37 - 21:37	5.05	5.02
05 NOV 2011	22:37 - 23:37	5.06	5.02
06 NOV 2011	00:37 - 01:37	5.04	5.04
06 NOV 2011	02:37 - 03:37	5.02	5.02
Number of measurements (n)		10	10
Average		5.05	5.02
Standard deviation (s_r)		0.02	0.01
Repeatability (r_l)		**0.04**	**0.03**
Standard uncertainty (u_r)		0.02	0.01
Requirement of EN 14663-3		0.25	0.25
Requirement fulfilled?		yes	yes

7.5 Assessment

The repeatability (r_l) at 1/10 of the limit value amounts to 0.03 µg/m³ for system 1 and 0.03 µg/m³ for system 2. For repeatability at the limit value the following results were obtained: 0.04 µg/m³ for system 1 and 0.03 µg/m³ for system 2.

The values obtained at 1/10 of the limit value which are used as contribution for the total uncertainty calculation are the following: 0.02 µg/m³ for system 1 and 0.01 µg/m³ for system 2. The contributions to the total uncertainty obtained at the limit value amount to 0.02 µg/m³ for system 1 and 0.01 µg/m³ for system 2.

Minimum requirement fulfilled? yes

7.6 Detailed presentation of test results

Not required for this performance criterion.

7.1 8.5.6 Dependence on sample gas pressure

The dependence of sample gas pressure shall not exceed ± 1 %/kPa.

7.2 Equipment

No additional equipment is required.

7.3 Method

The benzene analyser VOC72M measures the content of benzene in ambient air. It is equipped with a pump, with which it absorbs the ambient air to be analysed (approx. 0.05 l/min total flow). This pump works against surrounding conditions, i.e. the pressure at the sample gas inlet is the same as the pressure at the sample gas outlet. A forced induction of overpressure or underpressure in the system could damage the analyser.

The VOC72M is equipped with internal pressure measurement provisions which measure the atmospheric pressure. The output signals always compensate the pressure.

During the three-month field test, surrounding pressures of 100.7 kPa (4 April 2012) and 103.6 kPa (06 February 2012) were measured on the days on which the drift checks were carried out. No particular behaviours of the analysers with respect to changes on the surrounding air pressure and, by extension, to the pressure conditions of the sampled test gases could be observed during this period

The partial standard uncertainty due to pressure changes u_p was estimated according to the following equation:

$$u_p \frac{b_p * \left|\Delta P\right|}{2x\sqrt{3}}$$

where the sensitivity coefficient bp [(µg(m³)/kPa] is given by:

$$b_p = \frac{\left|c_{P\max} - c_{P\min}\right|}{\left|\Delta P\right|}$$

and:

$c_{P\max}$ = average of the individual measurements at maximum sampling gas pressure p_{max} at limit value concentration

$c_{P\min}$ = average of the individual measurements at minimum sampling gas pressure p_{min} at limit value concentration

7.4 Evaluation

The minimum value of surrounding pressure = 100.7 kPa was recorded during the field test on 4 April 2012. On this day the drift checks at span resulted in values of 34.33 µg/m³ for system 1 and 34.18 µg/m³ for system 2.

The highest value of surrounding pressure = 103.6 kPa was recorded on 6 February 2012. On this day the drift checks at span resulted in values of 34.20 µg/m³ for system 1 and 34.15 µg/m³ for system 2.

7.5 Assessment

The drift check data result in a sensitivity coefficient of surrounding pressure of 0.045 for system 1 (SN 005) and 0.010 for system 2 (SN 006)

For the calculation of the total uncertainty, a value u_p of 0.038 µg/m³ is used for system 1 (SN 005) and 0.008 µg/m³ for system 2 (SN 006).

Minimum requirement fulfilled? yes

7.6 Detailed presentation of test results

Not required for this performance criterion.

7.1 8.5.7 Dependence on surrounding air temperature

The dependence on surrounding air temperature shall not exceed ± 0.2 %/K.

7.2 Equipment

Zero and test gases of suitable concentrations as well as a gas mixing unit were used to test this performance criterion.

7.3 Method

The influence of the surrounding air temperature was determined at the minimum and maximum temperature specified by the manufacturer as the operating range of the analyser.

The influence was determined at approximately 1/10 of the limit value and at a span concentration in the range 70 % to 90 % of the maximum of the certification range. The criteria for warm-up or stabilisation time shall be met at each temperature.

The uncertainty caused by changes in surrounding temperature u_{Ts} was then determined according to the following equation:

$$u_{Ts} \frac{b_{Ts} * \left|\Delta T_s\right|}{2x\sqrt{3}}$$

where the sensitivity coefficient b_{Ts} [(µg(m³)/K] is given by:

$$b_{Ts} = \frac{\left|c_{Ts\max} - c_{Ts\min}\right|}{\left|\Delta T_s\right|}$$

and:

$c_{Ts\max}$ = average of the individual measurement at maximum surrounding temperature $T_{s,max}$

$c_{Ts\min}$ = average of the individual measurement at minimum surrounding temperature $T_{s,min}$

7.4 Evaluation

Table 30 shows the results of the test of dependence on surrounding air temperature at 1/10 of the limit value. Table 31 presents the test results at 70% of the certification range.

Table 30: Dependence on surrounding air temperature at 1/10 of the limit value

1st run					
Zero point	**T [° K]**	**Average System 005 [µg/m^3]**	**Determined b_{Ts} [µg/m^3/K]**	**Average System 006 [µg/m^3]**	**Determined b_{Ts} [µg/m^3/K]**
T_{min}	278	0.51		0.48	
T_{max}	308	0.51	**-0.0001**	0.50	**0.0006**
2nd run					
Zero point	**T [° K]**	**Average System 005 [µg/m^3]**	**Determined b_{Ts} [µg/m^3/K]**	**Average System 006 [µg/m^3]**	**Determined b_{Ts} [µg/m^3/K]**
T_{min}	278	0.51		0.49	
T_{max}	308	0.51	**0.0000**	0.48	**-0.0002**
3rd run					
Zero point t	**T [° K]**	**Average System 005 [µg/m^3]**	**Determined b_{Ts} [µg/m^3/K]**	**Average System 006 [µg/m^3]**	**Determined b_{Ts} [µg/m^3/K]**
T_{min}	278	0.51		0.51	
T_{max}	308	0.52	**0.0002**	0.50	**-0.0001**
Maximum b_{Ts}			**0.0001**		**0.0002**
Maximum u_{Ts}			**0.0010**		**0.0019**

Table 31: Dependence on surrounding air temperature at 70 % of the certification range

1st run					
Span point	**T [° K]**	**Average System 005 [µg/m³]**	**Determined b_{Ts} [µg/m³/K]**	**Average System 006 [µg/m³]**	**Determined b_{Ts} [µg/m³/K]**
T_{min}	278	35.63		35.52	
T_{max}	308	35.65	**0.0008**	35.51	**-0.0003**
2nd run					
Span point	**T [° K]**	**Average System 005 [µg/m³]**	**Determined b_{Ts} [µg/m³/K]**	**Average System 006 [µg/m³]**	**Determined b_{Ts} [µg/m³/K]**
T_{min}	278	35.65		35.53	
T_{max}	308	35.68	**0.0010**	35.57	**0.0016**
3rd run					
Span point	**T [° K]**	**Average System 005 [µg/m³]**	**Determined b_{Ts} [µg/m³/K]**	**Average System 006 [µg/m³]**	**Determined b_{Ts} [µg/m³/K]**
T_{min}	278	35.63		35.52	
T_{max}	308	35.66	**0.0010**	35.53	**0.0002**
Maximum b_{Ts}			**0.0010**		**0.0016**
Maximum u_{Ts}			**0.0087**		**0.0135**

7.5 Assessment

The dependence on surrounding air temperature (bTs) at 1/10 of the limit value amounts to 0.0001 µg/m³ for system 1 and 0.0002 µg/m³ for system 2. At 70 % of the certification range, the dependence on surrounding air temperature amounts to 0.0010 µg/m³ for system 1 and 0.0016 µg/m³ for system 2.

The following values obtained at 1/10 of the limit value are used as contribution for the total uncertainty calculation: 0.0010 µg/m³ for system 1 and 0.0019 µg/m³ for system 2. The contributions obtained at 70 % of the certification range amount to 0.0087 µg/m³ for system 1 and 0.0135 µg/m³ for system 2.

Minimum requirement fulfilled? yes

7.6 Detailed presentation of test results

Table 32 and Table 33 show the individual values of the test of dependence on surrounding air temperature.

Table 32: Individual results of test of dependence on surrounding air temperature at zero point

Date	**Zero point**			
	Time	**Temperature [°K]**	**System 1 (005) [µg/m³]**	**System 2 (006) [µg/m³]**
05 DEC 2011	17:06 - 17:21	**278**	0.51	0.48
05 DEC 2011	18:06 - 18:21	**278**	0.51	0.49
05 DEC 2011	19:06 - 19:21	**278**	0.51	0.48
	Average		**0.51**	**0.48**
06 DEC 2011	11:06 - 11:21	**308**	0.51	0.50
06 DEC 2011	12:06 - 12:21	**308**	0.51	0.50
06 DEC 2011	12:06 - 13:21	**308**	0.50	0.50
	Average		**0.51**	**0.50**
07 DEC 2011	05:06 - 05:21	**278**	0.52	0.49
07 DEC 2011	06:06 - 06:21	**278**	0.51	0.49
07 DEC 2011	07:06 - 07:21	**278**	0.51	0.49
	Average		**0.51**	**0.49**
07 DEC 2011	23:06 - 23:21	**308**	0.52	0.48
08 DEC 2011	00:06 - 00:21	**308**	0.51	0.48
08 DEC 2011	01:06 - 01:21	**308**	0.51	0.49
	Average		**0.51**	**0.48**
08 DEC 2011	17:06 - 17:21	**278**	0.51	0.51
08 DEC 2011	18:06 - 18:21	**278**	0.51	0.51
08 DEC 2011	19:06 - 19:21	**278**	0.52	0.50
	Average		**0.51**	**0.51**
09 DEC 2011	11:06 - 11:21	**308**	0.51	0.51
09 DEC 2011	12:06 - 12:21	**308**	0.53	0.50
09 DEC 2011	12:06 - 13:21	**308**	0.52	0.50
	Average		**0.52**	**0.50**

Table 33: Individual results of test of dependence on surrounding air temperature at span point

Date	Span point			
	Time	Temperature [°K]	System 1 (005) [µg/m³]	System 2 (006) [µg/m³]
05 DEC 2011	17:36 - 17:51	**278**	35.62	35.54
05 DEC 2011	18:36 - 18:51	**278**	35.64	35.51
05 DEC 2011	19:36 - 19:51	**278**	35.62	35.52
	Average		**35.63**	**35.52**
06 DEC 2011	11:36 - 11:51	**308**	35.64	35.50
06 DEC 2011	12:36 - 12:51	**308**	35.64	35.50
06 DEC 2011	13:36 - 13:51	**308**	35.67	35.54
	Average		**35.65**	**35.51**
07 DEC 2011	05:36 - 05:51	**278**	35.62	35.56
07 DEC 2011	06:36 - 06:51	**278**	35.64	35.51
07 DEC 2011	07:36 - 07:51	**278**	35.68	35.51
	Average		**35.65**	**35.53**
07 DEC 2011	23:36 - 23:51	**308**	35.68	35.56
08 DEC 2011	00:36 - 00:51	**308**	35.67	35.58
08 DEC 2011	01:36 - 01:51	**308**	35.68	35.58
	Average		**35.68**	**35.57**
08 DEC 2011	17:36 - 17:51	**278**	35.62	35.52
08 DEC 2011	18:36 - 18:51	**278**	35.63	35.51
08 DEC 2011	19:36 - 19:51	**278**	35.64	35.54
	Average		**35.63**	**35.52**
09 DEC 2011	11:36 - 11:51	**308**	35.66	35.51
09 DEC 2011	12:36 - 12:51	**308**	35.66	35.56
09 DEC 2011	13:36 - 13:51	**308**	35.66	35.52
	Average		**35.66**	**35.53**

7.1 8.5.8 Dependence on voltage

The dependence on voltage shall not exceed ± 0.2 %/V.

7.2 Equipment

Zero and test gases of suitable concentrations as well as a gas mixing unit were used to test this performance criterion.

7.3 Method

The dependence on line voltage was determined by tests at the minimum and maximum of the voltage range specified by the manufacturer (V_{max}, V_{min}). The benzene concentrations were approximately 1/10 of the limit value and around 70 % to 90 % of the maximum of the certification range. At least 4 individual measurements were taken at each voltage level and concentration.

The uncertainty from voltage dependence u_v was calculated according to the following equation:

$$u_v \frac{b_v * |\Delta V|}{2x\sqrt{3}}$$

where the sensitivity coefficient b_v [(µg(m³)/V] is given by:

$$b_{Ts} = \frac{|c_{v\max} - c_{v;\min}|}{|\Delta V|}$$

and:

$c_{v\max}$ = average of the individual measurement at maximum voltage V_{max}

$c_{v\min}$ = average of the individual measurement at minimum voltage V_{min}

7.4 Evaluation

Table 34 and Table 35 show the individual results of the test of dependence on voltage.

Table 34: Dependence on voltage at zero point

Date	Time	System 1 (005)	System 2 (006)
		[µg/m³]	[µg/m³]
Zero gas at 210 V			
20 DEC 2011	09:06 - 09:21	0.52	0.55
20 DEC 2011	09:21 - 09:36	0.51	0.54
20 DEC 2011	09:36 - 09:51	0.51	0.54
20 DEC 2011	09:51 - 10:06	0.51	0.54
Average		**0.51**	**0.54**
Zero gas at 245 V			
20 DEC 2011	10:06 - 10:21	0.52	0.53
20 DEC 2011	10:21 - 10:36	0.53	0.55
20 DEC 2011	10:36 - 10:51	0.52	0.55
20 DEC 2011	10:51 - 11:06	0.52	0.56
Average		**0.52**	**0.55**
Sensitivity coefficient (b_v)		**0.0003**	**0.0001**
Uncertainty (u_v)		**0.0029**	**0.0014**

Table 35: Dependence on voltage at span point

Date	Time	System 1 (005)	System 2 (006)
		[µg/m³]	[µg/m³]
Test gas at 210 V			
20 DEC 2011	11:21 - 11:36	35.32	34.99
20 DEC 2011	11:36 - 11:51	35.36	34.96
20 DEC 2011	11:51 - 12:06	35.34	34.97
20 DEC 2011	12:06 - 12:21	35.36	34.98
Average		**35.35**	**34.98**
Test gas at 245 V			
20 DEC 2011	12:21 - 12:36	35.26	35.01
20 DEC 2011	12:36 - 12:51	35.31	35.00
20 DEC 2011	12:51 - 13:06	35.28	34.98
20 DEC 2011	13:06 - 13:21	35.29	34.99
Average		**35.29**	**35.00**
Sensitivity coefficient (b_v)		**0.0017**	**0.0006**
Uncertainty (u_v)		**0.0172**	**0.0058**

7.5 Assessment

The dependence on voltage (b_v) at 1/10 of the limit value amounts to 0.0003µg/m³ for system 1 and 0.0001 µg/m³ for system 2. At 70 % of the certification range, the dependence on voltage amounts to 0.0017 µg/m³ for system 1 and 0.0006 µg/m³ for system 2.

The following values obtained at 1/10 of the limit value are used as contribution for the total uncertainty calculation: 0.0029 µg/m³ for system 1 and 0.0014 µg/m³ for system 2. The contributions obtained at 70 % of the certification range amount to 0.0172 µg/m³ for system 1 and 0.0058 µg/m³ for system 2.

Minimum requirement fulfilled? yes

7.6 Detailed presentation of test results

Not required for this performance criterion.

7.1 8.5.9 Interference

The influence of the interferences shall comply with the following performance criteria: Ozone: <± 5 %, relative humidity: <± 4 %, sum of possible interfering organic compounds at span value: <± 5 %.

7.2 Equipment

Zero and test gases of suitable concentrations, a gas mixing unit, a concentration enrichment device (including water bath) as well as a dilution system were used to test this performance criterion.

7.3 Method

The analyser response to certain interferents, which are to be expected to be present in ambient air, was tested. The interferents can have a positive or negative effect. The test was performed at benzene concentrations of 1/10 of the limit value and at 70 % to 90 % of the maximum of the certification range.

Note:

The test was conducted in accordance with the EN 14662-3:2005 at benzene concentrations of 1/10 of the threshold value, and at a concentration of 70% to 90% of the maximum of the certified range. The calculation of the cross sensitivity has been done in accordance with the draft standard EN 14662-3 from July 2012, as the original formulas in standard EN 14662-3:2005 have proven as faulty.

Also, the uncertainty calculation for the rel. humidity is determined according to the draft standard EN 14662-3 from July 2012. The calculation of the uncertainty of ozone and organic components is refused according to the draft Directive EN 14662-3 from July 2012.

Ozone

The influence of the cross interference component ozone is, unlike Directive EN 14662-3:2005, according to the current draft directive EN 14662-3 from July 2012 no longer audit ingredient. The examination of the impact of ozone was measured in the present examinations yet, though not considered in the uncertainty analysis.

The influence of ozone was checked by adding 180 µg/m³ of O_3 from an interconnected ozone generator to a benzene test gas at span concentration.

The influence quantity of ozone b_{O3} was calculated as follows:

$$b_{O3} = \frac{\left|\overline{c}_{O3} - \overline{c}\right|}{\left|c_{\text{int},O3}\right|}$$

where:

$\overline{c}_{O3}$ = average of individual measurements at maximum ozone concentration $c_{int,O3}$

$\overline{c}$ = average of individual measurements without ozone

Relative humidity

The influence of relative humidity was checked at 20 % to 80 % relative humidity at standard temperature and pressure and the relative uncertainty contribution u_{H2O} was calculated from:

$$u_{H2O} = b_{H2O} * \frac{I_a}{c_t} \sqrt{\frac{c_{H2O,max}^2 + c_{H2O,max} c_{H2O,min} + c_{H2O,min}^2}{3}}$$

The sensitivity coefficient in [(µg/m³)/mmol/mol] is given by:

$$b_{H2O} = \frac{x_{+W} - x_{-W}}{c_W}$$

It is:

b_{H2O}	Sensitivity coefficient in [(µg/m³)/mmol/mol]
x_{+W}	average at concentrations c_t in presence of water vapour in µg/m³
x_{-W}	average at concentrations ct in absence of water vapour in µg/m³
c_W	test concentration of water
c_t	test concentration of benzene in
I_a	anual limit value of benzene in µg/m³ (=5 µg/m³)

Organic compounds

Possible interference from organic compounds was investigated by a gas mixture of the substances listed in Table 36 at known concentrations of 3 – 10 10 µg/m³ for each compound

Table 36: Organic interferents

Compound
Methylcyclopentane
2,2,3-Trimethylbutane
2,4-Dimethylpentane
Tetrachloromethane
Cyclohexane
2,3-Dimethylpentane
2-Methylhexane
3-Ethylpentane
Trichlorethylene
n-Heptane

The relative uncertainty from interference of the sum of organic compounds u_{corg} is calculated from:

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

and

x_+ = average of individual measurements in the presence of the gas mixture selected

x_- = average of individual measured concentrations without interference

7.4 Evaluation

In order to determine the interference of ozone, test gases with a benzene concentration of 1/10 of the limit value and 70 % of the certification range were admitted to the measuring system. Then, an ozone concentration of 180 µg/m³ was mixed to both concentration levels.

Table 37: Interference of ozone

	Benzene conc.		Device 1 (0005) [µg/m³/nmol/mol]	Device 2 (0006) [µg/m³/nmol/mol]
Ozone	1/10	$b_{int,O3}$	0.00	0.00
	70%	$b_{int,O3}$	0.00	0.00

For the determination of the influence of humidity, test gases with a benzene concentration of 1/10 of the limit value and 70 % of the certification range were fed to the AMS. Then, a defined humidity concentration of 20 % and 80 % relative humidity was applied.

Table 38: Interference of H_2O

	Benzene conc.		Device 1 (0005) [µg/m³/mmol/mol]	Device 2 (0006) [µg/m³/mmol/mol]
H_2O 20%	1/10	b_{H2O}	0.00	0.00
	1/10	u_{rh}	**0.003**	**0.006**
	70%	b_{H2O}	-0.05	0.04
	70%	u_{rh}	**-0.094**	**0.085**
H_2O 80%	1/10	b_{H2O}	0.00	0.00
	1/10	u_{rh}	**0.002**	**0.001**
	70%	b_{H2O}	0.00	0.01
	70%	u_{rh}	**0.006**	**0.014**

The interference of organic compounds was determined by admitting test gas with a benzene concentration of 1/10 of the limit value and 70 % of the certification range to the AMS and then adding organic compounds in two steps.

To test the interference of organic compounds, a concentration enrichment device was used. The interferents were available as solutions. Each hydrocarbon to be vaporised was filled into a special glass container equipped with an immersion tube as well as a gas inlet and outlet, and tempered in a water bath. The gas inlet was connected to a thermic mass flow controller station, whose flow range was adjusted to just a few ml/min. The outlet of the vaporising container was connected to a mixing chamber. The mixing container was connected to a second mass flow controller station for diluting the components. In order to test, as stipulated, all compounds simultaneously, several mass flow controller stations were used. Furthermore, some vaporising containers were connected in series.

Table 39: Interference of organic compounds

Benzene conc.			Device 1 (0005) [µg/m³]	Device 2 (0006) [µg/m³]
Organic compounds	1/10	Δx_{oc}	0.01	0.01
	70%	Δx_{oc}	-0.22	-0.16

7.5 Assessment

The following interferences (u) were determined at 1/10 of the limit value: For component ozone, interference amounts to 0,00 µg/m³ for system 1 and 0,00 µg/m³ for system 2. For humidity, interference totals 0,00 µg/m³ for system 1 and 0,00 µg/m³ for system 2. For organic substances, interference was found to be 0,01 µg/m³ for system 1 and 0,001 µg/m³ for system 2.

The following interferences (u) were determined at a concentration of 70% of certification range: For component ozone, interference amounts to 0,00 µg/m³ for system 1 and 0,00 µg/m³ for system 2. For humidity, interference totals 0,00 µg/m³ for system 1 and 0,01 µg/m³ for system 2. For organic substances, interference was found to be -0,22 µg/m³ for system 1 and -0,16 µg/m³ for system 2.

For the calculation of the total uncertainty, the following contributions were determined at 70 % of the certification range: For humidity: 0.006 µg/m³ for system 1 and 0.014 µg/m³ for system 2.

Minimum requirement fulfilled? yes

7.6 Detailed presentation of test results

Table 40 to Table 43 shows the individual results of the interference tests.

Table 40: Individual results of interference test for ozone

Date	Time	System 1 (0005) [µg/m³]	System 2 (0006) [µg/m³]
1/10 of limit value without ozone			
03 JAN 2012	09:07 - 09:22	0.50	0.51
03 JAN 2012	09:22 - 09:37	0.50	0.51
03 JAN 2012	09:37 - 09:52	0.50	0.50
03 JAN 2012	09:52 - 10:07	0.49	0.51
Average		**0.50**	**0.51**
1/10 of limit value with ozone			
03 JAN 2012	10:22 - 10:37	0.52	0.52
03 JAN 2012	10:37 - 10:52	0.53	0.54
03 JAN 2012	10:52 - 11:07	0.51	0.53
03 JAN 2012	11:07 - 11:22	0.54	0.52
Average		**0.53**	**0.53**
Concentration c_t without ozone			
03 JAN 2012	12:07 - 12:22	34.89	35.21
03 JAN 2012	12:22 - 12:37	34.95	35.23
03 JAN 2012	12:37 - 12:52	34.99	35.08
03 JAN 2012	12:52 - 13:07	34.93	35.16
Average		**34.94**	**35.17**
Concentration c_t with ozone			
03 JAN 2012	13:22 - 13:37	35.02	35.22
03 JAN 2012	13:37 - 13:52	35.05	35.28
03 JAN 2012	13:52 - 14:07	35.01	35.17
03 JAN 2012	14:07 - 14:22	35.12	35.23
Average		**35.05**	**35.23**

Table 41: Individual results of interference test for H_2O 20 % rel. humidity

Date	Time	System 1 (0005)	System 2 (0006)
		[µg/m³]	[µg/m³]
1/10 of limit value without H_2O 20 %			
04 JAN 2012	09:07 - 09:22	0.51	0.52
04 JAN 2012	09:22 - 09:37	0.52	0.51
04 JAN 2012	09:37 - 09:52	0.52	0.51
04 JAN 2012	09:52 - 10:07	0.52	0.52
Average		**0.52**	**0.52**
1/10 of limit value with H_2O 20 %			
04 JAN 2012	10:22 - 10:37	0.53	0.52
04 JAN 2012	10:37 - 10:52	0.54	0.53
04 JAN 2012	10:52 - 11:07	0.52	0.53
04 JAN 2012	11:07 - 11:22	0.51	0.54
Average		**0.53**	**0.53**
Concentration c_t without H_2O 20 %			
04 JAN 2012	12:07 - 12:22	35.23	35.36
04 JAN 2012	12:22 - 12:37	35.26	35.31
04 JAN 2012	12:37 - 12:52	35.36	35.28
04 JAN 2012	12:52 - 13:07	35.34	35.31
Average		**35.30**	**35.32**
Concentration c_t with H_2O 20 %			
04 JAN 2012	13:22 - 13:37	35.49	35.39
04 JAN 2012	13:37 - 13:52	35.54	35.37
04 JAN 2012	13:52 - 14:07	35.52	35.41
04 JAN 2012	14:07 - 14:22	35.52	34.29
Average		**35.52**	**35.12**

Table 42: Individual results of interference test for H_2O 80 % rel. humidity

Date	Time	System 1 (005) [µg/m³]	System 2 (006) [µg/m³]
1/10 of limit value without H_2O 80 %			
05 JAN 2012	10:07 - 10:22	0.51	0.53
05 JAN 2012	10:22 - 10:37	0.50	0.52
05 JAN 2012	10:37 - 10:52	0.50	0.52
05 JAN 2012	10:52 - 11:07	0.49	0.51
Average		**0.50**	**0.52**
1/10 of limit value with H_2O 80 %			
05 JAN 2012	11:22 - 11:37	0.51	0.52
05 JAN 2012	11:37 - 11:52	0.52	0.52
05 JAN 2012	11:52 - 12:07	0.52	0.53
05 JAN 2012	12:07 - 12:22	0.52	0.53
Average		**0.52**	**0.53**
Concentration c_t without H_2O 80 %			
05 JAN 2012	13:07 - 13:22	35.21	35.21
05 JAN 2012	13:22 - 13:37	35.05	35.23
05 JAN 2012	13:37 - 13:52	35.09	35.08
05 JAN 2012	13:52 - 14:07	35.03	35.16
Average		**35.10**	**35.17**
Concentration c_t with H_2O 80 %			
05 JAN 2012	14:22 - 14:37	35.24	35.34
05 JAN 2012	14:37 - 14:52	35.10	35.31
05 JAN 2012	14:52 - 15:07	35.19	35.28
05 JAN 2012	15:07 - 15:22	35.09	35.28
Average		**35.16**	**35.30**

Table 43: Individual results of interference test for organic compounds

Date	Time	System 1 (0005)	System 2 (0006)
		[µg/m³]	[µg/m³]
1/10 of limit value without organic compounds			
11 JAN 2012	10:37 - 10:52	0.51	0.52
11 JAN 2012	10:52 - 11:07	0.52	0.52
11 JAN 2012	11:07 - 11:22	0.51	0.52
11 JAN 2012	11:22 - 11:37	0.51	0.53
Average		**0.51**	**0.52**
1/10 of limit value with organic compounds			
11 JAN 2012	11:52 - 12:07	0.52	0.54
11 JAN 2012	12:07 - 12:22	0.51	0.52
11 JAN 2012	12:22 - 12:37	0.53	0.52
11 JAN 2012	12:37 - 12:52	0.52	0.53
Average		**0.52**	**0.53**
Concentration c_t without organic compounds			
11 JAN 2012	13:22 - 13:37	35.23	35.39
11 JAN 2012	13:37 - 13:52	35.37	35.41
11 JAN 2012	13:52 - 14:07	35.34	35.41
11 JAN 2012	14:07 - 14:22	35.36	35.43
Average		**35.33**	**35.41**
Concentration c_t with organic compounds			
11 JAN 2012	14:37 - 14:52	35.56	35.56
11 JAN 2012	14:52 - 15:07	35.54	35.57
11 JAN 2012	15:07 - 15:22	35.49	35.58
11 JAN 2012	15:22 - 15:37	35.58	35.55
Average		**35.54**	**35.57**

7.1 8.5.10 Carry-over (memory effect)

The second analysis of zero air immediately following analysis of the highest concentration of benzene shall not exceed a measured benzene concentration of 0.5 µg/m³ (10 % of limit value).

7.2 Equipment

Zero and test gases of suitable concentrations as well as a gas mixing unit were used to test this performance criterion.

7.3 Method

During the linearity test the influence of a memory effect caused by the retention of benzene in the measuring system due to inappropriate materials or a large dead volume was checked.

The second analysis of zero air immediately following analysis of the highest concentration of benzene required for the linearity test shall not exceed a measured benzene concentration of 10 % of the limit value (0.5 µg/m³).

The value of every first analysis of the zero air measurements should be below 20 % of the limit value (= 1 µg/m³). Due to the sampling procedure, it was not possible to determine the response time exactly, and according to the definitions, the response time is at least one analysis cycle. Therefore the first analysis after an abrupt concentration change could not be taken into account. Evaluation of this test indicates only the suitability of the measuring system.

7.4 Evaluation

This test could not be carried out as part of the linearity test, since the zero point during the latter was adjusted to 1/10 of the limit value.

In order to test the memory effect, a change in concentration was brought about three times by feeding a span value of approx. 90 % of the certification range and then switching to zero gas. The results are listed in Table 44.

Table 44: Results of memory effect test

Date	Time	Nominal value [µg/m³]	System 1 (005) [µg/m³]	System 2 (006) [µg/m³]
1st run				
11 NOV 2011	14:22 - 14:37	45.0	45.230	45.170
11 NOV 2011	14:37 - 14:52	0.0	0.522	0.487
11 NOV 2011	14:52 - 15:07	0.0	0.024	0.011
11 NOV 2011	15:07 - 15:22	0.0	0.012	0.006
			ok	**ok**
2nd run				
11 NOV 2011	15:52 - 16:07	45.0	45.410	45.681
11 NOV 2011	16:07 - 16:22	0.0	0.487	0.523
11 NOV 2011	16:22 - 16:37	0.0	0.012	0.023
11 NOV 2011	16:37 - 16:52	0.0	0.007	0.004
			ok	**ok**
3rd run				
11 NOV 2011	17:07 - 17:22	45.0	45.385	45.681
11 NOV 2011	17:22 - 17:37	0.0	0.623	0.428
11 NOV 2011	17:37 - 17:52	0.0	0.042	0.019
11 NOV 2011	17:52 - 18:07	0.0	0.008	0.001
			ok	**ok**

7.5 Assessment

The minimum requirement was fulfilled. The VOC72M measuring system outputs a value close to 10 % of the limit value even during the first zero analysis after the change in sample gas.

Minimum requirement fulfilled? yes

7.6 Detailed presentation of test results

Not required for this performance criterion.

7.1 8.6.5 Long-term drift

The long-term drift at span value shall not exceed 10 %.

7.2 Equipment

Zero and test gases of suitable concentrations were used to test this performance criterion.

7.3 Method

Long-term drift was evaluated from the averages of 4 independent measurements at span concentration, with these sets of measurements performed at intervals of 14 days.

The long-term drift at span level was calculated as follows:

$$d_{14d} = \frac{\left|\bar{c}_n - \bar{c}_{n-1}\right|}{\bar{c}_n} x 100\%$$

where:

d_{14d} = drift at span concentration c_t as percentage

$\bar{c}_{nx}$ = average of the 4 analyses at the beginning of the drift period

$\bar{c}_{n-1}$ = average of the 4 analyses at the end of the drift period (14 days)

The largest d_{14d} value in the testing period shall comply with the performance criterion in Table 5 of EN 14662-3.

The uncertainty u_d due to the long-term drift at span was calculated as follows:

$$u_d = \frac{\left|\bar{c}_n - \bar{c}_{n-1}\right|}{2\sqrt{3}}$$

where:

$\bar{c}_{nx}$ = average of the 4 analyses at the beginning of the drift period

$\bar{c}_{n-1}$ = average of the 4 analyses at the end of the drift period (14 days)

7.4 Evaluation

Table 45 shows the results of the long-term drift test.

Table 45: Long-term drift test

	System 1 (005) [µg/m³]	System 2 (006) [µg/m³]
$C_{S,1}$ Start	34.07	34.10
c_{14d} 06 FEB 2012	34.31	34.32
d_{14d} 06 FEB 2012	**0.72%**	**0.65%**
u_d	**0.07**	**0.06**
c_{14d} 22 FEB 2012	34.85	34.82
d_{14d} 22 FEB 2012	**2.29%**	**2.13%**
u_d	**0.22**	**0.21**
c_{14d} 06 MAR 2012	34.76	34.72
d_{14d} 06 MAR 2012	**2.03%**	**1.84%**
u_d	**0.04**	**0.18**
c_{14d} 21 MAR 2012	34.87	34.80
d_{14d} 21 MAR 2012	**2.35%**	**2.06%**
u_d	**0.23**	**0.20**
c_{14d} 04 APR 2012	34.29	34.20
d_{14d} 04 APR 2012	**0.65%**	**0.31%**
u_d	**0.06**	**0.03**
c_{14d} 16 APR 2012	34.36	34.96
d_{14d} 16 APR 2012	**0.85%**	**2.53%**
u_d	**0.08**	**0.25**
c_{14d} 27 APR 2012	34.30	34.55
d_{14d} 27 APR 2012	**0.69%**	**1.34%**
u_d	**0.07**	**0.13**
Maximum d_{14d}	2.35%	2.53%
Maximum u_d	0.23	0.25

7.5 Assessment

The maximum long-term drift d_{14d} amounts to 2.35 % for system 1 and 2.53 % for system 2. The associated uncertainty u_d calculation resulted in a maximum value of 0.23 µg/m³ for system 1 and 0.25 µg/m³ for system 2.

Minimum requirement fulfilled? yes

7.6 Detailed presentation of test results

The individual results of the determination of long-term drift are listed in Table 46.

Table 46: Results of long-term drift test

Date	Time	System 1 (005)	System 2 (006)
	Span point		
	[hh:mm]	[µg/m³]	[µg/m³]
23 JAN 2012	10:00	34.06	34.11
24 JAN 2012	08:00	34.09	34.12
25 JAN 2012	11:00	34.07	34.09
26 JAN 2012	11:00	34.08	34.11
27 JAN 2012	13:00	34.03	34.05
Average		**34.07**	**34.10**
06 FEB 2012	15:00	34.20	34.15
	15:15	34.28	34.26
	15:30	34.56	34.52
	15:45	34.21	34.34
	Average	34.31	34.32
22 FEB 2012	14:00	34.85	34.82
	14:15	34.74	34.88
	14:30	34.92	34.76
	14:45	34.87	34.83
	Average	34.85	34.82
06 MAR 2012	14:00	34.74	34.75
	14:15	34.85	34.77
	14:30	34.75	34.68
	14:45	34.69	34.69
	Average	34.76	34.72
21 MAR 2012	15:00	34.89	34.88
	15:15	34.97	34.69
	15:30	34.85	34.87
	15:45	34.76	34.76
	Average	34.87	34.80
04 APR 2012	13:00	34.22	34.18
	13:15	34.36	34.22
	13:30	34.28	34.23
	13:45	34.29	34.17
	Average	34.29	34.20
16 APR 2012	10:00	34.30	34.96
	10:15	34.36	35.01
	10:30	34.35	34.87
	10:45	34.41	34.99
	Average	34.36	34.96
27 APR 2012	12:00	34.28	34.49
	12:15	34.36	34.58
	12:30	34.33	34.62
	12:45	34.24	34.52
	Average	34.30	34.55

7.1 8.6.6 Maintenance interval

The maintenance interval shall be at least two weeks.

7.2 Equipment

No additional equipment is required.

7.3 Method

This test consisted of determining the maintenance work and the corresponding time intervals necessary for a correct functioning of the measuring system. Furthermore, the results on the determination of zero and span point drift described in Section 7.1 8.6.5 Long-term drift were considered in the evaluation of this performance criterion.

7.4 Evaluation

All drifts observed during the field test lay within the permissible limits. Therefore, the maintenance interval depends solely on the tasks to be performed during maintenance.

During operating time, maintenance can be limited to contamination checks, plausibility checks and possible status/error messages

7.5 Assessment

The maintenance interval depends on the amount of necessary maintenance works and has been set to 4 weeks.

Minimum requirement fulfilled? yes

7.6 Detailed presentation of test results

Not required for this performance criterion.

7.1 8.6.7 Availability

The availability shall be greater than 90 %.

7.2 Equipment

No additional equipment is required.

7.3 Method

Checks on the correct operation of the instrument were made at least every 14 days. It is recommended that these checks are performed daily. They included checks on the plausibility of measured data, status signals when these are available, and other relevant parameters. The time, duration and nature of any abnormalities were recorded.

The total time during the field test for which valid measurement data of the ambient air concentrations were obtained were used to calculate the availability. The time needed for calibrations, conditioning of sample lines and filters, and maintenance were not included in the field test period.

The data coverage was calculated as follows:

$$A_a = \frac{t_u}{t_t} x100\%$$

where:

A_a = availability of the analyser

t_u = total time period with validated measuring data

t_t = time period of the field test minus the time spent on zero and span check, and on maintenance

7.4 Evaluation

The field test was carried out from 13 January 2012 to 27 April 2012. This amounts to a total measurement time of 104 days. Table 47 presents a summary of the operating, maintenance, and outage times.

No malfunctions were observed.

7.5 Assessment

The availability of both instruments amounts to 100 %, excluding the period in which maintenance works required for testing were performed.

Minimum requirement fulfilled? yes

7.6 Detailed presentation of test results

Table 47: Determination of the availability (inclusive maintenance times)

		System 1 (SN 0005)	System 2 (SN 0006)
Total operating time	h	2520	2520
Outage time	h	0	0
Maintenance	h	39	39
Actual operation	h	2481	2481
Availability	%	98.4	98.4

Table 48: Determination of the availability (exclusive maintenance times)

		System 1 (SN 0005)	System 2 (SN 0006)
Total operating time	h	2520	2520
Maintenance	h	39	39
Operation time without maintenance		2481	2481
Outage time	h	0	0
Actual operation	h	2481	2481
Availability	%	100	100

7.1 8.6.8 Reproducibility standard deviation under field conditions

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

7.2 Equipment

No additional equipment is required.

7.3 Method

The standard deviation from paired measurements was determined under field conditions during the three-month field test with two identical measuring systems by paired measurements at the same site.

Since the benzene content in ambient air at traffic congested sites in Germany is in general rather low, the sample air was sporadically enriched in benzene in order to demonstrate that the measuring system also operates correctly at higher concentrations.

Furthermore, the values measured during the two-week long-term drift checks at the span point were taken into account for the determination of the standard deviation from paired measurements.

7.4 Evaluation

The reproducibility standard deviation under field conditions was calculated from the parallel measurement data obtained during the field test.

The difference for each parallel measurement *i* was calculated from:

$$d_{f,i} = (c_{1,f})_i - (c_{2,f})_i$$

The average difference from these measurements was calculated from:

$$\bar{d}_f = \frac{\sum d_{f,i}}{n}$$

where

$d_{f,i}$ = *i*th difference in a parallel measurement

$(c_{1,f})_i$ = *i*th measurement result of analyser 1

$(c_{2,f})_i$ = *i*th measurement result of analyser 2

n = number of parallel measurements

The reproducibility (under field conditions) standard deviation s_{Rf} was calculated according to:

$$s_{Rf} = \sqrt{\frac{\sum d^2{}_{f,i}}{2n}}$$

The standard uncertainty according to the reproducibility in the field was calculated as:

$$u_{Rf} = s_{Rf}$$

7.5 Assessment

The standard uncertainty corresponding to the reproducibility in the field amounts to 0.025 µg/m³ for component benzene.

Minimum requirement fulfilled? yes

7.6 Detailed presentation of test results

The test results are presented in Table 49 and Figure 11.

Table 49: Standard deviation from paired measurements

Component:	Benzene			
AMS:	VOC72M			
Date of measurement:	23 JAN 2012 to 24 APR 2012			
Certification range	CR	=	0 - 50	µg/m³
Concentration range	System 1	=	0.3 - 34.9	µg/m³
Concentration range	System 2	=	0.3 - 35	µg/m³
Average	System 1	=	1.43	µg/m³
Average	System 2	=	1.40	µg/m³
y = b* x + c Slope	b	=	0.9998	
Axis intercept	c	=	-0.0217	µg/m³
Determination coefficient	r	=	0.9999	
No. of measurements	n	=	2146	
t-value	$t_{0,95,n}$	=	1.9611	
Standard deviation from paired measurements	$s_{D,abs}$	=	0.035	µg/m³
Relative standard deviation	$s_{D,rel}$	=	0.025	µg/m³
Limit		=	0.25	µg/m³

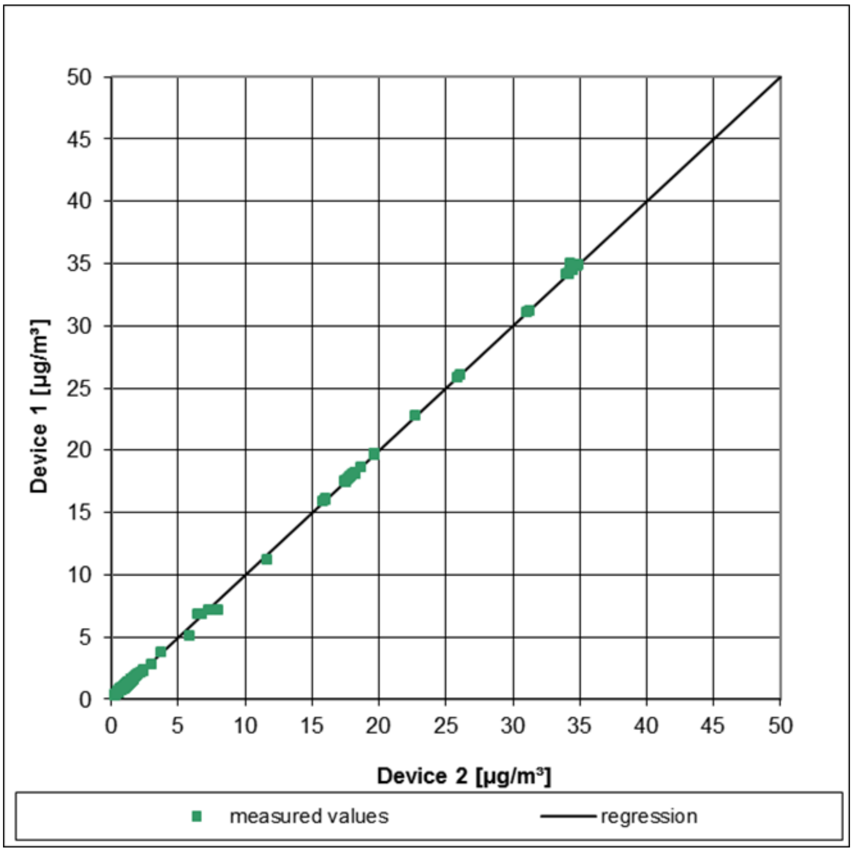


Figure 11: Graphic representation of the standard deviation from paired measurements

7.1 8.7 Total uncertainty calculation according to Section 8.7 of EN 14662-3

The expanded uncertainty of the measuring system shall be determined. The value determined shall not exceed the corresponding data quality objectives in the applicable associated EU Directives (Requirements on data quality: For continuous benzene measurements, the expanded measurement uncertainty shall not exceed 25 %)

7.2 Equipment

No additional equipment is required.

7.3 Method

The total measurement uncertainty of the measuring system was calculated for the performance characteristics determined during type approval testing.

7.4 Evaluation

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

a) Each individual performance characteristic shall fulfil the criterion stated in Table 2 and Table 5 of EN 14662-3;
b) The total uncertainty shall fulfil the criterion stated in the relevant EU directive.

The total uncertainty calculation was performed in two steps:

c) Calculation of the total uncertainty with the values of the performance characteristics determined in laboratory tests;
d) Re-calculation of the total uncertainty found in a) using the field test by replacing the values for the short-term drift from the laboratory test by the values for the long-term drift of the field test and by replacing the values for the repeatability (from the laboratory test) by the value of the reproducibility in the field.

The uncertainty of the measured values given by an analyser is influenced not only by the performance characteristics of the analyser itself, but also by site-specific conditions and gas mixtures, for example. As these factors are not generally known, default values are used in order to be able to type approve an analyser. However, during suitability evaluation for each individual analyser at a specific site, the real values for the site-specific conditions and uncertainty of the calibration gas shall be used.

The combined uncertainty was estimated from the individual contributions in accordance with the equation:

$$u_c = c_{test}\sqrt{\sum \frac{u_i^2}{c_i^2}}$$

where:

u_c = combined uncertainty connected to the concentration of benzene c_{test}

u_i = partial contribution of the uncertainty at concentration c_i

The expanded uncertainty at the 95 % confidence level was obtained by multiplying u_c with a coverage of factor 2.

7.5 Assessment

The requirement regarding expanded measurement uncertainty was fulfilled.

Minimum requirement fulfilled? yes

7.6 Detailed presentation of test results

The total uncertainty was calculated in compliance with the specifications of EN 14662-3 according to the example illustrated in Annex B of said Standard. Table 50 shows the calculation of the expanded uncertainty Uc related to the results of laboratory tests of both instruments.

The total uncertainty was calculated in compliance with the specifications of EN 14662-3 according to the example illustrated in Annex B of said Standard. Table 51 shows the calculation of the expanded uncertainty Uc related to the results of field tests of both instruments.

Table 50: Total uncertainty related to the laboratory tests

Standard uncertainty for the laboratory test		Device 1	Device 2		related concentration	
		SN 005	SN 006		SN 005	SN 006
Uncertainty of test gas	u_{span} [µg/m^3]	0,1230	0,1230	c_{Benz} [µg/m^3]	5,00	5,00
Lack of fit	u_{fit} [µg/m^3]	0,0280	0,0200	c_{Benz} [µg/m^3]	5,00	5,00
Repeatability standard deviation	u_r [µg/m^3]	0,0200	0,0100	c_{Benz} [µg/m^3]	5,00	5,00
Interference of H2O	u_{rh} [µg/m^3]	0,0060	0,0140	c_{Benz} [µg/m^3]	35,00	35,00
Coefficient of sample pressure	u_p [µg/m^3]	0,0380	0,0080	c_{Benz} [µg/m^3]	35,00	35,00
Coefficient of surrounding temperatur	u_{Ts} [µg/m^3]	0,0087	0,0135	c_{Benz} [µg/m^3]	35,00	35,00
Coefficient of electrical voltage	u_v [µg/m^3]	0,0172	0,0058	c_{Benz} [µg/m^3]	35,00	35,00
Standard uncertainty uc/c		**2,56%**	**2,50%**			
Expanded uncertainty $U_{c, rel}$		**5,11%**	**5,00%**			

Table 51: Total uncertainty related to the field tests

Standard uncertainty for the field test		Device 1	Device 2		related concentration	
		SN 005	SN 006		SN 005	SN 006
Uncertainty of test gas	u_{span} [µg/m^3]	0,1230	0,1230	c_{Benz} [µg/m^3]	5,00	5,00
Lack of fit	u_{fit} [µg/m^3]	0,0280	0,0200	c_{Benz} [µg/m^3]	5,00	5,00
Reproducibility in field	u_{rf} [µg/m^3]	0,0250	0,0250	c_{Benz} [µg/m^3]	1,43	1,40
Interference of H2O	u_{rh} [µg/m^3]	0,0060	0,0140	c_{Benz} [µg/m^3]	35,00	35,00
Coefficient of sample pressure	u_p [µg/m^3]	0,0380	0,0080	c_{Benz} [µg/m^3]	35,00	35,00
Coefficient of surrounding temperatur	u_{Ts} [µg/m^3]	0,0087	0,0135	c_{Benz} [µg/m^3]	35,00	35,00
Coefficient of electrical voltage	u_v [µg/m^3]	0,0172	0,0058	c_{Benz} [µg/m^3]	35,00	35,00
Long term drift	u_d [µg/m^3]	0,2300	0,2500	c_{Benz} [µg/m^3]	35,00	35,00
Standard uncertainty uc/c		**3,14%**	**3,15%**			
Expanded uncertainty Uc, rel		**6,28%**	**6,30%**			

8. Recommendations for the practical application of the AMS

Tasks to be performed during maintenance interval (4 weeks)

The following tasks are to be performed regularly on the AMS tested:

- Visual inspection at regular intervals / Telemetric monitoring
- Check of operating status
- Check of error messages
- Check of nitrogen nominal pressure (3.2 bar)
- Exchange of Teflon filter at the sample gas inlet
- Zero and span check with appropriate test gases

For the rest, the recommendations of the manufacturer shall be followed.

For further details please refer to the instruction manual.

Cologne, 16 August 2012

Dipl.-Ing. Martin Schneider	Dr. Peter Wilbring

9. Literature

[1] Guideline VDI 4202, Part 1, September 2010

Performance criteria for performance tests of automated ambient air measuring systems – Point-related measurement methods for gaseous and particulate air pollutants

[2] Guideline VDI 4203, Part 3, September 2010

Testing of automated measuring systems – Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants

[3] European Standard EN 14662-3, May 2005

Ambient Air Quality – Standard method for the measurement of benzene concentrations – Part 3: Automated pumped sampling with in situ gas chromatography

[4] Directive 2000/69/EC of the European Parliament and of the Council relating to limit values for benzene and carbon monoxide in ambient air, 16 November 2000

[5] European Standard EN 14662-3, July 2012 2005

Ambient Air Quality – Standard method for the measurement of benzene concentrations – Part 3: Automated pumped sampling with in situ gas chromatography

10. Annex

11. Manual

TECHNICAL MANUAL

VOC72M

GAS CHROMATOGRAPHY
VOC ANALYZER

- MAY 2012 -

Environnement S.A
L'instrumentation de l'environnement

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GENERAL CHARACTERISTICS
PRINCIPLE OF OPERATION
OPERATING INSTRUCTIONS

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.

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CHAPTER 3. OPERATING INSTRUCTIONS

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CHAPTER 1

GENERAL - CHARACTERISTICS

1. GENERAL - CHARACTERISTICS

Figure 1–1 – Presentation of the VOC72M

1.1 GENERAL

1.1.1 PRESENTATION

The VOC72M 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 VOC72M 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 VOC72M 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 nitrogen 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 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 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 DNP-ARM7 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:

A general switch (1)

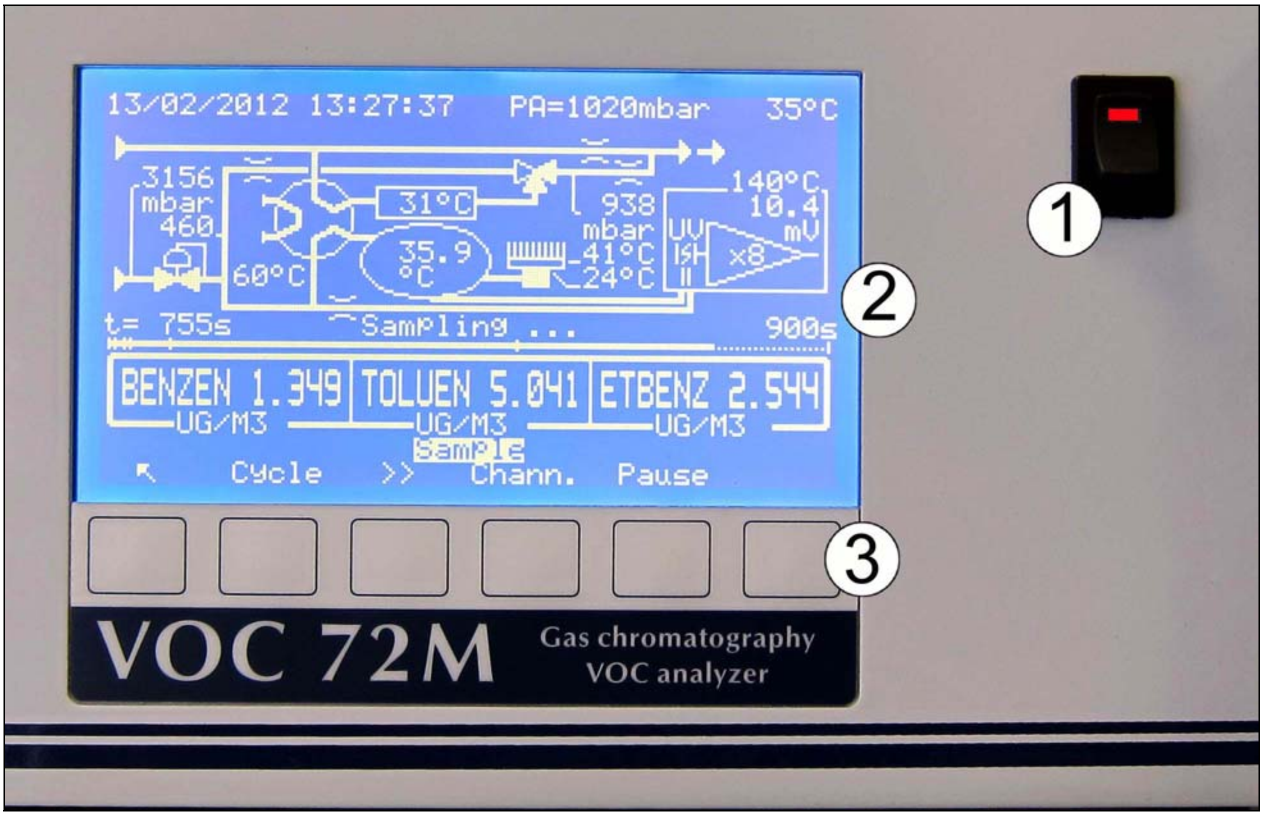
A backlit liquid crystal display (2)

- 16 lines 40 columns (240 x 128 pixels),
- The display provides the measurement values according to the selected unit, the information required for programming and testing the unit.

A keyboard with 6 touch-sensitive keys (3)

The control and check functions of the unit are performed using the keyboard.

- The function of each key varies with the different screens or menus.



(1) General switch, (2) backlit liquid crystal display, (3) keyboard with 6 sensitive keys

Figure 1–2 – Front panel

1.1.2.2 Rear panel

(1) Free slot for the optional Estel, Sorel, or RS4I boards, (2) mains fuse, (3) cooling fan exhaust, (4) screw of the sample inlet assembly, (5) sample inlet for 4mm OD (overall diameter) tube, (6) nitrogen inlet for 1/8” OD tube, (7) vent outlet for 4mm OD tube, (8) cooling fan of the heat sink, (9) USB port, (10) Ethernet output, (11) identification plate, (12) power socket.

Figure 1–3 – Rear panel of VOC72M

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.

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).

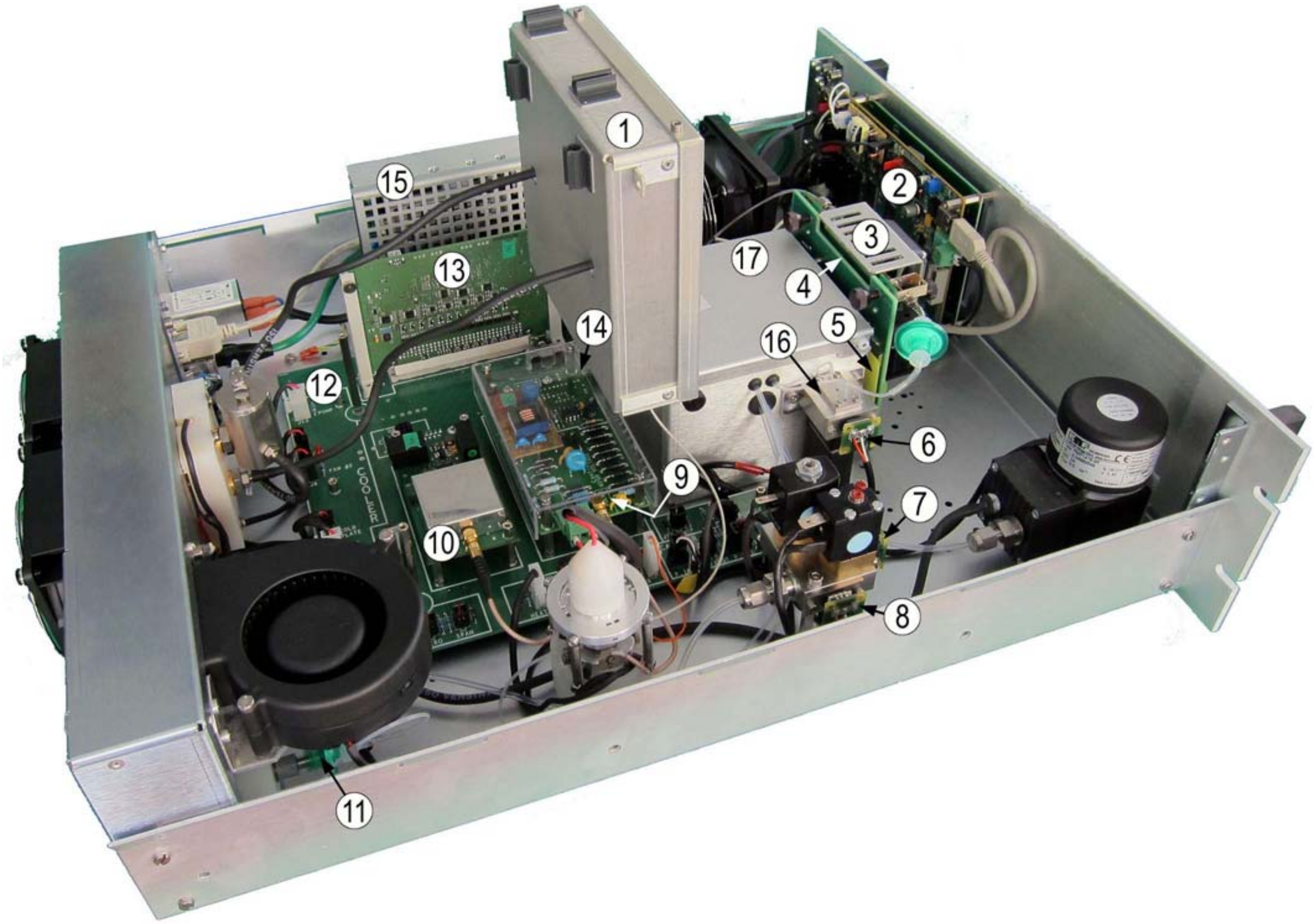
- The trap is able to heat from ambient temperature to 380°C (716°F) in less than 2 seconds. Do not run the instrument without the trap fan in position (mark 5 of Figure 1–4): its cover is also designed to avoid direct contact with the trap tube (mark 6 of Figure 1–4).

- The desorber board integrates a permanent power source able to produce a very important which can cause the short-circuit conductor. A protective cover is put in place to avoid this risk. **Do not remove its protective cover** (mark 5 of Figure 1–5).

- 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 nitrogen 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) DNP-ARM7 board, (31) purge assembly, (32) heat sink.

Figure 1–4 - Internal view



(1) GC column box, (2) DNP-ARM7 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 nitrogen 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

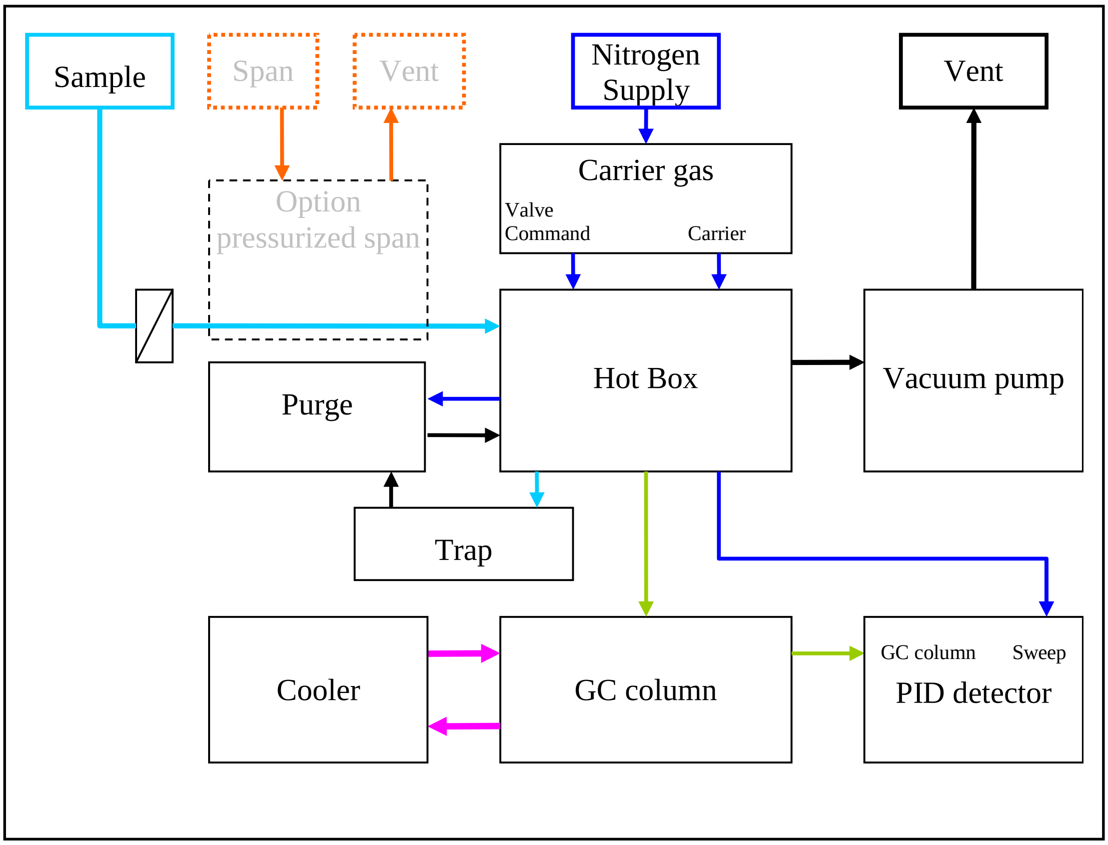


Figure 1–6 – Fluid block diagram

1.1.3.1.1 The carrier gas assembly.

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

This assembly receives the nitrogen from the nitrogen 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 nitrogen 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 nitrogen input pressure (6) of Figure 1–3.
- A 0.5 bar pressure sensor (10) monitors the regulated nitrogen 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 (7) and a pressure sensor. (Figure 1–4).

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 nitrogen source (10-11-12-13) through a restrictor and nitrogen 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 stop 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 nitrogen 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 nitrogen 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
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 nitrogen 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 nitrogen 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 nitrogen pressure via a heated micro capillary restrictor.

1.1.3.2 Electronic part

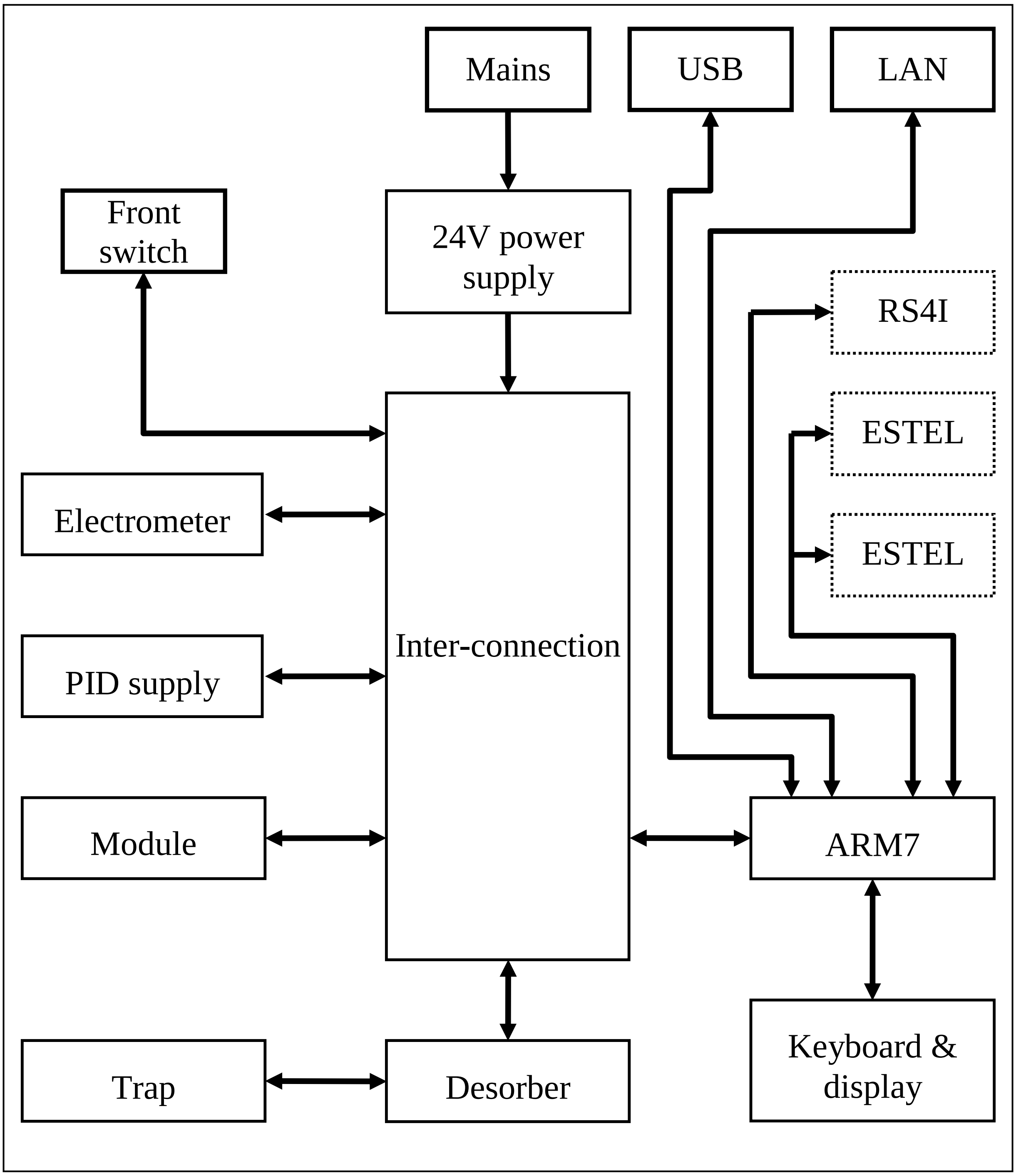


Figure 1–7 – Electronic block diagram

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.

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.

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 VOC72M 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.

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 DNP-ARM7 board at the beginning of each cycle and sends the resulting data to the DNP-ARM7 board.

The module board collects the chromatogram data points from the electrometer board and stores them in a temporary buffer which is periodically emptied by the DNP-ARM7 board.

1.1.3.2.5 The desorber board.

Refer to (4) of Figure 1–5.

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:

- the VOC72M is OFF.
- the flat cable is not connected.
- the 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.

- 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 *1.1.3.1.6 the trap and the transfer line.*

1.1.3.2.7 The DNP-ARM7 board.

Refer to (30) of Figure 1–4

The DNP-ARM7 board is a rapid calculation and interfacing board.

The DNP-ARM7 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 DNP-ARM7 board also collects data from the module board for the default and alarm messages.

The DNP-ARM7 board is also an interface board for the keyboard and display, 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.

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 DNP-ARM7 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/seconde
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 thermo-electric cooler
GC detector	:	Photo-ionization (PID) 10,6eV with nitrogen curtain
⇨ Detector temperature	:	140°C (programmable)
Display	:	LCD 240 x 128 text and graphic mode
Keyboard	:	6 keys

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 1.0
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	:	Nitrogen 6.0 (99.9999%) 3,2 +/– 0,2 bar 15 ml/minute
Working temperature	:	+ 5°C to + 35°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
Tests and diagnostics for maintenance	:	Keyboard selection and display of the whole parameters
Backup duration of stored-in-RAM data and real time clock	:	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 VOC72M requires the supplies and external connections shown in black below.

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

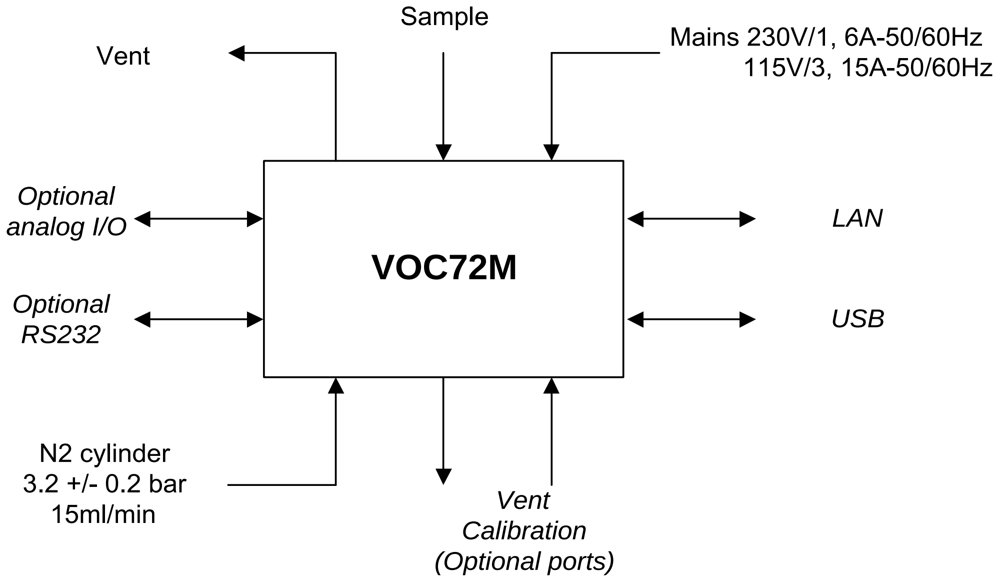


Figure 1–8 – Links between units

1.2.4.2 Dimensions and weight

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

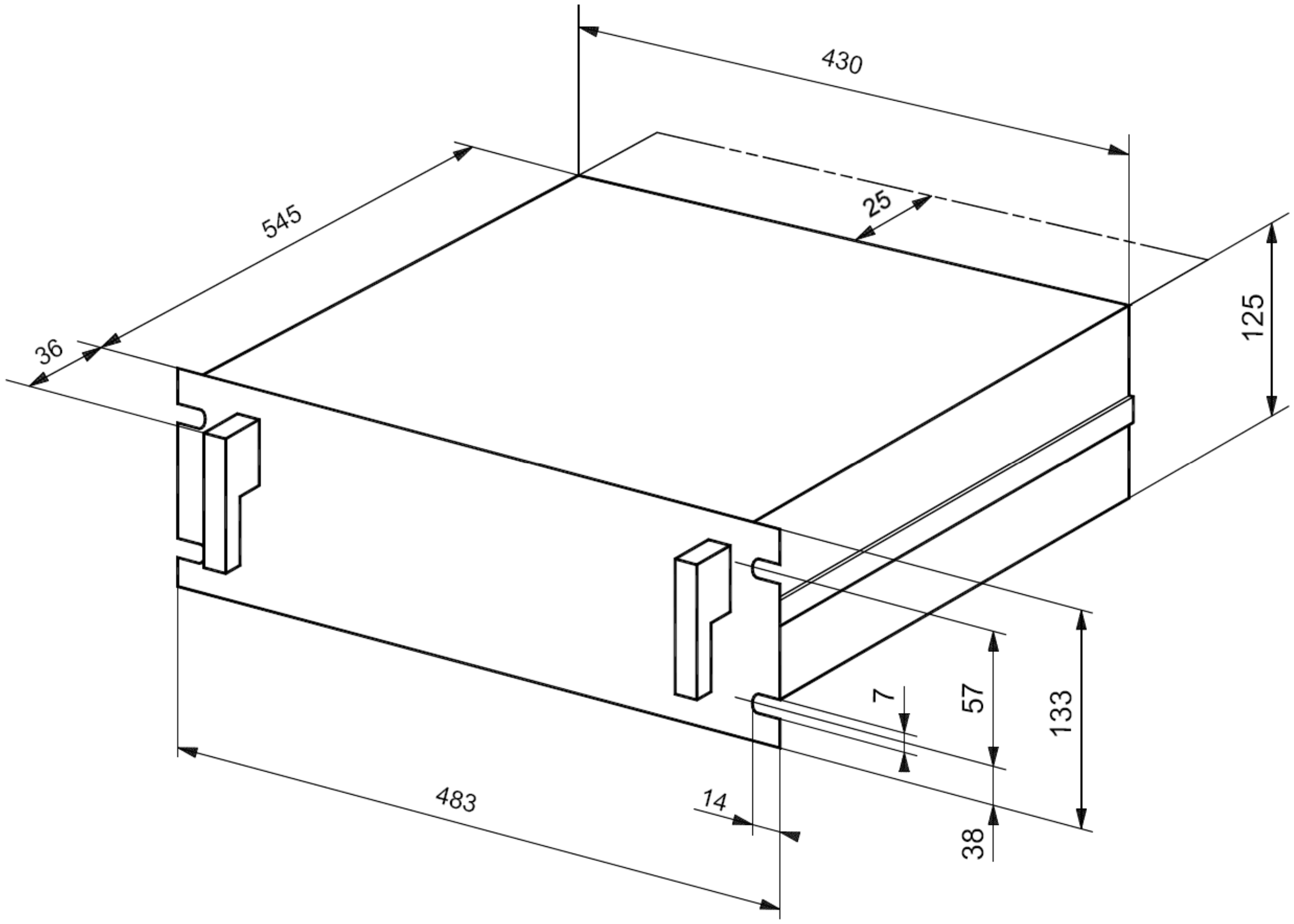
Length	:	606 mm
Width	:	483 mm
Height	:	133 mm
Weight	:	12.5 kg

1.2.4.3 Handling and storage

The VOC72M 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.

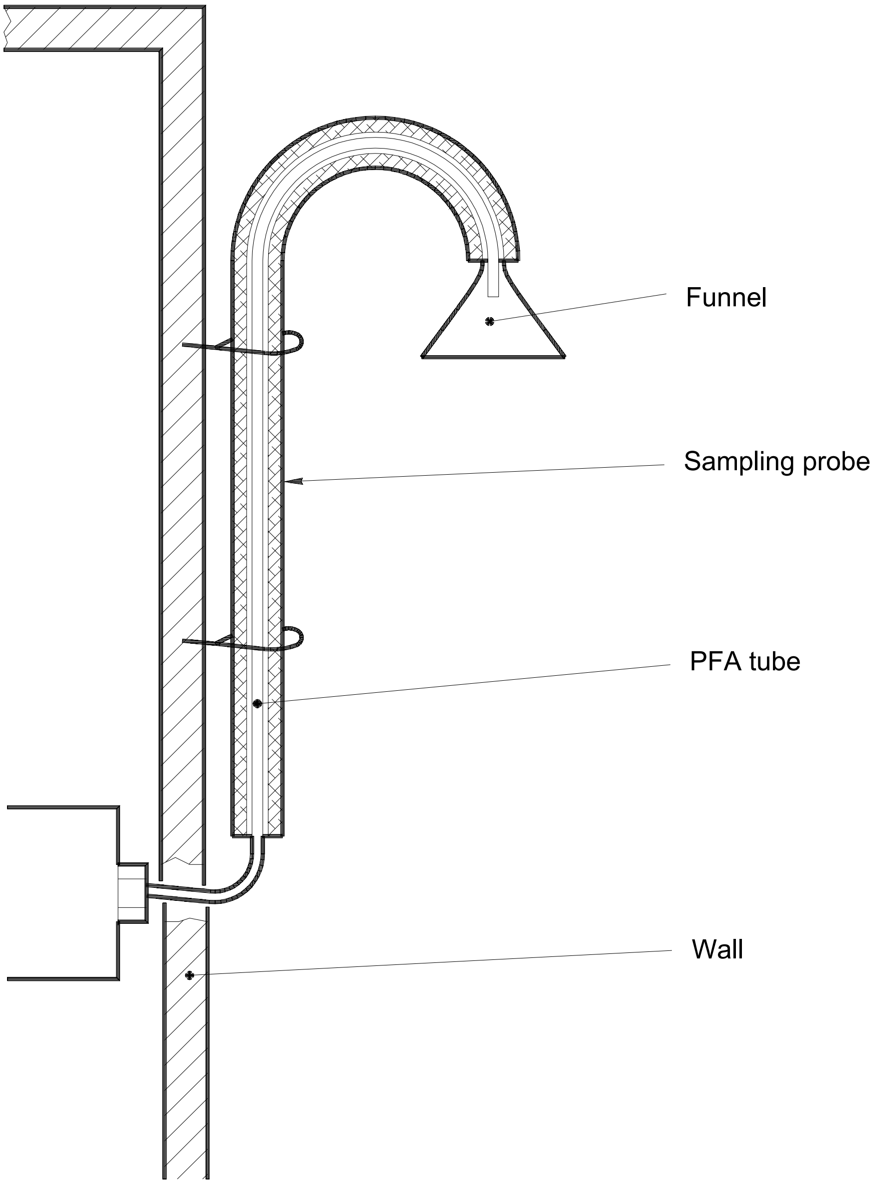


Figure 1–10 – Installation of the "sample gas" connector

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

CHAPTER 2

PRINCIPLE OF OPERATION

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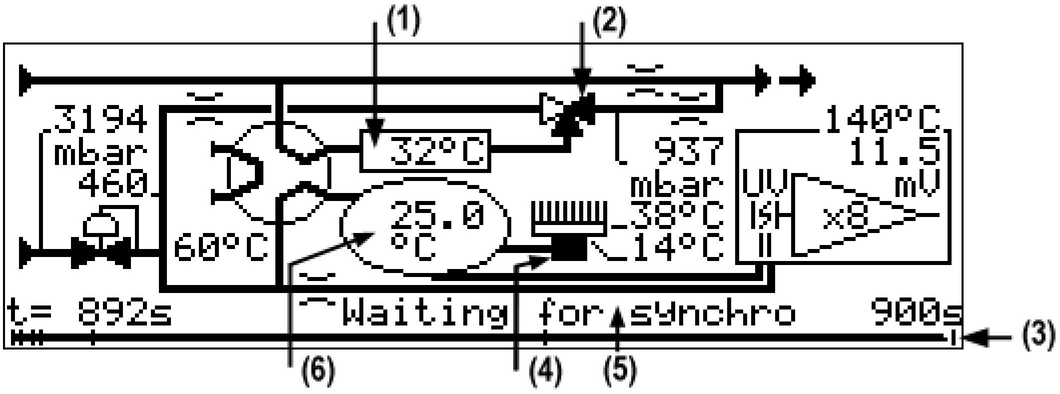
2. PRINCIPLE OF OPERATION

The VOC72M 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 VOC72M 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



t= 892s Waiting for synchro 900s

Figure 2–1 – End of previous cycle

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

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

2.2 COLD PURGE

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

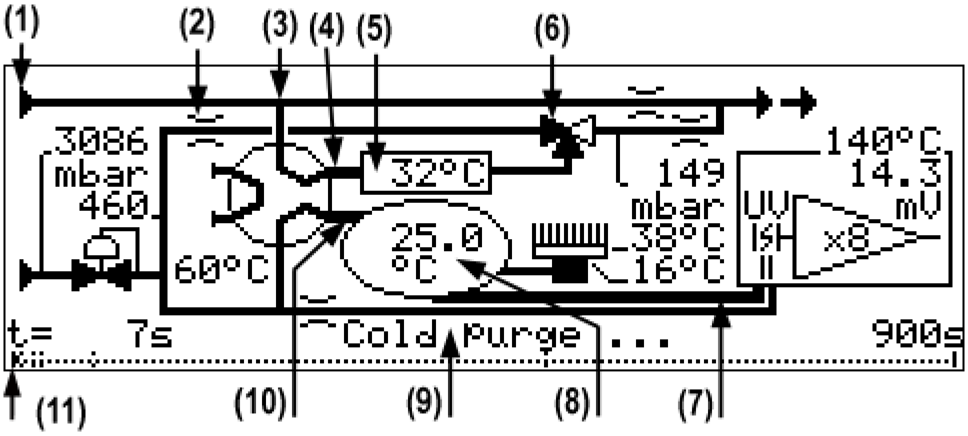


Figure 2–2 – Cold purge

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

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

Nitrogen flows from the purge restrictor (2) through the purge valve (6) to the trap (5) and drains oxygen and humidity back to the by-pass line (3).

NOTE : The by-pass flow (35 ml/min) is greater than the nitrogen flow (15ml/min), so the analyzer always sucks-in the sample on its inlet (1).

The GC column temperature remains on the cold step (8) and the trap status is “Cold purge” (9).

2.3 TRAP COUPLING

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

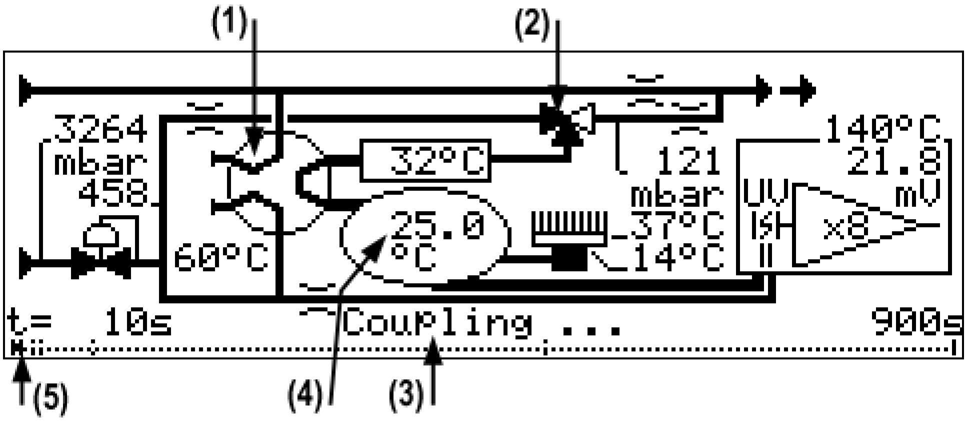


Figure 2–3 – Trap coupling

As the progression bar reaches the connecting mark (5), the Module board activates the 6-port injection valve (1) and switches the trap fan to OFF.

The trap is now connected to the GC column and the status is “Coupling” (3).

The GC column nitrogen supply comes from the purge valve (2).

The GC column is kept on the cold step (4).

The trap is ready for the thermal desorption.

2.4 INJECTION

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

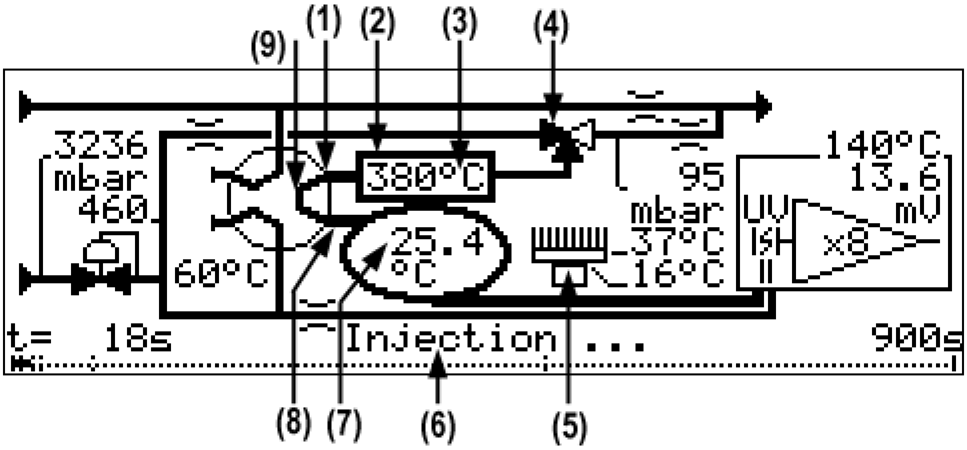


Figure 2–4 – Injection

The trap status is “Injection” (6) and 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 nitrogen coming from the purge valve (4) drains the compounds through the heated path (transfer line (1), 6-port valve (9), column end (8)) to the cold GC column (7).

The heavy compounds focus on the column head while the light compounds, pushed by nitrogen, begin to migrate through the GC column.

Meanwhile, the Module board switches the cooler OFF (5), starts the data acquisition of the detector signal for the chromatogram (sample N) and initiates the first temperature ramp on the GC column:

5°C/minute from 25 to 30°C (11 seconds < t < 71 seconds).

2.5 HOT PURGE

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

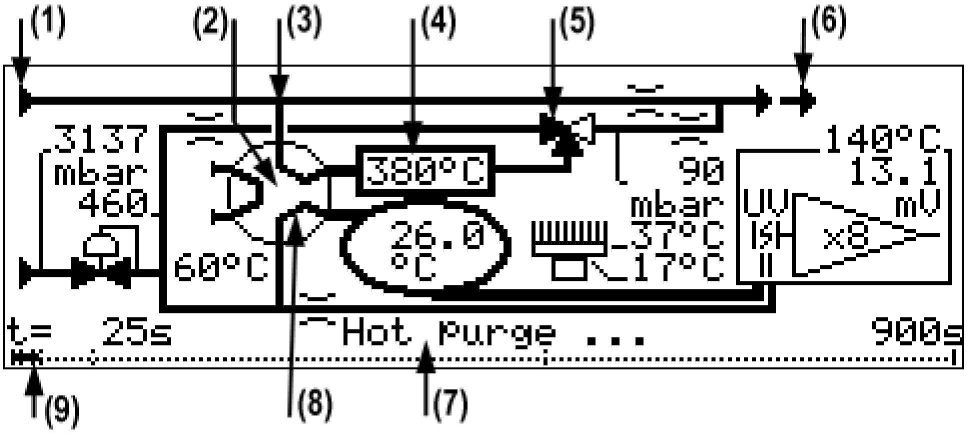


Figure 2–5 – Hot purge

When the progression bar reaches the hot purge mark (9), the “Hot purge” status is displayed (7).

The Module board deactivates the 6-port injection valve (2) that returns to its de-energized position.

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

Nitrogen 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 nitrogen flow (15 ml/min), so the analyzer always sucks-in the sample on its inlet (1).

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

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

2.6 TRAP COOLING

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

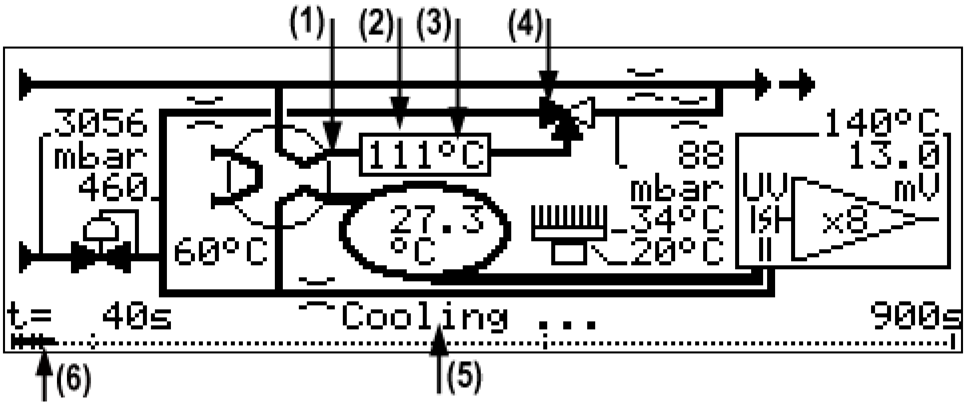


Figure 2–6 – Trap cooling

When the progression bar reaches the trap cooling mark (6), the “Cooling” status is displayed (5) and:

- The Module board switches OFF the trap heating (2) and the transfer line heating (1).
- The Module board activates the trap fan causing the trap temperature to quickly decrease (3).

At t = 71seconds, the GC columns starts the second thermal ramp:

15°C/minute from 30 to 115°C (71 seconds < t < 411 seconds).

2.7 TRAP SAMPLING

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

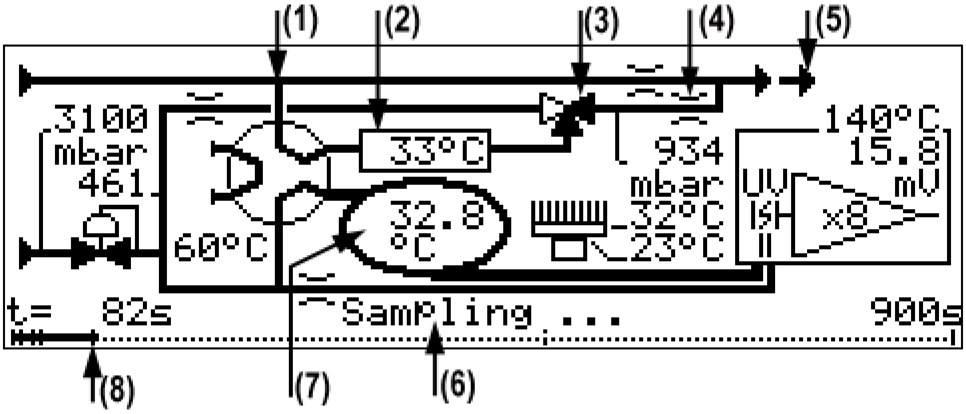


Figure 2–7 – Trap sampling

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).

The trap now concentrates sample N+1.

The trap status is “Sampling” (6).

The GC column is still heating its thermal ramp (7).

At t = 411 seconds, the third ramp is launched:

30°C/minute from 115 to 160°C (411 seconds < t < 501 seconds).

2.8 DATA PROCESSING

501 seconds < t < 601seconds (standard 15-minute cycle).

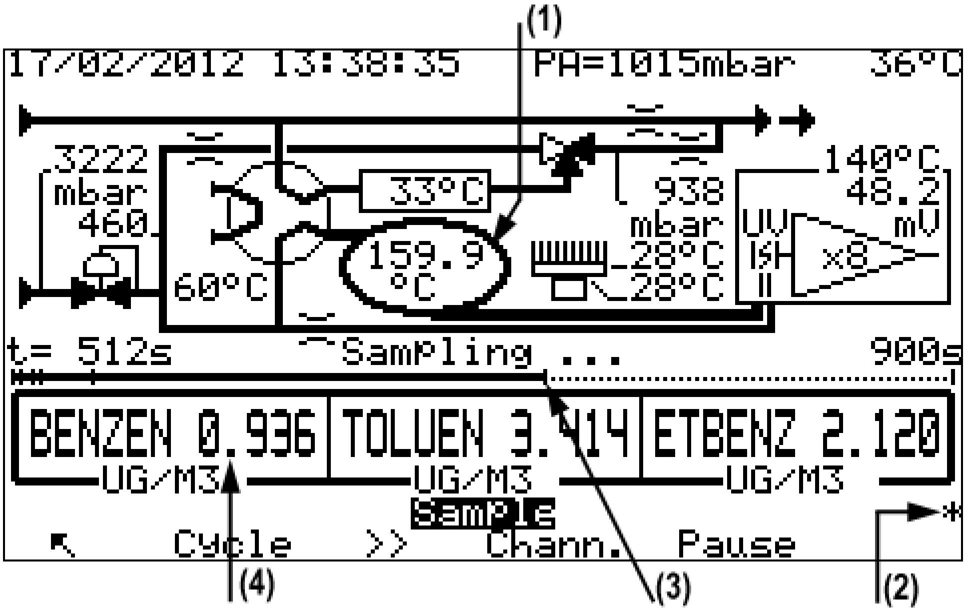


Figure 2–8 – Data processing

At t = 501seconds, the third thermal ramp is finished, the GC column reaches the 160°C hot step (1).

The chromatogram acquisition stops and the DNP-ARM7 board recovers the last data points from the temporary buffer of the Module board.

The screen still displays the concentration of sample N-1 (4).

When the progression bar reaches the calculation mark (3), the process star (2) appears indicating that the DNP-ARM7 board is now processing the chromatogram:

- The chromatographic peaks are detected, the corresponding baselines are calculated, and the peak areas are calculated.
- The peaks, the retention time of which falls 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 N sample) 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 N sample).
- The compound peak areas are multiplied by the response factor of this compound to gives the concentration of theses compounds.

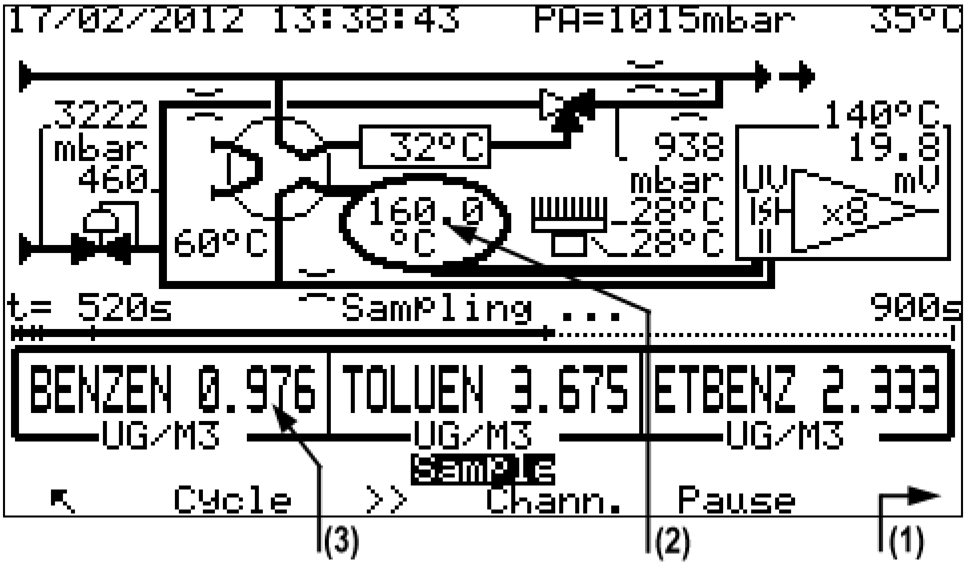


Figure 2–9 – Refresh of concentration display

When the calculation star extinguishes (1), the calculations for sample (N) are finished and the compound concentrations are refreshed (3).

The GC column remains on the hot step (2) allowing the heavy compounds to be flushed out.

The trap is still concentrating sample N+1.

2.9 GC COLUMN COOLING

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

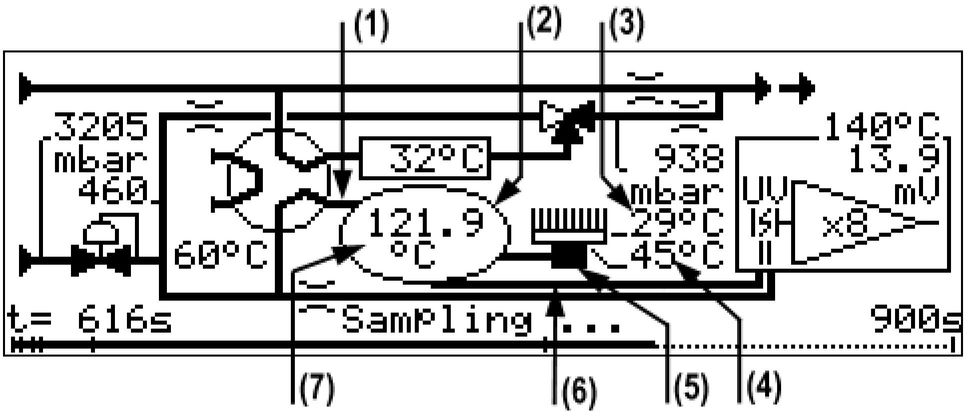


Figure 2–10 – GC column cooling

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

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 thermoelectric element dumps the calories from the cold plate to the heat sink the temperature of which slowly increases (3).

If the Peltier heat sink temperature reaches a high threshold, the Module board turns ON the two fans located on the rear panel of the analyzer in order to cool the heat sink.

If the temperature of the Peltier heat sink reaches the low threshold, the Module board turns OFF the two fans located on the rear panel of the analyzer.

2.10 END OF CYCLE

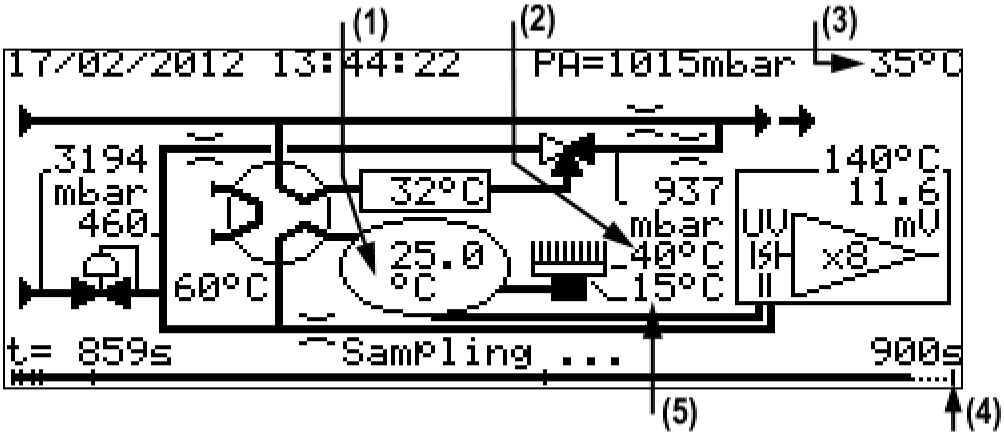


Figure 2–11 – GC column cooling (end)

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 temperature of the column 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 heat sink temperature (2) slowly decreases.

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

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

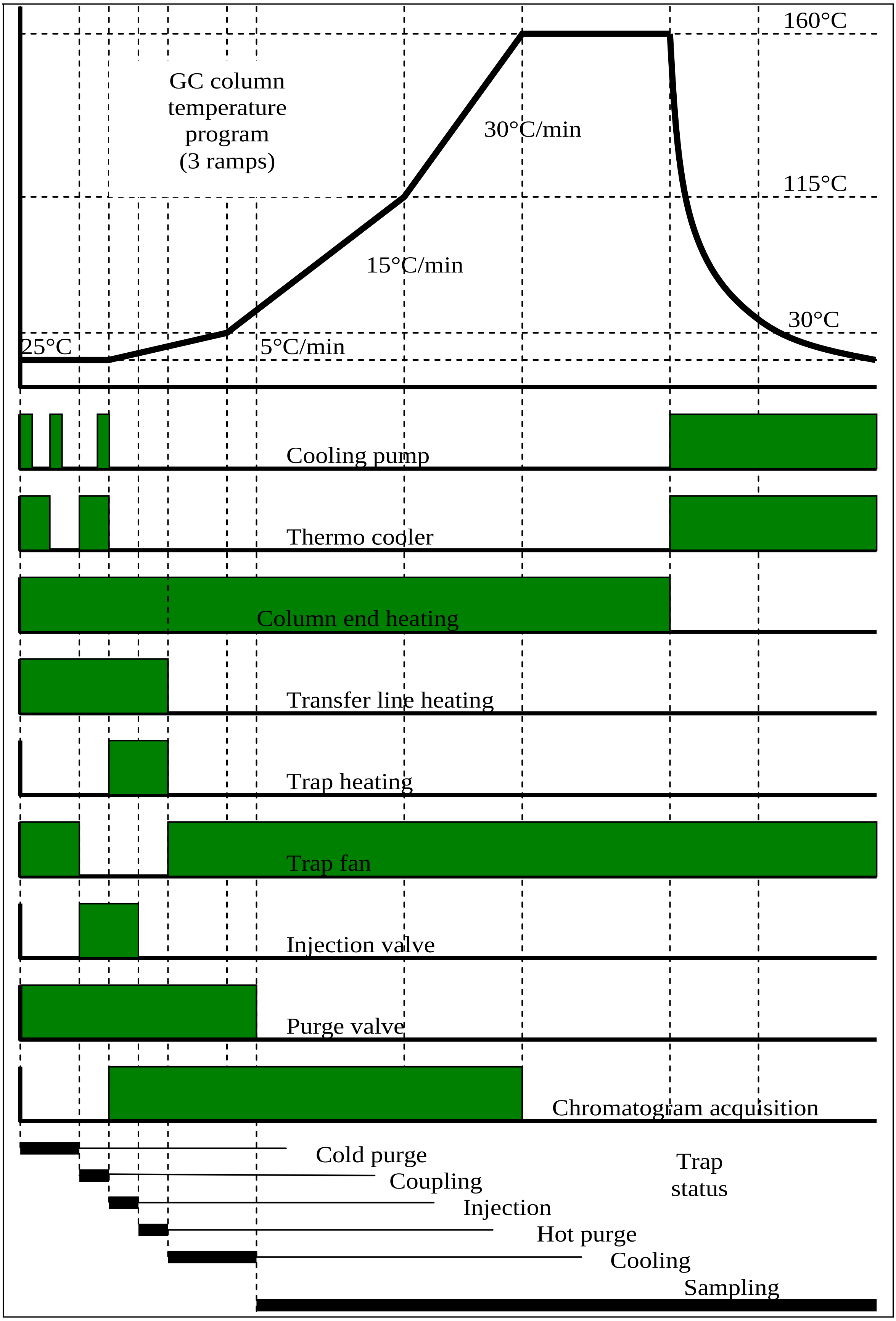


Figure 2–12 – Chronogram

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

– Nitrogen 6.0 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. A 5.0 Nitrogen source would fit with additional filter for oxygen, hydrocarbon and water removal.

– Nitrogen tube between the source and the analyzer.

1/8” tube GC grade (stainless steel or brass or copper) is suitable. PFA is acceptable on short length (less than 4 meter).

DO NOT USE PTFE OR OTHER PLASTIC FOR THE NITROGEN TUBE.

– Electricity.

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

– Clearance.

A 10cm (4”) clearance is required between the rear panel of the VOC72M 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 NITROGEN INLET BEFORE ITS CONNECTION TO THE NITROGEN TUBE.

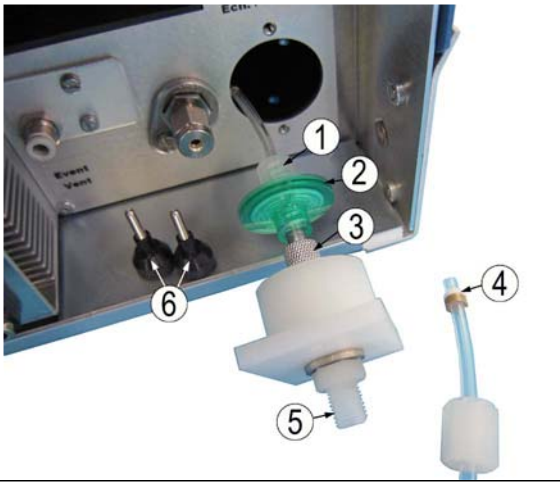
3.1.3 CONNECTION

(1) Empty slot for the optional ESTELÍ, SOREL, or RS4I boards, (2) mains fuse, (3) cooling fan exhaust, (4) screw of sample input filter assembly, (5) sample inlet for 4mm OD (overall diameter) tube, (6) nitrogen inlet for 1/8” OD tube, (7) vent exhaust for 4mm OD tube, (8) heat sink cooling fan, (9) USB socket, (10) Ethernet socket, (11) identification plate, (12) power socket.

Figure 3–1 – 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.

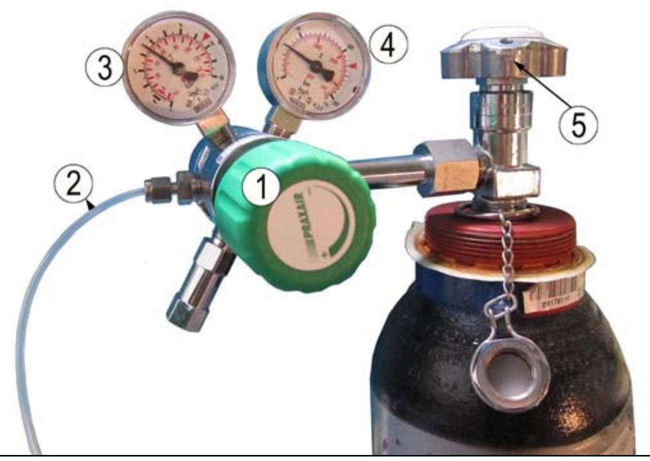
(6) Assembling screws.

Figure 3–2 – Sample input connection

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

NOTE : 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 Nitrogen connection



(1) Pressure adjustment knob.

(2) 1/8” OD tube (PFA shown).

(3) Output regulated pressure indicator.

(4) Cylinder high pressure indicator.

(5) Nitrogen cylinder valve.

Figure 3–3 – Nitrogen cylinder connection

- Mount the pressure reducer on the nitrogen cylinder (6.0 grade) and connect the nitrogen 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 nitrogen 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 N_2 protection cap off the N2 inlet of the VOC72M rear panel and connect the nitrogen tube to the Swagelok® 1/8” 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 6.0 grade nitrogen.

3.1.3.3 Vent outlet connection

- Connect a 4mm OD plastic tube in order to collect the vacuum pump exhaust and throw it out of the room where the VOC72M is installed. The vent gas composition is similar to sample. An alternate solution consists in connecting the vent tube to an active charcoal cartridge.

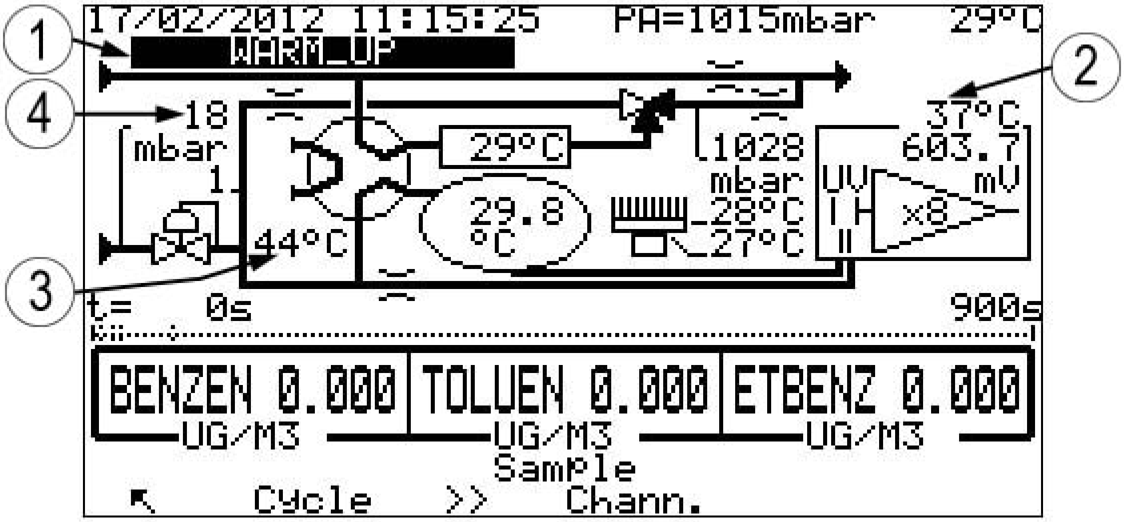
NOTE : A blocked vent port can damage the vacuum pump. Always make sure that the vent outlet is connected to the atmospheric pressure.

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 VOC72M.

3.1.4 STARTING UP THE UNIT

- Plug the power cord to the mains socket and switch ON the VOC72M.
- After some seconds, the display shows the warm-up synoptic:



(1) Warm-up flag, (2) PID detector temperature (cold), (3) Hot box temperature, (4) Nitrogen supply pressure (rel.)

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

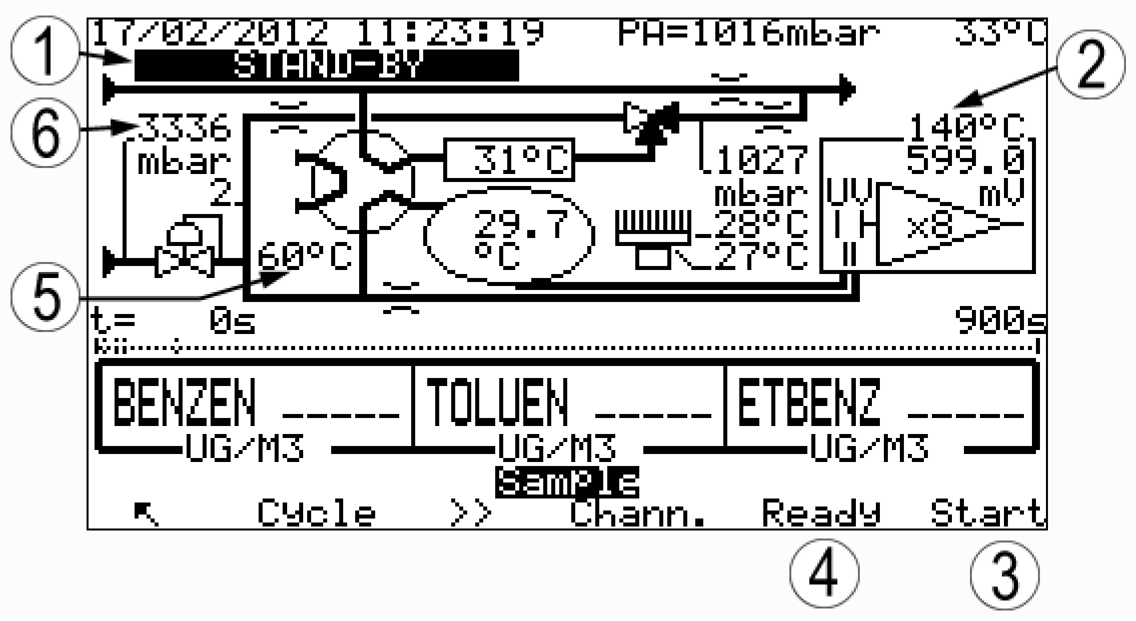
Slowly screw clockwise the cylinder pressure reducer knob until the supply pressure (4) indicates 3200+/-200mbar on the synoptic display.

NOTE : – If the N2 pressure is too high, unscrew a little turn the cylinder pressure reducer knob and loosen the nut of the N2 inlet fitting of the analyzer, to release the excess of nitrogen. Then tighten again the nut and readjust the pressure with the knob.

– Without a valid supply pressure of N2, (3.2 +/- 0.2 bar), the VOC72M 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.

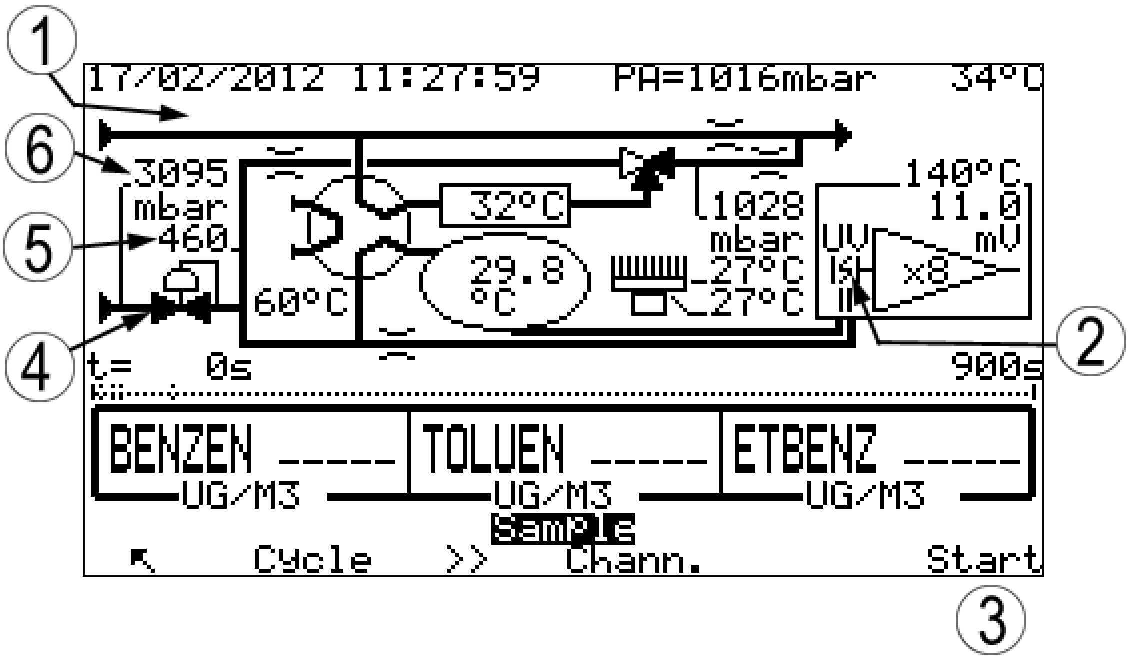
STOP **After 8 hours without action on any key, the screen switches into stand-by mode (screen backlighting off). Pressing down any key makes it going back to screen backlighting on.**



(1) Stand-by flag, (2) PID at set point temperature, (3) Start command available, (4) Ready command available, (5) Hot box at set point temperature, (6) Nitrogen supply pressure adjusted.

Figure 3–5 – The «Stand-by» synoptic display

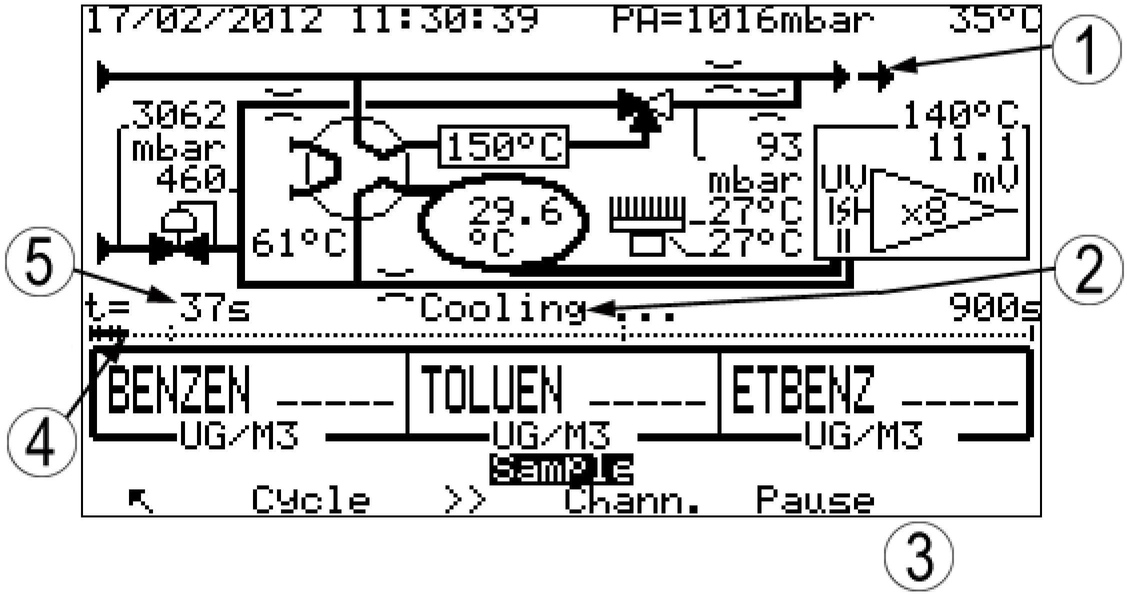
Pressing down F5 **[Ready]** enables to access the READY mode:



(1) Stand-by flag OFF, (2) PID lamp ON, (3) Start command available, (4) Proportional valve is active, (5) Regulated pressure at set point, (6) Nitrogen supply pressure is adjusted.

Figure 3–6 – The «Ready» synoptic display

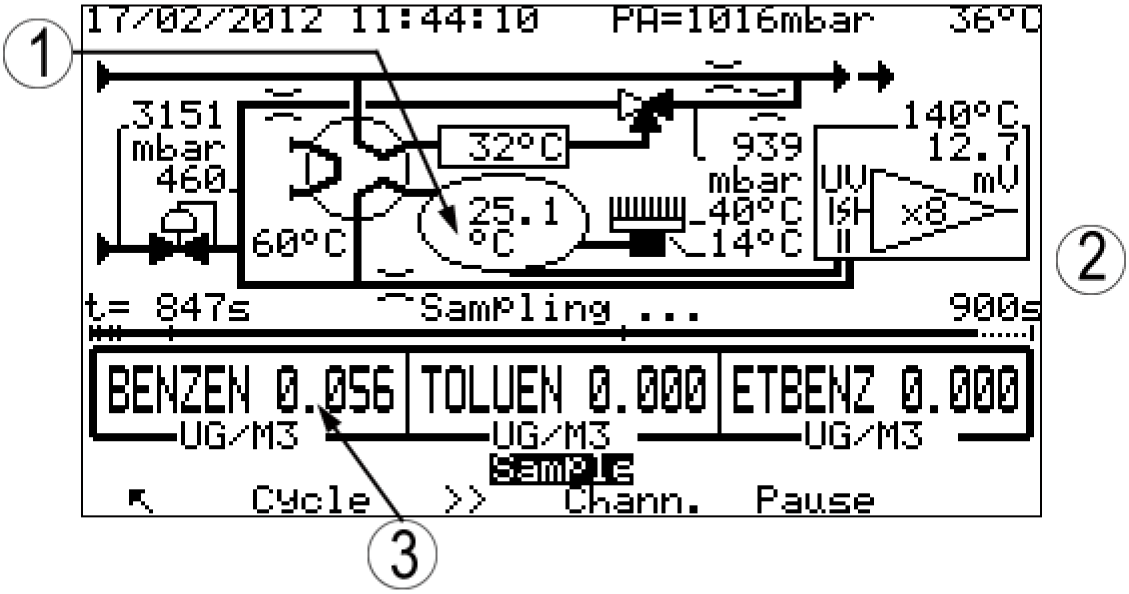
Pressing down F6 **[START]** enables to start the analysis cycles:



(1) The vacuum pump is active, (2) A trap status is displayed, (3) Pause command available, (4) The progression bar is active, (5) The cycle clock is active.

Figure 3–7 – The «Start» synoptic screen

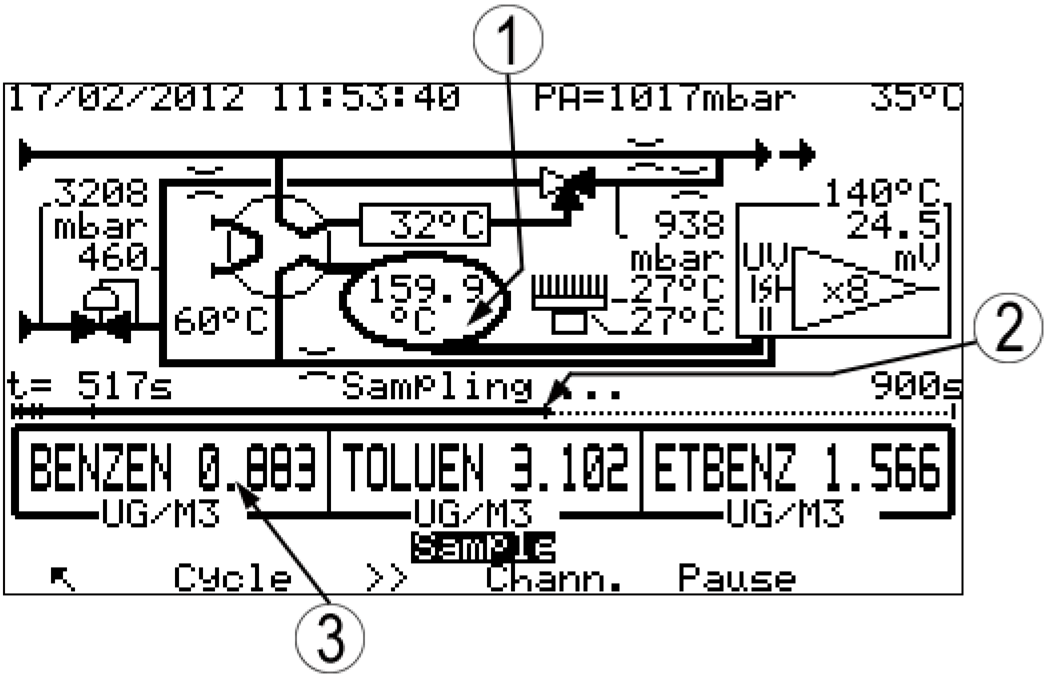
The first cycle starts with a trap thermal desorption which cleans it in anticipation of the first cycle of sampling. The GC column also carries out a thermal cycle for purging it before the next cycle.



(1) GC column back to the cold step, (2) Progression bar close to the mark of the cycle end, (3) Result of the column cycle (invalid analysis cycle).

Figure 3–8 – The first sampling cycle

The VOC72M now starts the second sampling cycle and the analysis of the first sampling cycle. When the progression bar reaches the calculation mark, the first result is displayed.



(1) GC column on the hot step, (2) Progression bar over the calculation mark, (3) Analysis result of the first sample.

Figure 3–8 – The first analysis cycle

The next analysis result will occur 15 minutes later.

Pressing down F5 [Pause] aborts the present cycle:

- The VOC72M returns to the READY mode.
- The current sampling in the trap is lost.
- If the progression bar (3) has not passed the calculation mark (2), the GC analysis cycle is also lost.

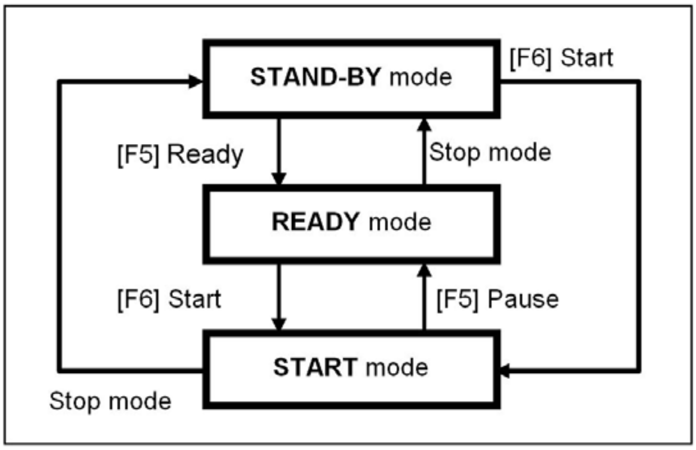


Figure 3–9 – The functional diagram.

NOTE : – The Stop mode is available in the main menu. The user can access the main menu by pressing down F1 twice in the synoptic screen.

– If a power supply outage occurs, when the current is on again, the VOC72M passes to warm-up mode. Then, when the warming-up period is finished, the VOC72M automatically returns to the status it had before the outage,

Be careful when switching on the VOC72M: after a power OFF/ON action (either front switch activation or power outage), the VOC72M automatically returns (after warm-up) to the previous state :

- If the PID UV lamp was ON, the PID power supply board will automatically restart after the warm-up delay and generate a high voltage on the PID lamp.
- It is the same with the trap: if the OFF/ON action occurs during an analysis cycle, a new cycle will restart automatically after warming-up, and involve the high temperature heating (380°C) of the trap.

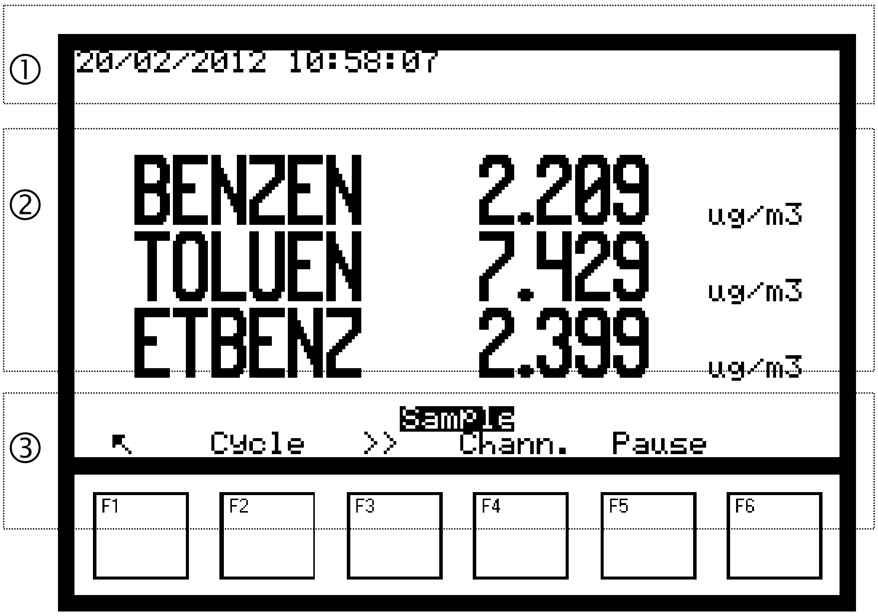
3.2 PROGRAMMING THE VOC72M

3.2.1 SELECTION AND MODIFICATION OF PROGRAMMABLE PARAMETERS

The keyboard is located under the LCD screen. The bottom line gives the function of each key for the current screen.

The title of the menu and the selected fields are displayed in reverse video. By default the first line of the menus is selected. In the next paragraphs, the selected parameters are symbolized in white on black background.

3.2.1.1 Screen areas definition



```
20/02/2012 10:58:07

BENZEN   2.209  ug/m3
TOLUEN   7.429  ug/m3
ETBENZ   2.399  ug/m3

                    Sample
 ↖    Cycle    >>   Chann.   Pause
```

① Information area: it displays the date and time in the top left corner. The «WARM UP» or «AUTO-CALIBRATION» messages blink. The «ALARM» message is displayed if a fault concerning the operating parameters of the analyzer is detected.

② Measurement or configuration area: it displays the measurement parameters (gas, value, units ...) or the configurable parameters according to the selected menu.

③ Status area and key functions: it displays the keys function, the analyzer operating mode and the gas inlet ("sample" inlet in the above example).

NOTE : In the next paragraphs, the keys are symbolized by the icon or the function displayed inside a rectangle.

3.2.1.2 Definition of main functions of the 6 keys keyboard

The availability of these functions is context dependent.

[↖]	Used to display the previous menu or to abort the current operation (parameter programming, etc.)
[↑]	Used to select the required sub-menu and the parameter to be modified. It is also used to increase the digit whose modification is in progress.
[↓]	Used to select the sub-menu and the parameter to be modified. It is also used to decrease the digit whose modification is in progress.
[←]	Moves the cursor to the left (only available during numerical parameters modifications).
[→]	Moves the cursor to the right (only available during numerical parameters modifications).
[✶]	Used to modify selected parameters.
[↵]	Used to validate the selection or the digit whose modification is in progress.
[Print]	It is used to print out the current screen.
[>>]	Used to display the next page. When there are several parameters, pressing down this key allows to display the next parameters.

3.2.2 PROGRAMMING THE OPERATING PARAMETERS

3.2.2.1 Programming the numerical parameters

Select the parameter with the ↓ or ↑ key in the appropriate menu, press down the ✳ key to access to the modification of the parameter, the 1st digit blinks. Select the digit to be modified with the ← or → key then increase it with the ↑ key or decrease it with the ↓ key. The ↵ key validates the modifications of the selected field, the ↖ key cancels the modifications of the selected field.

3.2.2.2 Selection of a parameter in a toggle list

Select the parameter with the ↓ or ↑ key in the appropriate menu, press down the ✳ key to access to the modification of the parameter, the field blinks. Select with the ↑ or ↓ key the wanted value in the toggle list. The ↵ key validates the modifications of the selected field, the ↖ key cancels the modifications of the selected field.

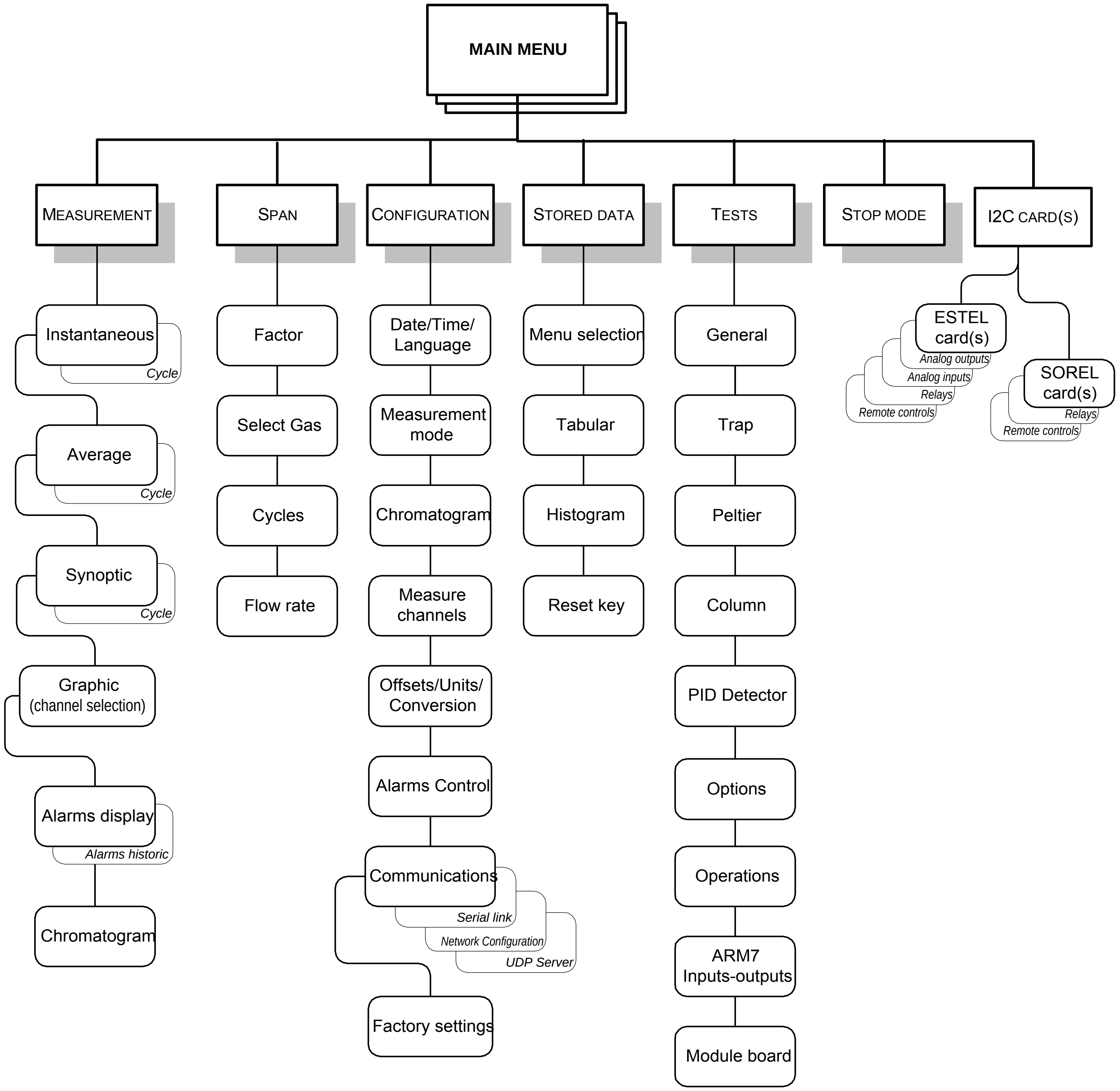
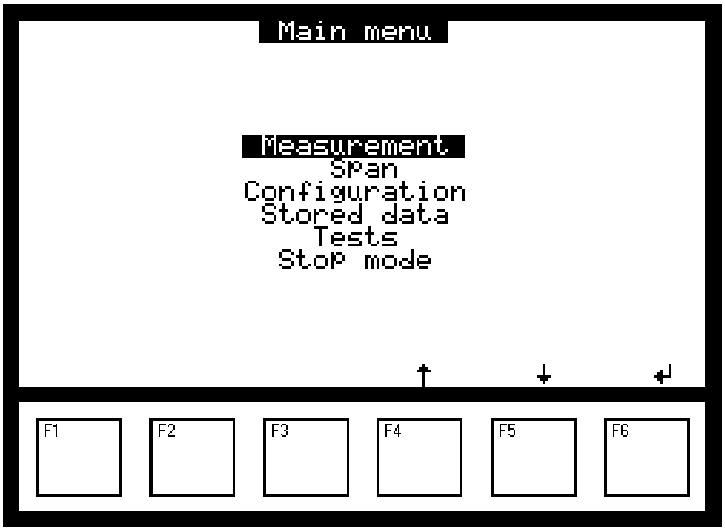


Figure 3–10 – Menu tree of VOC72M

3.3 DESCRIPTION OF THE DIFFERENT SCREENS

3.3.1 MAIN MENU

This screen is used to choose menus that will access analyzer operating parameters.



Select the menu with the [↑] or [↓] key, validate the selection with the [↵] key.

Example:

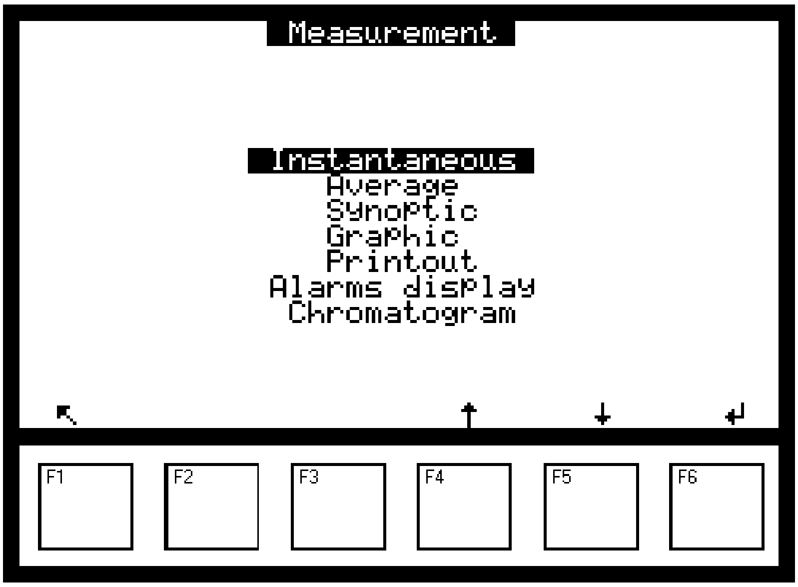
ACTION	DISPLAY	REMARKS
	Measurement Span Configuration Stored data Tests Stop mode	Display of the main menu, the 1^{rst} item is selected by default.
[↓]	Measurement Span Configuration Stored data Tests Stop mode	Selection of the next item.
[↓]	Measurement Span Configuration Stored data Tests Stop mode	Selection of the next item.
[↵]	Date/Time/Language Measurement mode Chromatogram Measure channels Offsets/Units/Conversions Alarms Control Communications Factory settings	Validates the selection (configuration menu) and displays the sub-menu. The first item is selected by default.
[⇱]	Measurement Span Configuration Stored data Tests Stop mode	Goes back to the previous menu.

NOTE : In order to make the reading easier, when a sub menu is quoted in the text, the corresponding menu is reminded before (ex. CONFIGURATION ⇨ Date / Time /Language).

3.3.2 MEASUREMENT

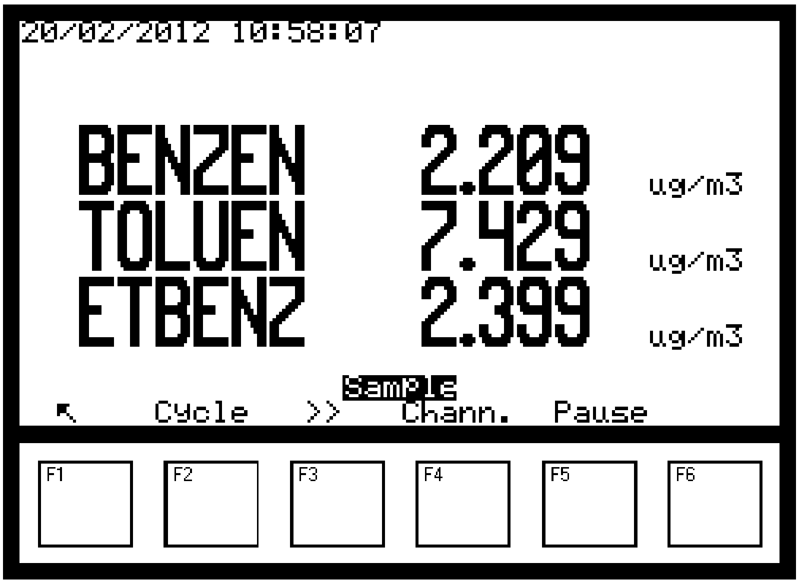
This screen is used to choose the measurement display mode: instantaneous, average, or graphic, to activate the continuous printing, display the possible alarms and their historic.

It must be noted that the « Alarms display » and the « Alarms historic » sub-menus are only displayed in this screen if they were previously activated to *« ON »* position in the *« Alarms control »* screen of the *« CONFIGURATION »* menu.



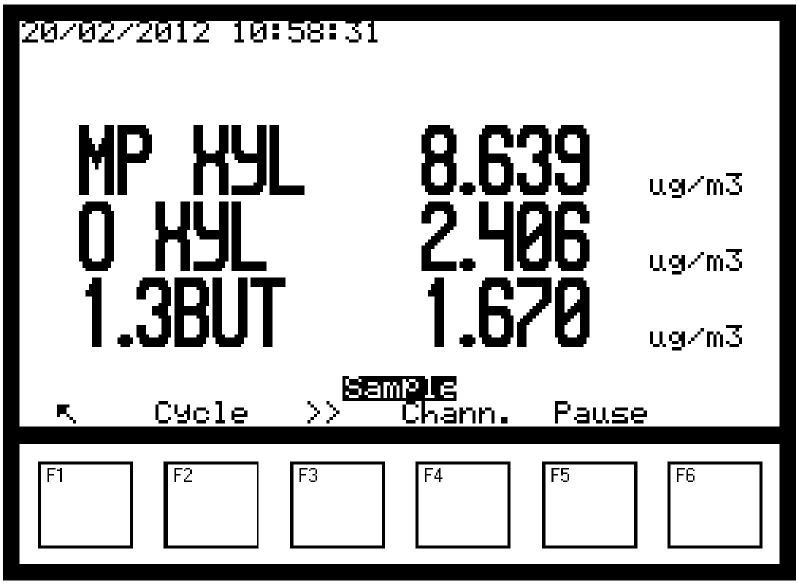
3.3.2.1 MEASUREMENT ⇨ Instantaneous

This screen enables to display the various channels of measurement and gives the instantaneous measurement values for each of them. It is possible to display 3 channels on one screen.


20/02/2012 10:58:07

BENZEN 2.209 ug/m3
TOLUEN 7.429 ug/m3
ETBENZ 2.399 ug/m3

Pressing down F3 **[>>]** will display the next 3 channels:


20/02/2012 10:58:31

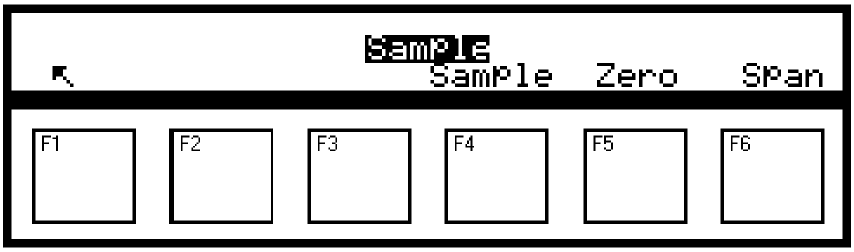
MP XYL 8.639 ug/m3
O XYL 2.406 ug/m3
1.3BUT 1.670 ug/m3

The 40 available channels can be displayed in this way.

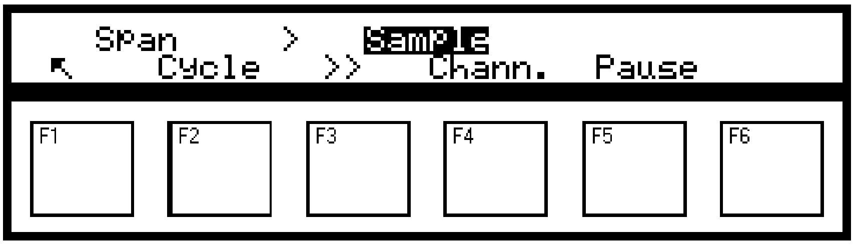
Definition of the specific keys of this screen

– Input channel selection.

- Pressing down F4 **[Chann.]** will display the inlet channels:



- Pressing down F6 **[Span]** will switch the analyzer to the span inlet (if span option available):



The «Span**»** message appears on the left indicating that the analyzer inlet will switch to Span at the beginning of the next sampling cycle.

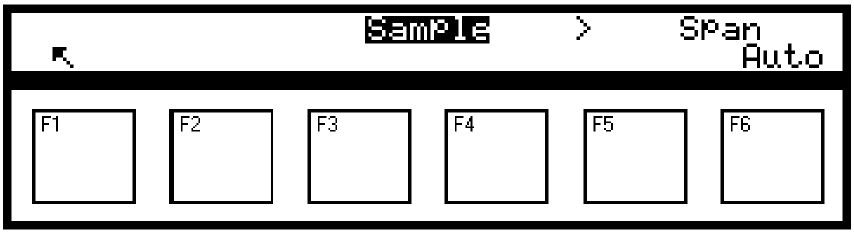
– Pause control.

- Pressing down F5 **[Pause]** aborts the current cycle and puts the analyzer into the **ready mode** in which the analyzer can immediately restart an analysis cycle.

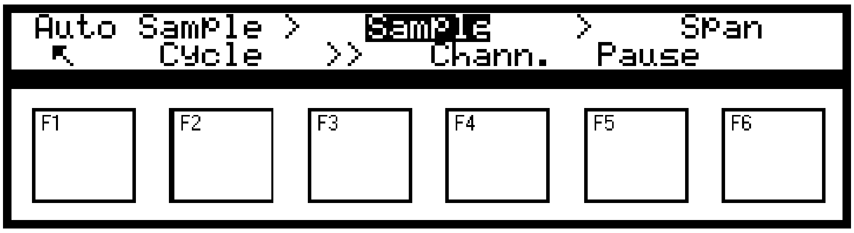
  The current sampling cycle is lost, as well as the analysis cycle if the progression bar did not pass over the calculation mark.

– Cycle control.

- Pressing down F2 **[Cycle]** enters the **Auto** display:



- Pressing down F6 **[Auto]** launches the Auto calibration according the Cycle configuration defined in the *«SPAN»* menu (see chapter 3.3.3).



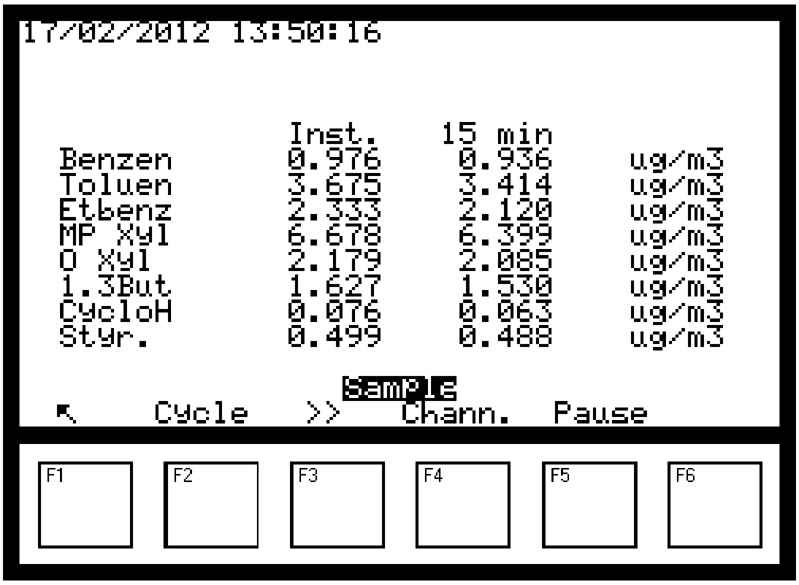
In this screen, the VOC72M:

- Analyzes the gas sampled on the span inlet during the previous cycle,
- Samples, on the sample inlet, the gas to be analyzed during the next cycle,
- Will perform, during the next sampling cycle, an auto span cycle on the gas taken from the sample inlet.

3.3.2.2 MEASUREMENT ⇨ Average

This screen enables to visualize, at the same time, the instantaneous values (the concentration values obtained at the end of the last measurement cycle), as well as the average values of concentration. The measurement is calculated during a period set in the *«STORED DATA»* screen, *«Settings»* heading, *«Data Recording Period»* field.

It is possible to display 8 channels on one screen.



```
17/02/2012 13:50:16


               Inst.    15 min
 Benzen        0.976     0.936     ug/m3
 Toluen        3.675     3.414     ug/m3
 Etbenz        2.333     2.120     ug/m3
 MP Xyl        6.678     6.399     ug/m3
 O Xyl         2.179     2.085     ug/m3
 1.3But        1.627     1.530     ug/m3
 CycloH        0.076     0.063     ug/m3
 Styr.         0.499     0.488     ug/m3
```

The averaged period (15 minutes) is defined in the *«STORED DATA»* screen, *«Settings»* heading, *«Data Recording Period»* field.

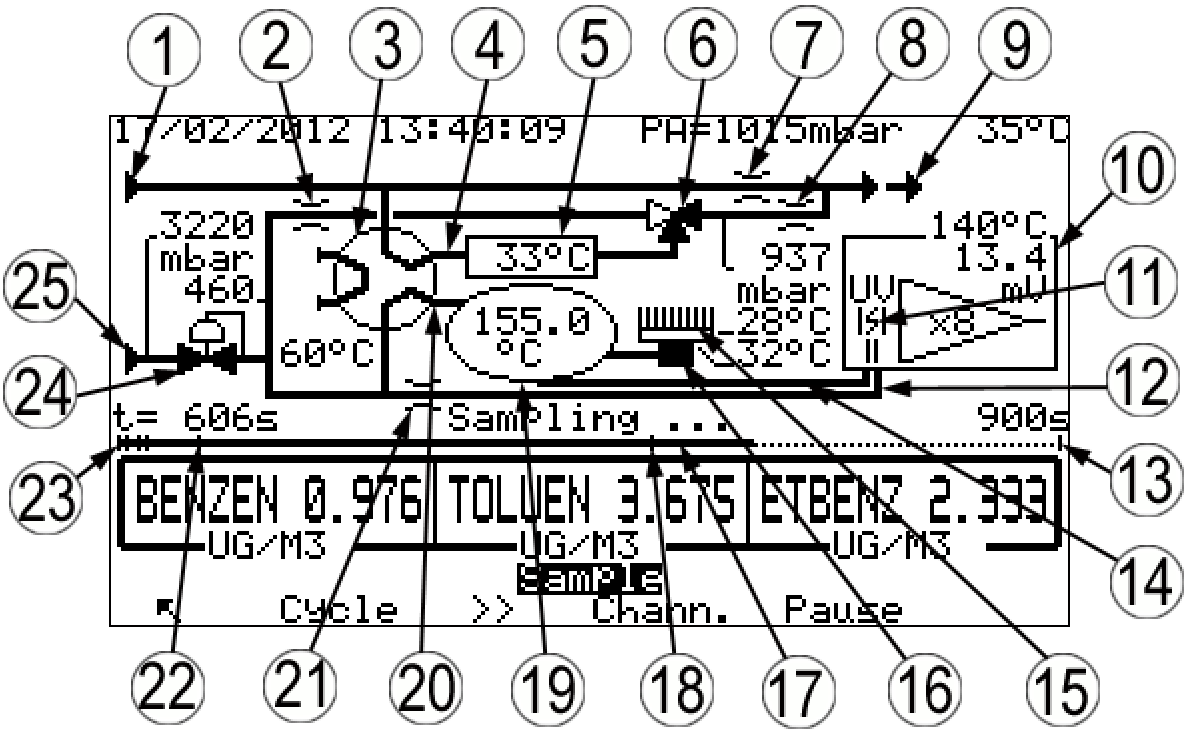
Pressing down F3 **[>>]** will display the next 8 channels. Thus, it is possible to display the 40 available channels.

Definition of the specific keys to this screen:

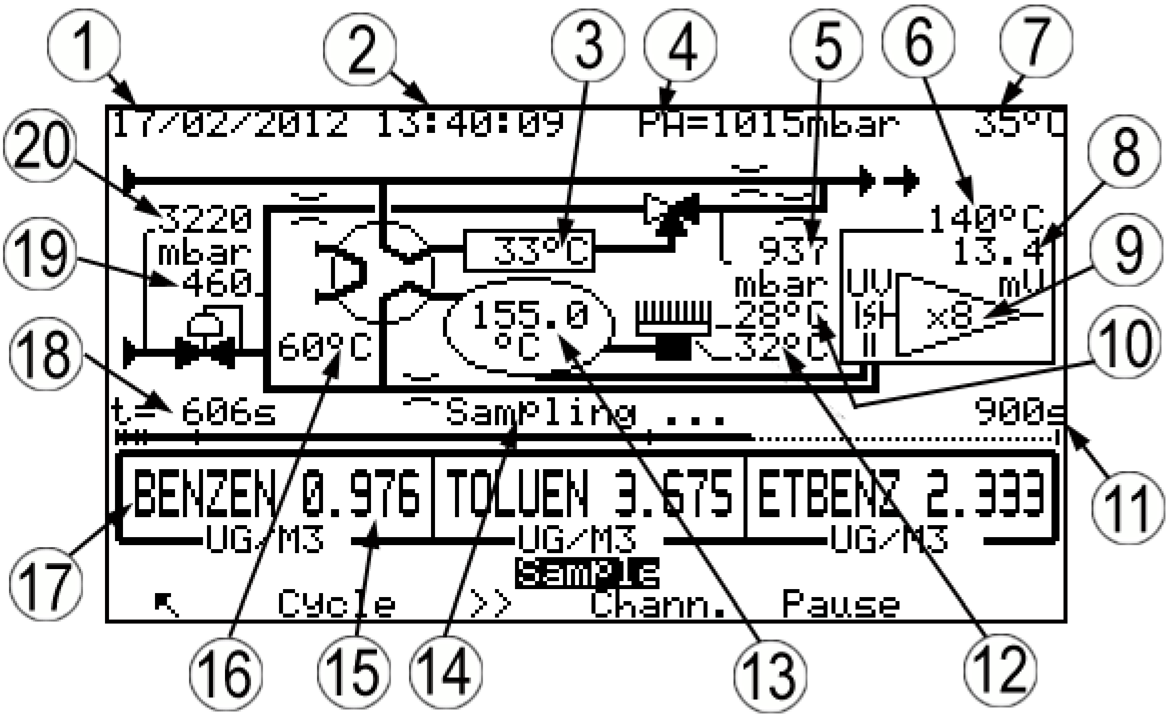
The keys of this screen have the same functions as shown in «*MEASUREMENT ⇨ Instantaneous*» screen.

3.3.2.3 MEASUREMENT ⇨ Synoptic

This screen represents the whole fluid circuit and displays the significant values for its control, as well as the measured compound concentration.



Mark	Description	Status shown
1	Sample inlet	
2	Purge flow restrictor	
3	6-way injection valve	Rest position
4	Transfer line	Heating OFF
5	Trap	Heating OFF
6	Purge valve	Rest position (sampling)
7	Sample by-pass flow restrictor	
8	Sample trapping flow restrictor	
9	Vacuum pump	Active
10	Photo ionization detector (PID)	
11	UV lamp ON	Active
12	PID nitrogen scavenging circuit	
13	Cycle end mark	
14	GC column end (detector side)	Heating OFF
15	Cooler heat sink	
16	Cooler cold plate	Active
17	Progression bar	
18	Calculation mark	
19	GC column	Heating OFF
20	GC column end (injection side)	Heating OFF
21	PID scavenging restrictor	
22	Trap sampling mark	
23	Cycle start mark	
24	Proportional valve	Active
25	Nitrogen inlet	



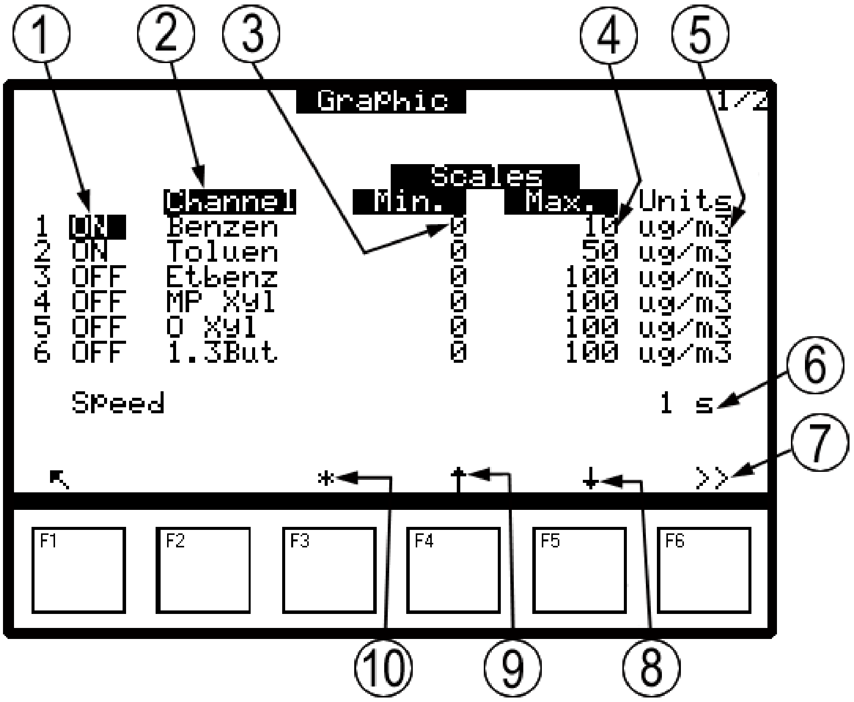
Mark	Description	Status shown
1	Date	DD/MM/YYYY
2	Hour	HH :MM :SS
3	Trap temperature	Celsius degree
4	Atmospheric pressure	Absolute millibar
5	Trap pressure	Absolute millibar
6	Photo ionization detector (PID) temperature	Celsius degree
7	Internal temperature	Celsius degree
8	Photo ionization detector (PID) signal	Millivolt
9	Photo ionization detector (PID) gain	NA
10	Cooler heat sink temperature	Celsius degree
11	Cycle duration	Second
12	Cooler cold plate temperature	Celsius degree
13	GC column temperature	Celsius degree
14	Trap status	NA
15	Compound concentration	µg/m3 (shown)
16	Hot box temperature	Celsius degree
17	Compound name	NA
18	Cycle clock	Second
19	Carrier gas pressure	Relative millibar
20	Nitrogen inlet pressure	Relative millibar

Definition of the specific keys to this screen:

The keys of this screen have the same functions as shown in «*MEASUREMENT ⇨ Instantaneous*» screen.

3.3.2.4 MEASUREMENT ⇨ Graphic

This screen is used for graphic plotting of measurement values on a short duration. For a longer duration of plotting, see the *«STORED DATA»* screen.



```
                     Graphic                    1/2

                              Scales
          Channel        Min.       Max.   Units
1 ON      Benzen            0         10   ug/m3
2 ON      Toluen            0         50   ug/m3
3 OFF     Etbenz            0        100   ug/m3
4 OFF     MP Xyl            0        100   ug/m3
5 OFF     O Xyl             0        100   ug/m3
6 OFF     1.3But            0        100   ug/m3

  Speed                                   1 s

  ↖                *        ↑        ↓        >>
```

(1) Display status (ON-OFF),

(2) Channel (Compound shown),

(3) Minimum scale,

(4) Maximum scale,

(5) Units,

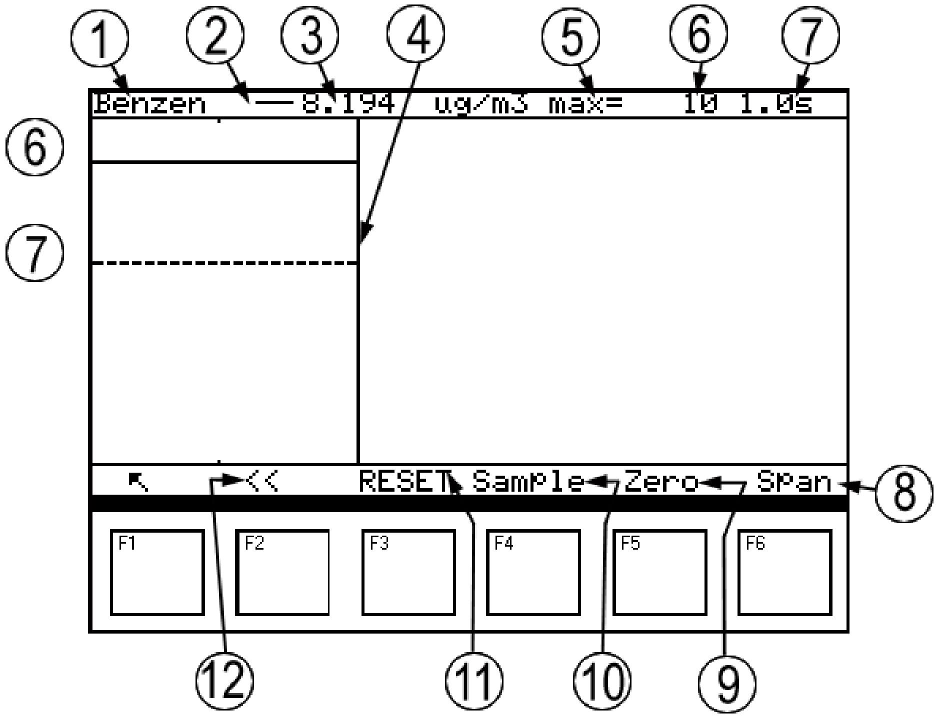
(6) Plotting speed (max 60 seconds),

(7) [F6] key to go to screen 2/2 and display the graph,

(8) [F5] key to select the next parameter,

(9) [F4] key to select the previous parameter,

(10) [F3] key to modify the selected parameter.



(1) Channel (compound name).

(2) Compound curve.

(3) Instant concentration value of the compound.

(4) Refreshment line.

(5) Scale indicator (max or min).

(6) Maximum scale (10µg/m3 in the present example).

(7) Refreshment rate (every 1 second in the present example).

(8) Press [F6] to select span inlet.

(9) Press down [F5] to select zero inlet.

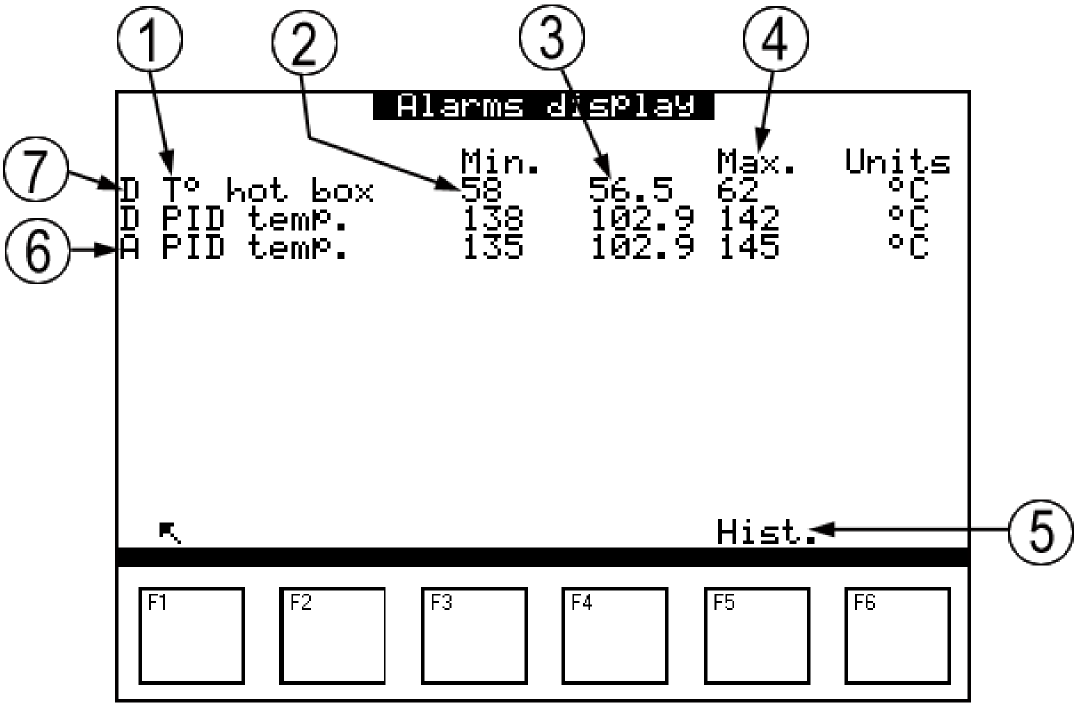
(10) Press down [F4] to select sample inlet.

(11) Press down [F3] to reset the refreshment line.

(12) Press down [F2] to return to the graphic configuration.

3.3.2.5 MEASUREMENT ⇨ Alarms display

This screen displays the operating faults in case of alarm. Possible corrective actions for these faults are given in chapter 5.



```
                 Alarms display
                 Min.     Max.   Units
D T° hot box     58   56.5  62      °C
D PID temp.      138  102.9 142     °C
A PID temp.      135  102.9 145     °C

 ↖                        Hist.
```

(1) Location and type of alarm.

(2) Low limit.

(3) Present measurement of the parameter.

(4) High limit.

(5) Press down [F5] to go to Historic.

(6) A ⇔ Alarm.

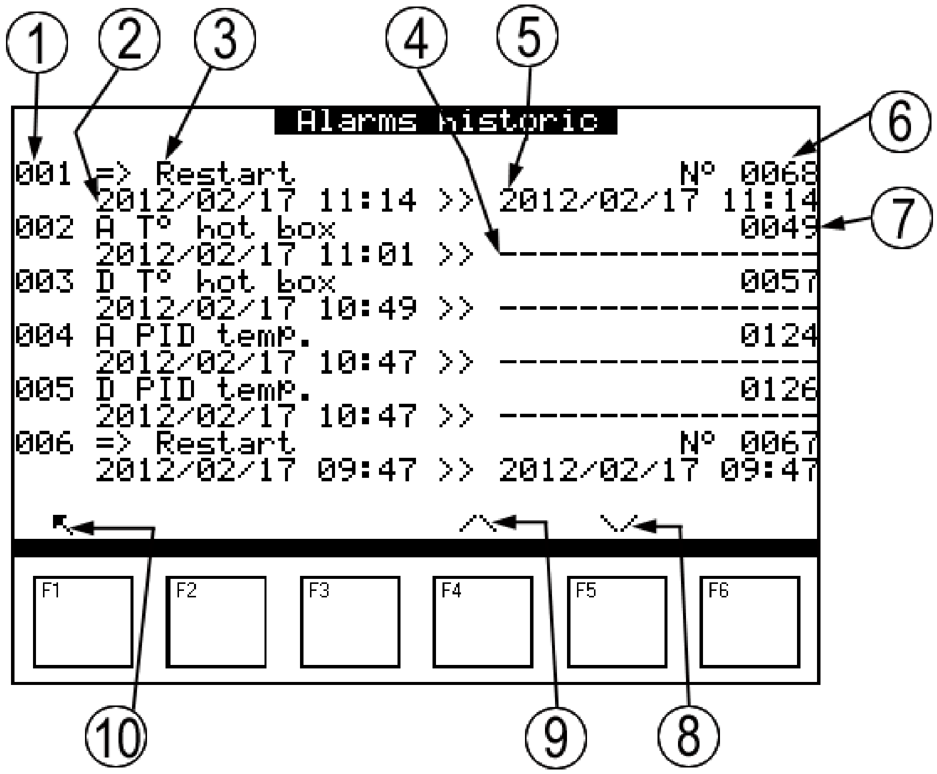
(7) C ⇔ Control.

The VOC72M uses a triple alarm level:

- Level 1: **Control (C)**. The measurement given by the analyzer is still valid but the user is informed that one of the analyzer parameters is close to the alarm level.
- Level 2: **Alarm (A)**. One parameter is outside the acceptable limits for the measurement. The analysis cycle is interrupted and the VOC72M passes into stand-by mode (in most cases).
- Level 3: **Safety (S)**. One of the analyzer parameter is outside the safety limits and may damage the analyzer. The safety relay cuts OFF the 24V power supply of the interconnection board.

In most cases, passing to stand-by mode is sufficient to clear the alarm status. When the VOC72M is found in stand-by mode, it is advised to check the alarm historic in order to identify the cause of the switch to stand-by mode.

Pressing down F5 **[Hist]** will display the alarm historic.



```
               Alarms historic
001 => Restart                     N° 0068
    2012/02/17 11:14 >> 2012/02/17 11:14
002 A T° hot box                      0049
    2012/02/17 11:01 >> ----------------
003 D T° hot box                      0057
    2012/02/17 10:49 >> ----------------
004 A PID temp.                       0124
    2012/02/17 10:47 >> ----------------
005 D PID temp.                       0126
    2012/02/17 10:47 >> ----------------
006 => Restart                     N° 0067
    2012/02/17 09:47 >> 2012/02/17 09:47
```

(1) Alarm rank (001⇔ the most recent).

(2) Event start time

(3) Event description : in this field, “A” indicates that the event is an alarm.

(4) Event end time (no end shown in the above example).

(5) Event end time.

(6) Number of event type (68th restart action).

(7) Measurement value in cause (49°C).

(8) Press down [F5] to go down in the Historic.

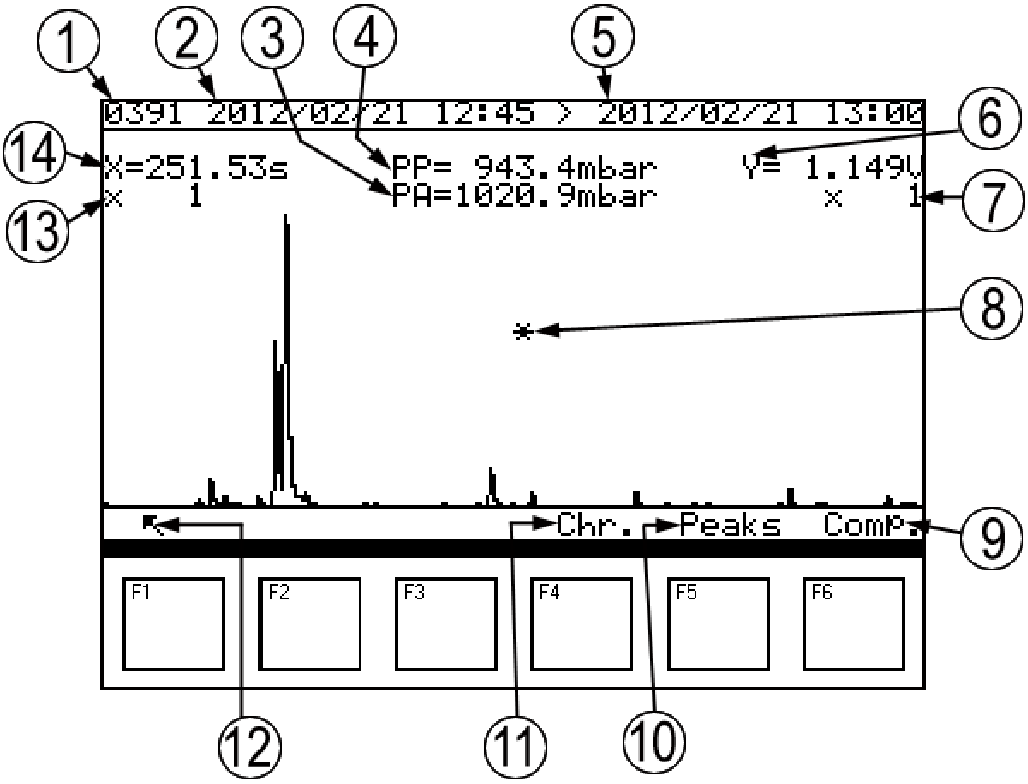
(9) Press down [F4] to go up in the Historic.

(10) Press down [F1] to go back to the alarm display.

NOTE : Even if the instrument means to correctly working, it is advised to regularly examine the alarm historic for possible random defaults which may lead to an alarm situation on short time.

3.3.2.6 MEASUREMENT ⇨ Chromatogram

This screen displays the last GC chromatogram acquired.



(1) Chromatogram number #

(2) Sampling start date and hour.

(3) Averaged atmospheric pressure (mbar) during the analysis cycle.

(4) Averaged trap pressure (mbar) during the sampling cycle.

(5) Date and hour of sampling end.

(6) Y marker position (volts).

(7) Y axis zoom (vertical axis).

(8) Marker.

(9) Press down [F6] to access the **Comp**ounds display screen.

(10) Press down [F5] to access the **Peaks** display screen.

(11) Press down [F4] to access the **Chr**omatogram display screen.

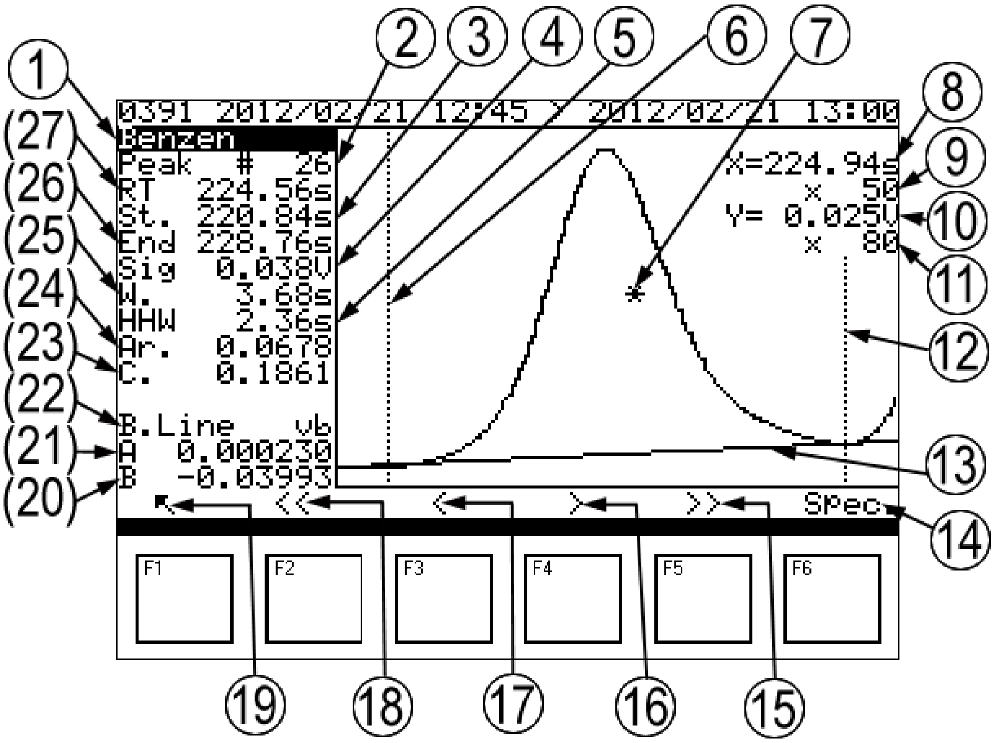
(12) Press down [F1] to return to the Measurement menu.

(13) X axis zoom (horizontal axis).

(14) X marker position (seconds).

3.3.2.6.1 MEASUREMENT ⇨ Chromatogram ⇨ Compound

Pressing down F6 **[Comp]** enables to display the chromatographic peak of the first compound :



```
0391 2012/02/21 12:45 > 2012/02/21 13:00
Benzen
Peak   #   26          X=224.94s
RT   224.56s                  x  50
St.  220.84s           Y= 0.025V
End  228.76s                  x  80
Sig   0.038V
W.     3.68s
HHW    2.36s
Ar.   0.0678
C.    0.1861

B.Line    vb
A   0.000230
B   -0.03993
```

(1) Compound name.

(2) **Peak** # (24th peak).

(3) Peak **St**art time (second).

(4) **Sig**nal maximum amplitude (volt).

(5) **H**alf **H**eight **W**idth (second).

(6) Peak start line.

(7) Marker.

(8) X Marker position (seconds).

(9) X axis zoom (horizontal axis).

(10) Y Marker position (volt).

(11) Y axis zoom (vertical axis).

(12) Peak end line.

(13) Peak baseline.

(14) Press down F6 **[Spec]** to access the marker checking.

(15) Press down F5 **[>>]** to go to last compound.

(16) Press down F4 **[>]** to go to next compound.

(17) Press down F3 **[<]** to return to previous compound.

(18) Press down F2 **[<<]** to return to the first compound.

(19) Press down F1 to return to the chromatogram.

(20) Baseline origin (Ax+**B**).

(21) Baseline slope (**A**x+B).

(22) **Base****Line** type (**v**alley-**b**ase)

(23) **C**orrected area of the peak.

(24) Peak **AR**ea (second x volt).

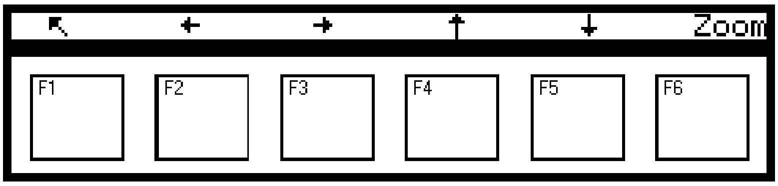
(25) Peak **W**idth (second).

(26) Peak **End** (second).

(27) Peak **R**etention **T**ime (second).

NOTE : The retention time of the peak (27) and the corrected area of the peak (23) are required for the manual calibration (see chapter 3.4.5).

Pressing down F6 **[Spec]** enables to access the specific keyboard of the marker:



[F1] Return to previous screen.

[F2] Move the marker to the left.

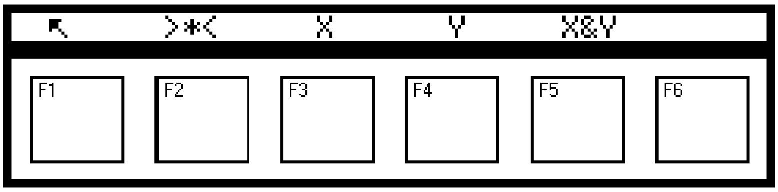
[F3] Move the marker to the right.

[F4] Move the marker upside.

[F5] Move the marker downside.

[F6] Change the keyboard function (Zoom).

Pressing down F6 **[Zoom]** enables to access the zoom keyboard:



[F1] Return to previous screen.

[F2] Centre the display on the present marker position.

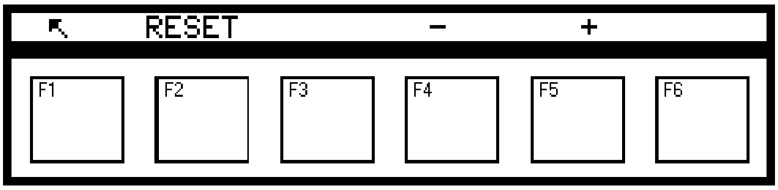
[F3] Select X zoom.

[F4] Select Y zoom.

[F5] Select X and Y zoom.

[F6] N/A.

Pressing down F3 or F4 or F5 enable to access the selected zoom:



[F1] Return to previous screen.

[F2] Restoration of the default scale (refer to here-below notes.

[F3] N/A.

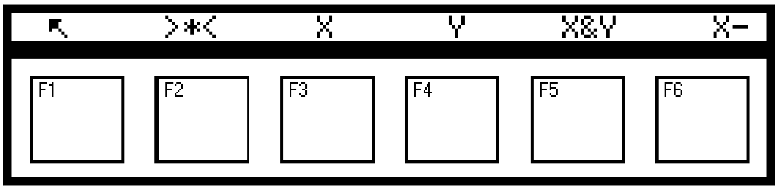
[F4] Zoom (+).

[F5] Zoom (-).

[F6] N/A.

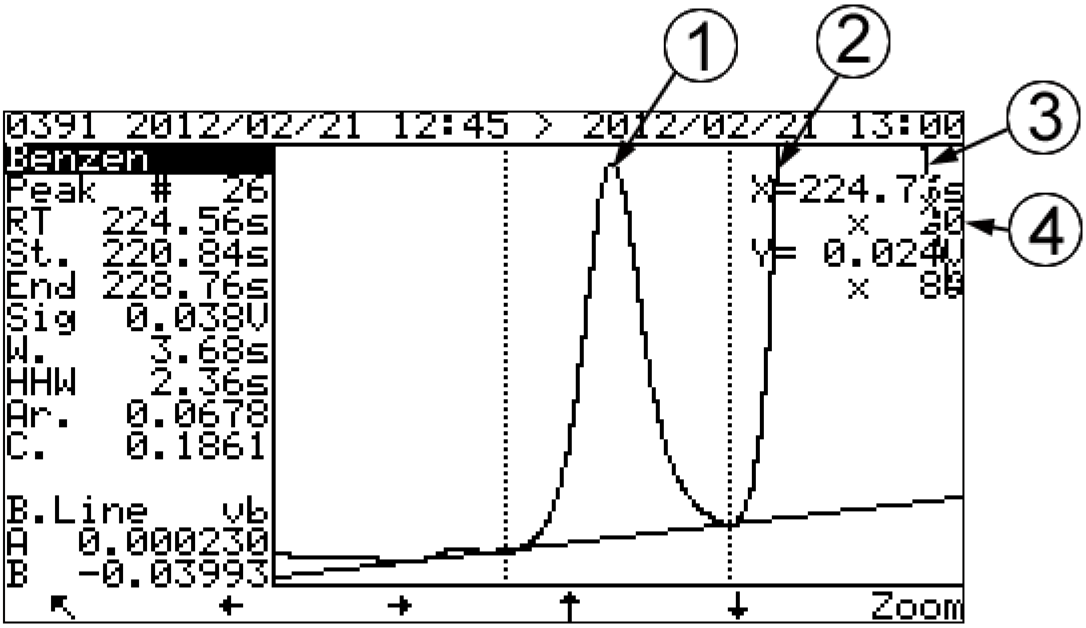
NOTE : The default X axis scale (time) is the whole chromatogram and the default Y axis scale (amplitude) is the maximal dynamics of the signal (2500mV).

Pressing down F4 **[-]** enables to access the Zoom (-) keyboard:



Pressing down F6 **[X-]** activates the zoom (-).

Here-below is the zoom (-) result on the benzene peak, which was previously displayed as compound with a X50 zoom.



```
0391 2012/02/21 12:45 > 2012/02/21 13:00
Benzen
Peak   #   26
RT   224.56s
St.  220.84s
End  228.76s
Sig   0.038V
W.     3.68s
HHW    2.36s
Ar.   0.0678
C.    0.1861

B.Line    vb
A  0.000230
B  -0.03993
```

```
X=224.76s
      x 20
Y= 0.024V
      x 80
```

(1) Benzene peak

(2) Start of intense peak close to the benzene peak

(3) End of intense peak

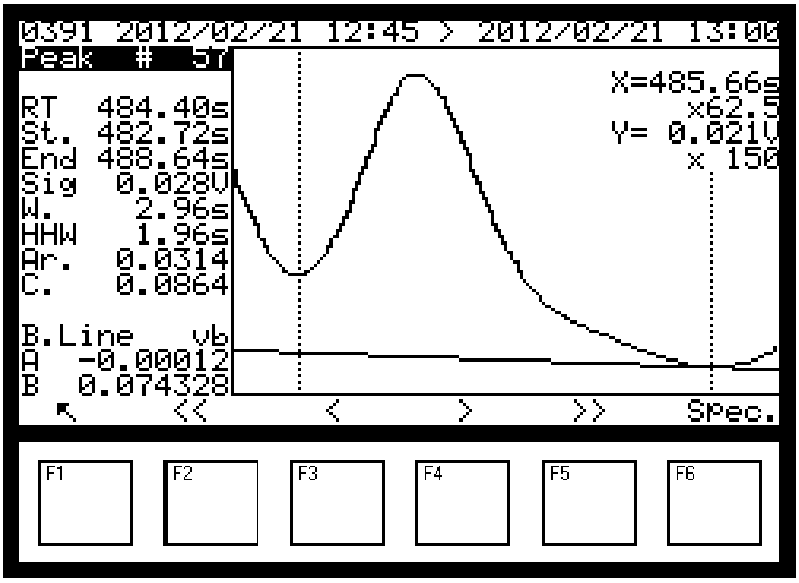
(4) X20 zoom

The screen always displays the benzene peak in the centre while an intense peak appears on its right side.

The zoom (+) operates in the same way than the zoom (-) in X (seconds) or Y (volts).

3.3.2.6.2 *MEASUREMENT ⇨ Chromatogram ⇨ Peak*

Pressing down F5 **[Peaks]** enables to access the peak display screen:



```
0391 2012/02/21 12:45 > 2012/02/21 13:00
Peak  #  57
RT   484.40s
St.  482.72s
End  488.64s
Sig   0.028V
W.     2.96s
HHW    1.96s
Ar.   0.0314
C.    0.0864
B.Line    vb
A   -0.00012
B   0.074328
X=485.66s
x62.5
Y= 0.021V
x 150
```

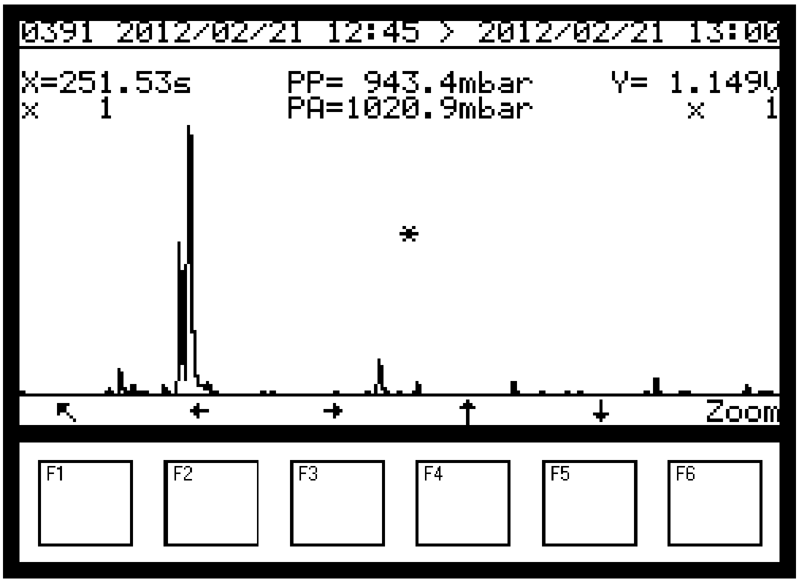
This screen is similar to the one of compound peaks display. It is possible to display all the detected peaks detected on the chromatogram, which is useful for calibrating a new compound.

Definition of keys specific to this screen:

The keys of this screen have the same functions as shown in the *«MEASUREMENT ⇨ Chromatogram ⇨ Compound»* screen.

3.3.2.6.3 *MEASUREMENT ⇨ Chromatogram ⇨ CHR*

Pressing down F4 **[Chr]** enables to access the chromatogram display screen:



0391 2012/02/21 12:45 > 2012/02/21 13:00

X=251.53s PP= 943.4mbar Y= 1.149V

x 1 PA=1020.9mbar x 1

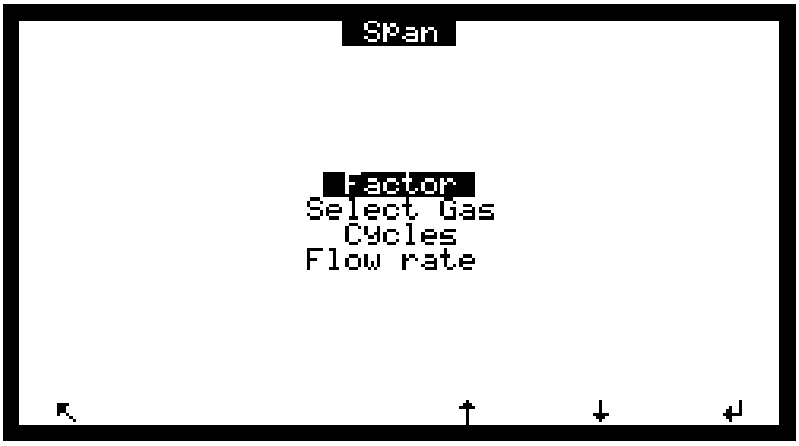
This screen gives an idea about the global level of pollutants.

Definition of the specific keys to this screen:

The keys of this screen have the same functions as shown in the *«MEASUREMENT ⇨ Chromatogram ⇨ Compound»* screen.

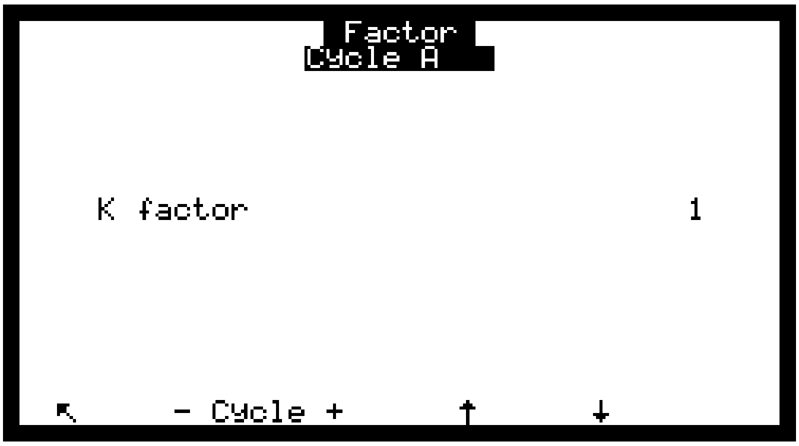
3.3.3 SPAN

This menu gives access to the calibration functions.



3.3.3.1 SPAN ⇨ Factor

This menu enables to adjust the global sensitivity for the whole compounds.



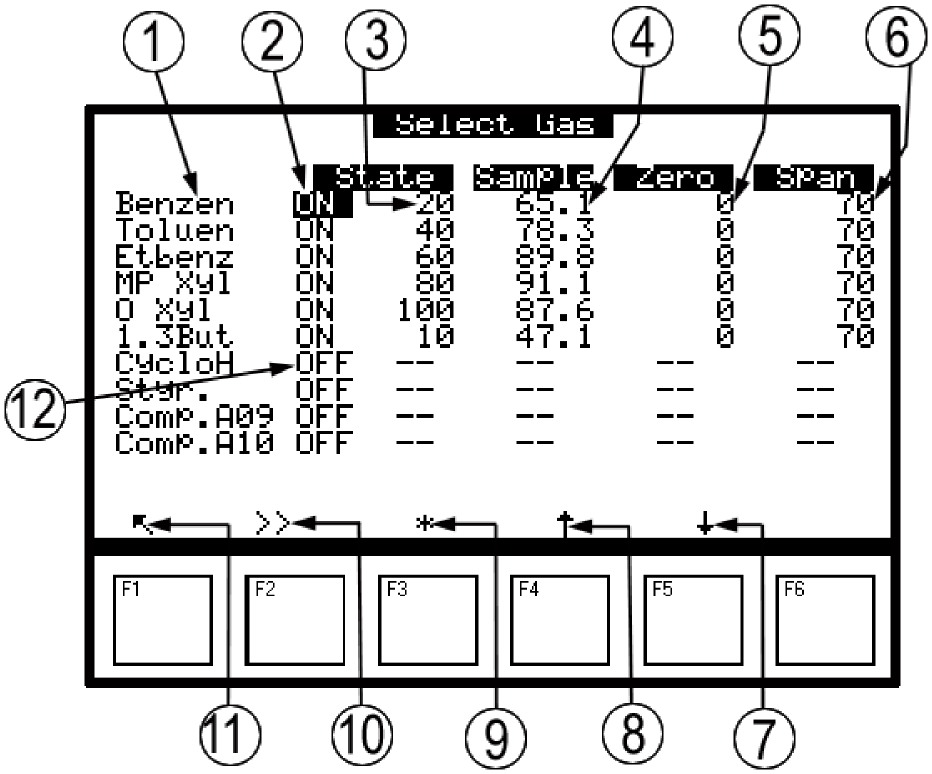
K factor 1

The default value for the K factor is 1.

Changing the K factor must be considered as a “quick fix” when a sensitivity modification is noticed and when there is no span gas available for re-calibrating the analyzer.

3.3.3.2 SPAN ⇨ Select gas

This screen is used to define the gas mixture for the automatic calibration of VOC72M.



Select Gas

	State		Sample	Zero	Span
Benzen	ON	20	65.1	0	70
Toluen	ON	40	78.3	0	70
Etbenz	ON	60	89.8	0	70
MP Xyl	ON	80	91.1	0	70
O Xyl	ON	100	87.6	0	70
1.3But	ON	10	47.1	0	70
CycloH	OFF	--	--	--	--
Styr.	OFF	--	--	--	--
Comp.A09	OFF	--	--	--	--
Comp.A10	OFF	--	--	--	--

(1) Compound #1 (benzene).	(7) Next .
(2) Compound selection ON = selected.	(8) Previous
(3) Compound elution rank.	(9) Change
(4) Compound span concentration if sample inlet is used.	(10) Next screen (compound 11 to 20)
(5) Compound span concentration if zero inlet is used.	(11) Return to span menu.
(6) Compound span concentration if span inlet is used.	(12) Compound selection OFF = ignored.

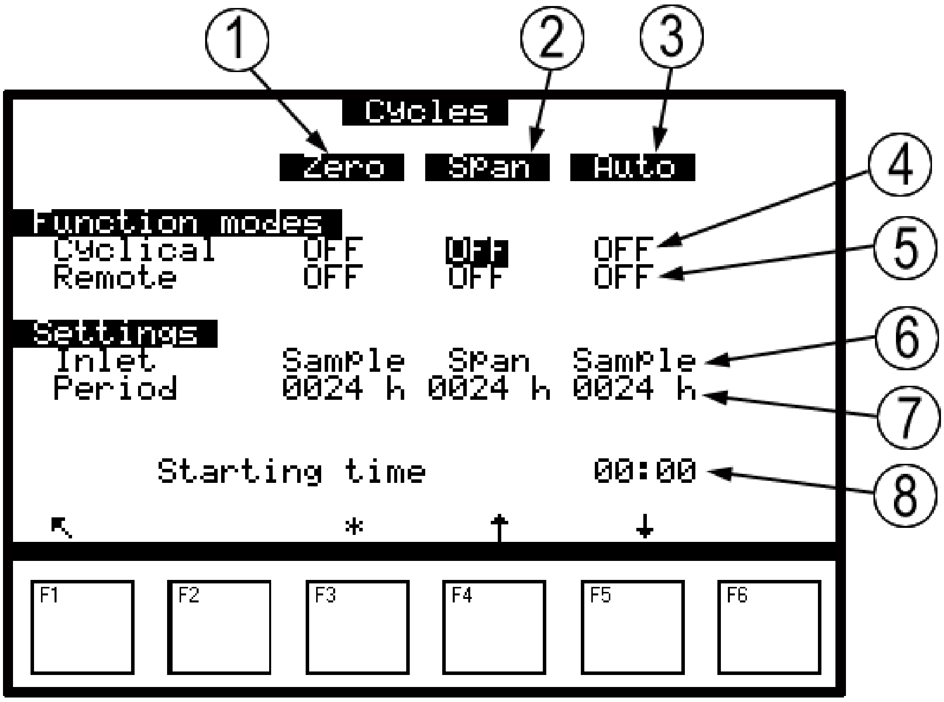
Up to 10 compounds can be displayed in this screen. Pressing down [F2] will display the next 10 compounds.

The value in the compound elution rank (3) is an integer which informs the VOC72M about the relative position of the peak compounds in the chromatogram:

Example: the elution rank displayed here-below for benzene is 20. The integer “20” indicates that the benzene peak is located between the 1.3 butadiene peak (elution rank 10) and the toluene peak (elution rank 40). In fact, any integer value between 11 and 39 could fit as benzene elution rank.

3.3.3.3 SPAN ⇨ Cycles

This screen is used to define manual, automatic or remote cycles for span check, zero check or automatic calibration.



```
                    Cycles
                 Zero    Span    Auto
Function modes
  Cyclical       OFF     OFF     OFF
  Remote         OFF     OFF     OFF
Settings
  Inlet        Sample   Span    Sample
  Period       0024 h  0024 h  0024 h

      Starting time              00:00
```

(1) Zero check

(2) Span check

(3) Auto calibration.

(4) Cyclical fields.

(5) Remote fields.

(6) inlet fields.

(7) Period field.

(8) Starting time field.

The *«Cyclical»* fields (4) use the internal clock to launch the cycles.

The *«Remote»* fields (5) are used to configure the remote controls of cycles (ESTEL card option). The state programmed in “Remote” fields (ON = active, OFF = inactive) controls analyzer reaction when a dry contact is closed on remote controls inputs.

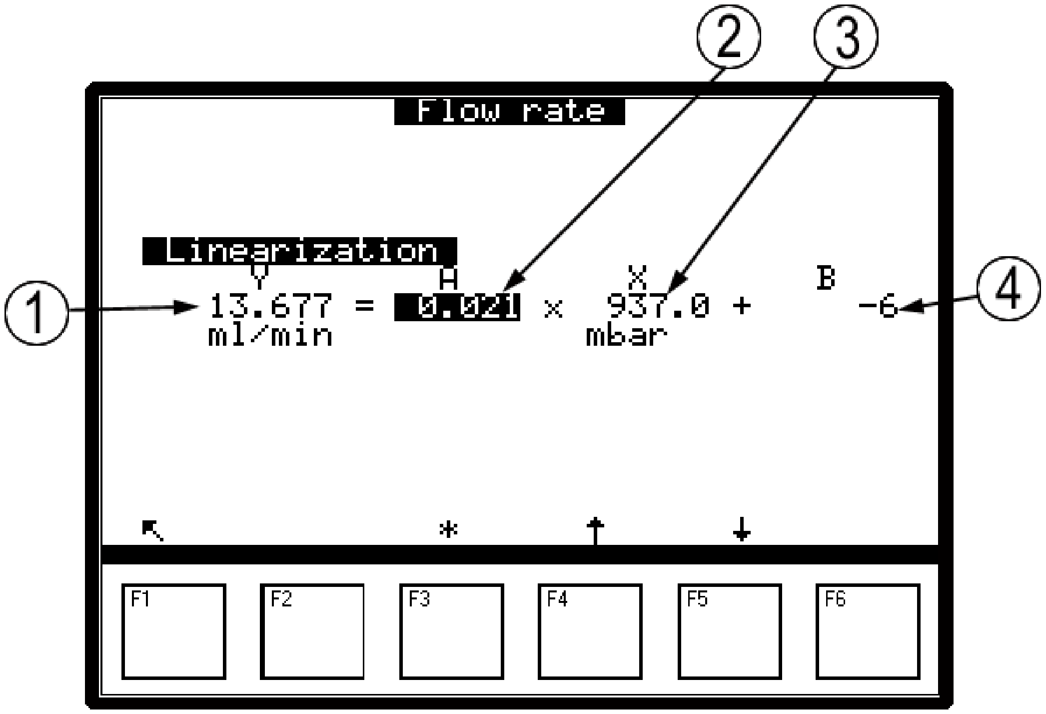
The *«Inlet»* fields (6) enable to select gas inlets used during the automatic sequences. The reference concentrations for automatic calibration are those programmed in the *Select gas* menu.

The *«Starting time»* field (8) is used to program the time when cycles will be launched.

To inhibit an automatic cycle, program 0000 h in *«Period»* field (7).

3.3.3.4 SPAN ⇨ Flow rate.

This screen corresponds to the flow rate calculation from the trap pressure measurement.



Flow rate

Linearization

```
  Y          A          X          B
13.677 =   0.021  x   937.0  +    -6
ml/min               mbar
```

(1) Calculated trap flow.

(2) Slope factor (A)

(3) Trap absolute pressure (X).

(4) Origin (B).

The flow rate calculation corresponds to the equation:

Y = A X + B

Y: Flow in millilitres per minute.

A: Slope.

X: Trap absolute pressure in millibar.

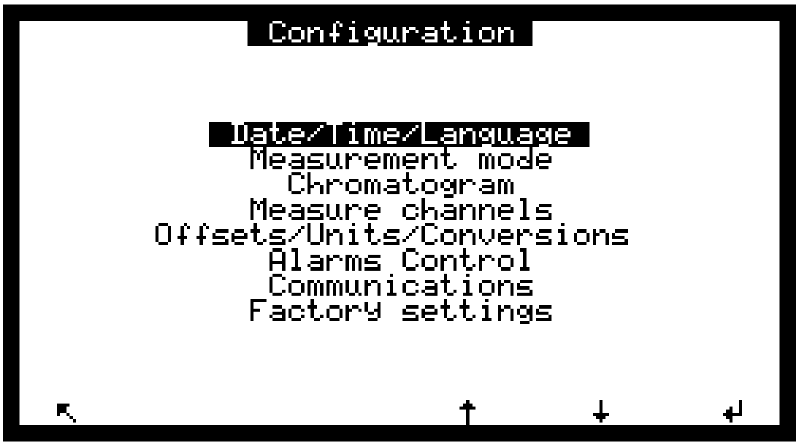
B: Origin.

The flow rate calculation has a direct effect on the compound measurement: a 10% decrease of the calculated flow rate will correspond to a similar reduction of the trap sampling volume (as the sampling time is constant) and involves a 10% increase in the compound concentration readings.

It is advised to run a span calibration of the compounds after a flow rate calibration.

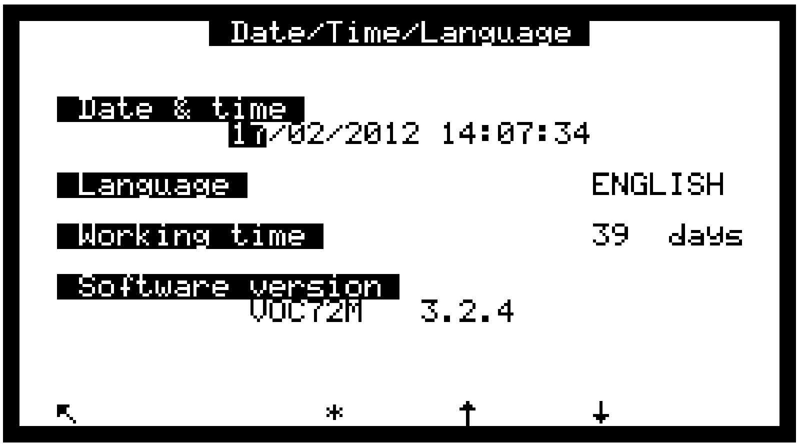
3.3.4 CONFIGURATION

The configuration menu defines the setup of the analyzer.



3.3.4.1 CONFIGURATION ⇨ Date / Time / Language

This screen is used to set the internal clock of the analyzer, as well as to choose the displayed language (French, English, German, Italian, Spanish). It also shows the software version number to remind in case of software dysfunction.



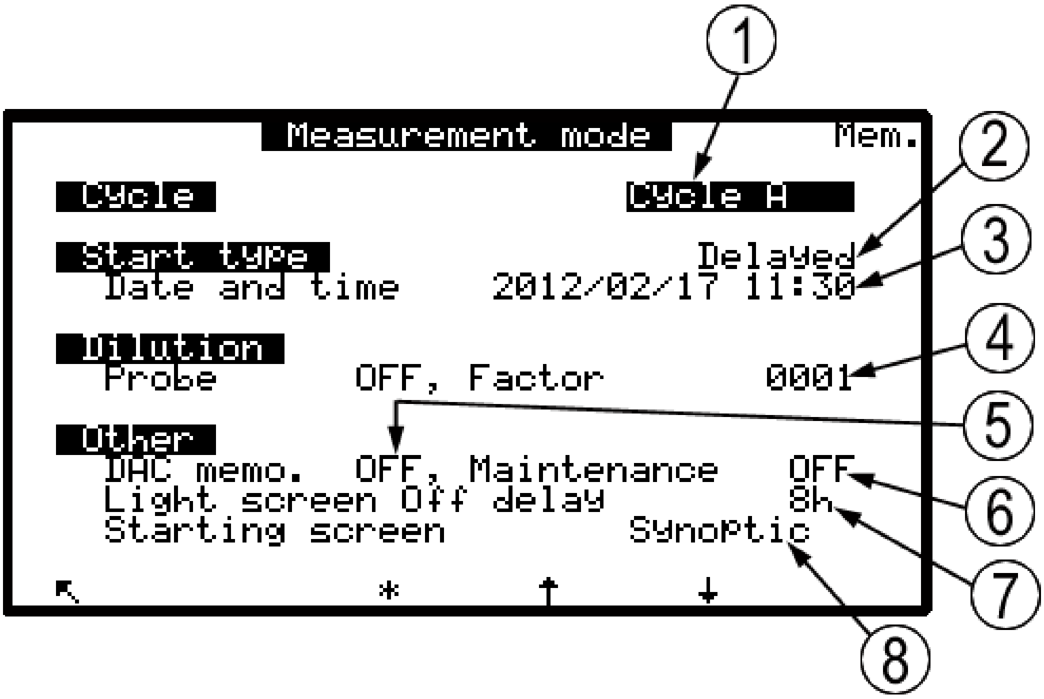
Date & time
17/02/2012 14:07:34

Language ENGLISH

Working time 39 days

Software version
VOC72M 3.2.4

3.3.4.2 CONFIGURATION ⇨ Measurement mode



```
        Measurement mode              Mem.
 Cycle                         Cycle A
 Start type                       Delayed
   Date and time    2012/02/17 11:30
 Dilution
   Probe      OFF, Factor       0001
 Other
   DAC memo.  OFF, Maintenance   OFF
   Light screen Off delay        8h
   Starting screen        Synoptic
 ↖             *     ↑     ↓
```

(1) *«Cycle» field*: up to 8 cycles are available, each cycle corresponds to a various configuration of the analyzer. The name of the cycle is given at (1). In this screen, the cycle is named «Cycle A»: this name can be modified by the user with the keys [↑], [↓], [✱].

(2) *«Start type» field:* it defines the starting condition for the first cycle. Two conditions (2) are possible:

- **Immediate**: the first cycle is launched just after the Start command is activated.
- **Delayed:**
  - If the date and time (3) is in the future, the first cycle is launched at the date and time indicated (3). Example: if present date and time is 2012/02/08 08:00, the first cycle will start on 2012/02/17 at 11:30.
  - If the date and time (3) is located in the past, the first cycle will start in order to be able to match the minute timing in a future cycle. Example: if present date and time is 2012/12/25 12:12, the first cycle will start at 12:15 for a 15 minute cycle because the next cycle will start at 12:**30** which matches with 11:**30**. If a 30 minute cycle was selected, the first cycle will start at 12:**30** which matches with 11:**30**.

«Dilution» field: it gives access to the Dilution function. To measure very high concentrations (ex. industrial environment), it is necessary to bring them to values corresponding to the range of analyzer by inserting a dilution system in the sampling line in order to get:

$$C_{\text{analyser inlet}} = {}^{C_{\text{sample}}}\!\big/_{K_{\text{dilution}}}$$

The real concentration display is obtained by applying a «K_{dilution}» multiplying coefficient to the measured concentration.

When the *«Probe»* filed is **ON**, the analyzer considers that a dilution device is connected upstream, and it applies the corresponding K dilution factor (4) to the measured concentration.

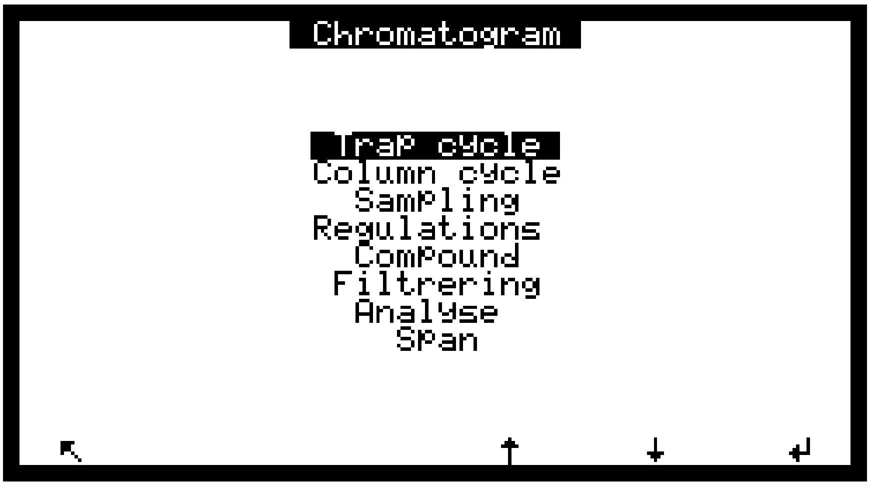
«Other» fields:

- **DAC memo**: when this field is ON (5), the analog outputs are latched during Zero, Span cycles, etc., in order not to disrupt data loggers. Requires the ESTEL option.
- **Maintenance:** when this field is **ON** (6), it activates the maintenance relay (if ESTEL option present), and the maintenance message and both screen and communication port (Ethernet or optional RS4i).
- **Light screen off delay:** this field defines the duration time (7) after which, with no user handling on the analyzer, screen passes into energy saving mode.
- **Starting screen:** this field: enables to select the warm-up screen to display when starting the analyzer. Four selections are possible: *Instantaneous, Average, Synoptic, Graphic,* corresponding to the MEASUREMENT menu.

3.3.4.3 CONFIGURATION ⇨ Chromatogram

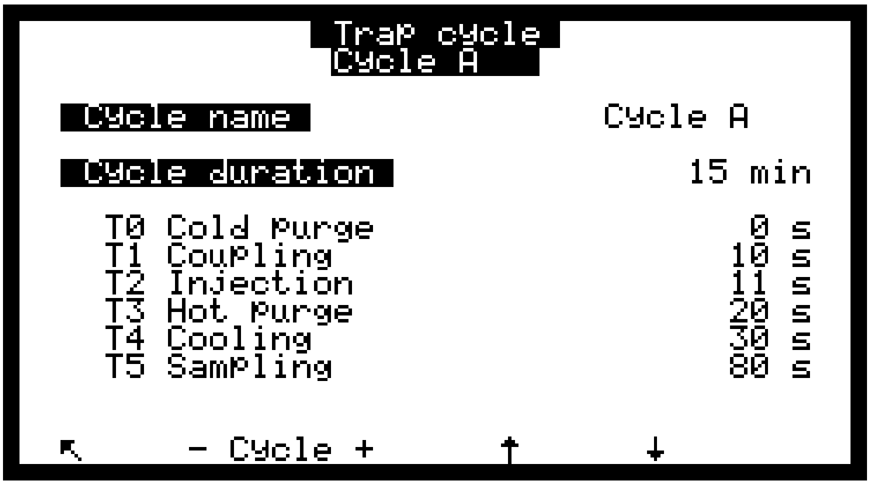
This menu is used for the GC (gas chromatography) setup.

WARNING: changing the GC setup invalidates the retention times and the calibration.



3.3.4.3.1 CONFIGURATION ⇨ Chromatogram ⇨ Trap cycle

This screen enables to define the trap timing during the analysis cycle.



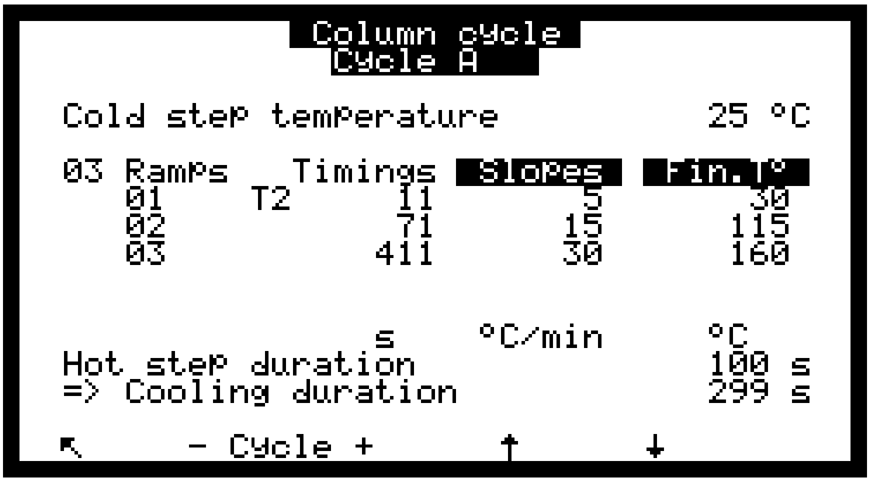
Cycle name Cycle A

Cycle duration 15 min

T0 Cold purge 0 s
T1 Coupling 10 s
T2 Injection 11 s
T3 Hot purge 20 s
T4 Cooling 30 s
T5 Sampling 80 s

3.3.4.3.2 *CONFIGURATION ➪ Chromatogram ➪ Column cycle*

This screen enables to parameter the thermal program of the GC (Gas Chromatography) column within the analysis cycle.



```
                  Column cycle
                   Cycle A

 Cold step temperature                25 °C

 03 Ramps    Timings  Slopes     Fin.T°
    01    T2      11       5        30
    02            71      15       115
    03           411      30       160


                   s    °C/min      °C
 Hot step duration                 100 s
 => Cooling duration               299 s

 ↖      - Cycle +       ↑       ↓
```

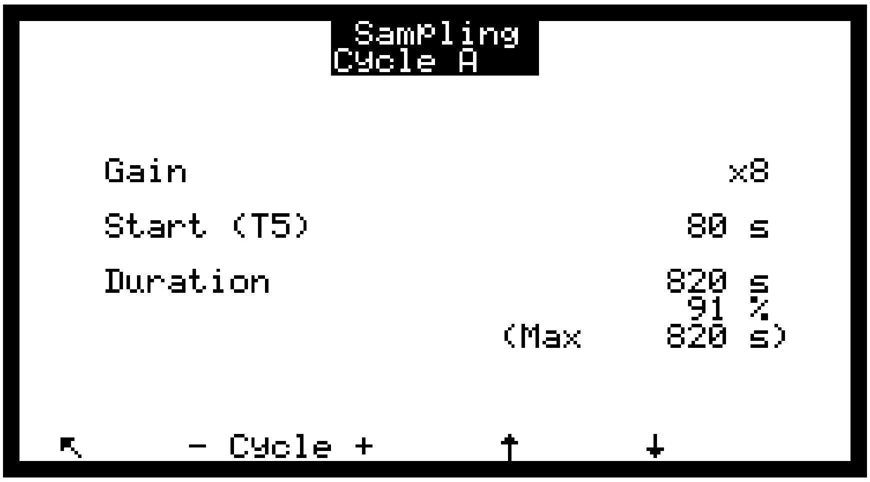
The here-above screen corresponds to the 15-minutes (or 900 seconds) setup with 3 thermal ramp:

Start 25°C, 5°C/min to 30°C, 15°C/min to 115°C, 30°C/min to 160°C, hot step at 160°C during 100 seconds before cooling.

The instrument manages up to 5 ramps, a 30°C/minute heating rate and a 170°C maximum GC column temperature.

3.3.4.3.3 *CONFIGURATION ➪ Chromatogram ➪ Sampling*

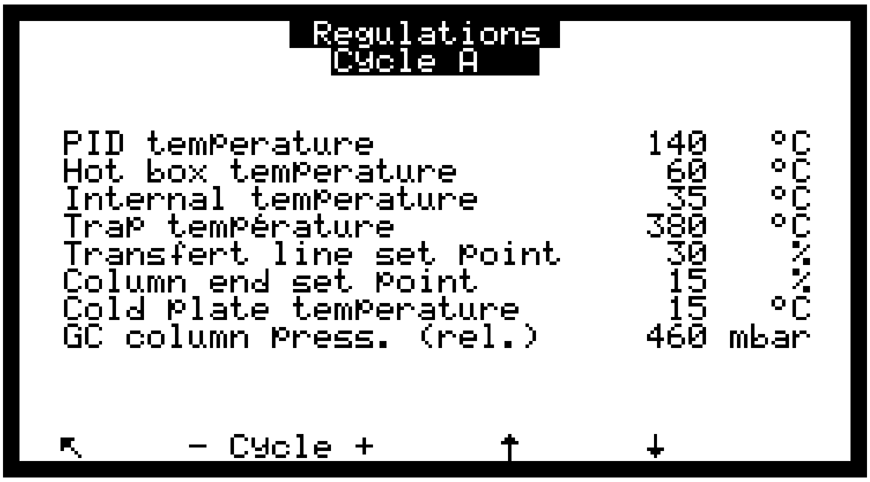
This screen is used to adjust the detector gain and displays the sampling rate (91% of the cycle duration in the here-below example).



```
                   Sampling
                   Cycle A


   Gain                               x8

   Start (T5)                       80 s

   Duration                        820 s
                                    91 %
                         (Max      820 s)


 ↖      - Cycle +       ↑       ↓
```

3.3.4.3.4 CONFIGURATION ⇨ Chromatogram ⇨ Regulations

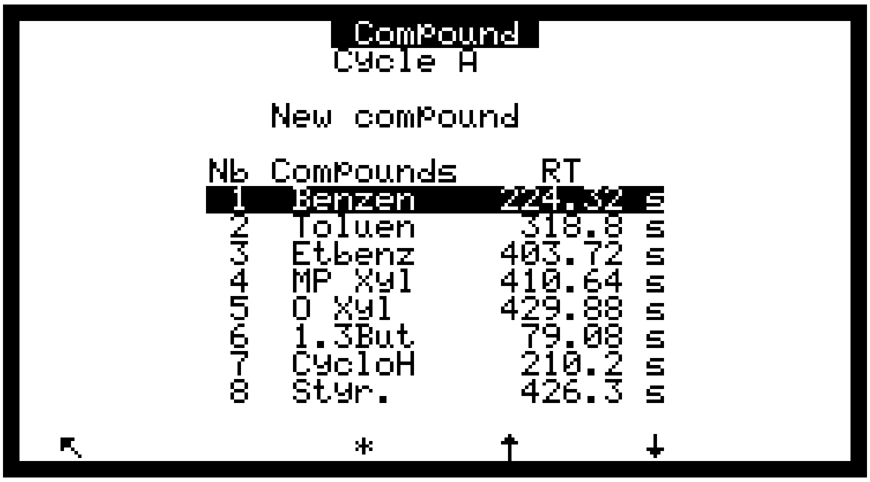
This screen is used to check the fixed set-points for temperature (°C), pressure (mbar) and power (%) on the analyser GC elements.



```
              Regulations
                Cycle A

PID temperature              140   °C
Hot box temperature           60   °C
Internal temperature          35   °C
Trap température             380   °C
Transfert line set point      30    %
Column end set point          15    %
Cold plate temperature        15   °C
GC column press. (rel.)      460 mbar

↖     - Cycle +      ↑      ↓
```

3.3.4.3.5 CONFIGURATION ⇨ Chromatogram ⇨ Compound

This screen displays the compound list and corresponding retention times. It is possible to display up to 8 compounds on one screen:



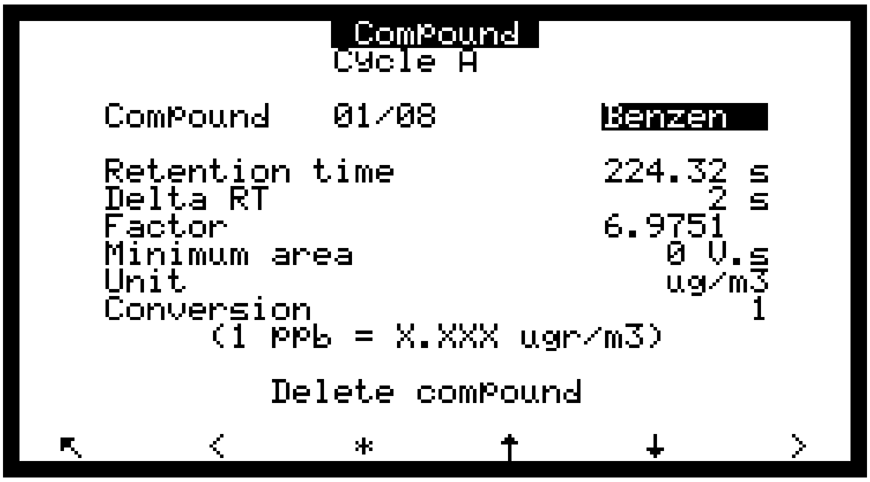
```
              Compound
              Cycle A

           New compound

      Nb Compounds     RT
       1  Benzen     224.32 s
       2  Toluen      318.8 s
       3  Etbenz     403.72 s
       4  MP Xyl     410.64 s
       5  O Xyl      429.88 s
       6  1.3But      79.08 s
       7  CycloH      210.2 s
       8  Styr.       426.3 s

 ↖             *        ↑        ↓
```

Definition of keys specific to this screen:

Selecting *[New compound]* and pressing down F3 **[∗]** adds a compound at the end of the present list.

Pressing down F6 **[>]** displays the next 8 compounds if these compounds exist.

Selecting *[1 Benzen …]* (as shown) and pressing down F3 **[∗]** gives access to the first compound screen, as shown here-below:



```
              Compound
              Cycle A

   Compound   01/08         Benzen

   Retention time           224.32 s
   Delta RT                      2 s
   Factor                   6.9751
   Minimum area                0 V.s
   Unit                      ug/m3
   Conversion                    1
        (1 ppb = X.XXX ugr/m3)

           Delete compound

 ↖      <      *        ↑        ↓      >
```

This screen enables to program for each compound:

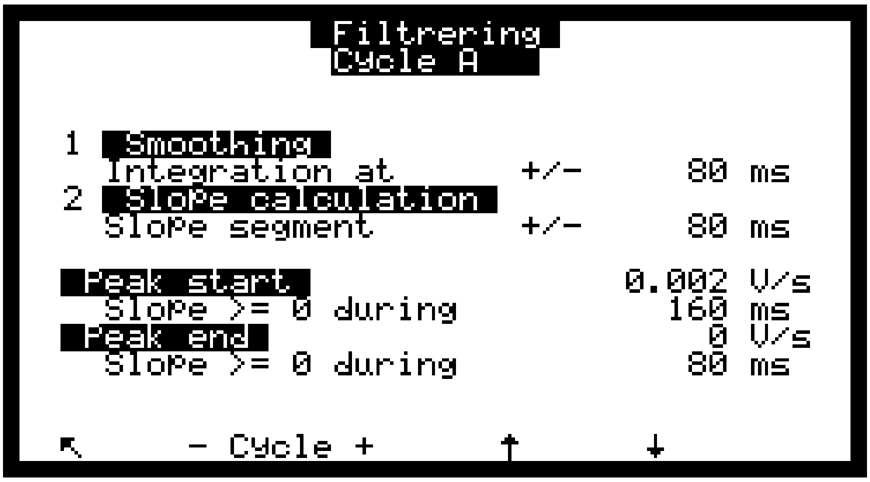
- the *«Retention time»* (RT),
- the acceptance window (*«Delta RT»*),
- the specific response factor (*«Factor»*),
- the *«Minimum area»* needed for the peak to be taken into account and thus for the corresponding concentration to be calculated.

NOTE : The *«Retention time»* (RT) and *«Factor»* are determined by the calibration process. They can be updated manually with the keyboard or automatically with the automatic calibration.

The measurement «Unit» is also selected in this menu from ppt, ppb, µg/m3. The selected unit is the one that will be used to display values.

3.3.4.3.6 *CONFIGURATION ⇨ Chromatogram ⇨ Filtering*

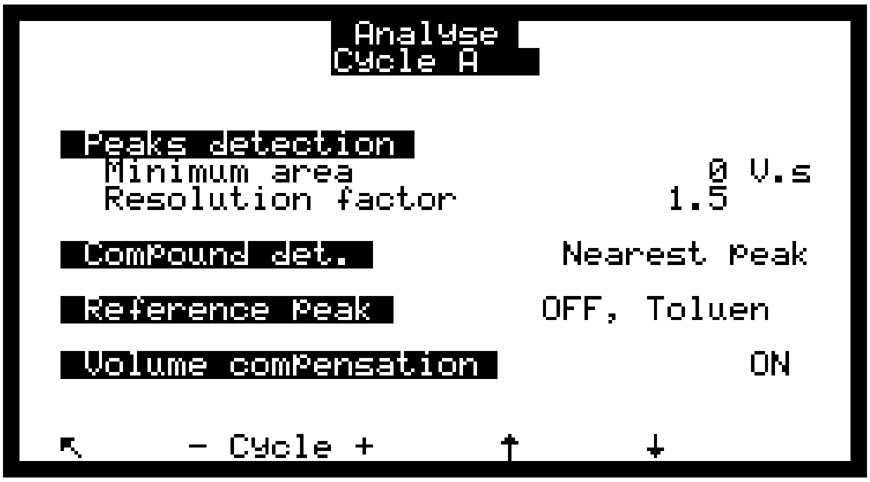
This screen defines the parameters used for detecting the *«Peak start»* and the *«Peak end»*.



```
             Filtrering
             Cycle A

 1 Smoothing
   Integration at      +/-     80 ms
 2 Slope calculation
   Slope segment       +/-     80 ms

 Peak start                 0.002 V/s
   Slope >= 0 during          160 ms
 Peak end                       0 V/s
   Slope >= 0 during           80 ms

 ↖     - Cycle +      ↑      ↓
```

3.3.4.3.7 *CONFIGURATION ⇨ Chromatogram ⇨ Analyse*

This screen is used to check the peak detection parameters.



```
              Analyse
             Cycle A

 Peaks detection
   Minimum area                 0 V.s
   Resolution factor          1.5

 Compound det.         Nearest Peak

 Reference Peak       OFF, Toluen

 Volume compensation           ON

 ↖     - Cycle +      ↑      ↓
```

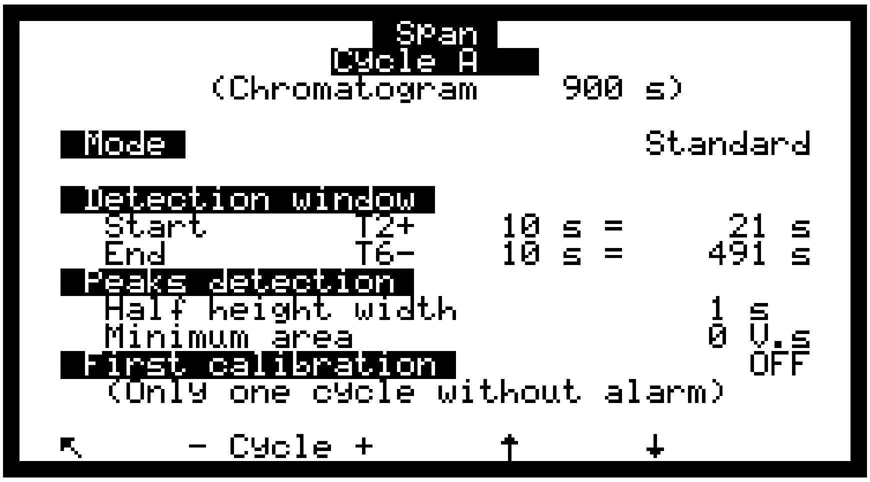
The «Resolution factor» is used to check the baseline on adjacent peaks (base or valley) according to the peak separation.

NOTE : – the *«Reference peak»* field must remain switched to OFF : the VOC72M does not require the relative retention times.

– the *«Volume compensation»* must remain switched to ON, otherwise the concentration readings will change with sample pressure.

3.3.4.3.8 CONFIGURATION ⇨ Chromatogram ⇨ Span

This screen is used to configure the automatic calibration of the analyzer.



```
                      Span
                    Cycle A
          (Chromatogram     900 s)

 Mode                            Standard

 Detection window
   Start         T2+    10 s =      21 s
   End           T6-    10 s =     491 s
 Peaks detection
   Half height width                 1 s
   Minimum area                      0 V.s
 First calibration                   OFF
   (Only one cycle without alarm)

 ↖     - Cycle +       ↑      ↓
```

The *«Mode»* field can be set to **Standard** for K factor calibration only, or **RT & K factor** for calibrating both retention times and K factors.

The *«Detection window»* field defines the section of the chromatogram used for the automatic calibration of the retention times. The peaks detected before T2 and after T6 are ignored.

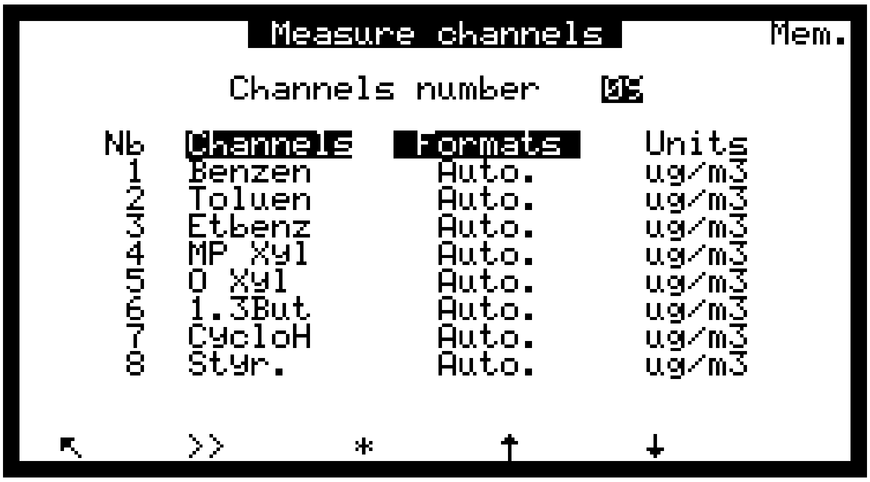
The *«Peaks detection»* field selects a minimum half height width and area for the detected peaks. The more narrow peaks or the surface of which is smaller are ignored.

The *«First Calibration»* field, when set to ON, ignores the calibration error #64 on K factor calibration. The *«First Calibration»* field remains to ON until the next calibration, then it automatically switches to OFF.

NOTE : After an automatic calibration, the new K factor must differ from the previous K factor of less than 50% (difference greater than 50% ⇔ calibration error #64). The ON status is only valid for the next automatic calibration.

3.3.4.4 CONFIGURATION ⇨ Measure channels

This screen is used to select the parameter, the display format and the unit for each measure channel. The measure channels programming allows to display (in «*MEASUREMENT ⇨ Instantaneous*» screen or in «*MEASUREMENT ⇨ Average*» screen) and to store («*STORED DATA*» menu) other parameters than those displayed by default (BTEX) such as internal temperatures or analog inputs (if ESTEL board present).



Measure channels Mem.

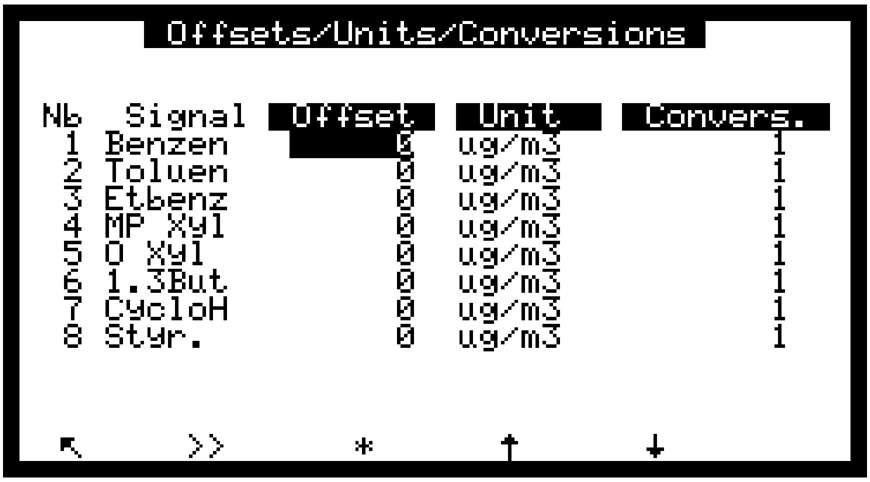
Channels number 05

Nb	Channels	Formats	Units
1	Benzen	Auto.	ug/m3
2	Toluen	Auto.	ug/m3
3	Etbenz	Auto.	ug/m3
4	MP Xyl	Auto.	ug/m3
5	O Xyl	Auto.	ug/m3
6	1.3But	Auto.	ug/m3
7	CycloH	Auto.	ug/m3
8	Styr.	Auto.	ug/m3

- The *«Formats»* fields are used to choose the display format from 4 possibilities (X.XXX, XX.XX, XXXX.X, XXXX). "Auto" format manages the comma place in order to display the best resolution at any time.
- The *«Units»* fields refer to the units programmed in the «*CONFIGURATION ⇨ Offsets/Units/Conversion*» and « *CONFIGURATION ⇨ Analog inputs* » screens.

3.3.4.5 CONFIGURATION ⇨ Offsets/Units/Conversion

This screen is used to program the offset: this value is added to the measurements value. It is also used to program the conversion factors from ppb to µg/m^3, when the µg/m^3 unit is selected. Then, the user must enter the suitable conversion factor.

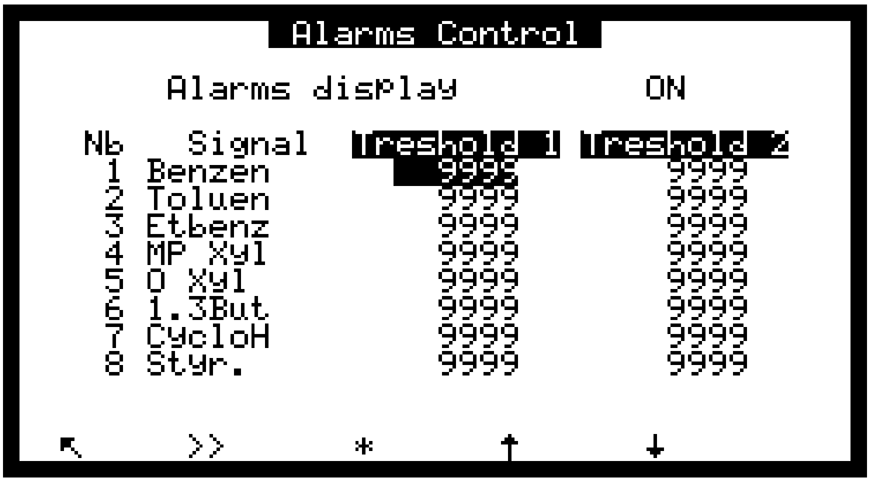


Offsets/Units/Conversions

Nb	Signal	Offset	Unit	Convers.
1	Benzen	0	ug/m3	1
2	Toluen	0	ug/m3	1
3	Etbenz	0	ug/m3	1
4	MP Xyl	0	ug/m3	1
5	O Xyl	0	ug/m3	1
6	1.3But	0	ug/m3	1
7	CycloH	0	ug/m3	1
8	Styr.	0	ug/m3	1

3.3.4.6 CONFIGURATION ⇨ Alarms control

Two thresholds by parameter are programmable: Threshold 1 and Threshold 2, they are used to activate relays and alarm messages. When the *«Alarms display»* field is *«OFF»*, the display and the alarm relays are inhibited.



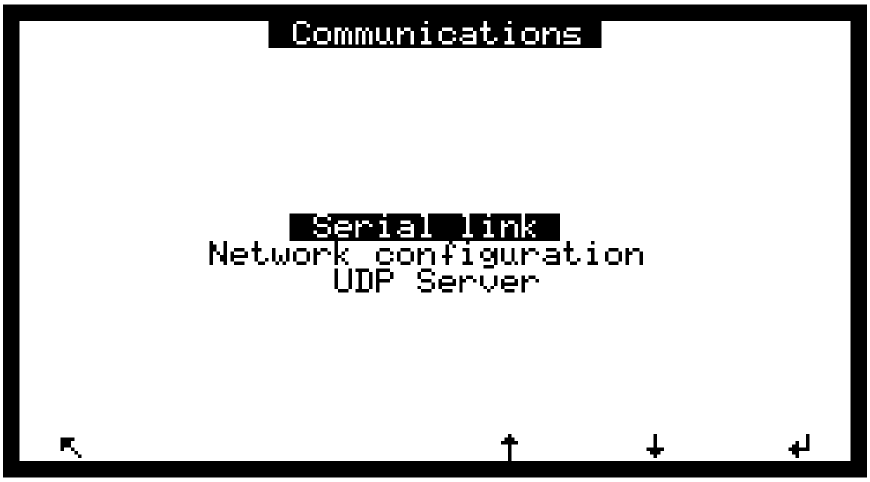
Alarms Control

Alarms display ON

Nb	Signal	Treshold 1	Treshold 2
1	Benzen	9999	9999
2	Toluen	9999	9999
3	Etbenz	9999	9999
4	MP Xyl	9999	9999
5	O Xyl	9999	9999
6	1.3But	9999	9999
7	CycloH	9999	9999
8	Styr.	9999	9999

3.3.4.7 CONFIGURATION ⇨ Communications

This menu is used to configure the various communication elements towards outside.

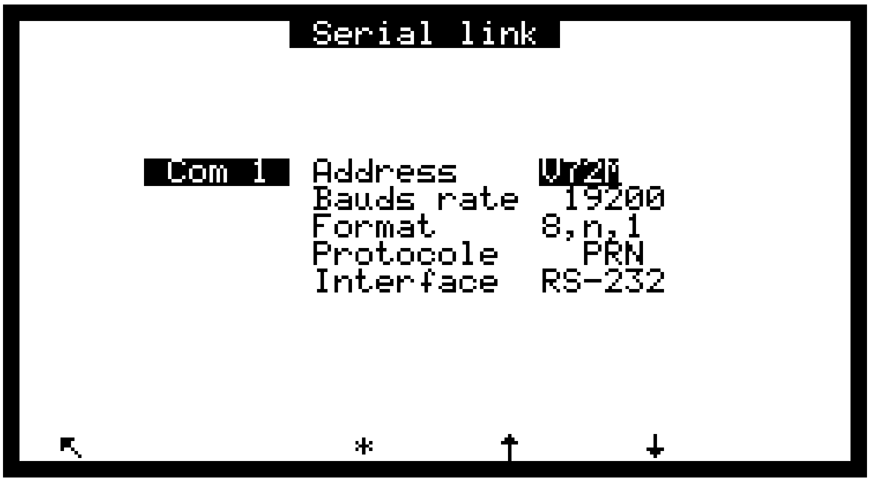


3.3.4.7.1 CONFIGURATION ⇨ Communication (DNP-Arm7) ⇨ Serial links

This screen is used to configure the serial link (COM 1), the COM2 being reserved for the communication with the Module board. The address, the baud, the format and the communication protocol of the COM1 serial link are configurable:

- The analyzer address: programmable with 4 digits.

  The name of the analyzer written with 4 digits, is used by default : V72M.
- Speed communication of the serial link, stated in Bauds: 1200, 2400, 4800, 9600, 19200, 38400
- Format: 7,n,1 ; 7,o,1 ; 7,e,1 ; 7,n,2 ; 7,o,2 ; 7,e,2 ; 8,n,1 ; 8,o,1 ; 8,e,1 ; 8,n,2 ; 8,o,2 ; 8,e,2
- Communication protocol: Mode4, JBUS, PRN (printer), BAYERN
- Interface: RS-422, RS-232.



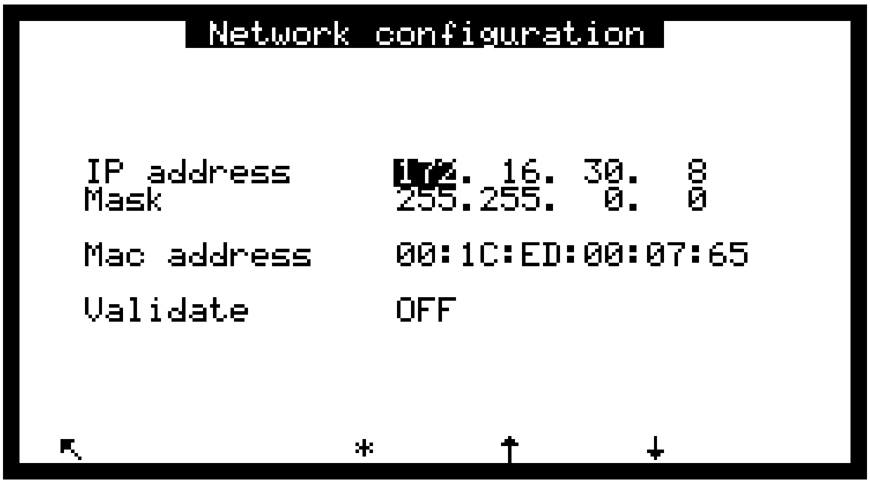
```
                Serial link

        Com 1  Address     V72M
               Bauds rate   19200
               Format      8,n,1
               Protocole     PRN
               Interface   RS-232
```

Function of the specific keys to this screen:

The F3 [✱] key enables to modify the selected field, the F4 [↑] and F5 [↓] keys are used to browse inside the menus and the selection lists, the F1 [↖] key enables to return to the previous screen.

3.3.4.7.2 *CONFIGURATION ⇨ Communication (DNP-Arm7) ⇨ Network configuration*

This screen enables to configure the network connection.



```
            Network configuration


   IP address      172. 16. 30.  8
   Mask            255.255.  0.  0

   Mac address     00:1C:ED:00:07:65

   Validate        OFF
```

- The **IP address** field is used to indentify the analyzer into the LAN. It is represented into decimal notation with 4 numbers, each number being included within 0 and 255, separated by points.
- The **Mask** field is used to configure the secondary network.
- The **Mac address** field is used to identify the analyzer. The **Mac Address** field value is specific to the DNP-Arm7 board mounted in the analyzer and cannot be modified. Consequently, it enables to identify this board.
- The **Validate** field switched to ON/OFF enables to valid, or not, the parameters set.

Function of the specific keys to this screen:

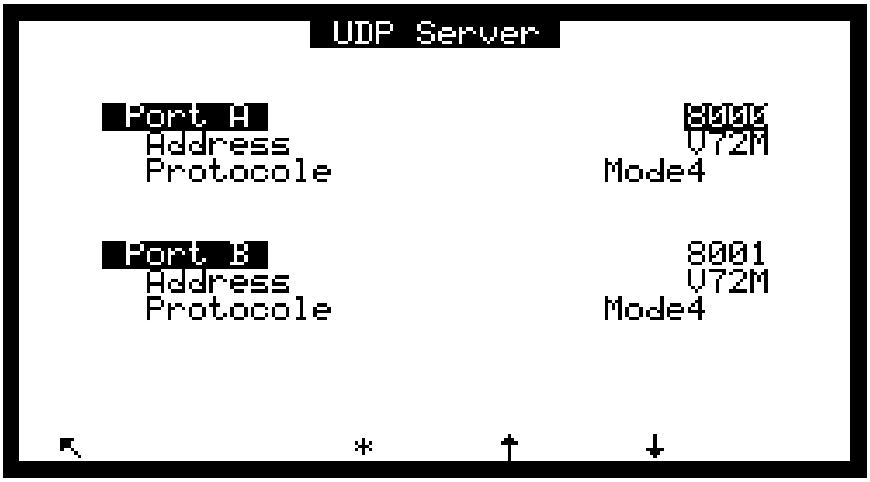
The F3 [✱] key enables to modify the selected field, the F4 [↑] and F5 [↓] keys are used to browse inside the menus and the selection lists, the F1 [↖] key enables to return to the previous screen.

3.3.4.7.3 CONFIGURATION ⇨ Communications ⇨ Network configuration

This screen is used to configure the addresses, port numbers and the communication protocol of the UDP server (User Datagram Protocol):

- Numbers of Port A and Port B of the UDP server : programmable from 1000 to 9999
- Address: programmable on 4 digits.

  By default: the analyzer name written with 4 digits : V72M
- Communication protocol: Mode 4, BAYERN, JBUS.



```
                 UDP Server

    Port A                        8000
      Address                     V72M
      Protocole                  Mode4

    Port B                        8001
      Address                     V72M
      Protocole                  Mode4

 ↖                 *        ↑        ↓
```

Functions of the specific keys to this screen:

The F3 [✱] key enables to modify the selected filed, the F4 [↑] and F5 [↓] keys are used to browse into the menus and selection lists, the F1 [↖] key enables to return to the previous screen.

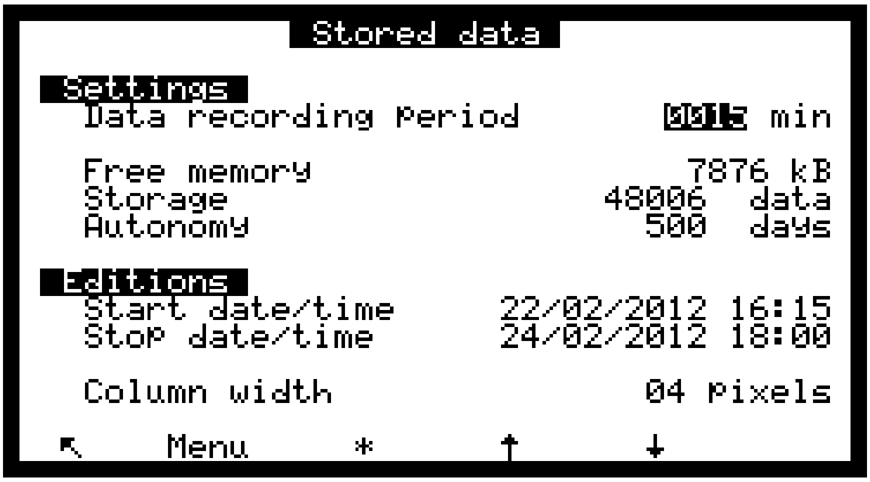
3.3.4.8 CONFIGURATION ⇨ Factory settings

When this item is selected, pressing down the **[↵]** key displays the screen shown here below:

Factory setting not available !

3.3.5 STORED DATA

Access to stored data management directly takes place from Main Menu. Stored data are the average of analyzer measurements within a defined time interval.



```
                  Stored data

Settings
  Data recording period          0015 min

  Free memory                     7876 kB
  Storage                       48006  data
  Autonomy                        500  days

Editions
  Start date/time       22/02/2012 16:15
  Stop date/time        24/02/2012 18:00

  Column width                 04 pixels

↖     Menu      *        ↑        ↓
```

This screen allows to parameter data recording period from 1 to 1440 min (i.e. 24 hours). A 15 minute data recording period is recommended when a 15-minute cycle with synchronization is used.

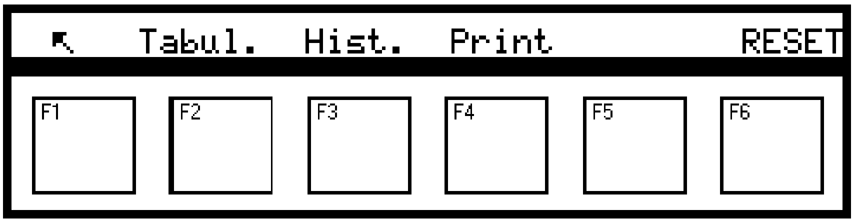
This screen also informs about memory state:

- Free memory: 7876 kB.
- Storage: it is the possible records number, it depends on free memory.
- Autonomy: is the duration while memory can store data before saturation, considering free space and data recording period. In the here-above example: 500 days.

NOTE : The available storage memory is 500 days, as indicated in the screen. But, the operation software of the analyzer is programmed for 365 days autonomy.

Data can be edited in the form as table or histogram: this screen allows to program date and hour of edition beginning, date and hour of edition end, histogram column width.

Pressing down the F2 **[Menu]** key changes the keyboard functions of this screen :



These keys give access to tabular [F2] or histogram [F3] data display, printing functions [F4], and memory reset-to-zero [F6].

Stored data edition in the form as tabular

This screen presents stored data list according to parameters defined in the screen before. The running mode (measurement, zero, calibration…), during a memorization period, is coded in the status column. The status codes meaning are:

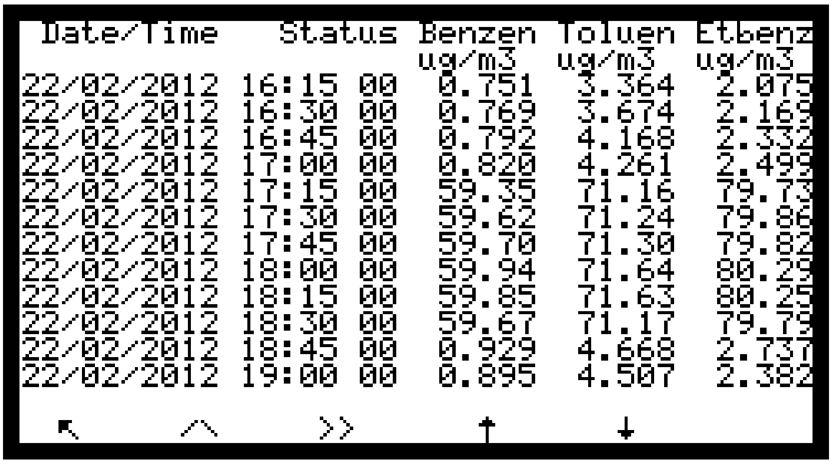
00	Measurement valid
01	Range 2 exceedence shooting
02	General alarm
04	Calibration fault
08	Zero measurement
10	Span measurement
20	Maintenance
40	Less than 2/3 of valid measurements during the average period
80	Power supply failure
FF	Configuration modification

The displayed status code corresponds to the sum of the status codes (hexadecimal numbers) that occurs during the memorization period.

Example: with an average period of 20 min:

5 min zero and 15 min measurement give the 00 status code and the displayed average is the 15 min. measurement average.

11 min. zero and 9 min. measurement give the 08 status code and the displayed average is the 11 min. zero average.



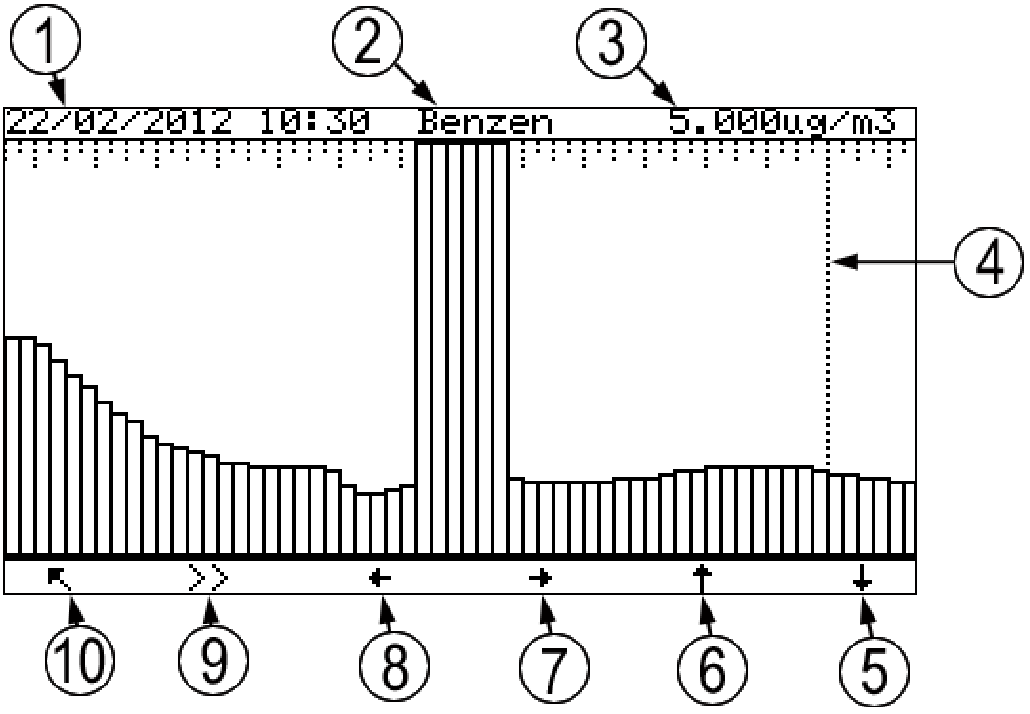
```
 Date/Time     Status Benzen Toluen Etbenz
                      ug/m3  ug/m3  ug/m3
22/02/2012 16:15 00    0.751  3.364  2.075
22/02/2012 16:30 00    0.769  3.674  2.169
22/02/2012 16:45 00    0.792  4.168  2.332
22/02/2012 17:00 00    0.820  4.261  2.499
22/02/2012 17:15 00    59.35  71.16  79.73
22/02/2012 17:30 00    59.62  71.24  79.86
22/02/2012 17:45 00    59.70  71.30  79.82
22/02/2012 18:00 00    59.94  71.64  80.29
22/02/2012 18:15 00    59.85  71.63  80.25
22/02/2012 18:30 00    59.67  71.17  79.79
22/02/2012 18:45 00    0.929  4.668  2.737
22/02/2012 19:00 00    0.895  4.507  2.382
```

Definition of the specific keys to this screen:

[↑]	**[↓]**	Selects the previous or the next page.
[^]	[v]	Selects stored data beginning or end.
[>>]		Displays the other measure channels if more than 3 channels are programmed in «*CONFIGURATION ⇨ Measure channels*» screen

Stored data edition in the form as histogram

This screen displays records in the form as columns; each column corresponds to the measurements average within the data-recording period as defined in *«STORED DATA»* screen. Only one channel is displayed at once. The information line gives date and hour of first record, the channel name, and, alternatively blinking, full scale with unit, and data recording period.



(1) Date and time of first plot.

(2) Compound name.

(3) Full scale.

(4) 00h00 mark of day changing.

(5) Decrease plot (increase full scale).

(6) Increase plot (reduce full scale).

(7) Increment recording time.

(8) Decrement recording time.

(9) Next compound.

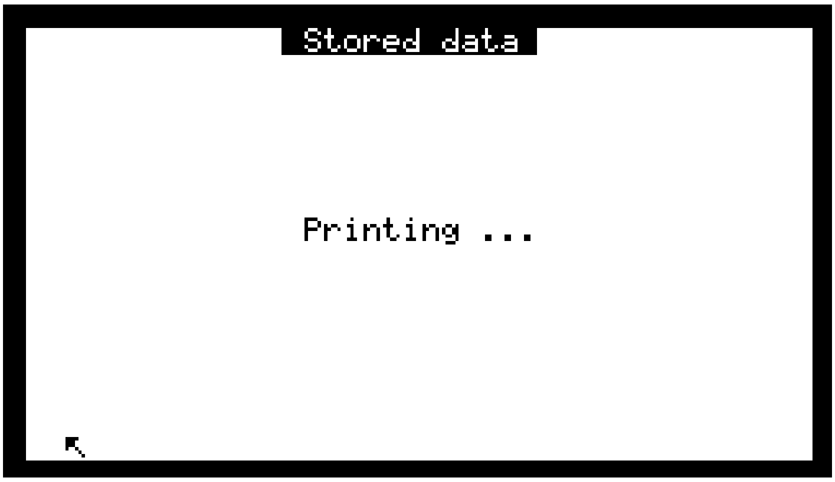
(10) Return to stored data menu.

Stored data printing

To print data, press down the **[Impr]** key found in "Menu" function of *«STORED DATA»* screen. The blinking message "Printing…" indicates printed data output. Data printing can be suspended at any time, pressing down F1 key. When printing is finished, the screen displays the message "Printing finished".

When none communication port is programmed on printer output (serial port), the error message *«Printing not set»* is displayed.

To program the « Print » mode, set parameters of the serial link into PRN Printer mode using the *« CONFIGURATION ⇨ Communication (DNP-Arm7) ⇨ Serial links »* screen.



Printing ...

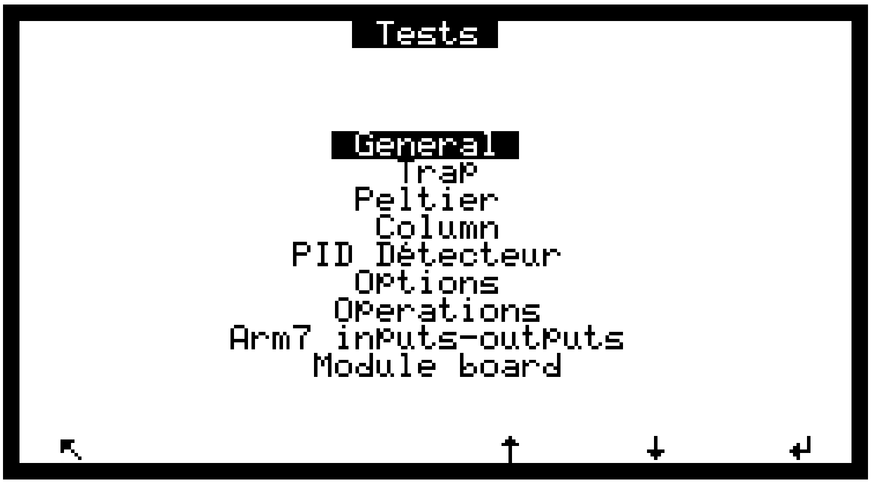
Printing finished.

Memory reset to zero

Pressing down the **[RESET]** F6 key enables to cancel the storage memory. **This action is irreversible**: before to do it, the software asks you to confirm. If your answer is "YES", the software resets dates and hours of end edition to current dates and hours.

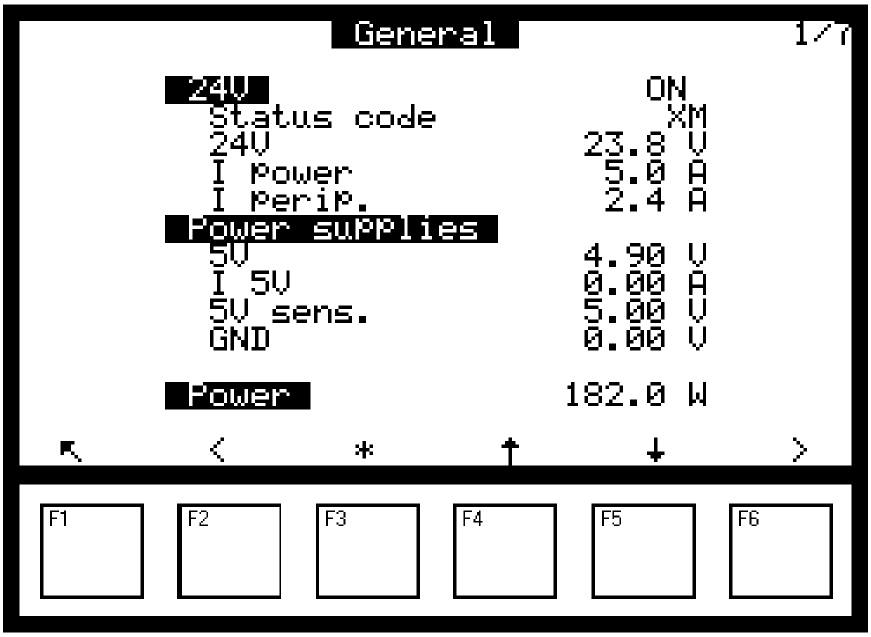
3.3.6 TESTS

This menu gives access to more technical parameters than those displayed in the *«MEASUREMENT ⇨ Synoptic»* screen.



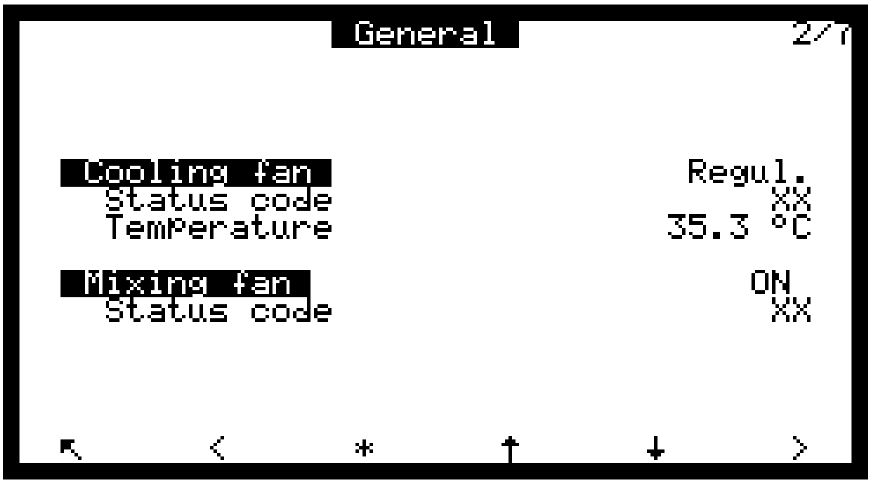
3.3.6.1 TESTS ⇨ General

The screen 1/7 displays the voltage, intensities and power of the internal power supplies.



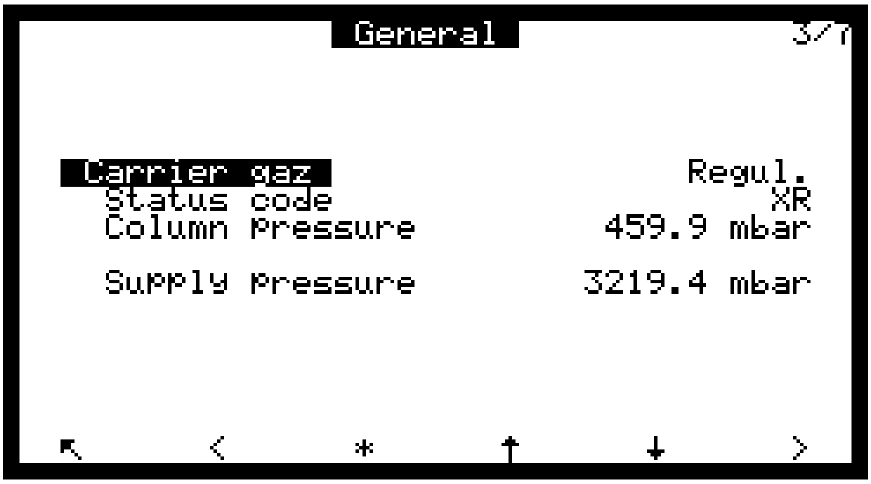
```
              General                1/7
24V                              ON
  Status code                    XM
  24V                          23.8 V
  I power                       5.0 A
  I perip.                      2.4 A
Power supplies
  5V                           4.90 V
  I 5V                         0.00 A
  5V sens.                     5.00 V
  GND                          0.00 V

Power                         182.0 W
```

The screen 2/7 displays the parameters related to the internal temperature control:



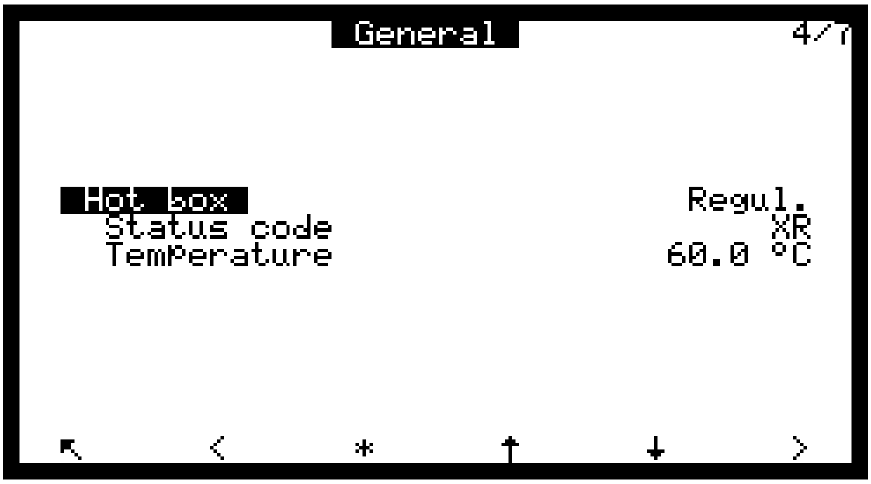
```
Cooling fan                 Regul.
  Status code                   XX
  Temperature              35.3 °C

Mixing fan                      ON
  Status code                   XX
```

The screen 3/7 displays the parameters related to the electronic control of the column pressure.



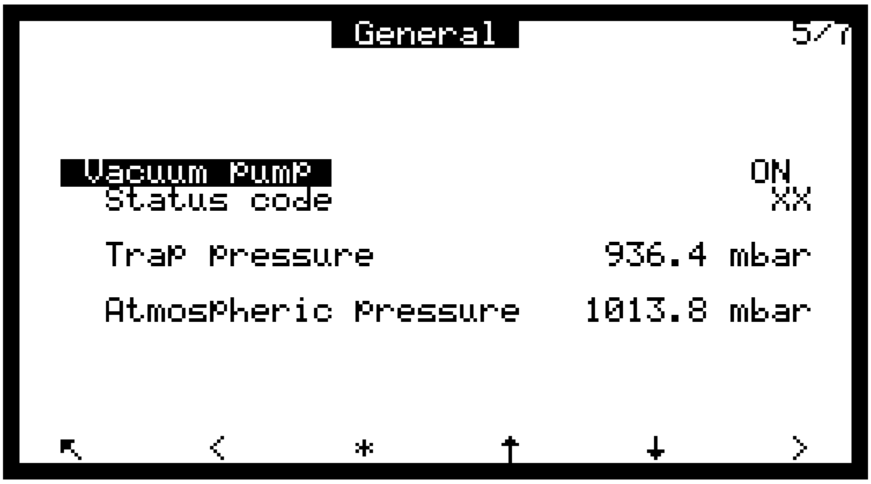
```
Carrier gaz                 Regul.
  Status code                   XR
  Column pressure       459.9 mbar

  Supply pressure      3219.4 mbar
```

The screen 4/7 displays the parameters related to the temperature control of the hot box.



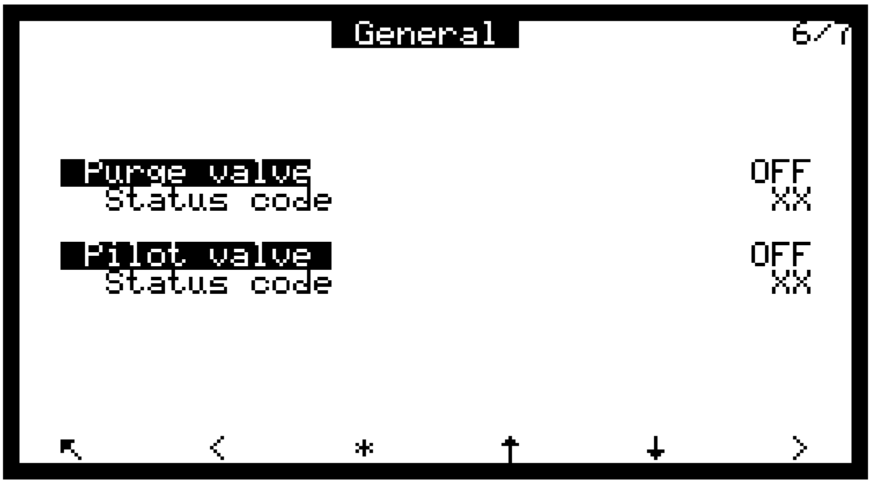
```
Hot box                     Regul.
  Status code                   XR
  Temperature              60.0 °C
```

The screen 5/7 displays the parameters related to the vacuum pump, the trap and atmospheric pressure sensors.



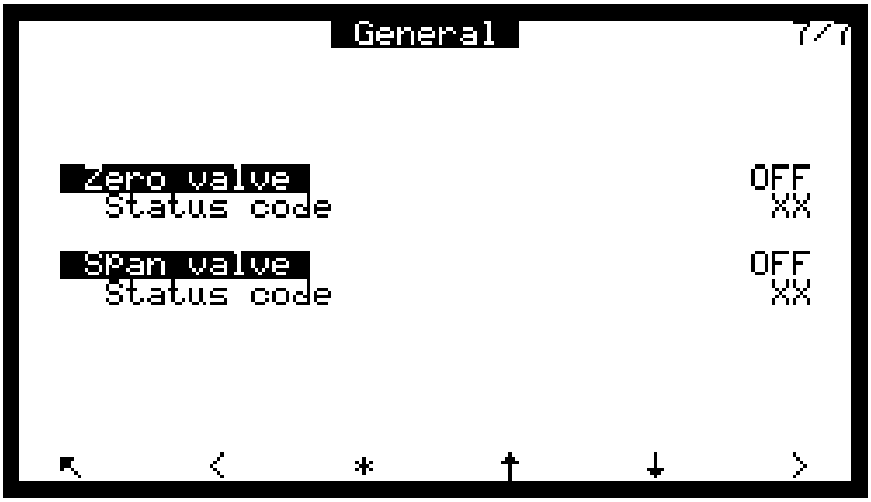
```
                    General                   5/7

 Vacuum Pump                            ON
   Status code                           XX

   Trap pressure                 936.4 mbar

   Atmospheric pressure         1013.8 mbar
```

The screen 6/7 displays the parameters related to the control of purge and pilot valve.



```
                    General                   6/7

 Purge valve                           OFF
   Status code                          XX

 Pilot valve                           OFF
   Status code                          XX
```

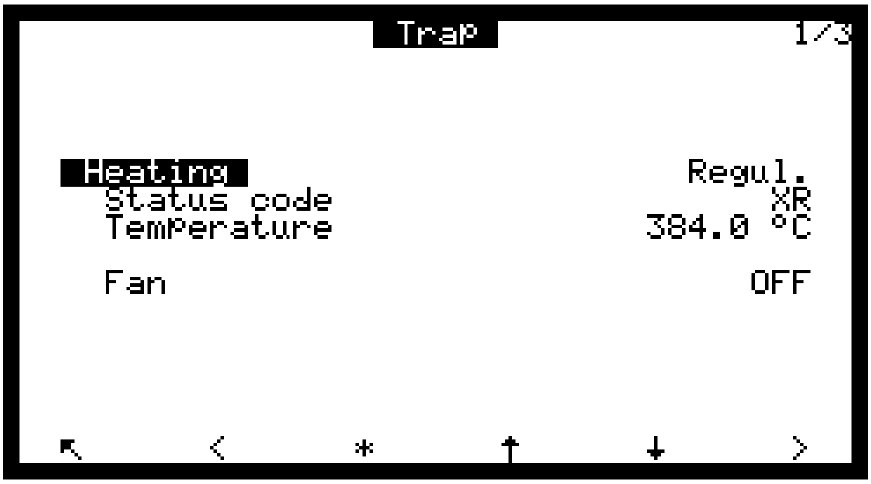
The screen 7/7 displays the parameters relative to the control of the optional Zero and Span valve.



```
                    General                   7/7

 Zero valve                            OFF
   Status code                          XX

 Span valve                            OFF
   Status code                          XX
```

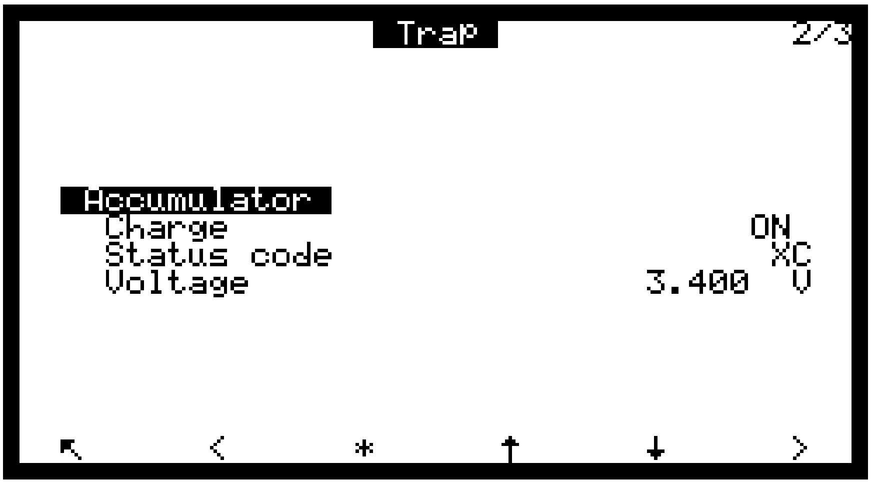
3.3.6.2 TESTS ⇨ Trap

The screen 1/3 displays the trap temperature and the status (ON-OFF) of the trap fan.



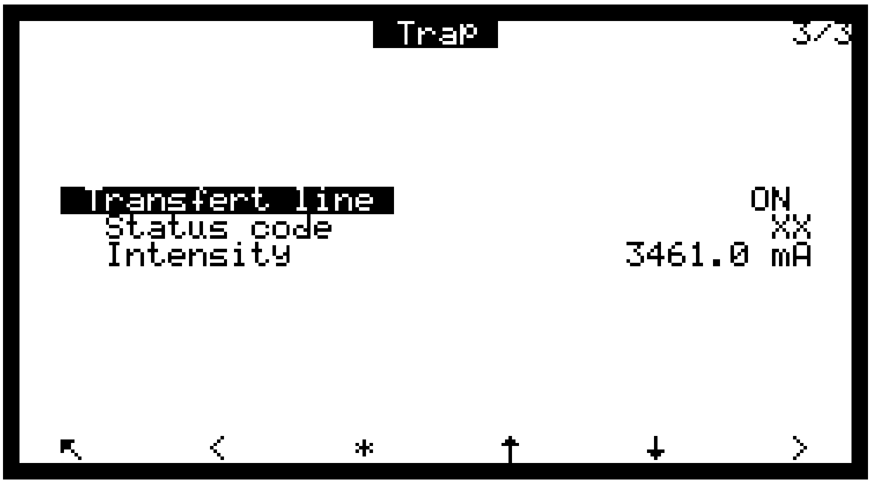
```
                 Trap                1/3

 Heating                      Regul.
   Status code                    XR
   Temperature              384.0 °C

   Fan                           OFF
```

The screen 2/3 displays the voltage of the power accumulator and the charging status (ON/OFF).



```
                 Trap                2/3

 Accumulator
   Charge                        ON
   Status code                    XC
   Voltage                  3.400  V
```

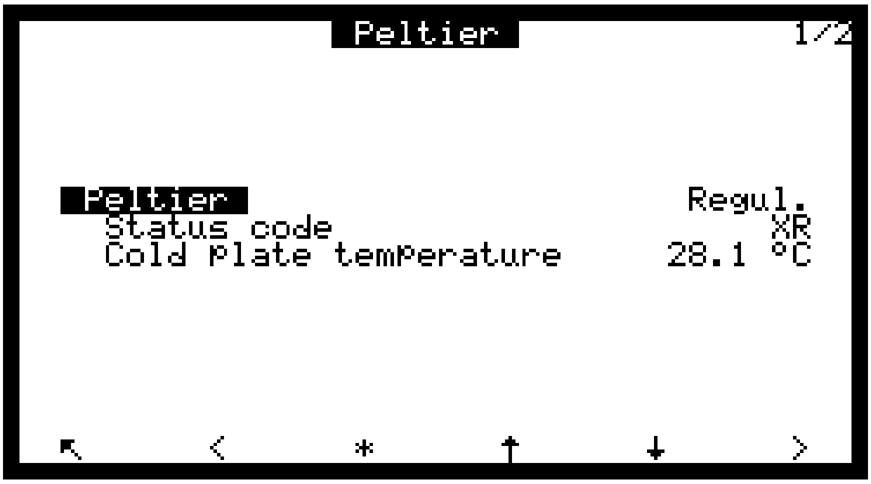
The screen 3/3 displays the transfer line heating status (ON-OFF) and the resulting heating current.



```
                 Trap                3/3

 Transfert line                  ON
   Status code                    XX
   Intensity               3461.0 mA
```

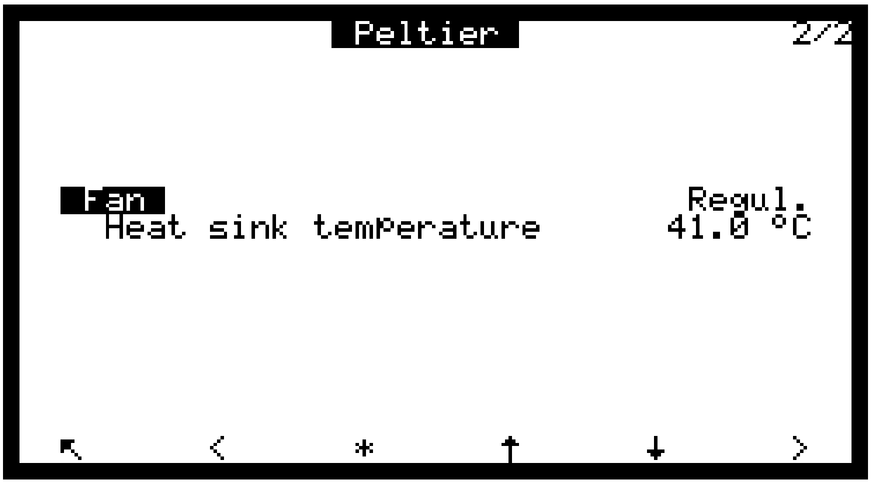
3.3.6.3 TESTS ⇨ Peltier

The screen ½ displays the Peltier status and the cold plate temperature.



```
                 Peltier                 1/2

 Peltier                          Regul.
   Status code                        XR
   Cold plate temperature      28.1 °C
```

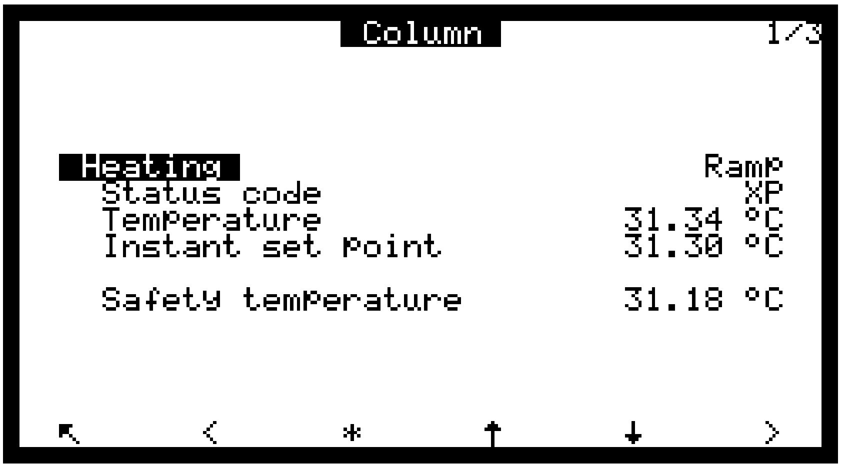
The screen 2/2 displays the external fan status and the heat sink temperature.



```
                 Peltier                 2/2

 Fan                              Regul.
   Heat sink temperature       41.0 °C
```

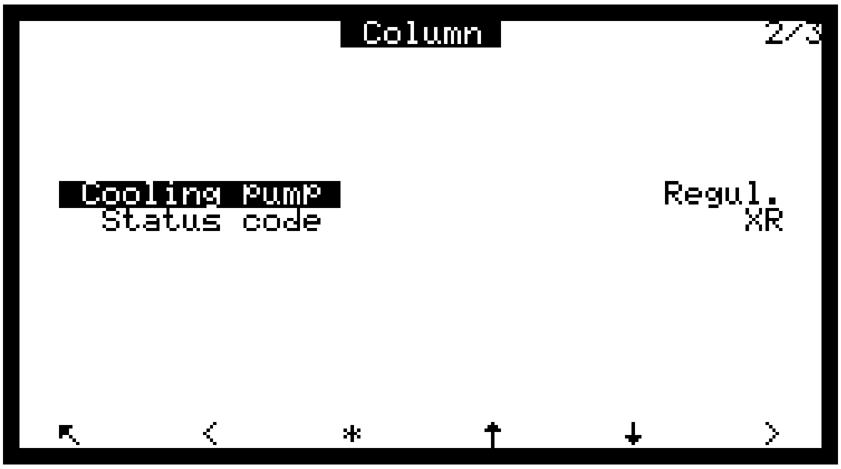
3.3.6.4 TESTS ⇨ Column

The screen 1/3 displays the GC column temperature, the instant set-point temperature of the ramp during heating and the safety temperature measured with the safety sensor of the column (redundant measurement).



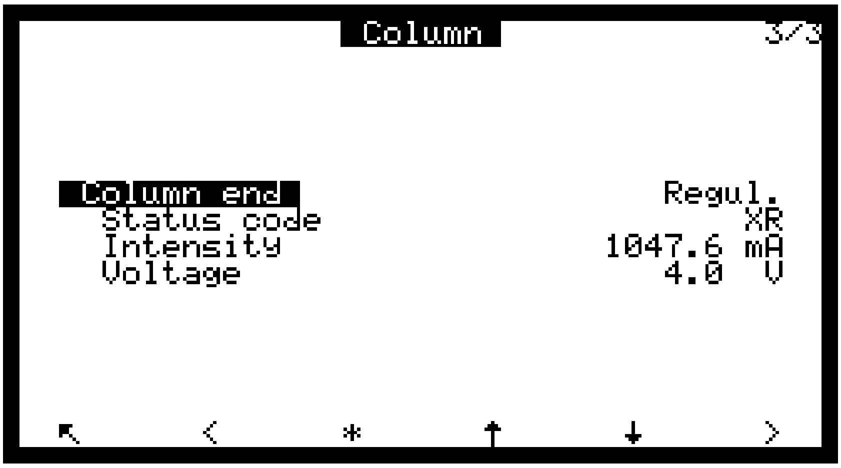
```
                     Column                    1/3

 Heating                                     Ramp
   Status code                                 XP
   Temperature                          31.34 °C
   Instant set point                    31.30 °C

   Safety temperature                   31.18 °C
```

The screen 2/3 displays the cooling pump status.



```
                     Column                    2/3

 Cooling pump                              Regul.
   Status code                                 XR
```

The screen 3/3 displays the column end heating voltage and the resultant intensity.

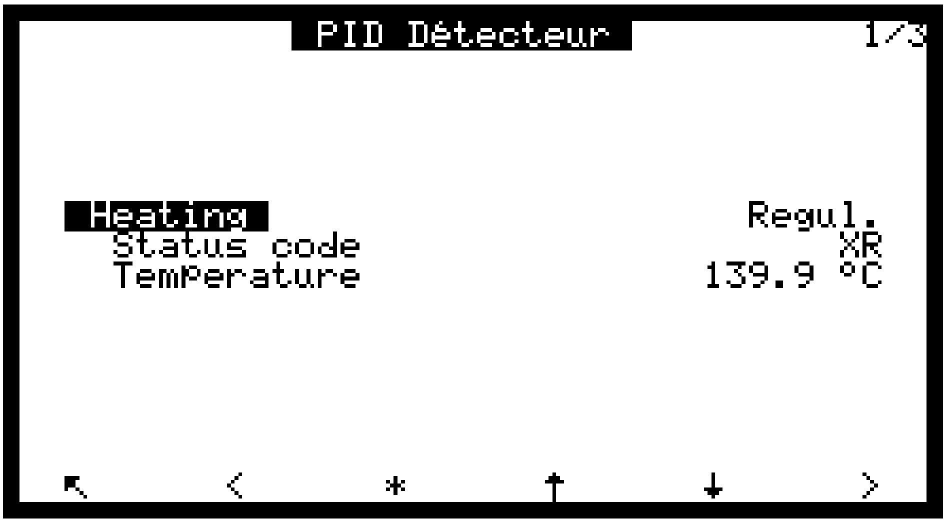


```
                     Column                    3/3

 Column end                                Regul.
   Status code                                 XR
   Intensity                           1047.6 mA
   Voltage                                4.0  V
```

Page intentionally left blank

3.3.6.5 TESTS ⇨ PID detector

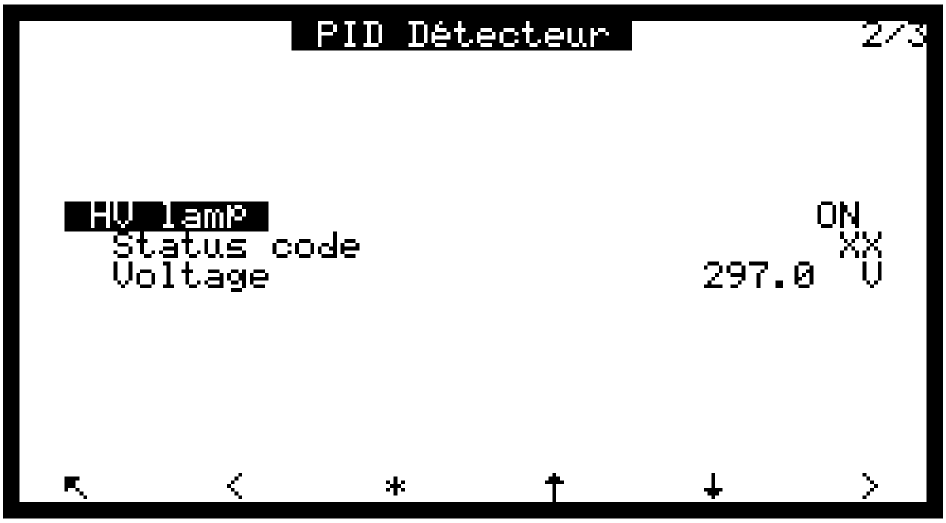
The screen 1/3 displays the PID heating status and resulting temperature.



PID Détecteur 1/3

Heating Regul.
Status code XR
Temperature 139.9 °C

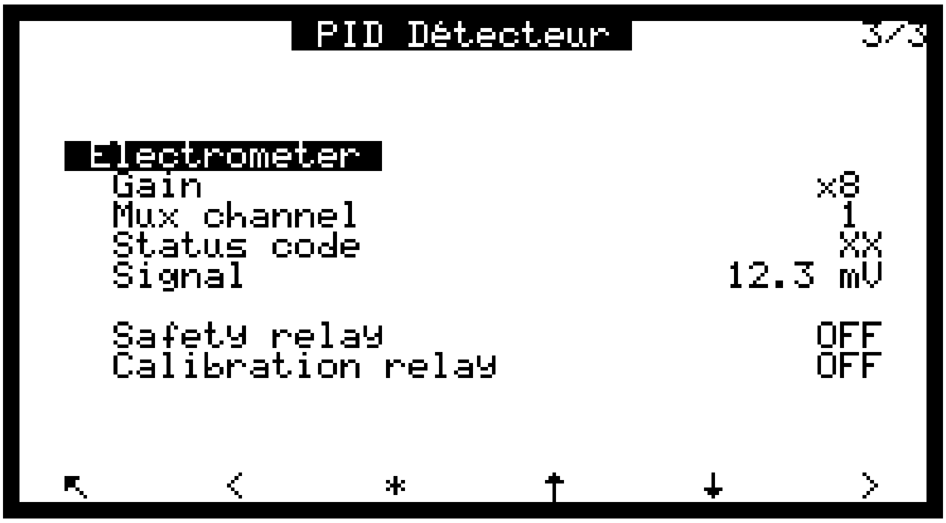
The screen 2/3 displays the voltage across the PID lamp and the HV power supply status (ON/OFF)



PID Détecteur 2/3

HV lamp ON
Status code XX
Voltage 297.0 V

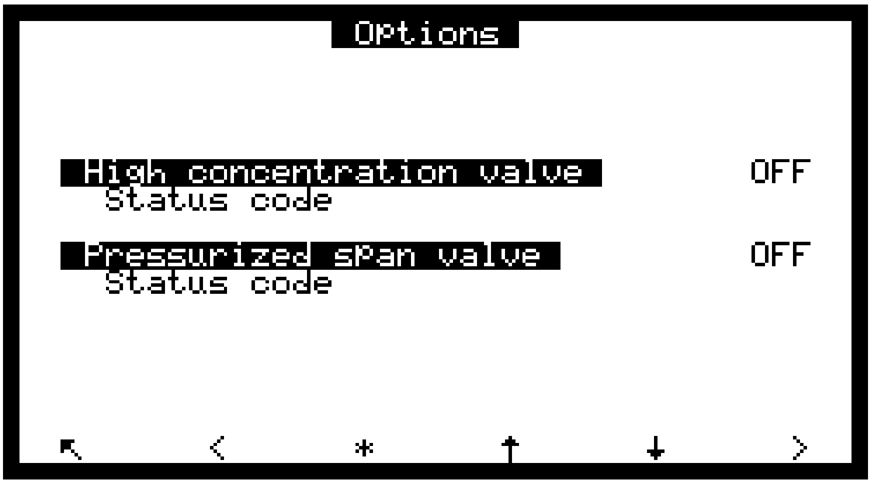
The screen 3/3 displays the electrometer gain and the instant value of signal and the status of both internal relays of the electrometer board.



```
          PID Détecteur               3/3


 Electrometer
   Gain                              x8
   Mux channel                        1
   Status code                       XX
   Signal                       12.3 mV

   Safety relay                     OFF
   Calibration relay                OFF


 ↖      <      *      ↑      ↓      >
```

3.3.6.6 TESTS ⇨ Options

This screen displays the parameters relative to the optional high concentration valve and pressurized span valve.



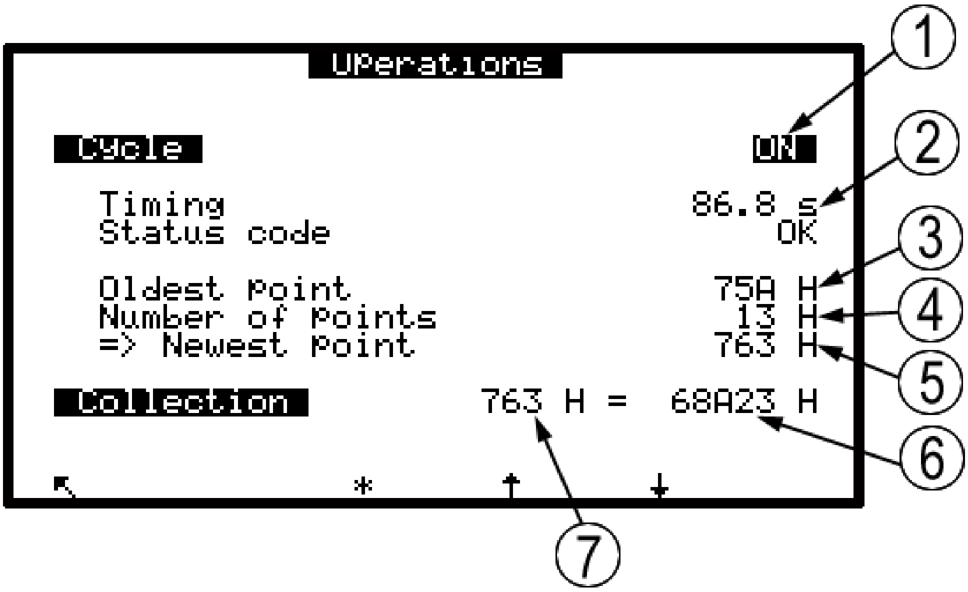
Options

High concentration valve OFF
Status code

Pressurized span valve OFF
Status code

3.3.6.7 TESTS ⇨ Operations

This screen displays the chromatogram data exchange between the module board storage loop and the DNP-ARM7 board.



Operations

Cycle ON

Timing 86.8 s
Status code OK

Oldest point 75A H
Number of points 13 H
=> Newest point 763 H

Collection 763 H = 68A23 H

(1) The VOC72M is running an analysis cycle,

(2) The cycle clock in seconds,

(3) The address of the oldest data point of the chromatogram in the module board,

(4) The number of chromatogram data points available on the module board,

(5) The address of the most recent chromatogram data point on the module board,

(6) The 24bit value of the last reading,

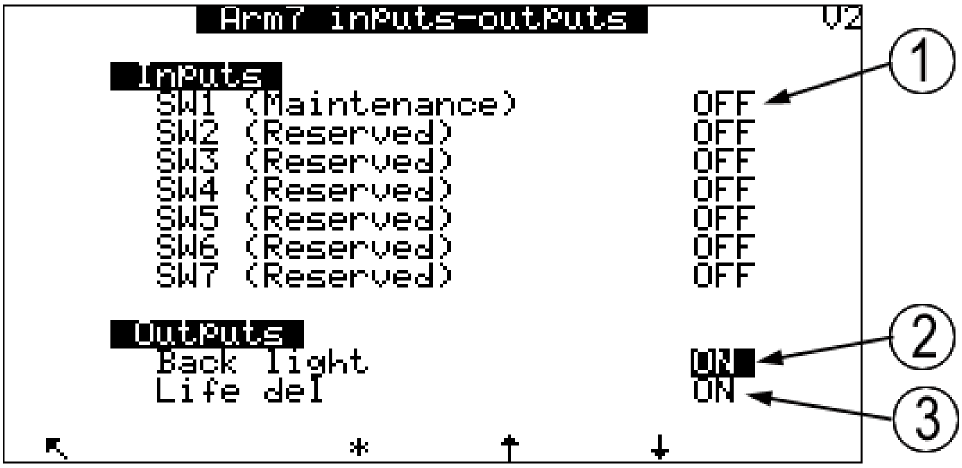
(7) The address of the last reading.

NOTE : the address and values are coded in hexadecimal (H).

3.3.6.8 TESTS ⇨ ARM7 Inputs-Outputs

This menu displays the switches status of the DNP-ARM7 board. It enables to test the "ON/OFF" switch of the backlit liquid crystal display.

The option LED activity (LED life time) enables to test a LED in order to show the DNP-ARM7 activity when none LCD display is available.



```
        Arm7 inPuts-outPuts           V2
  InPuts
    SW1 (Maintenance)          OFF
    SW2 (Reserved)             OFF
    SW3 (Reserved)             OFF
    SW4 (Reserved)             OFF
    SW5 (Reserved)             OFF
    SW6 (Reserved)             OFF
    SW7 (Reserved)             OFF

  OutPuts
    Back light                 ON
    Life del                   ON
 ↖            *      ↑      ↓
```

(1) Status of the SW1 jumper in S1 position,

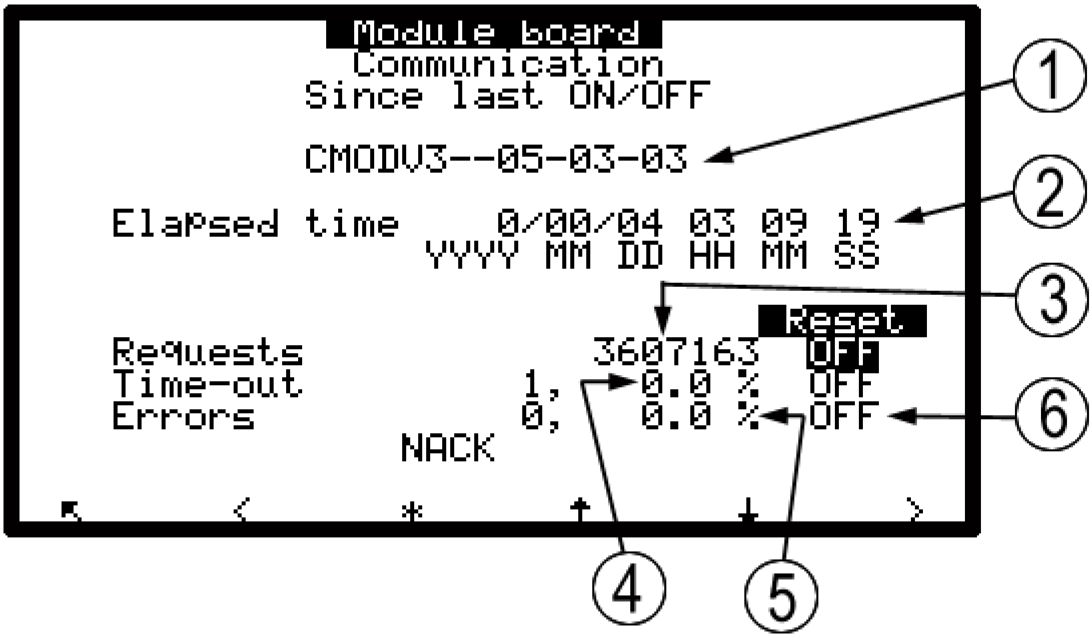
(2) Status of the display back light,

(3) Status of the ON-OFF front switch light.

- SW1 indicates if the analyzer is into maintenance mode or not.
- SW2, SW3, SW4 are not used.
- SW5 gives information if WatchDog is active or not.
- SW6 indicates, either the standard configuration, or the configuration of the application.
- SW7 gives information if AutoStart is ON or OFF.
- SW8 gives information if battery is ON or OFF.

3.3.6.9 TESTS ⇨ Module board

This screen displays the communication status between the DNP-ARM7 board and the Module board.



```
              Module board
              Communication
            Since last ON/OFF

            CMODV3--05-03-03

    Elapsed time    0/00/04 03 09 19
                YYYY MM DD HH MM SS

                                  Reset
    Requests          3607163  OFF
    Time-out        1,    0.0 %  OFF
    Errors          0,    0.0 %  OFF
                NACK
```

(1) Hardware and software version of the Module board.

(2) Elapsed time since the last OFF/ON command.

(3) Number of data requests from the DNP ARM7 board.

(4) Number and % of data time-out.

(5) Number and % of data errors.

(6) Reset status.

NOTE : A data time-out is a request of the DNP-ARM7 board which is not followed by a corresponding answer from the Module board within an acceptable delay. After the time-out, the DNP-ARM7 board sends the same request (retry). When the third try for the same request ends in a time-out, the DNP-ARM7 board records an error and carry-out an other request.

3.3.7 STOP MODE

The stop mode is a command which places the analyzer in stand-by condition:

- Both taking sample and chromatography analysis are stopped.
- The temperature regulation of PID detector and hot box are still operating.
- The PID UV lamp, GC column heating, thermo cooler and vacuum pump are switched OFF.
- The electronic pressure regulation of the column waits for the GC column cooling under 50°C and switches OFF the nitrogen flow.

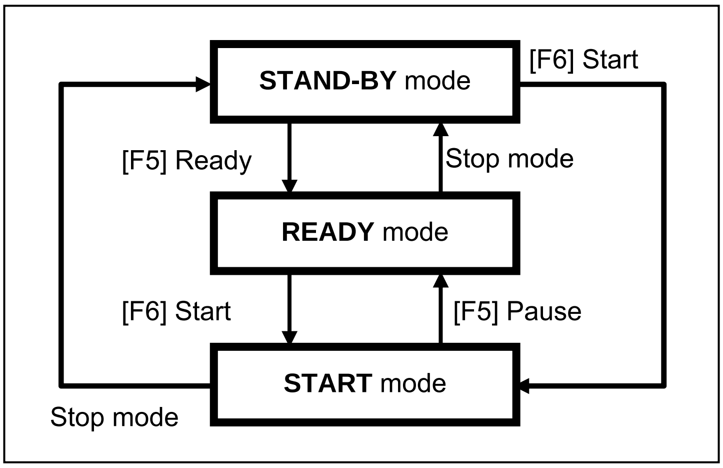
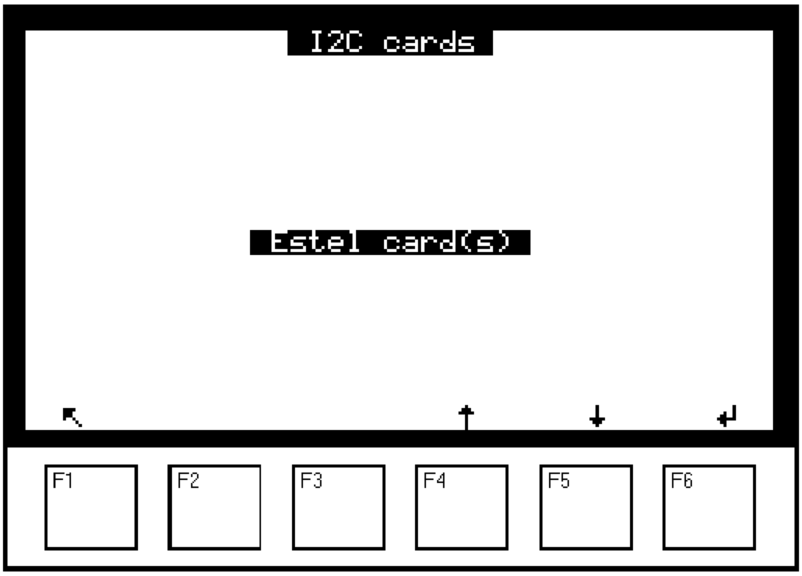


Figure 3–11 – The functional diagram.

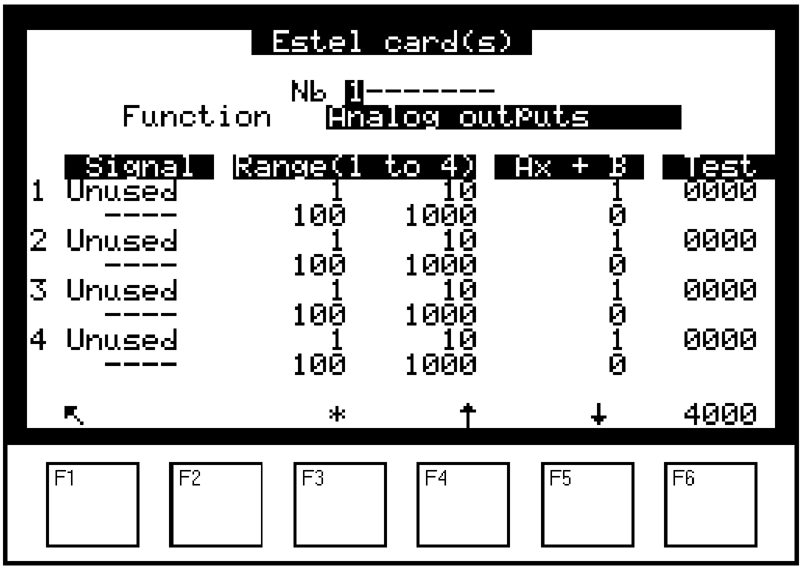
3.3.8 I2C CARD(S)

This menu is only displayed when the optional ESTEL and/or SOREL boards are assembled in the analyzer. It gives access to the configuration screens of these boards.



3.3.8.1 I2C CARD(S) ⇨ ESTEL Card(s)

To access the various screens of the ESTEL boards, select the current function and choose the wanted function using the F3 **[✱]**, F4 **[↑]** et F5 **[↓]** keys.



```
                    Estel card(s)
                    Nb 1-------
       Function    Analog outputs

  Signal    Range(1 to 4)    Ax + B    Test
1 Unused        1      10        1     0000
  ----        100    1000        0
2 Unused        1      10        1     0000
  ----        100    1000        0
3 Unused        1      10        1     0000
  ----        100    1000        0
4 Unused        1      10        1     0000
  ----        100    1000        0
```

Function « Analog outputs »

This screen enables to select analog output parameters for the ESTEL board whose n° indicated in the field “No” is highlighted. These parameters are:

- Concentration of the analyzed gases,
- Auxiliary channels (Multiplexer),
- Analog inlets.

The selected parameters correspond to the analog outputs. On an ESTEL board, analog outputs can be configured into: 0–1 Volt, 0–10 Volt, 0-20 mA, 4–20 mA.

This screen is used to program the ranges of each displayed parameter. There are 4 available ranges. Ranges correspond to the full scale of the analog output, units are those of the parameters displayed in the « Signal » column:

Range 1: from 0 to 1,

Range 2: from 1 to 10

Range 3: from 10 to 100

Range 4: from 100 to 1000.

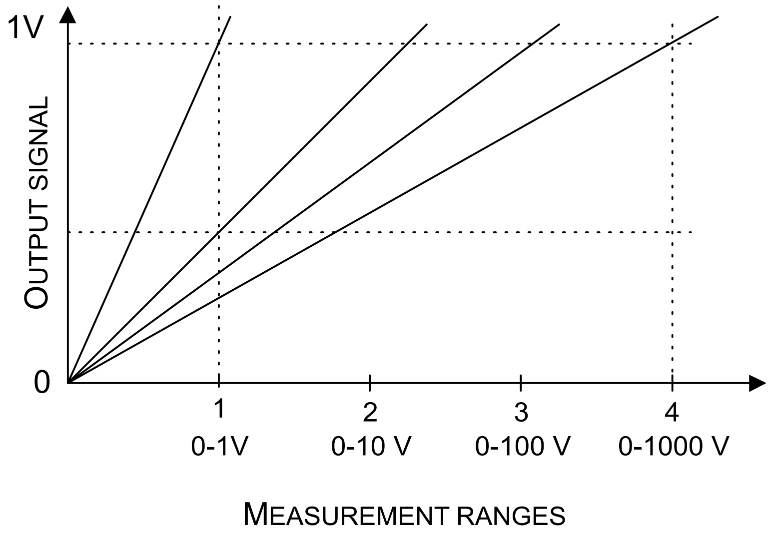
Operation principle of ranges:

- If range 1 AND 0–1V on the analog output, 1 ppb corresponds to 1 V on the analog output.
- If range 2 AND 0–1V on the analog output, 10 ppb correspond to 1 V on the analog output.
- If range 3 AND 0–1V on the analog output, 100 ppb correspond to 1 V on the analog output.
- If range 4 AND 0–1V on the analog output, 1000 ppb correspond to 1 V on the analog output.

Idem for 1–10 V, 0-20 mA and 4–20 mA.

When signal value is higher than the full scale of the current range, the analyzer switches to the next higher range. It switches again to the lower range when measurement again passes under 85% of the full scale of the current range.

Automatic scale adjustment of the output signal depends on the selected range. When the user operates on several measurement ranges and only one analog range for the output values, he can obtain an output identical value for different measurement values, as the here-below curve shows it.



To avoid the ranges commutation, the user can assign the same value to the 4 parameter ranges he will send to an analog output.

The linearization curve of Ax+B size is used to format the mV signal of the analog output: the A and B coefficients are used to adjust the calibration curve of the analog output, they are calculated as a function of the output measured value.

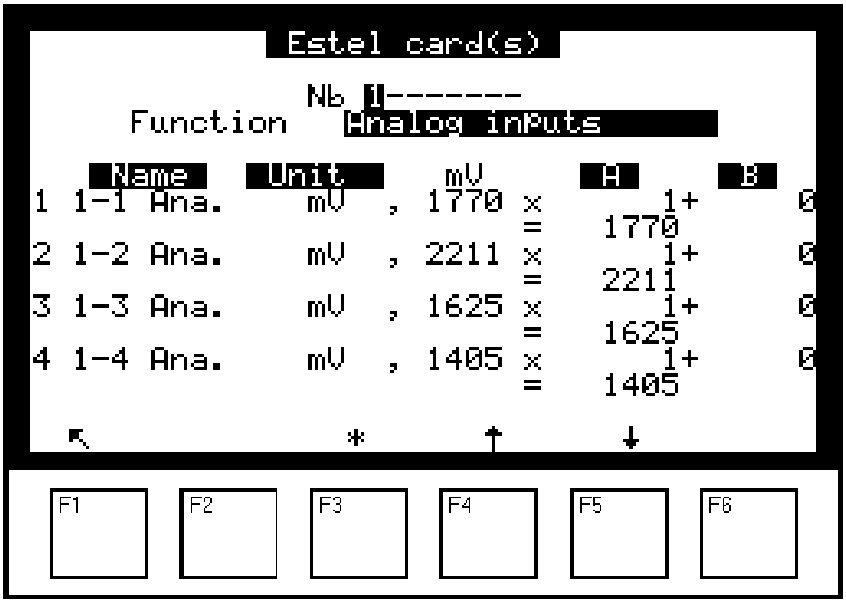
The « Test » column is used to test the 5 analog outputs and to adjust the points number.

For a range 1:

- 0 point (lower scale of output) ⇨ 0 volt obtained at output,
- 4000 points (higher scale of output) ⇨ 1 volt obtained at output.

F6 key [4000] enables to force the full scale on the whole analog outputs.

Function « Analog input » :

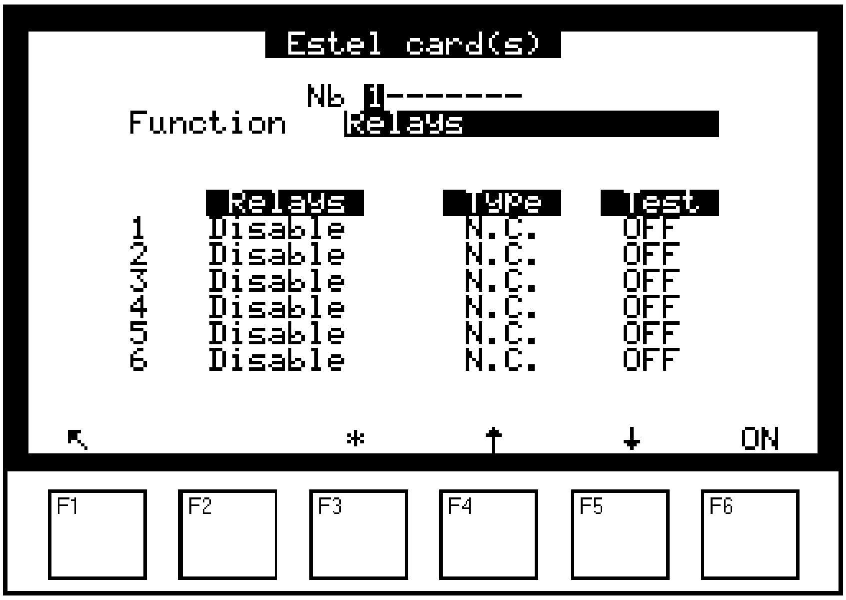


```
              Estel card(s)
                Nb 1-------
      Function   Analog inputs
   Name      Unit      mV        A       B
1 1-1 Ana.    mV   , 1770 x         1+      0
                          =    1770
2 1-2 Ana.    mV   , 2211 x         1+      0
                          =    2211
3 1-3 Ana.    mV   , 1625 x         1+      0
                          =    1625
4 1-4 Ana.    mV   , 1405 x         1+      0
                          =    1405
```

Each ESTEL board has 4 analog inputs: this screen is used to program characteristics of these analog inputs.

- "Name" fields are used to enter a name of 8 alphanumeric digits.
- "Unit" fields are used to select the unit by : none, ppt, ppb, ppm, µg/m3, mg/m3, gr/m3, µg/Nm3, mg/Nm3, gr/Nm3, µg/Sm3, mg/Sm3, gr/Sm3, %, µgr, mgr, gr, mV, U, °C, °K, hPa, mb, b,l, Nl, Sl, m3, l/min, Nl/min, Sl/min, m3/h, Nm3/h, Sm3/h, m/s or km/h, in the toggle menu.
- The "Ax + B" fields enable to enter the linearization curve of each parameter.

Function « Relays »:



Estel card(s)

Nb 1-------

Function Relays

	Relays	Type	Test
1	Disable	N.C.	OFF
2	Disable	N.C.	OFF
3	Disable	N.C.	OFF
4	Disable	N.C.	OFF
5	Disable	N.C.	OFF
6	Disable	N.C.	OFF

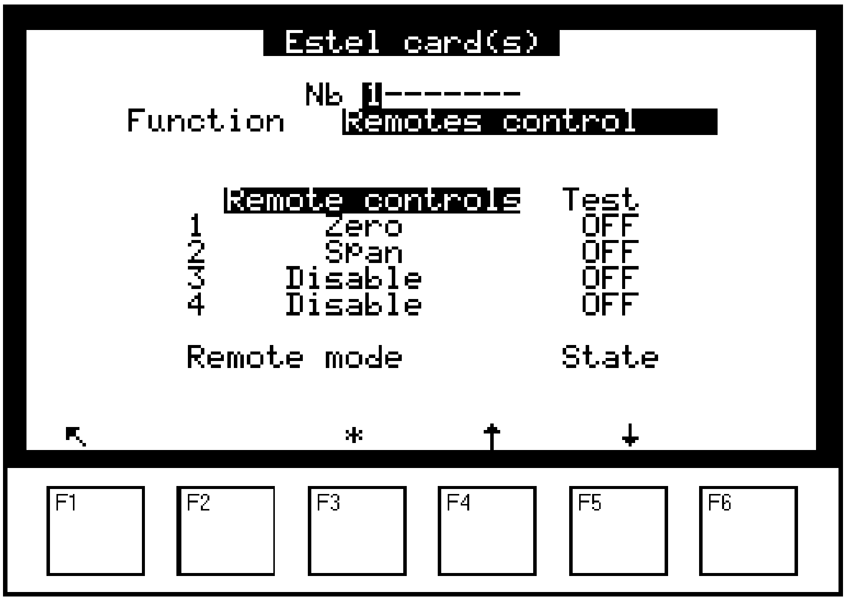
«Relays» fields are used to control relays according to the following conditions:

Disable	⇨ Relay not assigned
General alarm	⇨ Any operating fault triggers the relay
Warm-up	⇨ On warm-up, relay is triggered
Measurement	⇨ Relay triggered
Zero	⇨ On zero, relay is triggered
Span	⇨ On span, relay is triggered
Auto Span	⇨ On Auto Span, relay is triggered
Stop mode	⇨ In Stop mode, relay is triggered
Temperature	⇨ Abnormal temperature in the analyzer triggers the relay
Pressure	⇨ Barometric pressure in the chamber
Flow rate	⇨ Abnormal flow rate triggers the relays
Maintenance	⇨ In Maintenance mode, relay is triggered
Over-range	⇨ Exceeding the maximum range triggers the relay
x thresh. exceeding	⇨ Exceeding the n°x alarm threshold triggers the relay
Ez/Oy x-range	⇨ switching into the x-range of the y-output of the z-ESTEL, triggers the relay

« Ez/Oy x-range » : « E » indicates the ESTEL board, « z » indicates the ESTEL board number on which the user finds the range information, « O » indicates the analog output, « y » indicates the number of this analog output, « x » indicates the range number selected in the in the analog outputs screen.

- The "Type" fields are used to control (NC) or not (NO) the relays when alarms are OFF.
- "Test" fields are used to manually control these relays.

Function « Remotes controls »:



```
                Estel card(s)

                  Nb 1--------
        Function    Remotes control

            Remote controls    Test
         1       Zero           OFF
         2       Span           OFF
         3     Disable          OFF
         4     Disable          OFF

         Remote mode           State
```

This screen displays the assignment of remote control inlets.

The available assignment choices are: « Inactive», « Stop mode », « Zero-Ref. », « Zero », « Span », « Auto-span», « Zero Cycle », « Span Cycle », « Measurement ».

The «Test» column is used to display the value read at remote control inlet, for the selected assignment.

⚠ **« Zero » and « Span » status: To remain into the selected mode, the remote control must be kept active.**

3.3.8.2 I2C CARD(S) ⇨ SOREL Card(s)

Function « Relays »: this screen is the same as the ESTEL screen described here-above and operates in the same way.

Function « Remotes control »: this screen is the same as the ESTEL screen described here-above and operates in the same way.

⚠ **REMIND : A SOREL BOARD HAS 4 RELAYS AND 4 REMOTE CONTROLS.**

3.4 CALIBRATION

3.4.1 GENERAL

To ensure quality of the measurements performed using the VOC72M, 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 VOC72M 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 trap sample.

3.4.2 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 sources for the VOC72M:

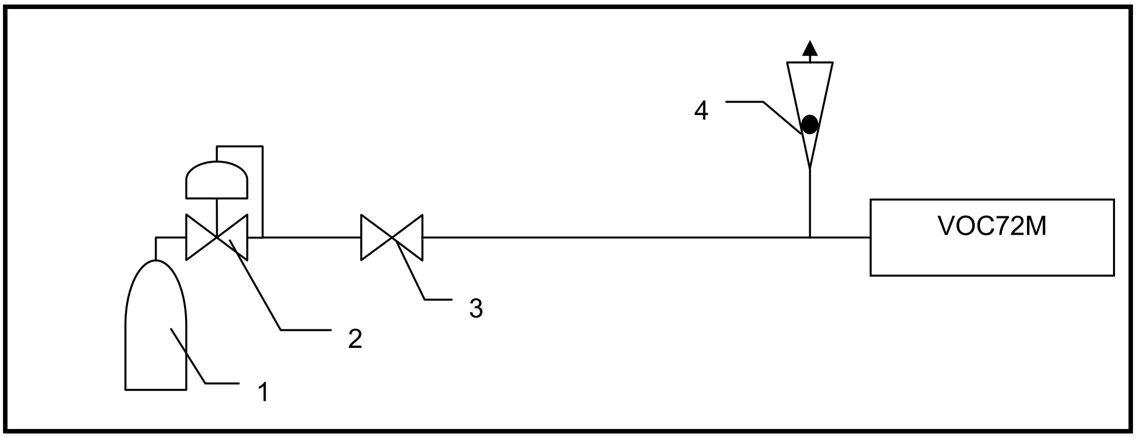
- The VOC72M nitrogen source (6.0 grade N2).
- A charcoal filter is also a good choice as zero filter for benzene.

3.4.3 SPAN GAS SOURCE

The recommended span gas concentration of benzene per EN14662-3 standard is 50µg/m3 (approx 15ppb) in zero air.

The possible sources are: a diluted span gas cylinder, a gas dilutor, a permeation bench.

3.4.3.1 Diluted span gas cylinder



(1) Span gas cylinder

(2) Pressure reducer

(3) Needle valve

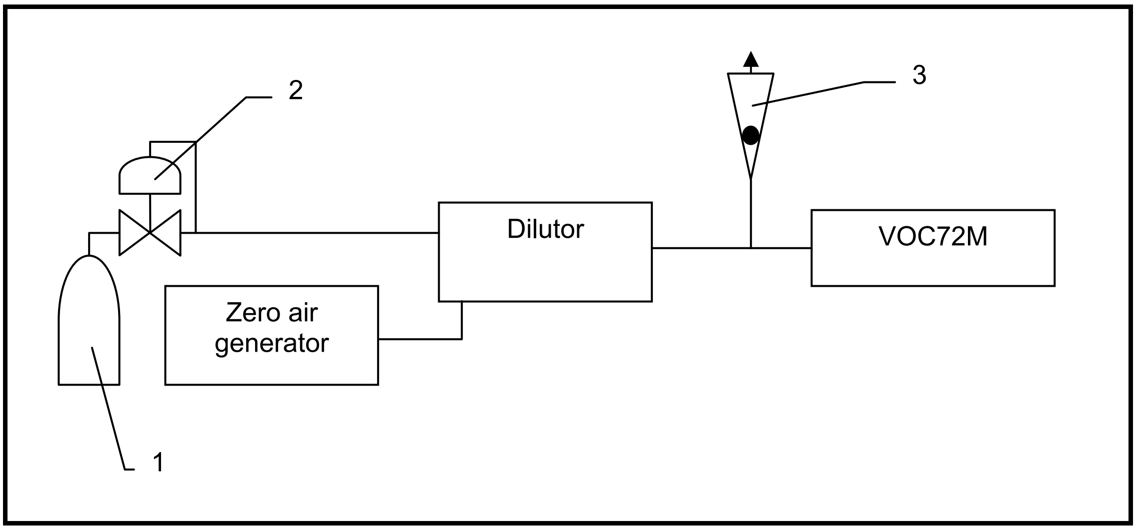
(4) Excess flow meter

\+ 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.

3.4.3.2 Gas dilutor



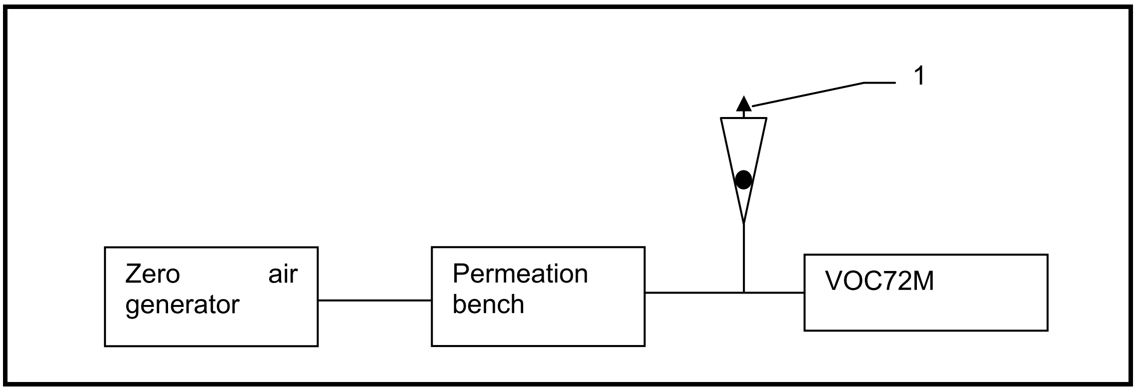
(1) Span gas cylinder

(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…).

3.4.3.3 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.

3.4.4 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 analyser 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 centred within the detection window (less than 0.5 second drift).
  - No extra significant peak in the GC chromatogram.

3.4.5 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.

3.4.5.1 The retention time and K factor calibration

This calibration requires a sheet of paper, a pen and a pocket calculator.

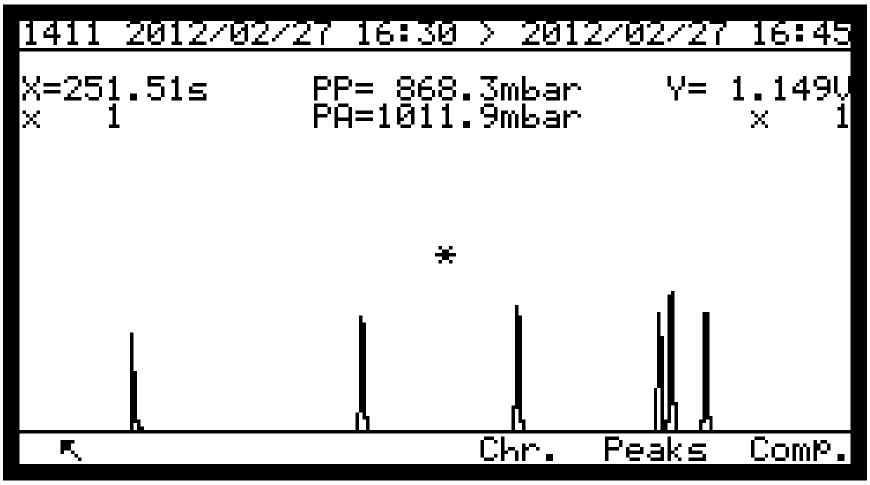
Inject the calibration gas (see 3.4.4).

As the VOC72M analyzes the span mixture, write down on the paper the name and the concentration of each compound of the span mixture in the increasing order of the elution times.

- Example with a benzene-toluene calibration.

Compound	**Concentration (µg/m3)**	**RT**	**C**	**K factor**
Benzene	65.1			
Toluene	78.3			

Examine the corresponding chromatogram in the screen «*MEASUREMENT ⇨ Chromatogram*»



```
1411 2012/02/27 16:30 > 2012/02/27 16:45
X=251.51s      PP= 868.3mbar    Y= 1.149V
x   1          PA=1011.9mbar        x   1
```

Span chromatogram of a BTEX + 1,3 butadiene mixture

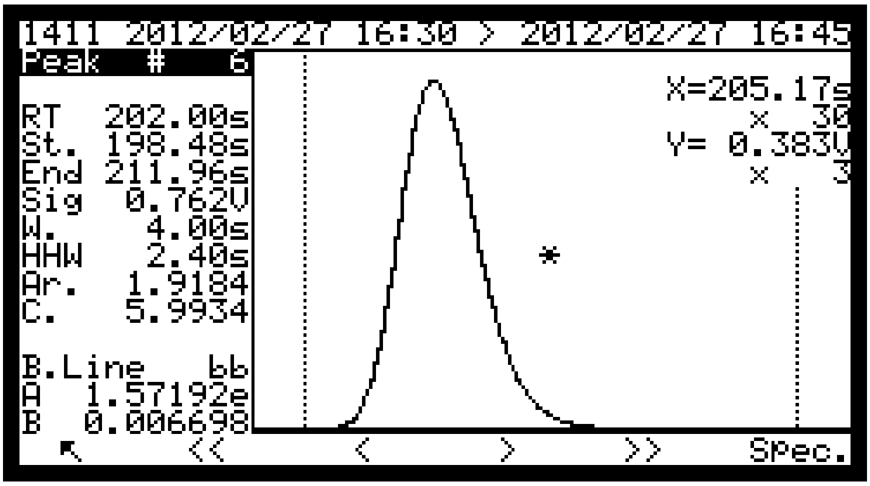
Example: the above 7-compound mixture (Benzene, Toluene, Ethylbenzene, m-xylene, p-xylene, o-xylene, 1,3-butadiene) exhibits 6 major peaks because m-xylene and p-xylene co-elute (same RT).

The peak elution order is always:

(1) 1,3-butadiene.
(2) Benzene.
(3) Toluene.
(4) Ethylbenzene.
(5) m-Xylene and p-Xylene.
(6) o-Xylene.

Press down F5 **[Peaks]** in the previous screen to display the chromatogram peaks.

Skip the minor peaks (refer to area values) and write down on the paper the RT values of the major peaks which correspond to the compounds present in the span gas.



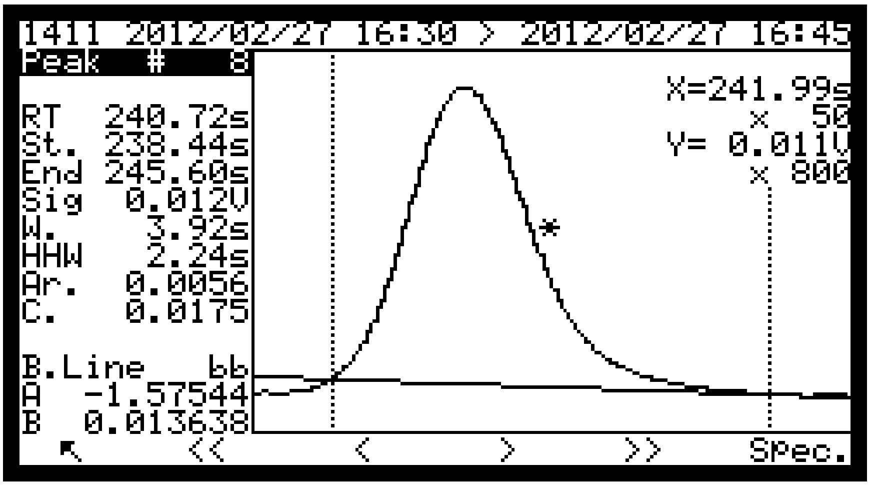
```
1411 2012/02/27 16:30 > 2012/02/27 16:45
Peak  #  6
RT   202.00s
St.  198.48s
End  211.96s
Sig   0.762V
W.     4.00s
HHW    2.40s
Ar.   1.9184
C.    5.9934
B.Line    bb
A  1.57192e
B  0.006698
```

Peak #6 area is 1.9. This is the second major peak (in retention time order) in the above *«MEASUREMENT ➩ Chromatogram»* screen. Thus, the peak*#6* is benzene.

Report RT and C values in the here-below table:

Compound	**Concentration (µg/m3)**	**RT**	**C**	**K factor**
Benzene	65.1	202.00	5.9934	
Toluene	78.3			

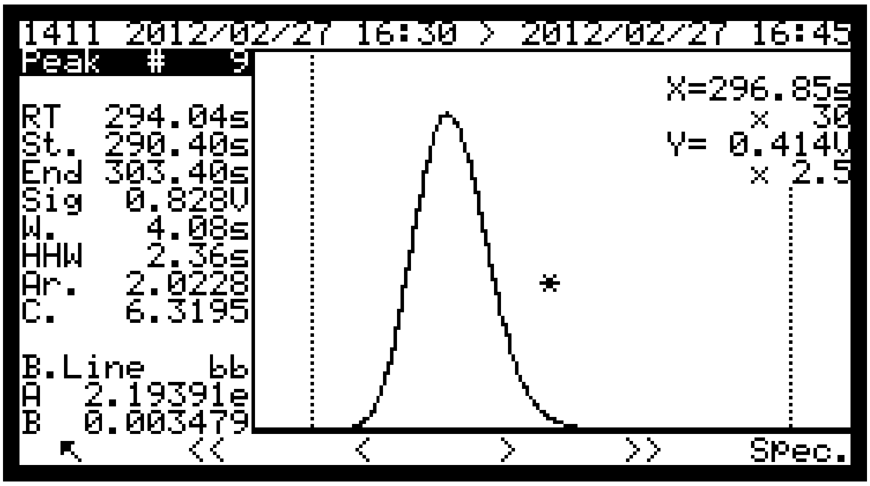
Press down F4 **[>]** in the previous screen to go to the next peak:



```
1411 2012/02/27 16:30 > 2012/02/27 16:45
Peak  #  8
RT   240.72s
St.  238.44s
End  245.60s
Sig   0.012V
W.     3.92s
HHW    2.24s
Ar.   0.0056
C.    0.0175
B.Line    bb
A  -1.57544
B  0.013638
```

Peak #8 area is only 0.0056. This is a minor peak and not the peak of a span gas compound.

Press F4 **[>]** in the previous screen to go to the next peak:



```
1411 2012/02/27 16:30 > 2012/02/27 16:45
Peak    #    9
                        X=296.85s
RT   294.04s                 x  30
St.  290.40s            Y= 0.414V
End  303.40s                 x 2.5
Sig   0.828V
W.     4.08s
HHW    2.36s
Ar.   2.0228
C.    6.3195

B.Line    bb
A  2.19391e
B  0.003479
```

Peak #9 area is 2.02. This is the third major peak (in retention time order). Consequently, the peak#9 is toluene.

Report RT and C values in the here-below table:

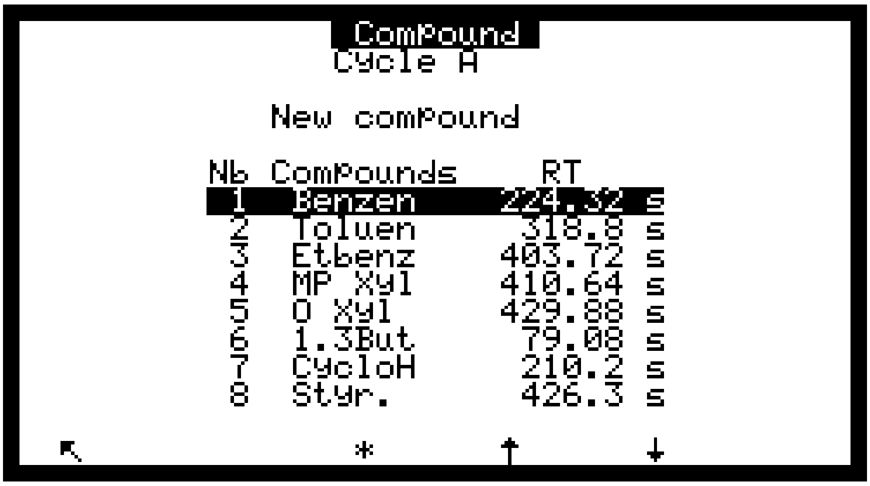
Compound	**Concentration (µg/m3)**	**RT**	**C**	**K factor**
Benzene	65.1	202.00	5.9934	
Toluene	78.3	294.04	6.3195	

With the pocket calculator, calculate the K factor = Concentration / C.

Report RT and C values in the here-below table:

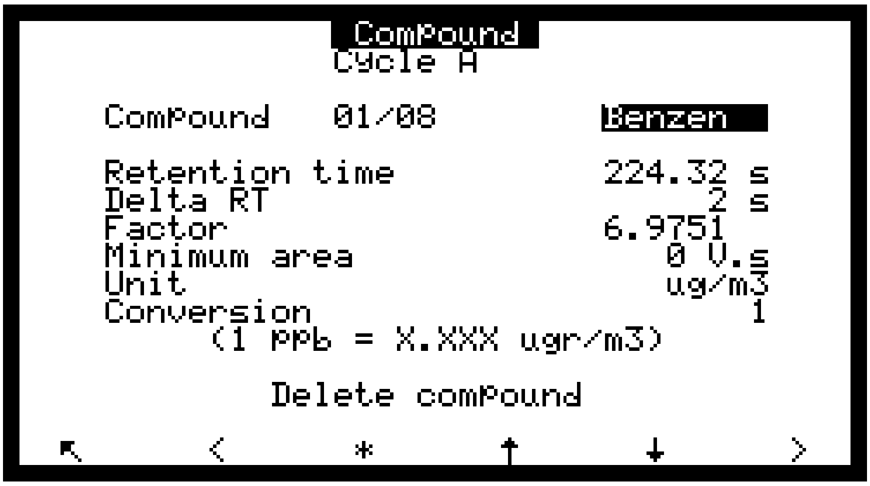
Compound	**Concentration (µg/m3)**	**RT**	**C**	**K factor**
Benzene	65.1	202.00	5.9934	10.86
Toluene	78.3	294.04	6.3195	12.39

Go to the compound list in the screen *«CONFIGURATION ➩ Chromatogram ➩ Compounds»* screen.



```
            Compound
            Cycle A

         New compound

     Nb Compounds      RT
      1  Benzen     224.32 s
      2  Toluen      318.8 s
      3  Etbenz     403.72 s
      4  MP Xyl     410.64 s
      5  O Xyl      429.88 s
      6  1.3But.     79.08 s
      7  CycloH      210.2 s
      8  Styr.       426.3 s
```

Select «Benzen» (as shown) and press **[✱]** in order to display the benzen parameters:



```
                 Compound
                 Cycle A

     Compound   01/08          Benzen

     Retention time            224.32 s
     Delta RT                       2 s
     Factor                    6.9751
     Minimum area                 0 V.s
     Unit                         ug/m3
     Conversion                       1
          (1 ppb = X.XXX ugr/m3)

             Delete compound
```

- Enter the new RT: replace 224.32 with 202.0
- Enter the new K factor: replace 6.9751 with 10.86
- Press F6 [**>**] to display the next compound (toluene) and enter the new RT and K factor for toluene.

On the next cycle the VOC72M will consider the new RT and K factor values for benzene and toluene.

3.4.5.2 The retention time calibration

This calibration requires a sheet of paper and a pen.

The method is similar to RT and K factor calibration, but only the RT values are recorded and reported to the compounds table.

3.4.5.3 The K factor calibration

This calibration requires a valid retention time calibration, a sheet of paper, a pen and a pocket calculator.

The method is similar to RT and K factor calibration but only the C values are recorded and the calculated K factor reported to the compounds table.

3.4.6 THE AUTOMATIC METHOD

3.4.6.1 The K factor calibration.

The requirements for the automatic calibration (K factor) are:

1) A compound table with valid retention times (RT). See paragraph 3.3.4.3.5

2) The sampling cycle and analysis cycle must be free of alarm
(alarm during the calibration ⇔ calibration error #1).

3) The chromatogram must not show saturated data
(one saturated data point ⇔ calibration error #4).

4) After calculation, the calculated K factor must range between 0.1 and 50
(K < 0.1 or K > 50 ⇔ calibration error #32).

5) After calculation, the new K factor must differ from the previous K factor of less than 50%
(difference greater than 50% ⇔ calibration error #64).

NOTE : The calibration error code is additive.
Example: calibration error #96 ⇔ Calibration error #64 and Calibration error #32.

- Go to the *«SPAN ⇨ Select gas»* screen, and complete the table with the span mixture concentrations. See paragraph 3.3.3.2.
- Go to the *«CONFIGURATION ⇨ Chromatogram ⇨ Span»* screen, *and s*et the «*Mode*» field to **Standard**. Set the «*First Calibration*» field to **ON** if the previous K factor is not significant (the VOC72M will ignore the calibration error #64). See paragraph 3.3.4.3.8.
- Using the F1 key, return to the «MEASUREMENT *⇨ Synoptic*» screen, and press down the F2 [Cycle], then the F6 [Auto] key. The «*Auto sample*» message is displayed on the left side of the screen:
  - Connect sample input to span source on the next cycle as the «*Auto sample»* flag moves on the centre of the screen.
  - Connect sample input to sample source as the «*Auto sample»* flag moves on the right side of the screen. The VOC72M now analyzes the span mixture.

When the progression bar reaches the calculation mark, the new K factors are calculated.

If no error is found, the VOC72M will consider the new K factor on the next cycle.

3.4.6.2 The retention time and K factor calibration.

The technical requirements for the automatic calibration (RT and K factor) are:

1) The sampling cycle and analysis cycle must be free of alarm

(alarm during the calibration ⇔ calibration error #1).

2) The resulting chromatogram must show at least as many peaks as compounds

(less peaks than compounds ⇔ calibration error #2).

3) The chromatogram must not have saturated data.

(one saturated data point ⇔ calibration error #4).

4) If n compounds are present in the calibration, the chromatogram must show n larger peaks called major peaks and some smaller peaks called minor peaks. The area of the major peaks must not differ from more than a factor 3

(greatest major peak area > 3 x smallest major peak area ⇔ calibration error #8).

5) The area ratio between the smallest major peak and the greatest minor peak must be greater than 5

(smallest major peak area < 5 x greatest minor peak area ⇔ calibration error #16).

6) After calculation the K factor must range between 0.1 and 50

(K < 0.1 or K > 50 ⇔ calibration error #32).

7) After calculation the new K factor must differ from the previous K factor of less than 50%

(difference greater than 50% ⇔ calibration error #64).

NOTE : the calibration error code is additive:

Example: calibration error #96 ⇔ Calibration error #64 and Calibration error #32.

- Go to the *«SPAN ⇨ Select gas»* screen to display the span list. See paragraph 3.3.3.2
- For each compound present in the span mixture, set the *«State»* field to **ON**.

NOTE : a compound not present in the span mixture must have an **OFF** status.

- Enter a rank position (the rank position defines the relative position of the GC peaks).
- Enter the concentration of the compound in the span mixture.
- Go to the *«CONFIGURATION ⇨ Chromatogram ⇨ Span»* screen to visualize the calibration sheet:
- Set the «*Mode*» field to **RT and Conc**.
- Set the «*First Calibration*» field to **ON** if the previous K factor is not significant (the VOC72M will ignore the calibration error #64).

- Using the F1 key, return to the «MEASUREMENT ➪ *Synoptic*» screen, and press down the F2 **[Cycle]**, then the F6 **[Auto]** key. The «*Auto sample*» message is displayed on the left side of the screen:
  - Connect sample inlet to span source on the next cycle when the «*Auto sample*» message moves on the centre of the screen.
  - Connect sample inlet to sample source when the «*Auto sample*» message moves on the right side of the screen at the beginning of the next cycle. The VOC72M now analyzes the span mixture.

When the progression bar reaches the calculation mark, the new RT and K factors are calculated.

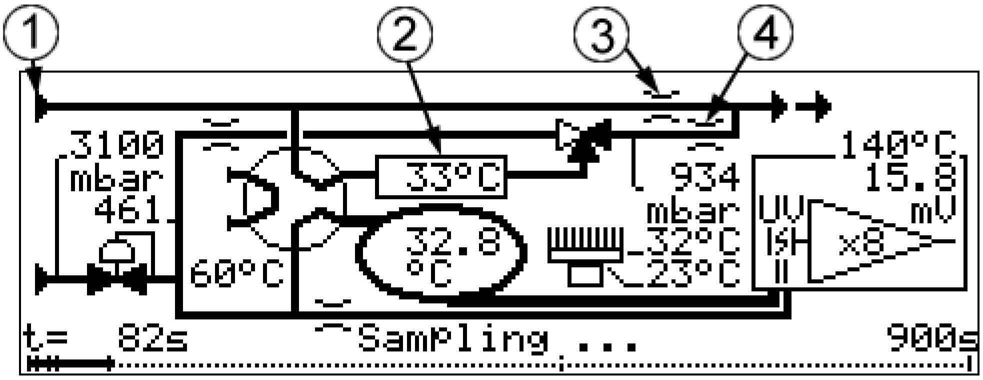
If no error is found, the VOC72M will consider the new RT and K factors on the next cycle.

3.4.6.3 Error codes and solutions.

Error code	Description	Possible cause and solution.
1	Invalid cycle: one alarm at least occurred during the analysis cycle	Go to the «*MEASUREMENT ⇨ Alarms display*» screen, and display the alarms historic. Fix the alarm origin and recalibrate. See paragraph 3.3.2.5
2	Less peaks found in the chromatogram than the compounds to calibrate	Remove the compounds not present (or not detected) in the span mixture from the span list visualized in the «*SPAN ⇨ Select gas» screen.* Set gas status to OFF See paragraph 3.3.3.2
4	There is a saturated peak in the chromatogram	Check the chromatogram visualized in the screen: «*MEASUREMENT ⇨ Chromatogram*». Reduce the detector gain if the major peaks are close to saturation: Go to the «*CONFIGURATION ⇨ Chromatogram ⇨ Sampling*» screen. If the saturated peak is much greater than the other major peaks, look for a possible contamination (example solvent vapour). See paragraph 3.3.4.3.3
8	Peak area ratio > 3 among the major peaks.	Check the chromatogram visualized in the screen: *«MEASUREMENT ⇨ Chromatogram»*. Verify that the chromatogram shows as many significant peaks as compounds in the span mixture. See paragraph 3.4.5.1
16	Peak area ratio < 5 between the smallest major peak and the highest minor peak	Check the chromatogram visualized in the screen: «*MEASUREMENT ⇨ Chromatogram*». Verify that the chromatogram shows as many significant peaks as compounds in the span mixture. Search for a possible contamination by another gas than those of the span mixture. See paragraph 3.4.5.1
32	K factor outside the 0.1-50 range.	Huge sensitivity loss. Check for a major leak (example: wrong connection on the sample filter) or a detector failure.
64	K factor of a compound has changed of more than 50%	If previous calibration was not significant, go to the «*CONFIGURATION ⇨ Chromatogram ⇨ Span*» screen, set the «*First Calibration*» field to **ON** and restart a calibration cycle. See paragraph 3.3.4.3.8

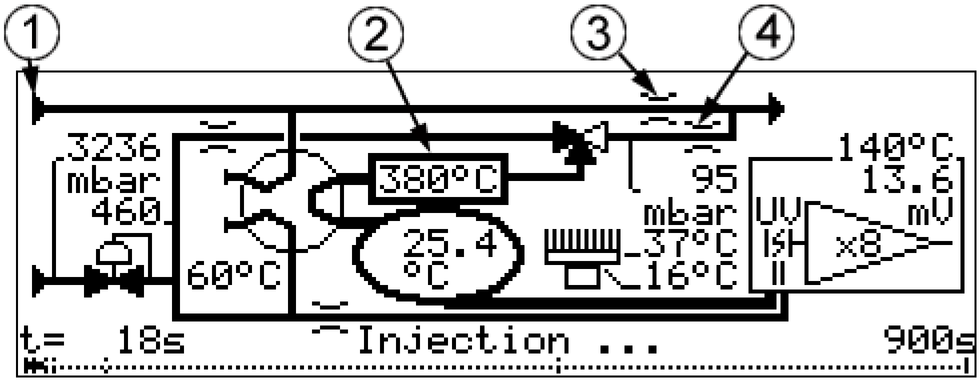
3.4.7 THE FLOW RATE CALIBRATION

3.4.7.1 The sample flow rate measurement.



In *«Sampling»* mode, the flow rate measured on the sample inlet (1) of the analyzer is the sum of:

- The by-pass flow (not trapped) flowing through the restrictor (3).
- The sample flow flowing through the trap (2) and the restrictor (4).



In injection mode, the flow rate measured on the sample inlet (1) of the analyzer corresponds to the by-pass flow that flows through the restrictor (3).

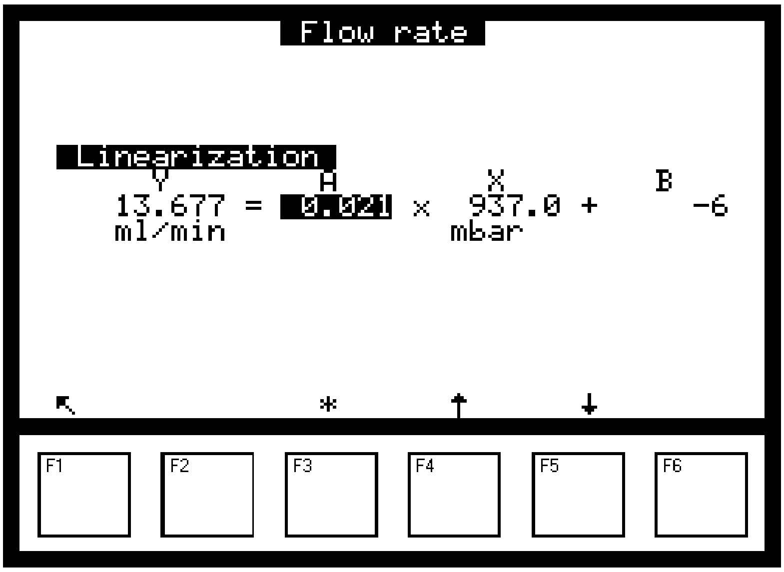
This leads to the following equation:

Sample flow rate = Inlet flow rate (sampling mode) – Inlet flow rate (injection mode).

3.4.7.2 Verification of flow rate calibration

- Connect the reference flowmeter to the sample inlet of the VOC72M.
- Write down the inlet flow rate Fi1 during the injection period (11 < t < 20 seconds) on the 15-minute standard cycle).
- Write down the input flow Fs1 during the sampling period (80 < t < 900 seconds) on the standard 15-minute cycle).
- Calculate the sample flow F1: F1 = Fs1 –Fi1

Go to the «*SPAN ⇨ Flow rate*» screen.



```
                Flow rate

 Linearization
       Y          A          X           B
    13.677 =   0.021  x   937.0 +          -6
    ml/min               mbar
```

Check that the calculated sample flow F1 matches the Y value displayed on the screen while the trap is in sampling mode.

3.4.7.3 The sample flow calibration.

- Carry out a sample flow rate verification as described above, and write down:
  - The trapped flow rate F1 measured with the reference flowmeter in millilitre per minute.
  - The P1 trap pressure (on the «*SPAN ⇨ Flow rate*» or «*MEASUREMENT ⇨ Synoptic*» screen) during sampling (80 < t < 900 seconds) on the 15-minute standard cycle.

- Install a restrictor between the reference flow meter and the sample inlet, in order to cause a pressure drop of about 100 millibar of the trap pressure during sampling (80 < t < 900 seconds) on the 15-minute standard cycle.

- Carry out a flow rate verification as described here-above, and write down:
  - The F2 trapped flow rate measured with the reference flow meter in millilitre per minute.
  - The P2 trap pressure measured on the synoptic screen during the sampling time (80 < t < 900 seconds) on the standard 15-minute cycle).
  - The P2 trap pressure (on the «*SPAN ⇨ Flow rate*» or «*MEASUREMENT ⇨ Synoptic*» screen) during the sampling time (80 < t < 900 seconds) on the 15-minute standard cycle).

From the equations:

$$F1 = A \times P1 + B$$

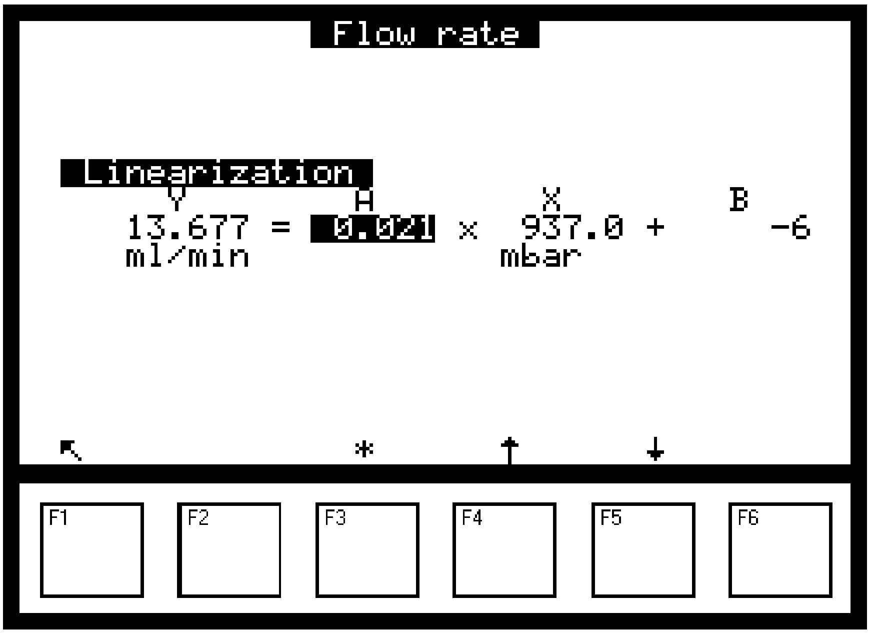
$$F2 = A \times P2 + B$$

Calculate the new parameters:

$$A = (F1 - F2) / (P1 - P2)$$

$$B = F1 - A \times P1$$

– Go to the «*SPAN ⇨ Flow rate*» screen.



```
Flow rate

Linearization
     Y          A          X          B
   13.677 = 0.021 x   937.0 +        -6
   ml/min              mbar
```

– In the equation displayed in the screen, replace the A and B parameters by the corresponding calculated values.

– Then verify that the Y value displayed matches now with the value indicated by the reference flow meter, the restrictor being connected on the sample inlet.

– Remove the flow meter and the restrictor, and then reconnect sample tube to the sample inlet.

NOTE : It is recommended to carry out a K factor calibration after every flow calibration.