TECHNICAL MANUAL

AC32e

CHEMILUMINESCENT NITROGEN

OXIDE ANALYZER

- JANUARY 2017 -

Environnement S.A
L'instrumentation de l'environnement

111 bd Robespierre, 78300 POISSY - -TEL. 33(0)-1.39.22.38.00 – FAX 33(0)-1.39 65.38.08
http://www.environnement-sa.com

WARNING

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

This document does not represent a commitment under part of ENVIRONNEMENT S.A.

CONTENTS

LIST OF FIGURES

INDEX OF PAGES

Page intentionally left blank

CHAPTER 1

GENERAL - CHARACTERISTICS

1 GENERAL - CHARACTERISTICS

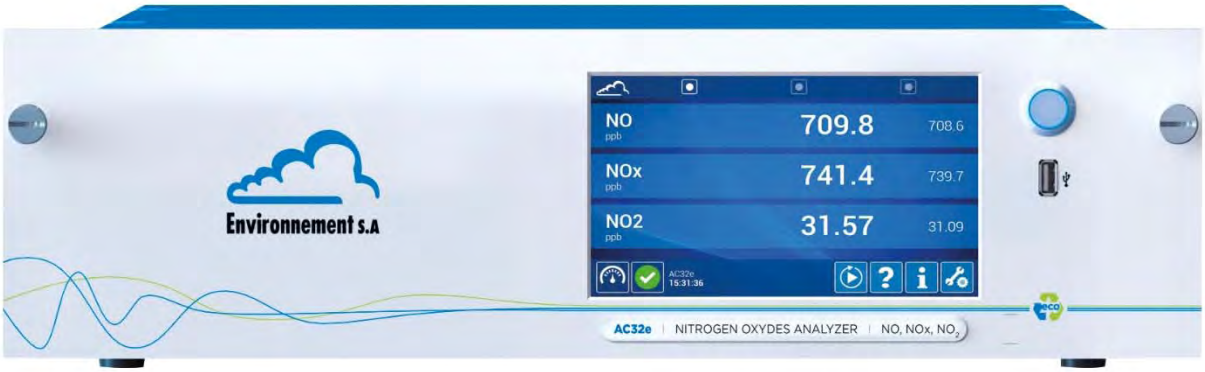


Figure 1–1 – Environnement S.A AC32e (with screen).

Figure 1–2 – Environnement S.A AC32e∗ (without screen).

1.1 GENERAL

1.1.1 PRESENTATION

The AC32e is a nitrogen monoxide and nitrogen dioxide analyzer specific to low concentrations in ambient air (with a detection limit of 0.2 pp).

Its measurement principle is based on the nitrogen oxide (NO) chemiluminescence in the presence of highly oxidizing ozone molecules.

Due to recent optical and electronic technologies, the device offers many advantages and requires only limited maintenance.

The sample is taken using a Teflon tube (6 mm external diameter) connected to the analyzer rear panel. The sample is aspirated by an external pump.

The measurement is displayed on a color display equipped with a touch screen located on the front panel.

This analyzer is also available in AC32e∗ (without screen) version.

1.1.2 DESCRIPTION

1.1.2.1 Front panel

The front panel includes the following:

- General switch.
- Backlit color TFT LCD (Thin Film Transistor Liquid Crystal Display):
  - Resolution of 800 x 480 (pixels), 7” screen,
  - The display provides the measurement values and other system parameters, as desired.
- Capacitive touch-screen projected on glass.
- USB port.

Figure 1–3 – Color screen fitted with touch-screen

1.1.2.2 Rear panel

All of the AC32e electrical connectors and gas inlets/outlets are located on the rear panel. Refer to Figure 1–4.

Gas inlets/outlets for standard analyzers (right-hand side):

- The inlet for the sample to be analyzed is composed of 4 mm (I.D.) and 6 mm (O.D.) tube fitting, attached to the dust filter holder. The dust filter holder is equipped with a Teflon filtering diaphragm (1).
- The ambient air inlet for supplying the ozone generator is composed of 4 mm (I.D.) and 6 mm (O.D.) Teflon fitting (2).
- The pump outlet (15), to connect the external pump, is composed of 4 mm (I.D.) and 6 mm (O.D.) tube.
- A general fan (9), and a Peltier cooler fan (14).
- The span gas inlet (3) is composed of 4 mm (I.D.) and 6 mm (O.D.) Teflon fitting to connect an external span gas at atmospheric pressure.

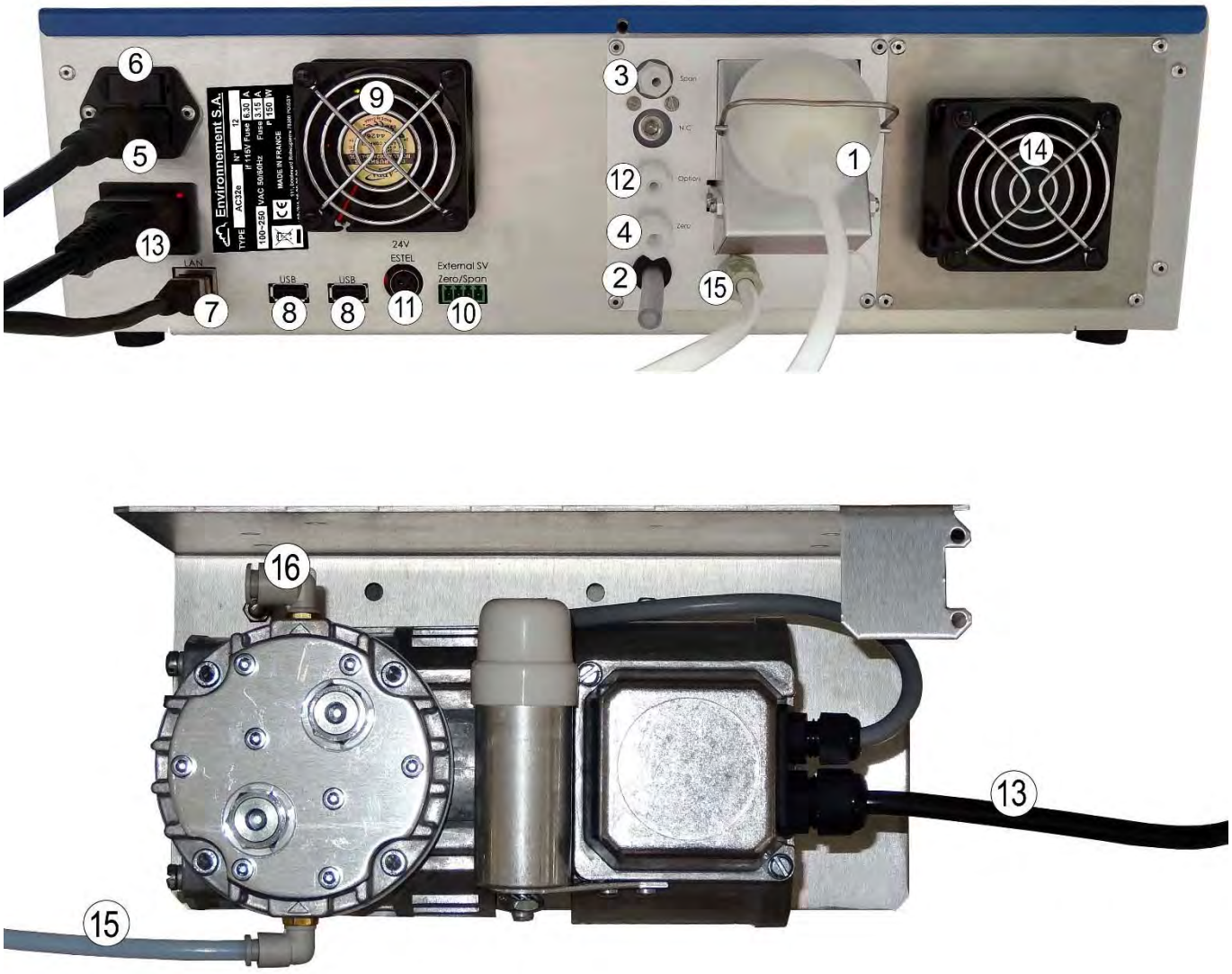
The following option is also located on the rear panel:

- Zero air inlet for permeation bench (12).

Electrical equipment and connections for all analyzers (left-hand side):

- One main power supply block consisting of a three-contact socket (5) to connect a standard power cable and the general fuse (6): 3.15 A/250V.
- One Ethernet output (7) and two USB ports (8).
- One 4-point BL connection to connect the optional solenoid valve for external calibration (10),
- One connection for the 24 V power supply for ESTEL board option (11).
- One supply plug for external pump (13).

NOTE : The analyzer is equipped with a power supply compatible with a 100-240V voltage and 50-60 Hz frequency main supply. However, the available main supply must be compatible with the voltage and frequency indicated on the pump housing.



(1) sample inlet, (2) ozone generator air inlet, (3) span inlet, (4) optional inlet, (5) three-contact socket for main power supply, (6) general fuse, (7) Ethernet output, (8) two USB ports, (9) fan, (10) duplicate the zero and span solenoid valves for optional solenoid valve of external calibration, (11) 24 V power supply for ESTEL board option, (12) permeation bench inlet (optional), (13) external pump supply, (14) Peltier fan, (15) fluid connection for external pump, (16) pump vent.

Figure 1–4 – Rear panel and external pump of AC32e

1.1.2.3 Internal view

The internal components of the analyzer are accessed by simply unscrewing the single knurled screw at the rear panel and sliding the upper cover.

The internal elements include (refer to Figure 1–5**)**:

- Sample inlet dust filter mounted on the rear panel (1),
- Optional dryer (2) used to remove sample gas humidity,
- Solenoid valve block (3) for sample/zero/span inlet,
- NOx cycle solenoid valve block (4) which selects the (NO-NOx) measurement cycle,
- Zero filter (5) which generates NO-free gas for the zero-reference cycle,
- Sample pressure sensor (6)
- Interconnections board (7), which allows Supply, Arm20, Controller and Measurement board interfacing,
- NOx cycle solenoid valve (9),
- Pressure sensor (10) of chemiluminescence reaction chamber,
- Converter case (11) which includes the NOx converter oven (8), and the ozone destructor (17),
- 24 VDC power supply unit (12), with automatic universal input voltage 100~250 Vac 50/60Hz,
- Ozone circuit consisting of air inlet filter (13), dryer (14), ozone generator (15) on which the ozone generator board (29) is mounted, ozone purifier (16), and ozone scrubber (17),
- ARM20 board (18),
- Measurement module (19) including chemiluminescence reaction chamber, refrigerated enclosure of photomultiplier tube (PM) and RTP board (Peltier temperature control) (28),
- Scavenging dryer filter (20),
- Measurement board (21),
- Controller board (22),
- Power supply board (23),
- Peltier fan (24), and electronic board cooler fan (25),
- Vacuum manifold (26),
- Preampli board housing (27),
- Pump relay board (30).

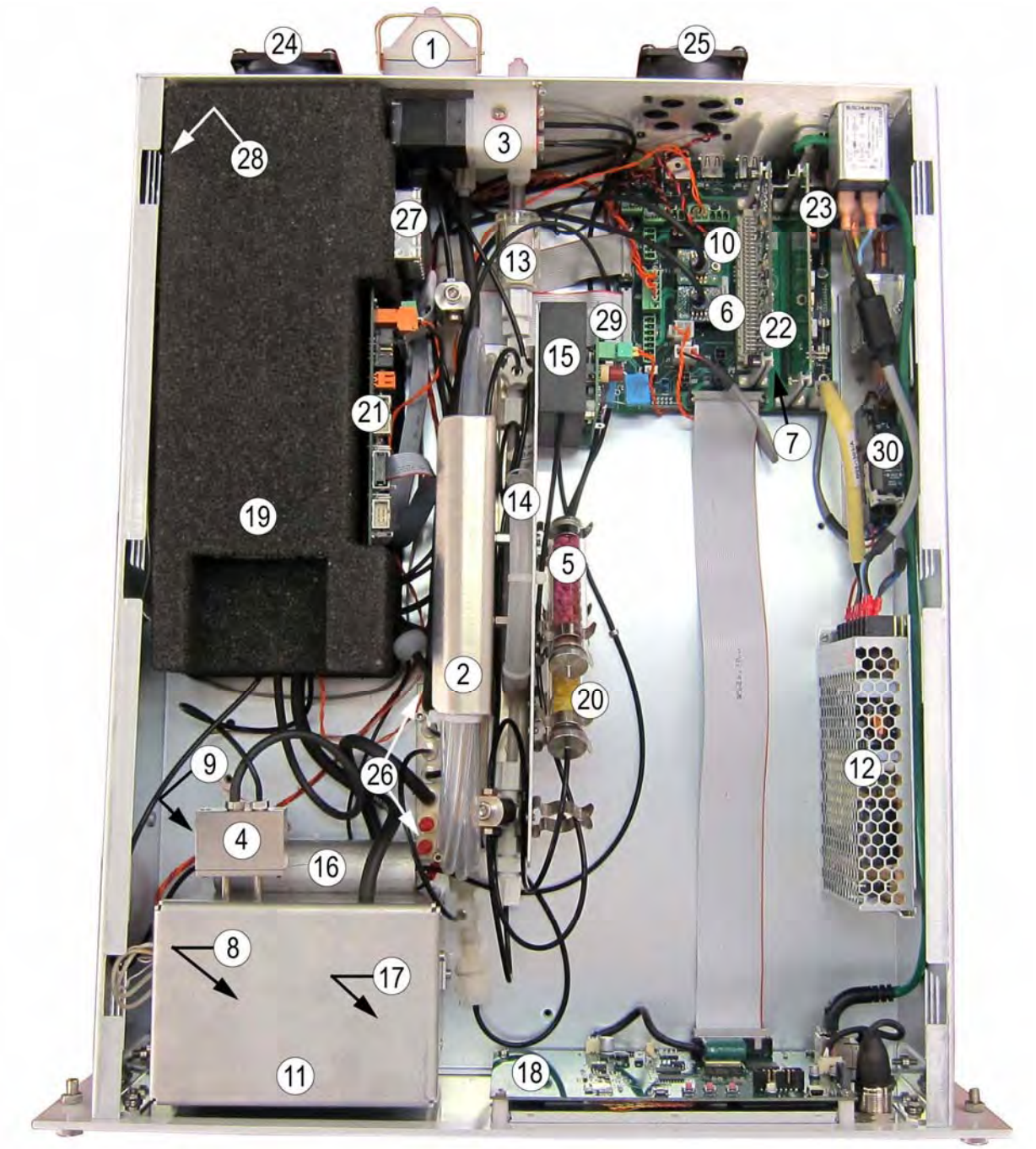
After passing through the dust inlet filter (1), the gas to be measured passes through the solenoid valve block (2) which selects the input port (sample, span, zero). The optional dryer (2), inserted between the dust filter and the solenoid valve block, eliminates any water interference.

The sample is aspired into the reaction chamber, by direct circuit for the NO cycle, and through the $NO_2 \rightarrow NO$ converter oven (8) for the NOx cycle.

The ozone generator is used to generate ozone needed for ambient air measurement. First, the aspirated air is dust-free, and dried through the inlet filter (13), then the dryer (14). At ozone generator outlet (15), the generated ozone is cleaned by passage through the scrubber (16) before entering the reaction chamber inside the measurement module (19). The ozone generator board (29) electrically supplies the high-voltage transformer of the ozone generator.

The dryer (14) also provides the scavenging air of the photomultiplier tube enclosure after passing through the scavenging dryer filter (20).

The vacuum manifold (26), connected to the external pump, connects the whole internal elements to be placed under vacuum.



(1) sample inlet dust filter, (2) optional dryer, (3) inlet solenoid valve block, (4) NOx solenoid valve block, (5) zero filter, (6) sample pressure sensor, (7) Interconnection board, (8) converter oven, (9) NOx cycle solenoid valve, (10) pressure sensor of reaction chamber, (11) converter enclosure, (12) 24 V power supply, (13) ozone generator air inlet filter, (14) ozone generator dryer, (15) ozone generator, (16) ozone purifier, (17) ozone destructor, (18) ARM20 board, (19) measurement module, (20) scavenging dryer filter, (21) measurement board, (22) Controller board, (23) Supply board, (24) Peltier fan, (25) cooler fan, (26) vacuum manifold, (27) Preampli board housing, (28) Peltier board, (29) ozone generator board, (30) pump relay board.

Figure 1–5 – AC32e internal view

1.1.3 VARIOUS OPERATING MODES

1.1.3.1 Standard

- Programmable measurement range until 10 ppm, with a detection limit of 0.2 ppb for 25 second response time.
- Automated monitoring of parameters influencing metrology (UV emitted energy, gas flow, temperature and pressure) and correct operation tests.
- Measurement values in ppb or µg/m^3 (integrated conversion coefficient).
- Memory storage of average measurements with programmable periods.

1.1.3.2 Option

The following analyzer options are available:

- One to two ESTEL board case(s), as accessories, to be directly connected to USB ports on rear panel,
- One RS case delivered as an accessory, to be directly connected to USB ports on rear panel.
- A permeation bench.

1.1.4 ASSOCIATED EQUIPMENT (OPTIONAL)

- Analog recorders and data loggers.
- Digital data acquisition system.

1.2 CHARACTERISTICS

1.2.1 TECHNICAL CHARACTERISTICS

Measurement range	:	Programmable (maximum 10 ppm)
Units	:	ppb, or µg/m^3 (programmable)
Noise (σ)	:	0.1 ppb (automatic response time)
Minimum detectable limit (2σ)	:	0.2 ppb (automatic response time)
Minimum response time (0-90 %)	:	40" (programmable)
Zero drift	:	< 1 ppb / 24 hours
Span drift	:	< 1% / 7 days
Linearity	:	1%
Repeatability	:	1%
Sample flow rate	:	0.66 l/min.
Sample flow rate if sample dryer option available	:	1 l/min.
Ozone flow rate	:	0.06 l/min.
Chamber pressure	:	200 hPa absolute
NOx converter	:	Molybdenum, regulated at 340°C
Ozone destructor		Heated catalytic
P.M temperature	:	Controlled to 0°C
Reaction chamber temperature	:	60°C
Display :	:	TFT LCD color screen, resolution : 800 (RGB) x 480, size : 7 inches
Control	:	Touch screen
Output signals (option)	:	4 analog outputs (0-1 V, 0-10 V, 0-20 mA, 4-20 mA)
Power supply	:	100~250Vac, 50/60Hz + ground
Consumption	:	250 VA when starting-up the unit
		160 VA in normal operation
Working temperature	:	0 °C to + 40 °C
Memory storage of measurement values	:	Capacity : 1 year, ¼ hour base
		EPROM flash storage
Alarm check	:	Detection and indication of operating anomalies: temperatures, pressures, currents, voltages, out of NO, NOx, NO_2 programmable measurement thresholds, calibration fault.
Maintenance test and diagnostics	:	Direct selection with the touch screen and/or remote selection with the embedded Web server.
Backup saving time for the real-time clock and RAM-stored data	:	1 year maximum.
ETHERNET output	:	RJ45 socket, UDP protocol.
USB port	:	Type A USB socket: 2.0 (3.0 compliant)
External Zero/span external SV control	:	Contact connector with screw terminals

1.2.2 STORAGE CHARACTERISTICS

– Temperature: – 10 °C to 60 °C.

1.2.3 INSTALLATION CHARACTERISTICS

1.2.3.1 Links between unit

The AC32e analyzer uses the external links and power supplies illustrated in Figure 1–6 :

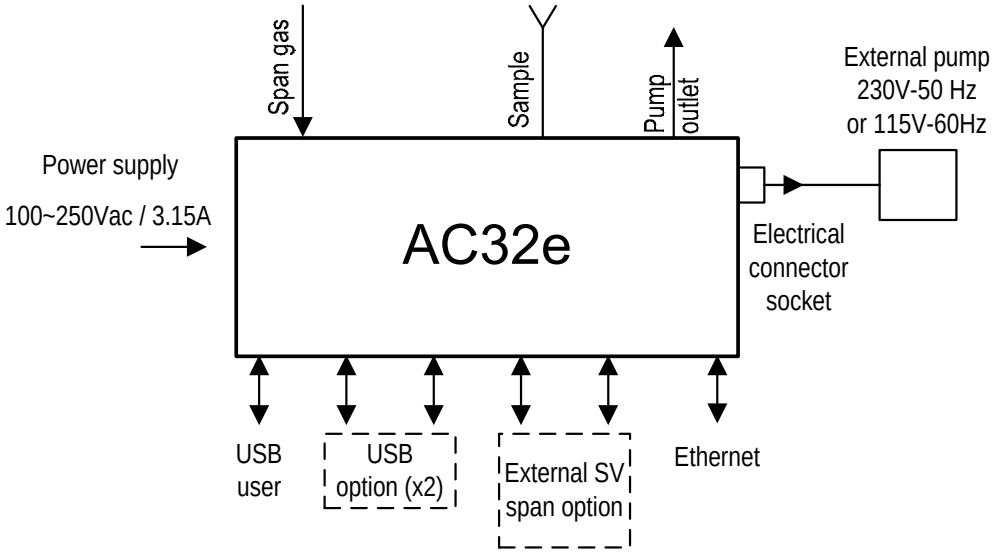


Figure 1–6 – Links between units

1.2.3.2 Dimensions and weight

The analyzer comes in a standard 19-inch, three-unit high rack.

Length : 606 mm

Width : 483 mm

Height : 133 mm

Weight : 10 kg + 4.5 kg (external pump)

1.2.3.3 Handling and storage

The AC32e analyzer must be handled with care to avoid damage to the various connectors and fittings on the rear panel.

Make sure that the analyzer fluid inlets and outlets are protected with caps during handling.

1.2.4 STORAGE

The unit should be stored in the foam-packed case provided for this purpose.

Make sure that the analyzer fluid inlets and outlets are protected with caps during storage.

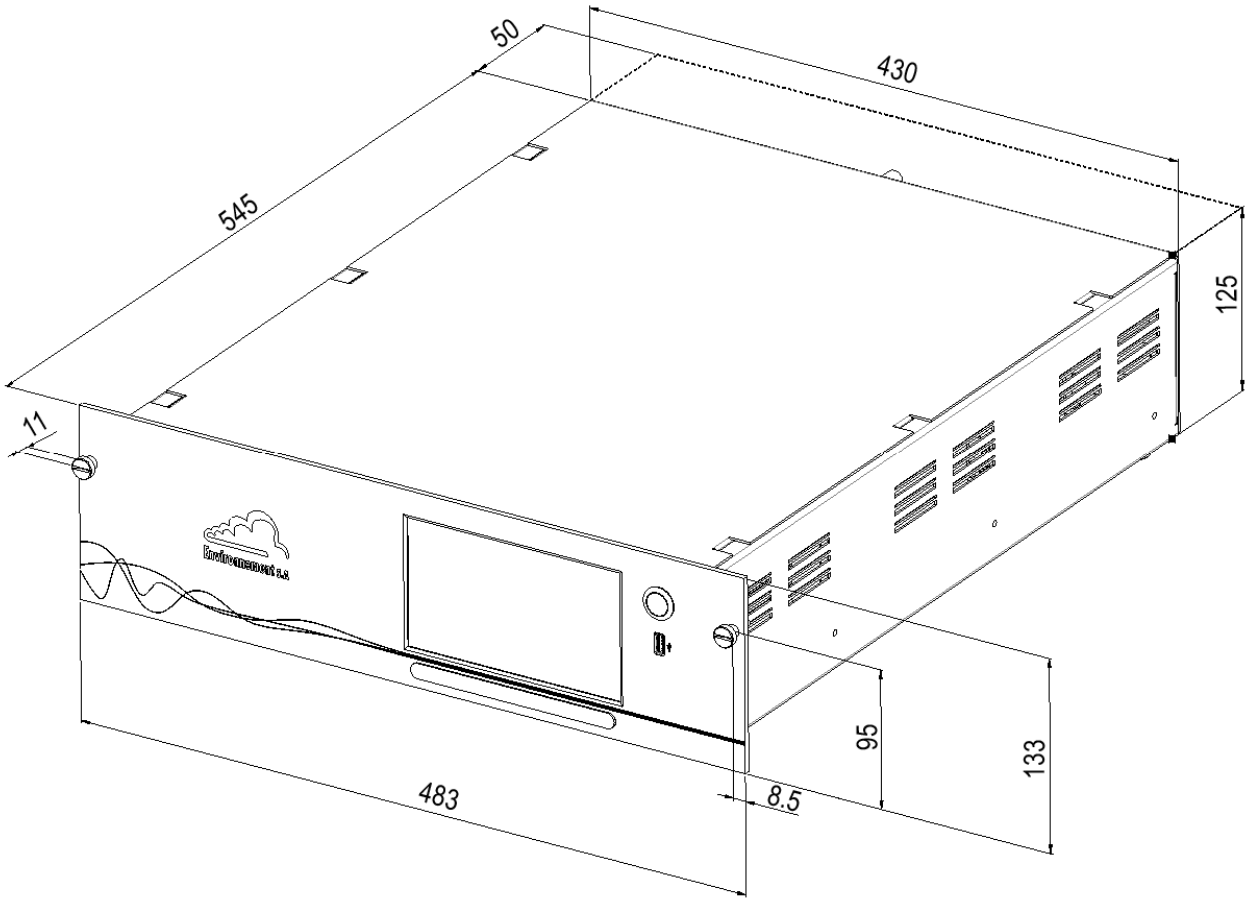


Figure 1–7 – AC32e dimensions (in mm)

CHAPTER 2

OPERATION PRINCIPLE

2. OPERATION PRINCIPLE

2.1 MEASUREMENT PRINCIPLE

Chemilunescence corresponds to an oxidation of NO molecules by ozone molecules:

$$NO + O_3 \rightarrow NO_2^* + O_2$$

The reaction is carried out in ozone excess in order to be only limited by the NO molecules number present in the chamber.

Ozone required for the chemiluminescence reaction is generated from the ambient air by a discharge ozone generator, according to the reaction:

$$3\ O_2 \rightarrow 2\ O_3$$

Ozone excess is removed at the reaction chamber outlet by a catalytic destructor, according to the reverse reaction:

$$2\ O_3 \rightarrow 3\ O_2$$

Return to ground state of the excited NO_2 * molecules is done:

- Either by light radiation on a 600-to-1200 nanometers spectrum:

$$NO_2^* \rightarrow NO_2 + hv$$

- Or by shock with some molecules present in the sample (Quenching) :

$$NO_2^* + M \rightarrow NO_2 + M$$

The probability of shock is reduced by lowering the reaction chamber pressure, allowing a better luminous efficiency. The chamber pressure lowering is obtained with a vacuum pump placed at circuit end enabling also sample circulation.

An optical filter separates the reaction chamber from the detector, it allows passing only the radiation of greater-than-610 nm wavelength, thus eliminating the interferences due to the hydrocarbons chemiluminescence.

A photomultiplier tube carries out the radiation measurement. The electrical signal delivered is amplified and digitized for the microprocessor processing.

To be measured by chemiluminescence, NO_2 must be first reduced to NO. A molybdenum converter is used for this redox reaction:

$$Mo + 3NO_2 \rightarrow MoO_3 + 3NO$$

Measurement is composed into three cycles: zero-reference cycle, NO cycle, NOx cycle.

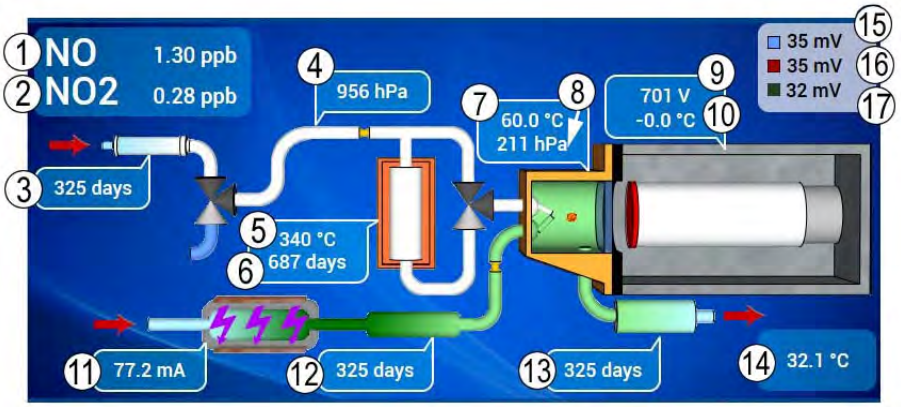
(*) Indicates that the molecule is in an excited status.

The zero-reference cycle:

The sample is replaced by processed air in a Purafil® filled cartridge which oxidizes NO to NO_2. The produced gas is injected into the reaction chamber but it does not generate any chemiluminescence reaction with ozone because it does not contain any NO.

The signal measured by the photomultiplier tube corresponds to the sum of the photomultiplier dark current and the electronics shift voltages.

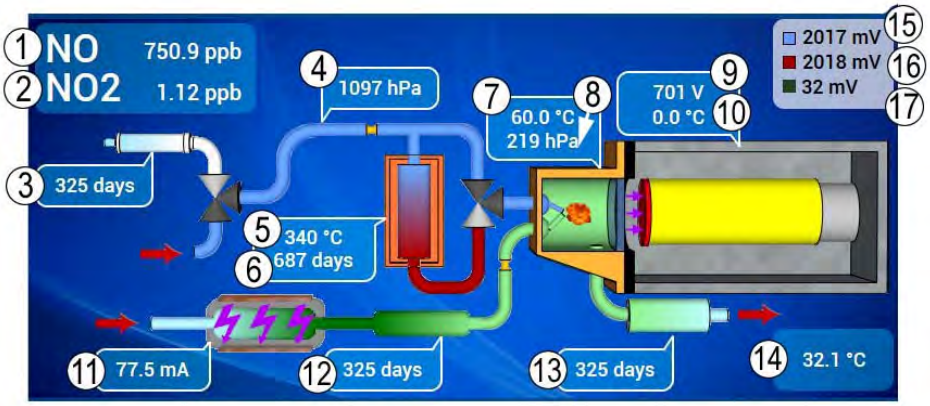
This signal is recorded as a black signal.



(1) NO measurement, (2) NO_2 measurement, (3) zero filter autonomy, (4) sample pressure, (5) NO_x converter oven temperature, (6) NO_x converter oven autonomy, (7) reaction chamber temperature, (8) internal pressure of reaction chamber, (9) high voltage of photomultiplier tube, (10) photomultiplier tube temperature, (11) ozone generator intensity, (12) ozone purifier autonomy, (13) ozone destructor (ozone scrubber) autonomy, (14) internal analyzer temperature, (15) photomultiplier tube signal for NO cycle, (16) photomultiplier tube signal for NO_x cycle, (17)) photomultiplier tube signal for zero-reference cycle (black signal).

Figure 2-1 – Black cycle (zero-reference) diagram

The NO cycle: The sample is directly conveyed into the measurement chamber where takes place the NO oxidation by ozone. The measured signal by the photomultiplier tube, minus the black signal, is proportional to the NO molecules number present in the sample.

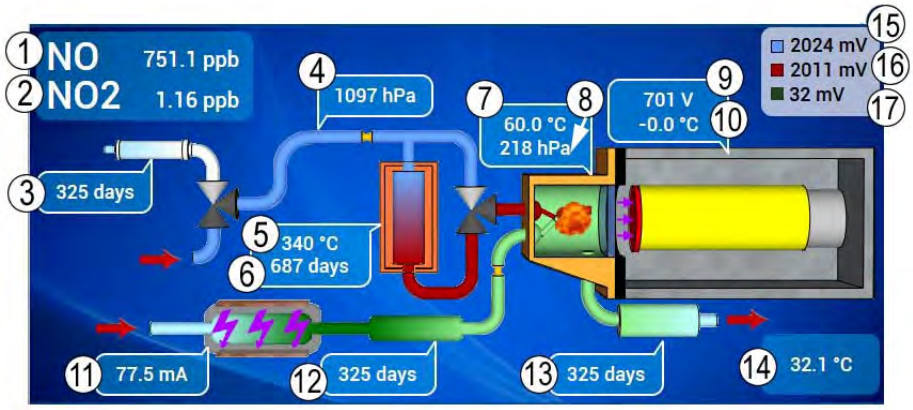


(1) NO measurement, (2) NO_2 measurement, (3) zero filter autonomy, (4) sample pressure, (5) NO_x converter oven temperature, (6) NO_x converter oven autonomy, (7) reaction chamber temperature, (8) internal pressure of reaction chamber, (9) high voltage of photomultiplier tube, (10) photomultiplier tube temperature, (11) ozone generator intensity, (12) ozone purifier autonomy, (13) ozone destructor (ozone scrubber) autonomy, (14) internal analyzer temperature, (15) photomultiplier tube signal for NO cycle, (16) photomultiplier tube signal for NO_x cycle, (17)) photomultiplier tube signal for zero-reference cycle (black signal).

Figure 2-2 – NO cycle diagram

NO_x cycle: The sample passes through the converter oven which reduces NO_2 to NO, then it is mixed with ozone in the reaction chamber.

The measured signal by the photomultiplier tube, minus by the black signal, is proportional to the NO and NO_2 molecule sum (reduced to NO in the converter) contained in the sample.



(1) NO measurement, (2) NO_2 measurement, (3) zero filter autonomy, (4) sample pressure, (5) NO_x converter oven temperature, (6) NO_x converter oven autonomy, (7) reaction chamber temperature, (8) internal pressure of reaction chamber, (9) high voltage of photomultiplier tube, (10) photomultiplier tube temperature, (11) ozone generator intensity, (12) ozone purifier autonomy, (13) ozone destructor (ozone scrubber) autonomy, (14) internal analyzer temperature, (15) photomultiplier tube signal for NO cycle, (16) photomultiplier tube signal for NO_x cycle, (17)) photomultiplier tube signal for zero-reference cycle (black signal).

Figure 2-3 – NOx cycle diagram

2.2 GENERAL PRINCIPLE DIAGRAMS

They are presented in Figure 2-4 and Figure 2-5.

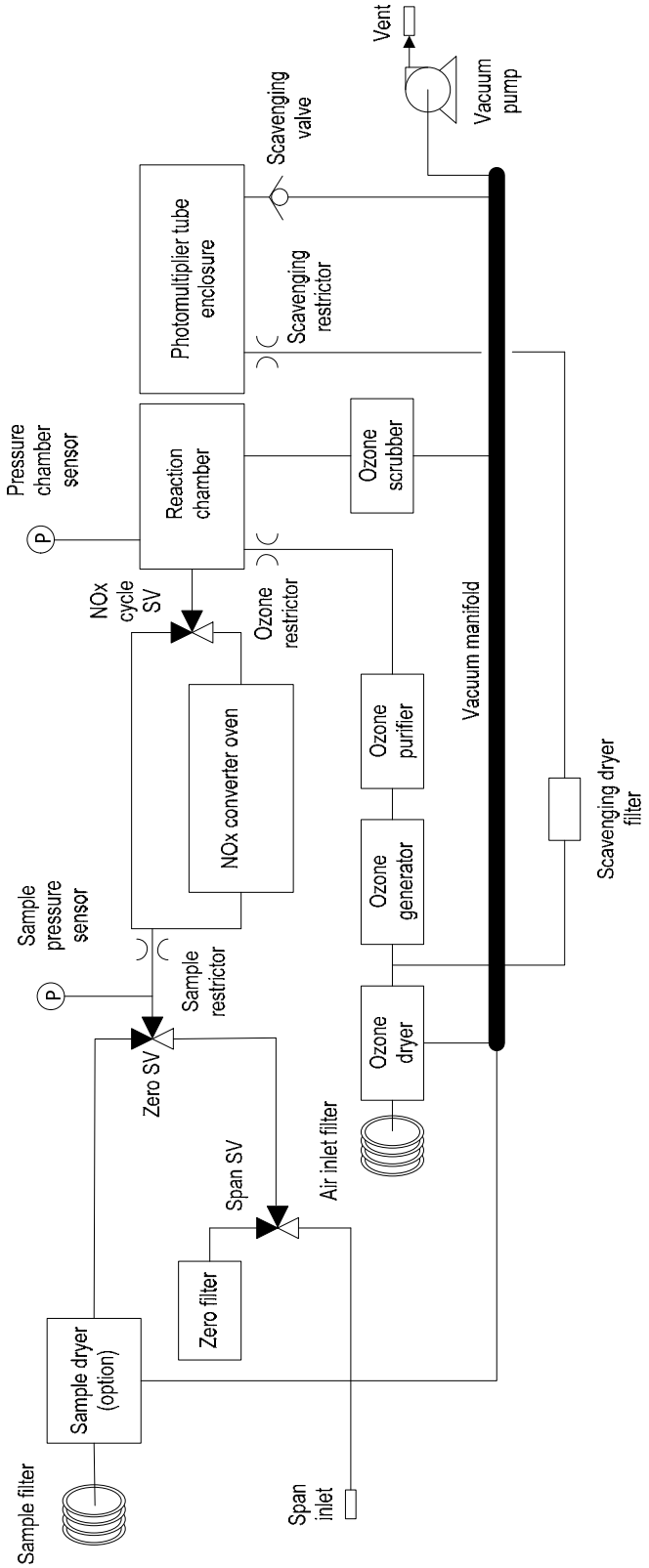


Figure 2-4 – Principle general diagram

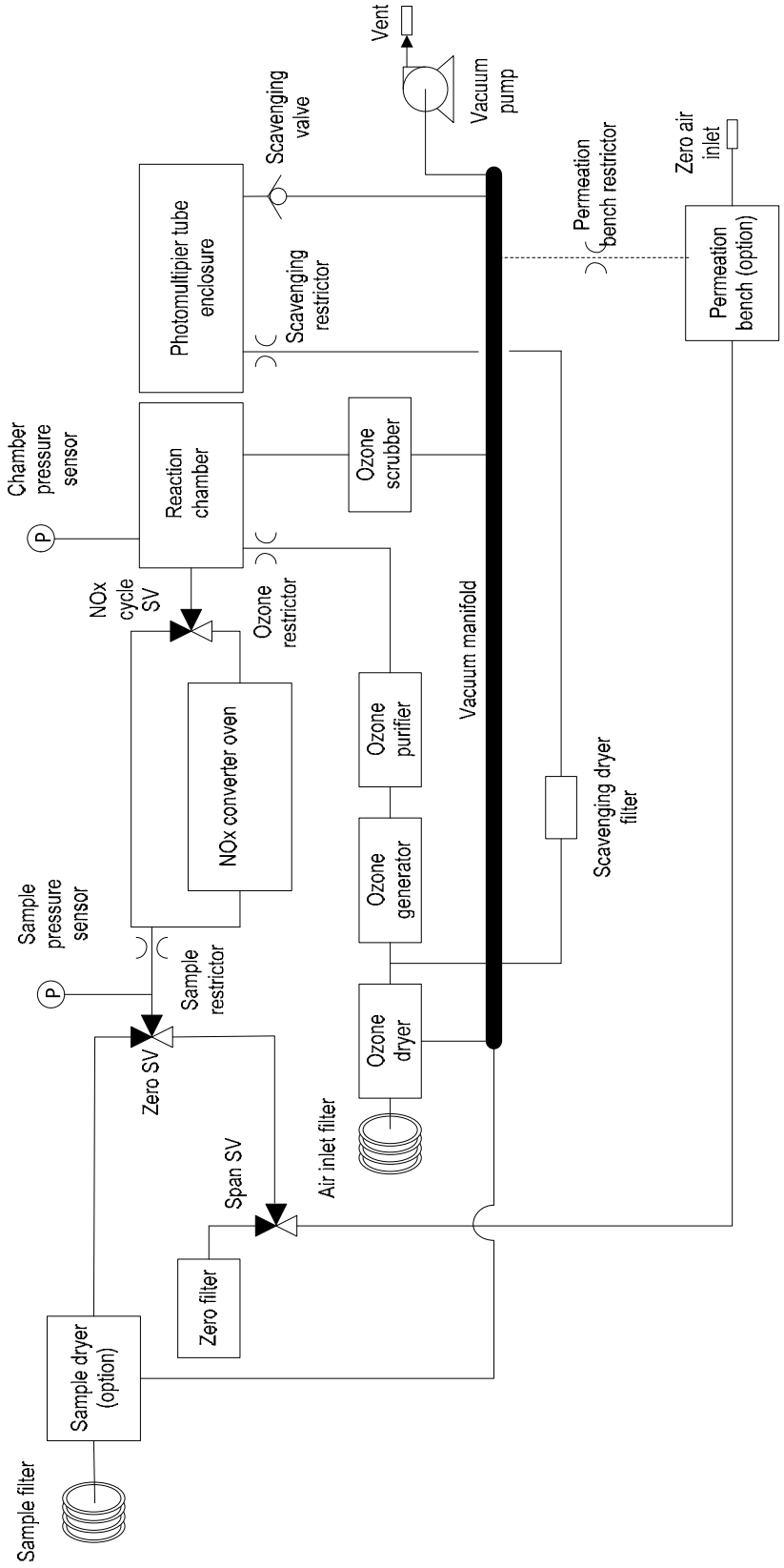


Figure 2-5 – General principle diagram with NO_2 permeation bench option

2.3 MAIN MODULE DESCRIPTION

2.3.1 NOX CONVERTER – OZONE DESTRUCTOR– OZONE PURIFIER ASSEMBLY

The NOx converter is made of a welded block containing molybdenum grids. The assembly is kept to 340°C. by a heating clip equipped with a Pt100 probe and insulated with glass wool. The control board enables the temperature control.

The ozone destructor consists of a removable cartridge including a copper and manganese oxide catalyst. The cartridge is maintained at high temperature since it is near the NOx converter.

The ozone purifier is inserted between the ozone generator and the chamber reaction. It consists of a removable glass cartridge including a reagent to retain impurities contained in ozone.

2.3.2 PM BLOCK (PHOTOMULTIPLIER)

This element is composed of two sub-assemblies: the reaction chamber and the PM enclosure (photomultiplier)

2.3.2.1 The reaction chamber

The reaction chamber is composed of a gold-plated aluminum block. It includes:

- Sample inlet block which receives three couplings:
  - Sample inlet coupler,
  - Sample pressure sensor coupler,
  - Coupler equipped with the sample restrictor which limits the flow towards the cycle valve.
- Ozone input block that includes the ozone restrictor.
- Chamber inlet and outlet fittings as well as the chamber pressure fitting which receive also the couplers.
- Reaction chamber is a cavity closed by a glass window.
- Temperature control to 60°C with a heating resistor and a Pt1000 probe is ensured by the Controller board.

2.3.2.2 The PM enclosure (photo multiplier)

A glass window separates the PM enclosure from the reaction chamber. The photo multiplier tube is placed inside a thermo-conductor tube equipped with a red optical filter.

The thermo-conductor tube is maintained to 0°C by a Peltier double-stage cooler whose radiator is the enclosure cover. The temperature is controlled by a Pt1000 probe screwed into the cold plate attached to the thermo-conductor.

The PM enclosure is put under vacuum to allow the thermal insulation of the thermo-conductor tube. A valve enables to connect the PM enclosure to the vacuum manifold linked to the external vacuum pump.

If the vacuum pump stops, the valve isolates the PM enclosure against a sudden pressure rise while an auxiliary circuit provides a slight dry air scavenging which is opposed to the backscattering of gases contained in the vacuum manifold.

The multiplier tube is connected to the fixed connector which ensures its high voltage supply and conveys the output signal on a coaxial cable.

The fixed connector is linked to the preamplifier board located outside the PM enclosure. The preamplifier board supplies the fixed connector and amplifies the PM signal.

The various cables (PM, Peltier, Pt1000) pass through the enclosure by vacuum-tight flanges.

2.3.3 GAS INPUT SOLENOID VALVE ASSEMBLY

An assembly of two 3-way solenoid valves is used to select one of the three analyzer inlets: « sample », « zero air » or « span gas ». Protection against dust is ensured by a PTFE filter connected to the « sample » inlet.

2.3.4 OZONE GENERATOR DRYER

Air for ozone generator is previously dried with a permeation dryer.

This dryer is made of two concentric tubes. The internal tube is made of Nafion, a special water-permeable polymer, inside which passes the gas to be dried. The space between this internal tube and the external tube contains the drying gas which flows counter-currently. The drying gas is obtained in sampling a part of dried gas and expanding it to reduce further its partial humidity pressure.

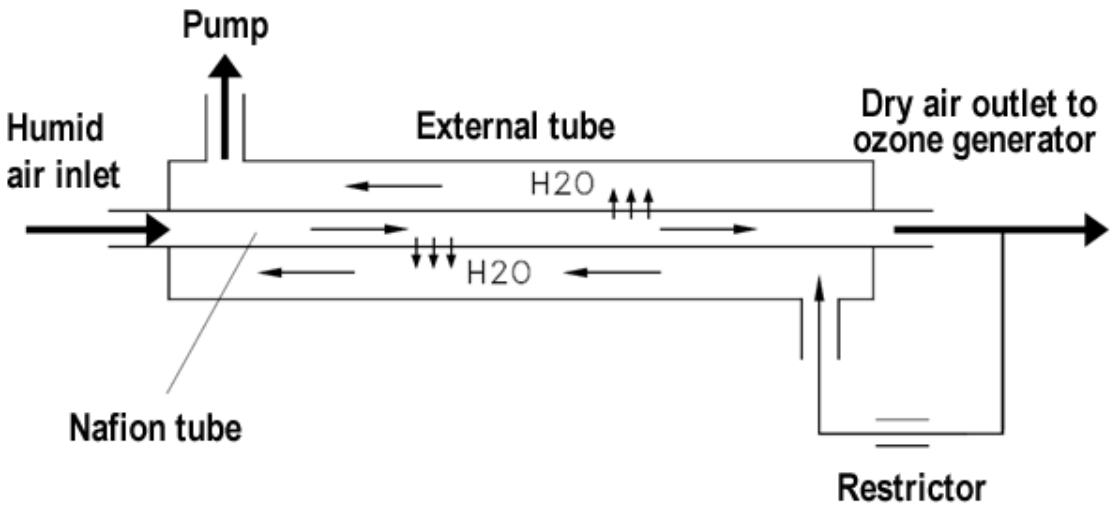


Figure 2-6 – PERMA-PURE dryer

2.3.5 SAMPLE DRYER (OPTION)

The optional sample dryer is inserted between the sample filter and the sample port of the gas inlet solenoid valve assembly. Its operating principle is identical to the ozone generator dryer.

2.3.6 OZONE GENERATOR

Ozone generator is composed of two assemblies:

- an electronic board generating a pulsed signal from the 24V supply,
- a high-voltage block containing the high-voltage transformer and the ozone generator tube.

The ozone generator tube is a double dielectric model: each of the two cylindrical electrodes is associated with its own dielectric which isolates it from the gas. Thus, there is no physical contact between the gas and the electrodes.

The ozone generator tube, the transformer and the high voltage wiring are placed into a casing. They cannot be dismantled and require no maintenance.

2.3.7 CYCLE SOLENOID VALVE

The cycle solenoid valve is installed on a fixed connector allowing connection between:

- NOx converter inlet and outlet.
- Sample restrictor and sample inlet of the reaction chamber.

2.3.8 VACUUM PUMP

Vacuum pump is external.

2.4 RESPONSE TIME PROGRAMMATION

In order to optimize its metrology, the AC32e is equipped with a software function called *Automatic Response Time,* which enables filtration of measurements.

The *Response Time Index,* or *RT*, is an index from which to choose the operating mode; consequently it has no unit. When the index is set to 13 (default), it corresponds to the analyzer's optimum response time, giving both a quick response and a low minimum detection limit.

2.4.1 PRINCIPLE

The RT allows the user to change the analyzer response time. The value of *RT* can be programmed from 01 to 20, which falls into two groups:

- *Manual RT* from 01 to 10
- *Automatic RT* from 11 to 20

01 to 10: For each acquisition 5 seconds time based, a number of elements equal to *RT* replaces the same number of oldest *RT* values in a group of 60 elements. Therefore, the response time varies from 60 x 5 to 6 x 5 seconds. To calculate the theoretical value of the response time (in seconds), it is necessary to **compute: 5 x** $\frac{60}{RT}$.

With *Manual RT*, the user is advised that the greater the RT, the noisier the measurement.

The greater the *RT*, the quicker the response.

11 to 20: The response time is automatically adjusted depending on the measurements. First of all, a group of 60 elements is filled every 5 seconds by [RT] element to form the averaged value calculated as follow:

$$[MEAS]_{AVERAGE} = \frac{1}{60}\sum_{1}^{60}[MEAS]_{INSTANTANE\,OUS}$$

IMPORTANT! Response Time Index [RT] = 13 determines entire buffer refresh every 5 seconds.

Then a weighted average between the filtered values ($[MEAS]_{FILTERED}$) and the average value ($[MEAS]_{AVERAGE}$) is recursively calculated according to the following formula:

$$[MEAS]_{FILTERED(t)} = X \times [MEAS]_{FILTERED(t-1)} + Y \times [MEAS]_{AVERAGE}$$

with (X + Y) = 100%

When the difference ($[MEAS]_{FILTERED(t-1)} - [MEAS]_{AVERAGE}$) exceeds a determined threshold, the value of *Y* is increased up to a 99 % to rapidly reach the concentration read.

When ($[MEAS]_{FILTERED\,(t\text{-}1)} - [MEAS]_{AVERAGE}$) is below the threshold, the value Y is progressively decreased to optimize filtration and noise

The more stable the measurement, the more *X* tends toward 99 %.

2.4.2 PROGRAMMING THE RESPONSE TIME

The *Automatic Response Time* function can be activated or inhibited in the *«Analyzer Advanced configuration»* screen. The minimum response time can also be modified in that menu.

2.5 E SERIES ELECTRONIC ARCHITECTURE

Communication between the ARM20 board and the other electronic boards (Measurement board, Interconnection board, Power supply board, Controller board, Pressure sensor board, et c.) follows the schematic shown below

The ARM20 board is a rapid calculation and interfacing (communication) board for the “e” series measurement modules. It is installed in all analyzers and offers one Ethernet output (RJ45 socket), and three USB ports (one on the front panel, and two on the rear panel through the Interconnection board). For these analyzers, the ARM20 board is the central element for electronic and metrological operation, and outward communication.

The measurement board performs measurement acquisition and operation parameter acquisitions. All metrological parameters are sent to the ARM20 board through an USB communication protocol.

The power supply board provides internal voltages from the 24 V cut-out power supply to the analyzer, as follows:

- +24 V filtered and secured,
- +12 V, for ARM20 board supplying,
- +5 V,
- +3.3 V.

The Controller board performs the main following functions:

- Provides (+ 24V) various power control for the internal solenoid valve switchings.
- Allows temperature acquisition and control management of the various internal heating elements.
- Allows pressure signal acquisition from the various pressure sensor boards.
- Integrates one USB hub to ensure communications between the various boards.

The Interconnection board allows interfacing of Power-supply, Arm20, Controller and Measurement boards, and allows connections of all the connectors and sensors together.

Additionally to the e series standard electronics, AC32e is equipped with the specific boards:

- The PM preamplifier board amplifies the photo multiplier tube signal and ensures the supply of its high voltage fixed connector.
- The RTP (Peltier temperature regulation) board converts in direct current the PWM signal coming from the controller board. This direct current supplies the Peltier module of the photomultiplier tube cooling. The RTP board returns the PM temperature signal to the controller board.

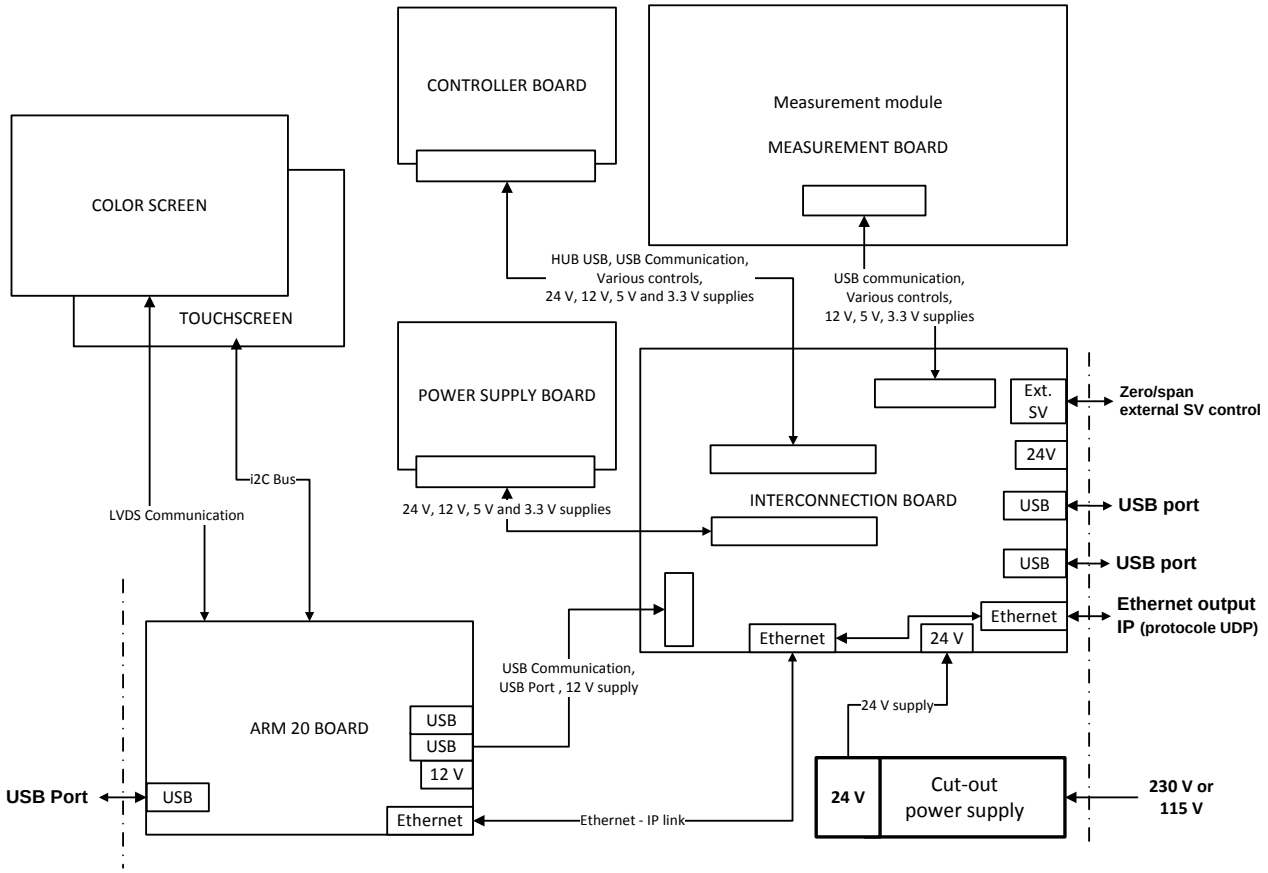


Figure 2-7 – Electronic architecture

2.6 NETWORK LINK AND USB PORTS

– Network link (Ethernet) :

One RJ45 connector is interfaced on the analyzer rear panel via the Interconnection board. Network communication (Ethernet) uses UDP protocol.

– USB ports:

Three USB ports are available in the “e” series electronic architecture.

Page intentionally left blank

CHAPTER 3

OPERATING INSTRUCTIONS

3. OPERATING INSTRUCTIONS

3.1. INITIAL STARTUP

The analyzer is checked and calibrated before delivery. Calibration is verified at the factory.

3.1.1. PRELIMINARY OPERATIONS

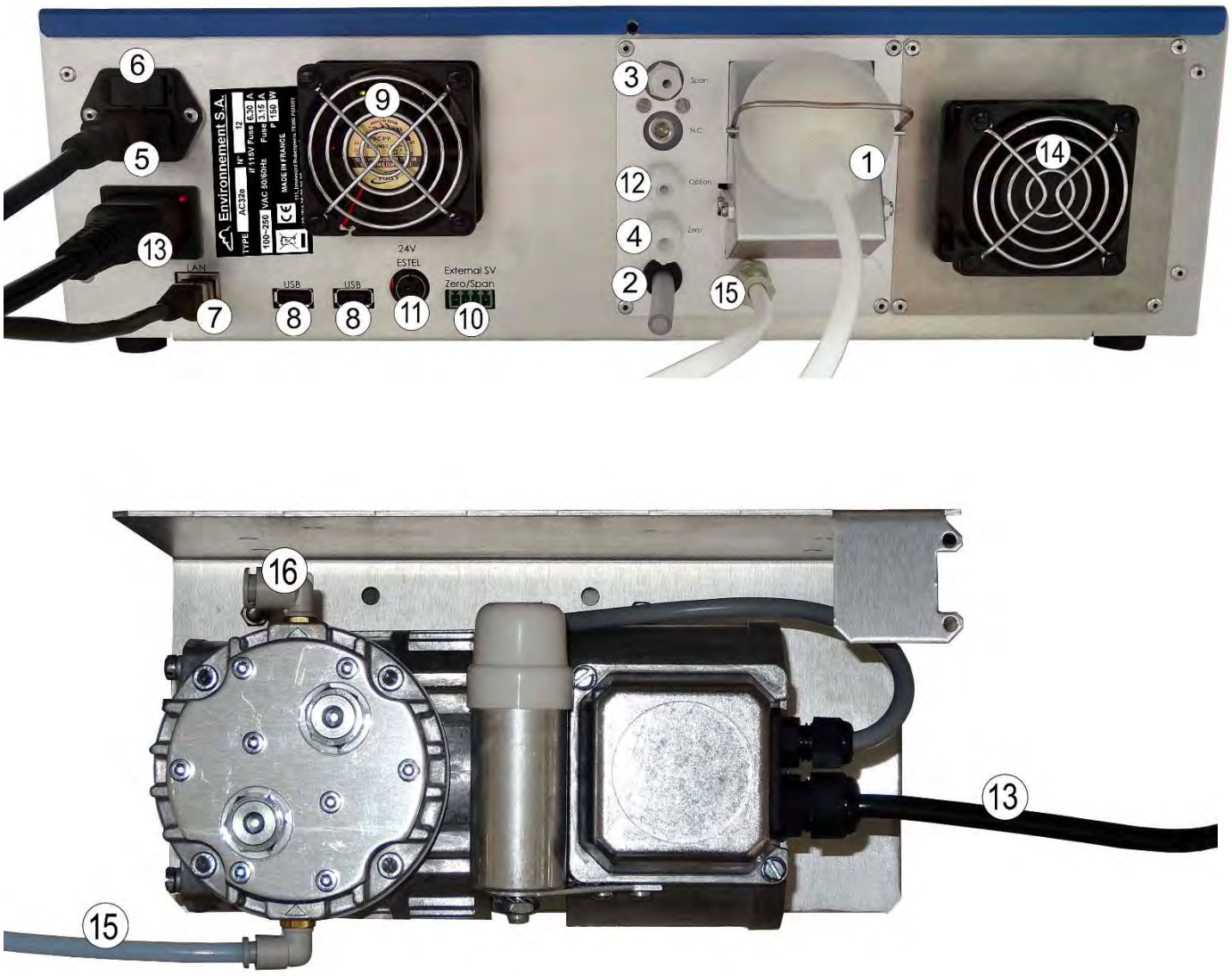
Refer to Figure 3–1.

It is necessary to leave a free space of at least 10 cm (4 in.) between the rear panel and the wall behind the analyzer to ensure correct ventilation of the analyzer.

Start-up involves the following preliminary operations:

- Visually examine the inside of the instrument to make sure no damage occurred during transport.
- Remove the caps from the gas inlet and outlet (1) (3) on the unit (set aside for future storage).
- Make sure a Teflon filter diaphragm is inside the dust filter, and then connect the 4 mm (I.D.) and 6 mm (O.D.) air sampling tube to the sample inlet (1).
- Connect the Ethernet output (7).
- If necessary, connect accessories via USB ports (8),
- Connect the analyzer supply plug (5) with the mains cable to a mains socket fitted with ground.
- Check that the voltage and the frequency indicated on the external pump casing correspond to those of the available mains. Then connect the power supply (13) of the external pump to the rear panel.
- Connect the external pump (15) with a 4 mm (I.D.) and 6 mm (O.D.) Teflon tube.
- Connect the pump outlet (16) with a 6 mm (I.D.) and 8 mm (O.D.) Teflon tube.

NOTE : The analyzer is equipped with a compatible power supply with a 100-240V voltage/50-60 Hz frequency mains. BUT, the available mains must be compatible with the voltage and frequency indicated on the pump casing.



(1) sample inlet, (2) air inlet for ozone generator, (3) span inlet, (4) inlet for external zero air generator, (5) three-contact socket for main power supply, (6) general fuse, (7) Ethernet output, (8) two USB ports, (9) fan, (10) duplicate the zero and span solenoid valves for optional solenoid valve of external calibration, (11) 24 V power supply for ESTEL board option, (12) permeation bench inlet (optional), (13) external pump supply, (14) Peltier fan, (15) external pump fluid connection, (16) pump vent.

Figure 3–1 – Fluid and electrical connections

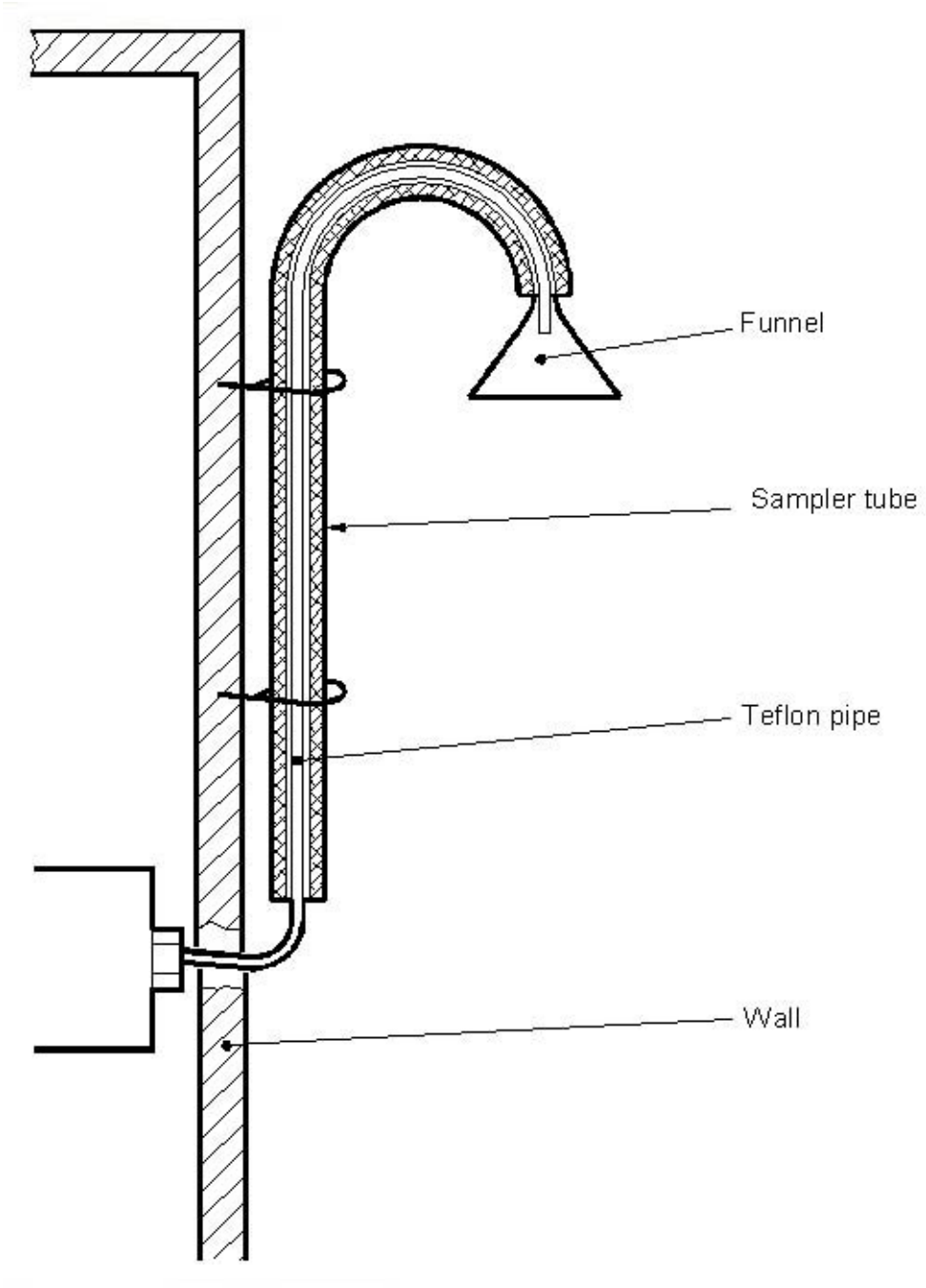


Figure 3–2 – Installation of the sample gas inlet

NOTE : Recommended height for sampling tap: 2.50 m
Maximum recommended length of Teflon sampling pipe: 6 m.

3.1.2. STARTING UP THE UNIT

Starting up the unit consists in carrying out, in the following order, the INSTALLATION / COMMISSIONING procedure described here-below.

1/ Press the ON/OFF push button located on the front panel. The analyzer starts running, it passes into warm-up cycle (duration of which is 1800 seconds maximum). The homepage is displayed: it allows to visualize the warm-up progress period.

The warm-up period is ended when all the metrology parameters are within the operational limits.

The warm-up progress icon will disappear and the analyzer automatically carries out a zero reference:

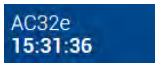
When zero-reference is finished, the progress icon disappear and the following screen is displayed.

This screen is the analyzer standard function homepage. It contains additional pages that are displayed by activating the buttons to , present at the top of the screen. These pages allow the measurement channel display, the *« Real-time graph »* of the instantaneous measurement channel values, and the *« Analyzer synoptic »* giving the main parameter values.

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

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

Button and icon definitions specific to these screens

	Displays the selection buttons of the analyzer fluid inlets:  sample inlet,  zero inlet,  span inlet.
	Warm-up status icon: indicates that analyzer is warming-up.
	Normal operation status icon: indicates that the analyzer operates normally.
	Information area: indicates the analyzer model and time.
	Allows to visualize the warm-up progress status
	Stop button of the current warm-up cycle
	Displays the starting buttons of the analyzer cycles:  starts calibration cycle,  starts zero reference cycle.
	Displays the contextual help
	Displays analyzer information panel.
	Gives access to the advanced analyzer functionalities.

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

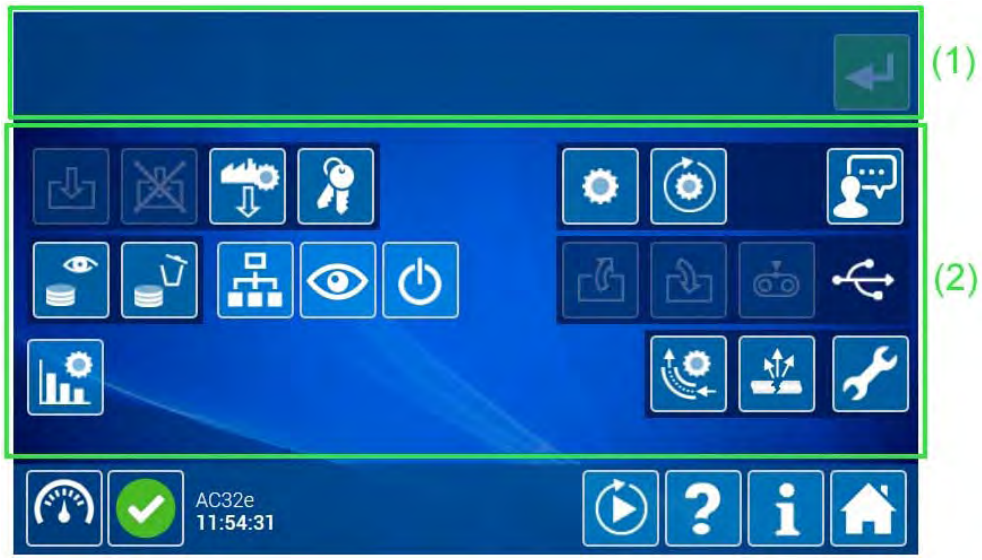
By using the touch screen mounted on the analyzer front panel: touch the button  in order to open the User password input pop-up (1). Touch the field (2) to display the QWERTY keyboard (3).

Touch  in order to switch alphanumeric keyboard to numeric keyboard. Enter the User password and validate with  : the pop-up and the keyboard closes, and the advanced functionalities homepage opens.

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

The button  allows to close the pop-up without input validation.

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



The accessible functions for the User appear in white with a blue background in zone (2). The function access depends of the password's level that was entered.

Each accessible function is activated by contact, it then changes color to green. The name of the selected function will appear in zone (1), and the button  is highlighted  . By double clicking on the function's icon or by using the button  , the user can access to the corresponding screen.

3/ Contextual help functioning

The contextual help is directly accessible through all the screens. The user activates it by touching / clicking on the button  that will become green  . Then, the user touches / clicks on the buttons or on a parametric screen part in order to display a pop-up that describes the use of the selected function or button. The pop-up is closed by clicking on  .

It is necessary to touch/ click on  again to deactivate the contextual help.

See the example below:

(1) Activated button (highlighted), (2) pop-up message explaining the function of the activated button, (3) icon to be used in order to close the pop-up.

3.2. PROGRAMMING THE AC32E

3.2.1. SCREEN AND KEYBOARD DESCRIPTION AND USE INSTRUCTIONS

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

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

3.2.1.1. Definition of the control screen areas

The areas of control screens are defined as follow:

(1)	Browsing area proper to the current screen: when the screen has more than one page, activate the button to allow to display the corresponding page.
(2)	Measurement or configuration area. It displays the measurement parameters (gas, value, units...) or the configurable parameters associated with the selected menu.
(3)	Manual control area: inlet fluid selection and manual launching of calibration and zero reference cycles. Information area and advanced functionality access.

Control and information area (3) description

This area is present in all the screens.

	Activating this button displays the buttons allowing to manually select the fluid inlets of the analyzer: sample inlet, zero inlet, span inlet.
	The icon displayed in this place indicates the currently operating status of the analyzer. The various status icons are: normal operation, warm-up, control, alarm, network disconnected, maintenance, stand-by.
AC32e 15:31:36	Information area indicating model and current time of the analyzer.

	Activating this button displays the buttons allowing to manually start the analyzer cycles: starts calibration cycle, starts zero reference cycle.
	Activating this button displays the contextual help.
	Activating this button displays the analyzer information panel.
	Activating this button gives access to the advanced analyzer functionality home page.

3.2.1.2. Contextual help functioning

The contextual help is directly accessible through all the screens. The user activates it by touching / clicking on the button that will become green . Then, the user touches / clicks on the buttons or on setting screen part in order to display a pop-up that describes the use of the selected function or button. The pop-up is closed by clicking on .

See the example below:

(1) Activated button (highlighted), (2) pop-up message explaining the function of the activated button, (3) icon to be used in order to close the pop-up.

3.2.1.3. Virtual keyboard input

The virtual input screen is used to modify the control screen parameters displayed on the front panel touchscreen. This screen is displayed instantly in the lower half-part of the screen when the user touches an input field to be modified. Two touch-button keyboard types are available: numeric and alphanumeric QWERTY. They are displayed depending on the input field nature: numeric keyboard if the field is numeric type, alphanumeric keyboard if the field requires number and letter inputs.

The examples below are showing the keyboard display in the *« General configuration »* screen. The keyboard operation is identical for all screens.

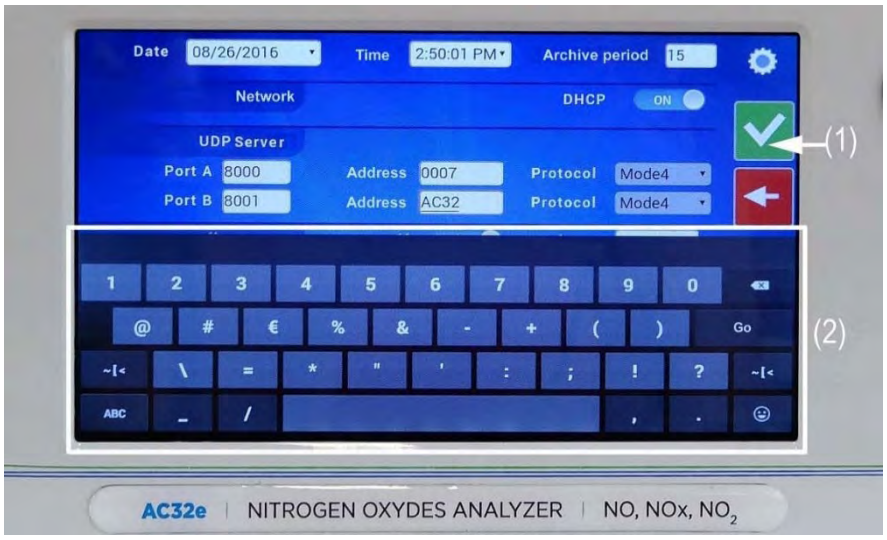
When the user presses down a key, the button (1)  at the top right corner is activated and highlighted to  . It is used to validate the whole inputs done in the screen, and to close the screen after.

NOTE : Field inputs are indexed.

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

The numeric keyboard:

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

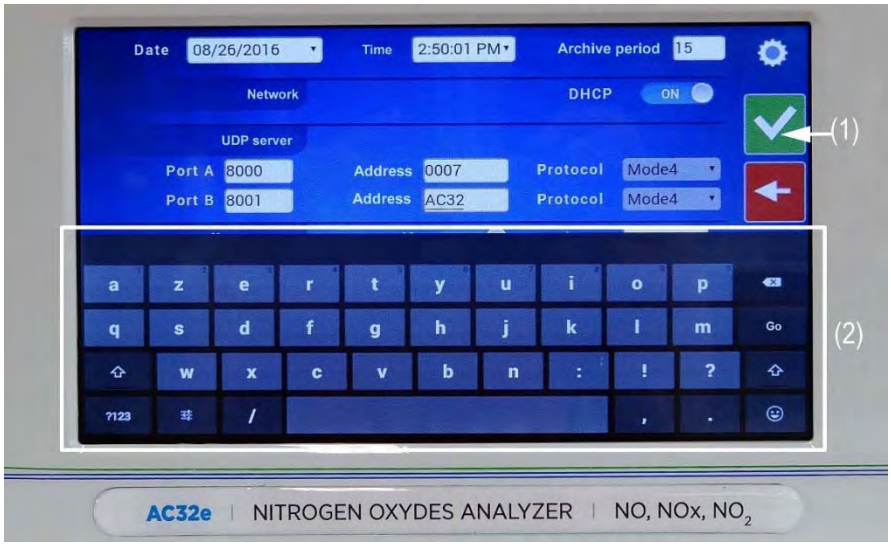


(1) button for input validation, (2) numeric keyboard with touchscreens.

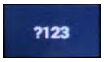
 : clears digits during input.

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

– The alphanumeric keyboard:



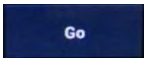
(1) button for input validation, (2) alphanumeric keyboard with touchscreens.



switches from alphanumeric to numeric keyboard.

switches from numeric to alphanumeric keyboard.

switches from numeric to symbol keyboard.



validates input of the considered field.

3.2.2. OPERATION PARAMETER PROGRAMMING

The standard functionalities do not require modifications. The user can only modify the advanced functionality parameters.

3.2.2.1. Field requiring character input

– Using the front panel touchscreen :

Touch the input field to be modified: if the field is alphanumeric, the QWERTY keyboard is displayed, if the field is numeric, the numeric keyboard is displayed.

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

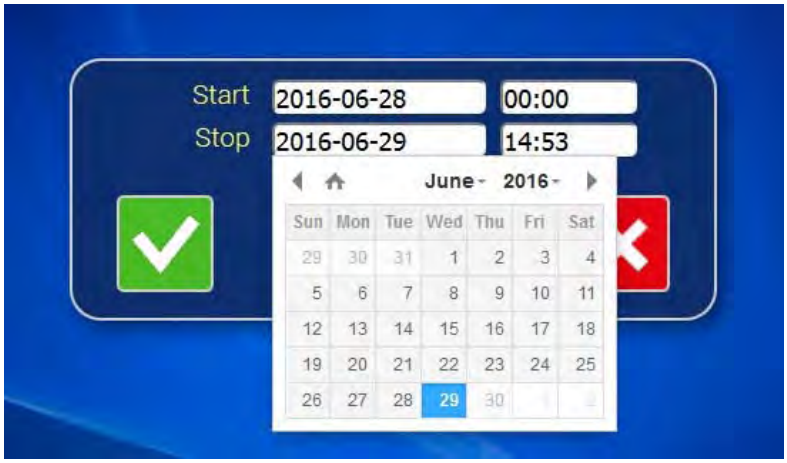
– From a remote PC:

Use keyboard and mouse of remote PC to input, modify and validate the field characters.

3.2.2.2. Fields requiring parameter selection in a list

Many cases are possible, depending on the input type.

Touch the field to be modified. The parameter or value list to be selected is displayed: the current parameter or value is displayed white in blue background. Touch (or click on with the remote computer mouse) the new parameter or value to be selected. The field is displayed white in blue background. Validate with  . The list closes, and this new parameter or this new value replaces the previous.



3.2.2.3. OFF/ON status modification button

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

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

3.3. BROWSING ERGONOMY

The AC32e home page is the following:

By default, the home page displays the SO_2 measurement channel.

From the front panel touchscreen, the homepage allows free (i.e. without password) and direct (i.e. the first browsing level) access to the standard functionalities of the analyzer.

Activating the buttons of top screen  to  allows to drag display sideways to view the *« Real-time graph »* of the instantaneous values of the selected measurement channels, and the *« Analyzer synoptic »* indicating the main operation parameter values.

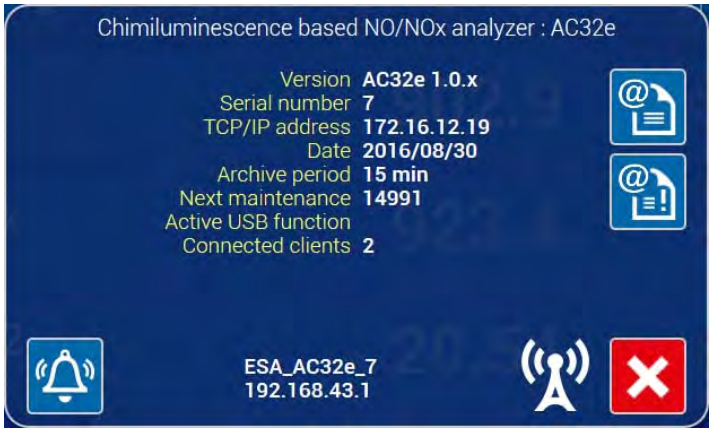
From a remote PC, the page below is displayed first:

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

Standard functionalities are the followings:

	Display of fluid inlet selection buttons.
	Manual selection of sample inlet.
	Manual selection of zero inlet.
	Manual selection of span inlet.
	Display of analyzer status.
	Indication of analyzer model and time.
	Display of analyzer cycle launching buttons.
	Manual start of calibration cycle.
	Manual start of zero reference cycle.
	Display of contextual help.
	Display of analyzer information panel.
	Access to the advanced analyzer functionalities.
	Access to homepage.

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



Icon and button definition specific to the information panel

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

The advanced function access is selectively assigned to password bearers only. There are three possible authorization levels for passwords: user level, advanced level, expert level.

The user-accessible functions are white in blue background. They depend on the hierarchical level of the assigned password.

The access page to the advanced functions is the following:

The analyzer advanced functions are the followings:

	Restores the factory settings. It is recommended to backup before executing this operation.
	Passwords management.
	General configuration. (Address, Protocol, Measurement channels...)
	Automatic cycle configuration.
	Language selection.
	Finds and displays the recorded averages.
	Deletes all the recorded averages (Warning! this operation is irreversible).
	List of the connected clients.
	Diagnostic functions. (alarm, input / output, mux...)
	Sets the analyzer to standby mode.
	Advanced analyzer configuration.
	Automatic flow linearization.
	Test for leaks.

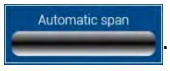
	Sets the analyzer to maintenance mode.
	Returns to the standard functionality home page.
	Gives the USB characteristics (free and total memory) when connected to the analyzer.
	Configuration and software backup on USB when connected to the analyzer.
	Restores software and configuration from USB when connected to the analyzer.
	Records instantaneous measurement on USB when connected to the analyzer.

3.4. ANALYZER FUNCTION DESCRIPTION

3.4.1. STANDARD FUNCTIONS

3.4.1.1. Analyzer controls

The analyzer controls are the followings:

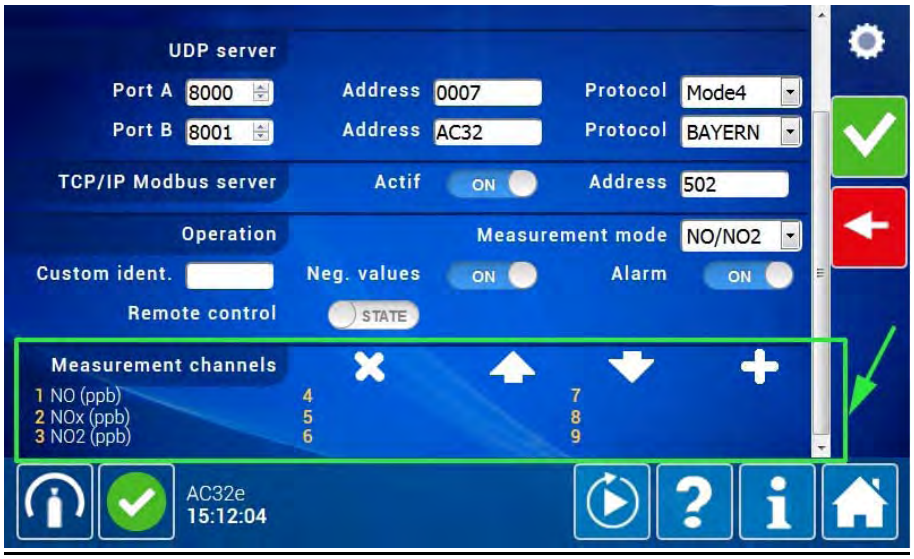
Controls	Function description
 Selects sample inlet	This function switches the analyzer to the sample gas inlet. The gas is continuously sampled through the dust inlet filter. This mode can be interrupted at any time by manually selecting another gas inlet (zero or span). The unit is selected in the *« Advanced analyzer configuration »* screen.
 Selects zero inlet	This function switches the analyzer to the zero gas inlet. This operation allows stability checking and zero drift to determine the need to launch a zero reference cycle or program its repetition period.
 Selects span gas inlet	This function switches the analyzer to the span inlet. The measured span gas value, possibly increased by a programmed offset, is displayed on the screen. This operation allows checking the stability and the span drift to determine the necessity of launching an auto-span cycle or programming its repetition period. An external calibrated span must be connected to this channel.
 Launches a calibration cycle	This function launches manually an automatic span cycle. The user activates  and views the cycle progression in the scroll bar  . At any time, it is possible to abort the current cycle by touching  , or stop the cycle and validating the current cycle by touching  . The current cycle stop results in the « Span Coeff. » value modification. During an automatic calibration cycle, the analyzer adjusts its « Span Coeff.» automatically to equal its reading value (minus the programmed offset) with span gas concentration. The span gas concentrations are programmable in the *« Advanced analyzer configuration »* screen. Adjustment of the cycle duration takes place in the *« Duration »* field of the *« Automatic cycle configuration »* screen. The cycle is finished when the scroll bar is completely grey,  . It closes automatically.

 Launches a zero reference cycle	This function launches manually an automatic zero correction cycle to adjust the zero drift. The user activates  and visualizes cycle progression in the scroll bar  . At any time, it is possible to abort the current cycle by touching  , or stop and validating the current cycle by touching  . The cycle is finished when the scroll bar is completely grey,  , it closes automatically.

3.4.1.2. Measurement channel display

By default, the homepage displays the compound channels to be measured:

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



Touch button definitions specific to this section:

	Deletes the selected measurement channel
	Moves upwards the selected measurement channel
	Moves downwards the selected measurement channel
	Adds a measurement channel

To select additional channels, activate  and open the selection pop-up. There are five channel groups: compound, voltage, sensor, calculation, analog input.

Then, to activate 

to 

in order to display the corresponding group elements, touch/click on the elements to be selected : they become sky-blue highlighted.

Once they are selected, the channels no more appear in the list. This allows not to select the same channel twice.

Then, activates  to validate this selection and close the pop-up. Do the same for the other channel groups: it is possible to select the whole available channels :

« Voltage » channels selection

« Sensors » channels selection

« Calculation » channel selection

The selected measurement channels take place in the numbered fields (see outlined frame with arrow):

When selection is finished, activates  to definitively validate the whole selection, then activates  to display the measurement channels in the home screen (home page of standard functions):

Three measurement channels are displayed per page. To display the whole selected channels, the GUI (graphic user interface) adds as many pages as necessary. These additional pages are symbolized by the buttons and displayed at the screen top (see the outlined frame with arrow). The user clicks-on/touches these buttons to display pages successively.

3.4.1.3. Measurement channel curve display

The user views the measurement channel graphs by touching / clicking-on the next-to-last button in the browsing bar at screen top (see outlined frame with arrow). If no channel was previously selected, the following message is displayed:

Touch / click-on the channel name to select: they change color and are displayed in green, as shown in the screen below:

Go back to the next-to-last page to display the corresponding curves:

The Y-axis scale setting is automatic and adjusted in real time for the current display optimization.

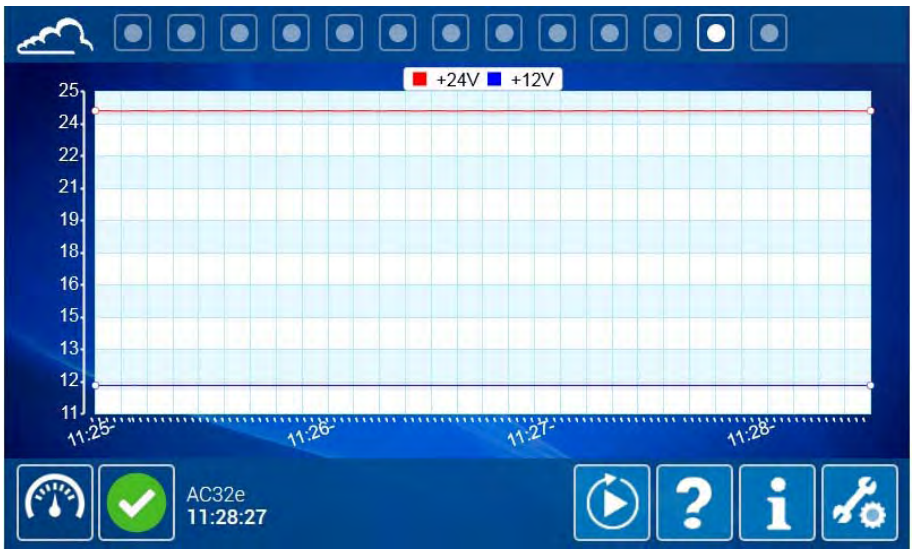
Maximum six curves can be displayed simultaneously.

By touching / clicking in the graph, the user activates the zoom function with the automatic scale, as shown in the screen below:

Switching ON to OFF the« Autoscale » field activates the zoom function with the manual scale, allowing the user setting the Y axis scale as desired.

The user selects the screen zone he wants to zoom:

Then, he touches/clicks on  to validate: the selected zone is zoomed-in in the screen.

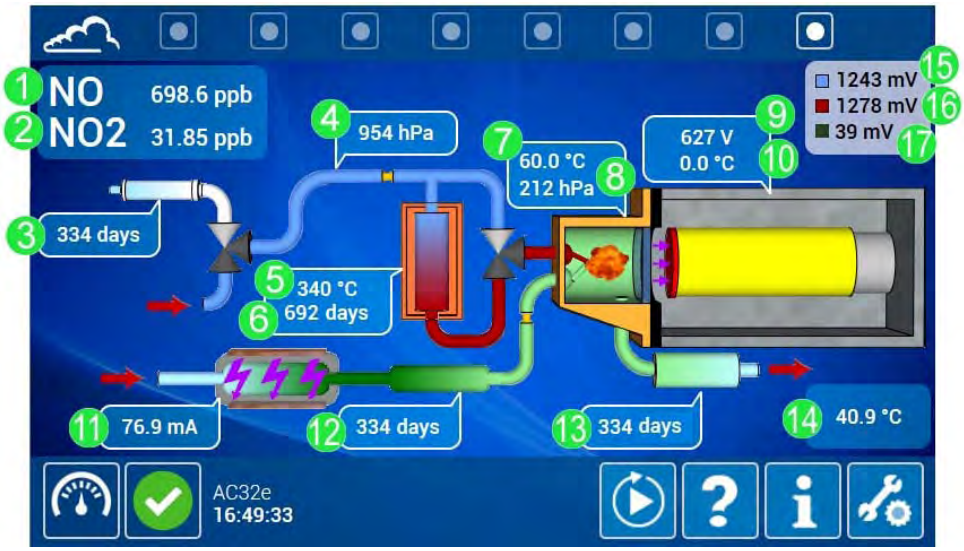


To exit zoom function, the user clicks in the screen two times

This zoom function is available for X-axis and Y-axis.

3.4.1.4. Analyzer synoptic diagram

The user views the synoptic diagram by clicking-on/touching the last button in the browsing bar at screen top (see outlined frame with arrow). This screen displays the entire fluid circuit and the significant operating parameter values.



Screen legends are as follows:

(1): NO measurement,

(2): NO_2 measurement

(3): Zero filter autonomy,

(4): Sample pressure,

(5): NO_x converter oven temperature,

(6): NO_x converter oven autonomy

(7): Reaction chamber temperature,

(8): Pressure inside the reaction chamber,

(9): High voltage of the photomultiplier tube,

(10): Photomultiplier tube temperature,

(11): Ozone generator intensity,

(12): Ozone purifier autonomy,

(13): Ozone destructor (ozone scrubber) autonomy,

(14): Internal analyzer temperature,

(15): Photomultiplier tube signal for NO cycle,

(16): Photomultiplier tube signal for NO_x cycle

(17): Photomultiplier tube signal for Zero-Ref. cycle

3.4.2. ADVANCED FUNCTIONS

The user accesses the advanced function homepage by touching/clicking-on  .

The advanced functions can only be accessed by authorized users with password. Three different password levels are available to authorize selective access: user level, advanced level, expert level.

The whole advanced functions authorized to users with expert level password are described below.

3.4.2.1. Password management

The « expert » user only can activate this function by touching/double-clicking on  to display the password management pop-up.

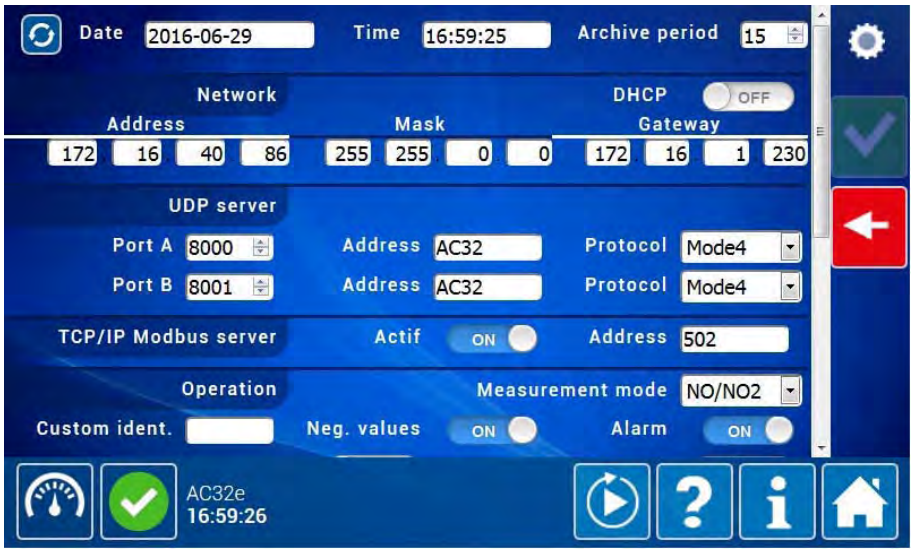
To modify passwords, fill-in the corresponding fields, then touch/click-on  to validate modifications and close the window.

Touch/click-on  to close the window without validating.

3.4.2.2. General configuration

This screen is accessed by touching/clicking-on  .

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



DATE and TIME fields: they indicate the current date and hour of the analyzer. They are modifiable with the « expert » level password only.

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

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

DHCP field: it is used to activate the automatic network configuration.

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

When OFF, the ADDRESS, MASK and GATEWAY fields are displayed to allow the user to define the TCP / IP address, gateway and mask necessary for connection. This can be done with the « expert » level password only.

WIFI/WPA field: it indicates the WPA encryption key of WiFi. It is modifiable with the « expert » level password only (8 to 63 characters, 0-9 and A-F authorized).

UDP SERVER section: it allows configuration of the two available UDP ports, Port A and Port B.

- Port number can be fixed within the range 1000 to 9999.
- Address is only used for Mode4 (four alphanumeric characters) and JBUS (number 0000 to 0255).

They are modifiable with the « expert » level password.

OPERATION section:

- NEG. VALUES field ON/OFF indicates if negative values are authorized or not.
- ALARM field ON/OFF enables or disables the alarm management.
- The MEASUREMENT MODE field defines the analyzer operating cycle. Depending on its options, the analyzer can carry out 3 types of measurement cycle:
  - NO cycle: sample enters the reaction chamber directly.
  - NOx cycle: sample passes through the NOx converter oven, then enters the reaction chamber.
  - Ny cycle: sample passes through the CNH_3 oven, then the NOx converter oven and enters the reaction chamber.

Combination of these cycles results in the following measurement modes: NO, NO/NO_2, NH_3, $NO/NO_2/NH_3$. The default mode is NO/NO_2.

The table below schematizes these measurement methods:

Cycle **Measurement mode**	NO	NOx	Ny
NO	1	0	0
NO/NO_2	1	1	0
NH_3	0	1	1
$NO/NO_2/NH_3$	1	1	1

MEASUREMENT CHANNEL section: allows to parameter the measurement channel displays.

3.4.2.3. Automatic cycle configuration

This screen is accessed by touching/clicking-on  .

This screen allows configuring the four periodic cycles of the analyzer: Zero, Span, Zero-Ref., and Calibration. These cycles can be triggered in automatic or manual mode.

INLET field: allows selecting the channel used for the cycle (Zero, Span, Ref-Zero, Calibration).

PROGRAMMED INLET field: when ON, the analyzer uses the programmed inlet when a cycle is launched manually. When it is OFF, the analyzer uses the active input.

REMOTE CONTROL field: allows triggering cycle on a remote-control input (when optional ESTEL board(s) is/are available...).

CYCLIC field: enables or disables cycle triggering in automatic mode.

DURATION field: allows fixing cycle time.

PURGE DURATION field: fixes purge time. Purge is applied before or after the cycle, depending on the analyzer.

PERIOD field: allows fixing periodicity of automatic triggering.

START HOUR field: allows fixing start hour of automatic cycle triggering. If several cycles are in automatic mode, they will be triggered in the following order: Zero-Ref, Calibration, Zero, and Span.

AT STARTUP field: this field is optional and allows to force a Zero-Ref cycle triggering at analyzer startup (at warm-up cycle end).

3.4.2.4. Language selection

The available languages are English and French.

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

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

3.4.2.5. Find and display recorded averages

This screen is accessed by touching/clicking-on  . It allows setting the data period the user wants to watch, and to display these data.

The user touches/clicks-on  to validate the selection, close the pop-up and display the screen to visualize the recorded averages for the period. Touch/click-on  to close the pop-up without validating date and hour modifications.

Button definition specific to this screen

	exports the displayed data as TXT file.
	opens the selection popup of dates and times period the user wants to view.

Icon meaning

	indicates an average stored with an alarm status. Alarm details are displayed by touching this icon.
	indicates an average stored with a warning status. Warning details are displayed by touching this icon.
	indicates an average stored with a “calibration” status. Calibration details are displayed by touching this icon (zero, span).

3.4.2.6. Delete all recorded averages

Touching/double clicking-on this button  delete all the recorded averages.

WARNING: **this action is irreversible.**

3.4.2.7. List of connected clients

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

Click-on/touch  to close the pop-up.

3.4.2.8. Diagnostic functions

This screen is accessed by touching/clicking-on  . It consists of four pages displayed by touching/clicking-on the white points in the screen top browsing bar.

The first page lists the alarms and significant events taking place currently on the analyzer and allows accessing page 4 for alarm solving.

Button definitions specific to this screen

	Displays or hides all the archived events.
	Displays or hides the simple events. Acts as filter.
	Exports the displayed data as TXT file.

The second page displays the analyzer signal values:

The third page displays the control status, the component list and status when detected on analyzer startup. The ON/OFF buttons are used to check that the corresponding elements are working correctly. When the user exits the screen, the elements return to their standard status.

Alarm solving:

When an alarm triggers, the alarm icon  is displayed at the bottom left side of the standard function screen. The user touches/clicks-on to access the diagnostic function first page displaying the current alarm and event list, as shown below: fields indicate triggering hour and fault nature. The user touches/clicks-on  to access the diagnostic function fourth page.

3.4.2.9. Set the analyzer in standby mode

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

Standby mode is used to stop the pump while all the other controls remain in operation. To reactivate the measurement mode, double-click/touch .

When the analyzer is switched to standby mode, the status icon (in bottom left side of screen) is modified to indicating standby status. However, alarm or control indication is a priority.

Consequently, if the analyzer is switched to standby mode while an alarm or control is active, the alarm icon or control icon will remain displayed and the standby icon will not be displayed.

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

3.4.2.10. Set the analyzer in maintenance mode

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

Maintenance mode activation is used to flag that the analyzer is in maintenance. When maintenance mode is activated, the recorded data are tagged with a status mark: "Maintenance" appears close by the concerned data when they are downloaded.

Double-click on/touch to reactivate the measurement mode.

When the analyzer is switched to maintenance mode, the status icon in the left bottom side of the screen changes to indicating maintenance status. However, alarm or control indication is a priority.

Consequently, if the analyzer is switched to maintenance mode while in alarm or control is active, the alarm icon or control icon will remain displayed and the maintenance icon will not be displayed.

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

3.4.2.11. Advanced analyzer configuration

This screen is accessed by touching/clicking-on . This screen allows configuration of the metrological parameters.

NO, NOx and NO_2 COMPOUND sections:

- *« Unit »* field: selects the compound measurement unit.
- *« Threshold 1 »* and *« Threshold 2 »* fields: fix a limit value to the measurement. If measurement value is out of this limit, an alarm triggers.
- *« Conversion Coef. »* field: displays the coefficient used for unit conversion (for ex. : ppb ➔ µg/Nm^3). This function is only applied if unit is µg/m^3, mg/m^3, g/m^3.
- *« Offset »* and *« Span Coef. »* fields: these two values are used to calibrate the measurement with the linearization curve Y = Ax + B. A is the span coefficient, B is the offset. The span coefficient can be modified by the user or by a calibration cycle.
- *« Zero adjust »* field: allows setting manually the compound baseline (zero).
- *« Delta (%) »* field: when the span coefficient is modified by a calibration cycle, this value indicates the difference between the new coefficient and the previous coefficient. If this value is greater than 50%, a span alarm is triggered. It is necessary to re-validate manually the span coefficient to disable this alarm. When the analyzer is in alarm, it does not take into account the new calculated calibration coefficient, but keeps the previous calibration coefficient.

« Span gas value » field: span gas cylinder concentration used to perform calibration check. This concentration is the reference value to be reached.

« Calib. ON/OFF » field: this field is used when the analyzer can measure many gases. It allows to perform a gas-by-gas calibration with no effect on the other gases. It invalidates or not the auto-calibration for the considered gas.

« Response time » field: shows response time value. Refer to Chapter 2 of this manual for more details.

« Filter autonomy (d) » field: shows the new zero air filter autonomy (day number). The analyzer decrements each day from this value (refer to synoptic display of the standard function screens). A control triggers when it lasts 120-day autonomy, and an alarm is triggers when it lasts one-day autonomy.

« Init. Counter OFF/ON » field: reset filter autonomy to the programmed value after a filter change.

« Dilution OFF/ON » field: used to activate the dilution function and to set the dilution coefficient.

3.4.2.12. Automatic linearization of the flow

This screen is accessed by touching/clicking-on  . It allows to linearize the flow value depending on the corresponding pump set point.

Before linearization launching, the user must connect a flowmeter (0-100 nl/h) to the suitable fluid inlet. Then, he clicks-on/touches the corresponding fluid inlet button  , or  , or  , and he inputs in the « Nominal » field the read value on the flowmeter. Then, he launches linearization by touching/clicking on  . Then, the analyzer will be in a maintenance mode for around 5 minutes.

REMARK: By-default, the in-factory pump setting is 100%.

3.4.2.13. Airproof test

This screen is accessed by touching/clicking-on  . It explains the procedure to follow for performing the airproof test of the analyzer fluid circuit. The user must follow the instructions detailed in the white-outlined frame.

When the user launches the airproof test, the analyzer switches to maintenance mode.

3.5. CALIBRATION

IMPORTANT NOTICE:

Analyzer use, as an equivalent method for EPA reportings, requires periodic multipoint calibration (called multipoint calibration) and subsequent zero/span checks as described below. All gases for calibration must be traceable to a National Institute of Standards and Technology (NIST) reference.

3.5.1. OVERVIEW OF CALIBRATION AND CONCEPTS

To ensure the accuracy of performed measurements using the AC32e analyzer, the unit must be regularly checked, calibrated and adjusted, following the user's quality assurance plan.

- Zero and span check :

  This operation compares the analyzer response, for the zero air and span points, to the used standard gases.

  This check is used to measure the analyzer drift in time without modifying the span coefficients.

  This check can be performed by using the internal zero air and span gas.

  Periodicity: generally 24 hours, in automatic cycle mode.

  Note: by default, the analyzer carries out an automatic zero-reference cycle once a day (typically at 0:00).

- 2-point calibration:

  This procedure is used for checking and correcting the analyzer response to zero and span points located at approximately 0 % and 80 % respective of the full scale of the measurement range used.

  Periodicity: monthly, or more frequently if the installation requires it.

- Multi-point span:

  This procedure involves a complete checkup of the analyzer's linearity performance.

  Periodicity: quarterly, or following out-of-tolerance calibration check results requiring analyzer intervention.

> *Note about gas cylinder connections:*
>
> The analyzer is equipped with an internal zero filter. The span inlet or sample inlet has to be used to connect the internal zero filter to an external zero air supply.
>
> When the analyzer is equipped with an internal permeation bench, the calibration gas supplies have to be connected to the sample inlet.

Note about gas generation devices:

For pressurized gas devices, it is necessary to provide an excess system to deliver gas at atmospheric pressure to the analyzer inlet. The device materials should be neutral for the gas used. When the device is used in automatic cycle with a cylinder, it is necessary to provide a shutoff solenoid-valve remote-controlled by the analyzer (refer to Figure 3–3).

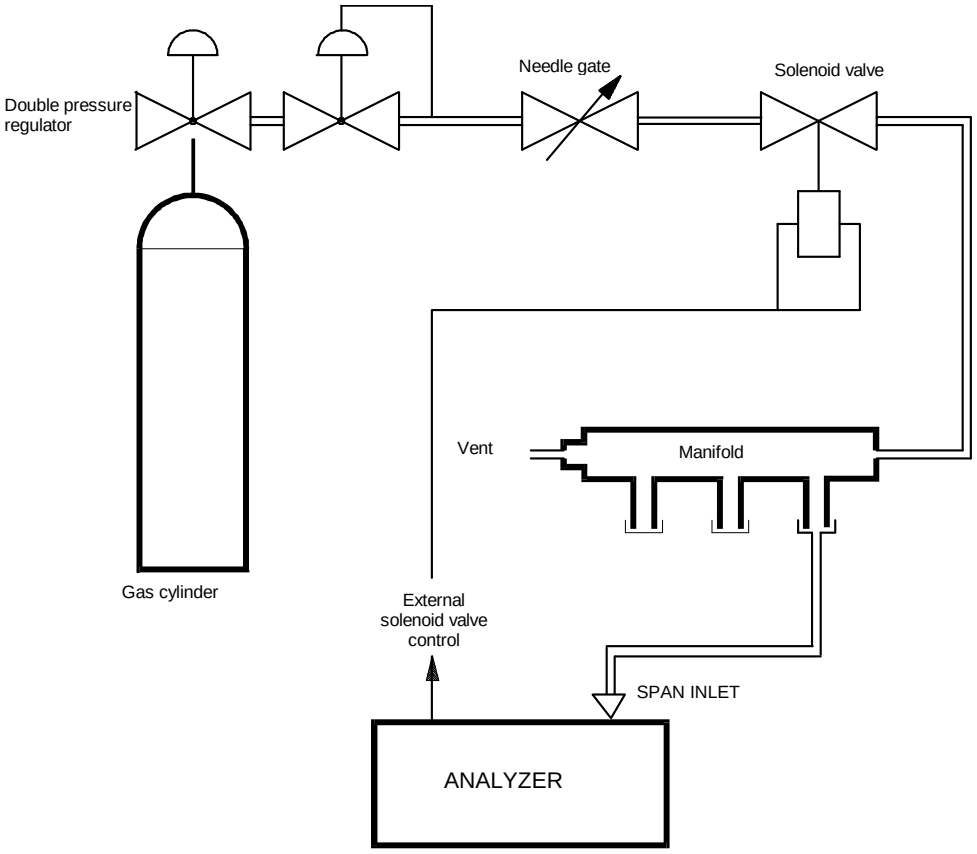


Figure 3–3 – Example of a pressurized gas connection

3.5.1.1. Zero air generation

Zero air can be used for zero checking or as a diluent in a gas dilutor. Several sources can be considered:

Internal zero filter. The internal zero filter (Purafil) is designed to oxidize NO to NO_2, which is sufficient to perform the zero-reference on NO cycle. But this filter does not completely remove NO_2, consequently it cannot be used to check the zero of the NOx channel.

External zero filter. NOx can be eliminated by associating:

- Purafil, at inlet, to oxidize NO to NO_2.
- Activated carbon, at outlet, to absorb NO_2.

A 1/4 liter volume of each adsorbent is sufficient for the analyzer inlet flow rate.

Moisture can be removed by inserting a silica gel cartridge before this filter.

Synthetic air cylinder. It is a mixture of 80% nitrogen and 20% oxygen.

Nitrogen cylinder, minimum 5.0 quality. WARNING: Nitrogen is not suitable for TPG diluent (TPG: gaseous phase titration).

Zero air generator. A zero air generator includes an air compressor and several filtration systems to remove moisture and gases measured by the analyzer. The zero air is supplied under pressure and can supply a diluter.

In all cases, zero air must contain less than 0.5 ppb NOx.

The zero air sources must be appropriate to their possible use.

	Internal filter	External filter	Synthetic air	Nitrogen	Generator
Zero reference	YES	YES	YES	YES	YES
NO zero check	YES	YES	YES	YES	YES
NOx zero check	NO	YES	YES	YES	YES
Permeation bench	NO	YES	NOT RECOMMENDED	NOT RECOMMENDED	YES
Diluent for dilutor	NO	NO	YES	YES	YES
Diluent for TPG	NO	NO	YES	NO	YES

NOTE : A permeation bench requires a permanent zero gas flow of for the tube scavenging, which can quickly empty a synthetic air or nitrogen cylinder.

3.5.1.2. Span gas (NOx) generation

The possible gas supplies are the following:

- **NO cylinder diluted** in nitrogen 80 % concentration of full scale i.e. 800 ppb with NOx titration (see Figure 3–3).
- **(Internal or external) permeation bench** equipped with NO_2 tube and supplied with dried air.
- **Gas dilutor** connected to NO cylinder pre-diluted in nitrogen (typically 50 ppm) with NOx titration, and to a zero air generator. The diluter can be equipped with an ozone generator for TPG (gaseous phase titration).

The precautions to be taken are:

- Gas cylinders must be equipped with a double-stage expansion valve to ensure a stable outlet pressure.
- When installing the expansion valve on a NO-in-nitrogen mixture cylinder, a purging procedure must be followed to avoid the air initially contained in the expansion valve return to the cylinder where it will oxidize NO, and consequently modify its concentration.
- The connection between the NO pre-mix cylinder and the diluter must preferably be done with a metallic tube (stainless steel). Plastic tubes (mostly PTFE) are permeable to oxygen which can false the NO concentration at the diluter inlet.
- The diluter-to-analyzer connection can be done with PTFE or PFA tube.
- All fittings, valves, pneumatic lines and other elements that may be in contact with span gases must be manufactured with highly inert-to-NOx materials (i.e., PTFE, PFA, glass or stainless steel).
- Zero air sources must be appropriate to their possible use.

	NOx diluted cylinder	Permeation bench	Simple dilutor	Dilutor with ozone generator
Scale point checking	YES	YES	YES	YES
2-point calibration	YES	YES	YES	YES
Multipoint calibration	NO	NO	YES	YES
NOx converter TPG	NO	NO	NO	YES

NOTE : The span gas cylinders used must be certified according to the user's quality assurance plan.

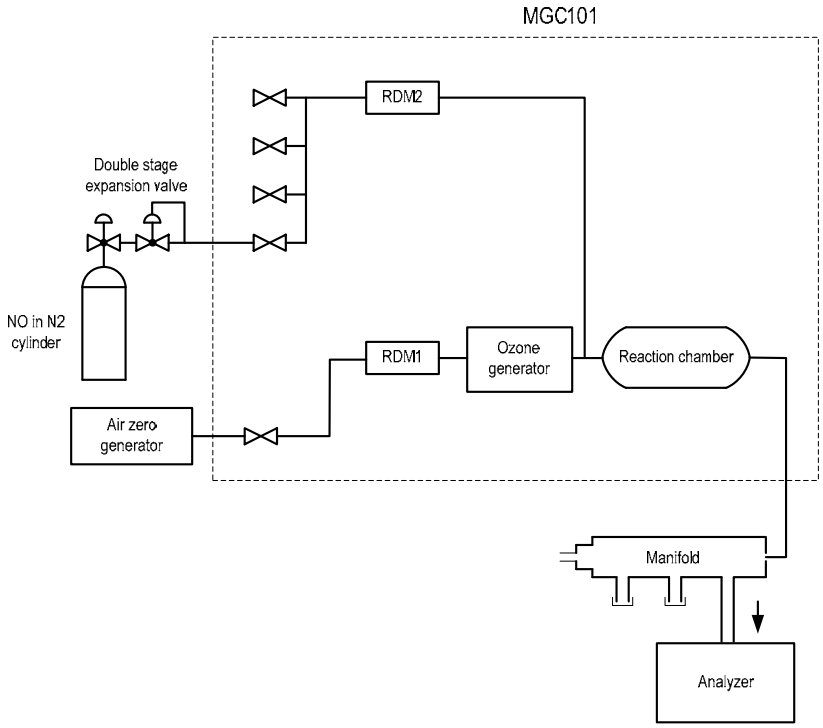


Figure 3-4 – Calibrator connection diagram

3.5.1.3. Internal solenoid valves

AC32e is equipped with an inlet selector with 2 solenoid valves allowing to select one gas inlet to be analyzed between 3 inlet ports:

- The zero inlet, with internal zero cartridge (Purafil). This inlet is automatically selected by the auto zero reference cycle.
- The span inlet, available on the rear panel.
- The sample inlet, available on the filter holder of the rear panel.

Sample and span inlets can be used for zero and span chekings. The user must verify that the analyzer response is the same for these two inlets. Otherwise, the internal solenoid valves must be cleaned or replaced.

3.5.2. ZERO AND SCALE POINT CHECKING

3.5.2.1. Required tools

– Zero checking:

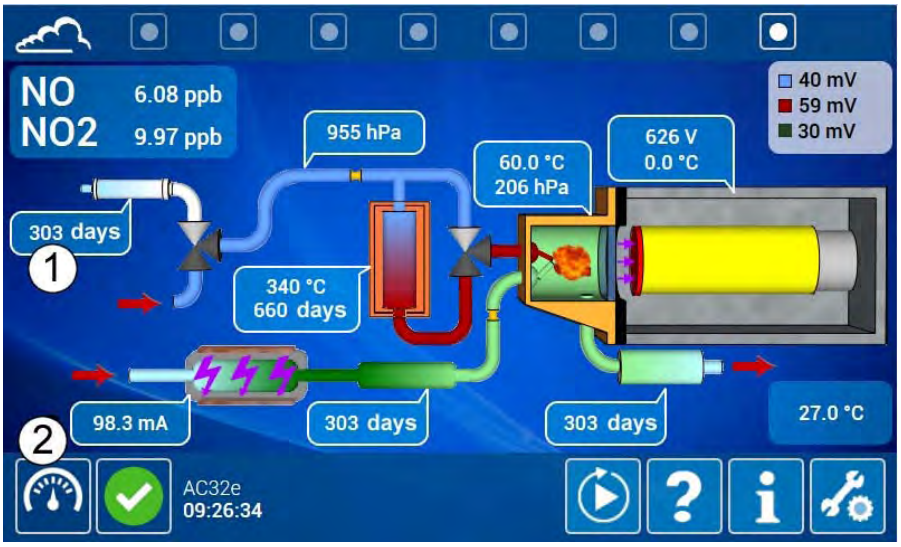
Use the internal zero filter, otherwise connect the zero air supply to the sample or span inlet.

– Span point:

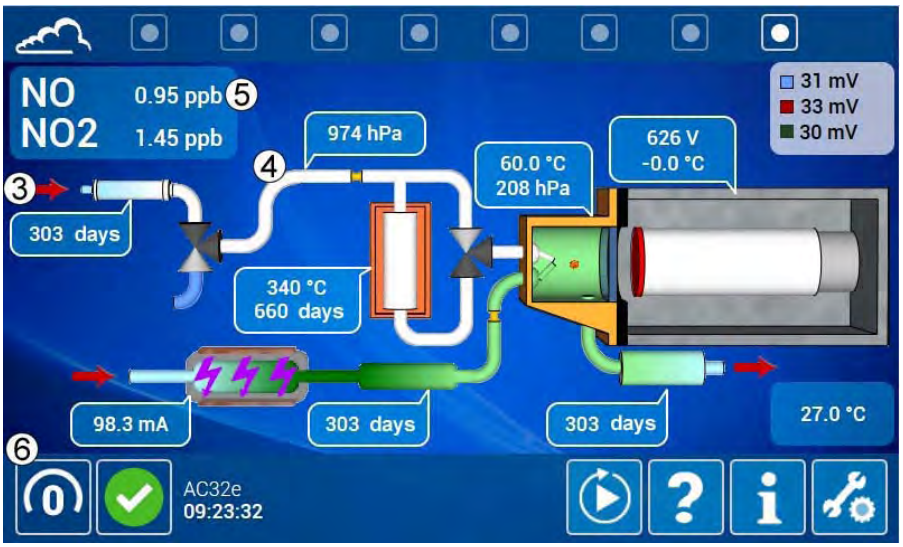
Connect the span supply to the span port.

3.5.2.2. Procedure

– Zero checking:



On the synoptic screen (1), check that the internal zero filter autonomy is greater than 30 days, touch/click on the button (2) to display the inlet port selection , , and touch/click on to select the zero inlet.

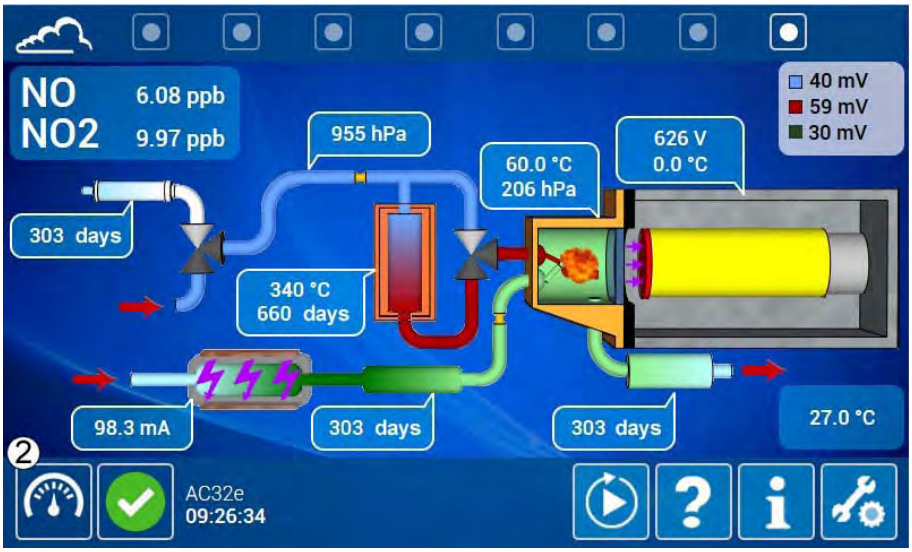


The gas inlet arrow on the synoptic screen moves in front of the zero filter (3), the fluid color changes from blue to white (4) and the zero inlet icon appears at the left bottom side of the screen (6).

Wait for the measurement to stabilize. The NO measurement (5) must be within ± 2 ppb (taking offset into account if programmed). Otherwise, it is necessary to carry out a zero reference.

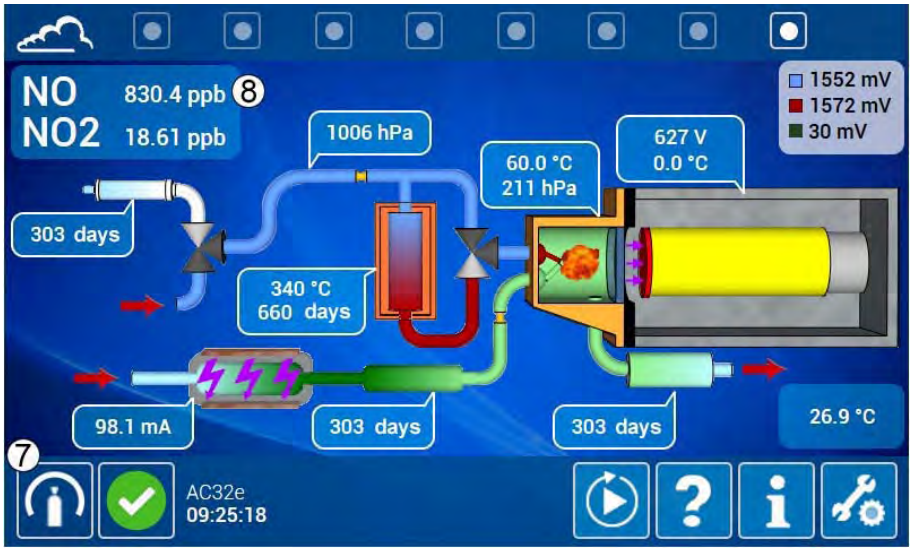
– Span checking:

Check that the span inlet is connected to the span gas supply, touch/click on the button (2) to display the inlet port selection , , , and touch/click on to select the span inlet.



The span inlet icon is displayed at the left bottom left side of the screen (7).

Wait for the measurement to stabilize. The result (8) will be compared with the generated concentration by the device used, taking into account its accuracy, as well as a possible programmed offset.



3.5.2.3. Use of automatic cycles

For cycle programming, touch/click on the button to access the *« Automatic cycle configuration »* screen (see paragraph 3.4.2.3).

– Zero-reference cycle:

The zero air filter is permanently connected to the analyzer zero inlet. The recommended duration for zero checking is 60 seconds and 30 seconds for purge, as indicated in the Duration field of the Cycles / Zero column in the screen below.

The « ON » programmed inlet (8) forces the analyzer to use the programmed inlet (9) which is the zero port in the screen below.

WARNING: if the programmed inlet is « OFF », the analyzer uses the port in operation before the cycle (10), i.e. the sample port in the example below.

The « ON » cyclic tab (13) forces the analyzer to perform zero-reference every day at 00:00.

The « ON » at startup tab (14) forces the analyzer to perform zero reference at each restart.

– Calibration cycle:

The span gas generation device is permanently connected to the analyzer span gas inlet port. The recommended duration for the calibration cycle is 120 sec and 60 seconds for purge, as indicated in the Duration field of the Cycles / Span column in screen shown below.

WARNING: these durations only take into account the analyzer response time. If the span gas supply is remote and requires a stabilization time, this duration must be integrated into the purge duration.

The « ON » programmed inlet (11) forces the analyzer to use the programmed inlet (12) which is the span port in the screen below.

WARNING: if the programmed inlet is « OFF », the analyzer uses the port in operation before the cycle (10), i.e. the sample port in the example below.

3.5.3. Two-point calibration

3.5.3.1. Tools required

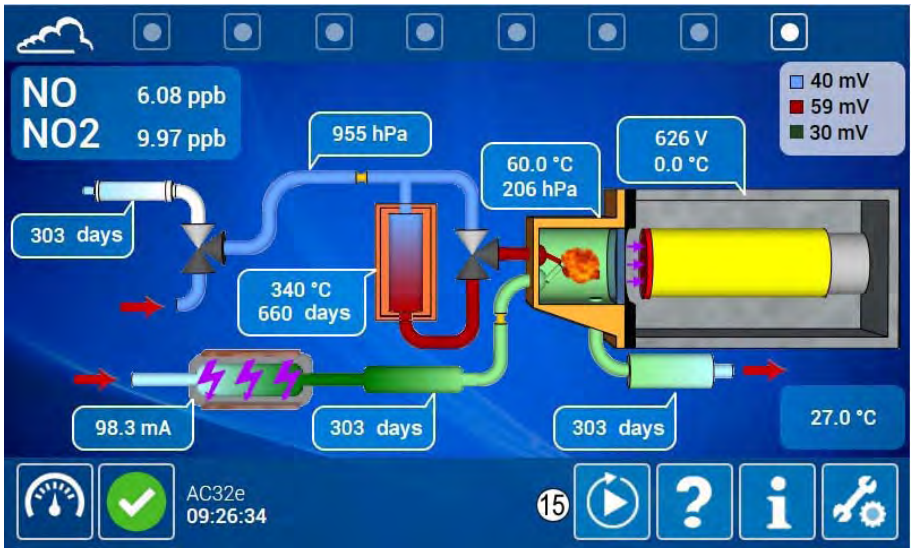
See paragraph 3.5.2.1.

3.5.3.2. Procedure

– Zero-reference:

Touch/click on the button (15) to display the automatic cycle controls  and  .

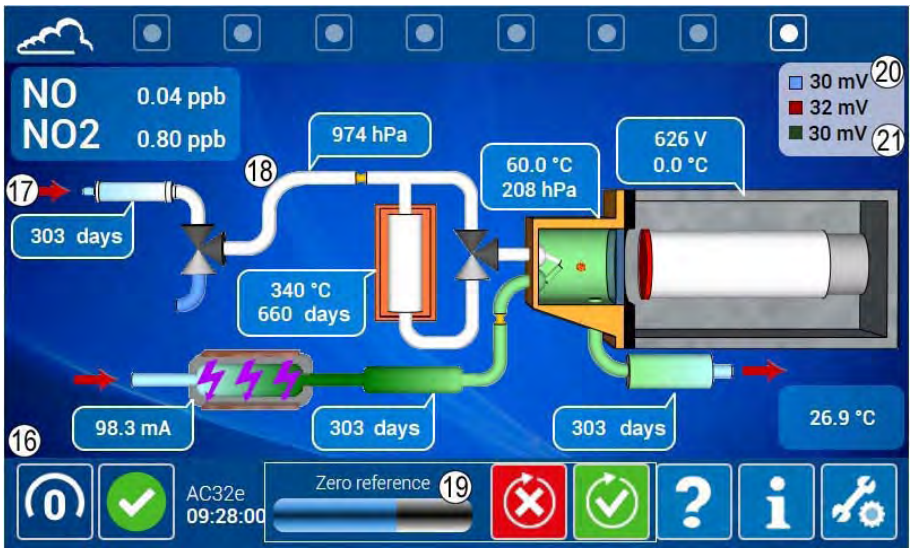
Use  to start a zero-reference cycle according to the control panel in paragraph 3.4.1.1.



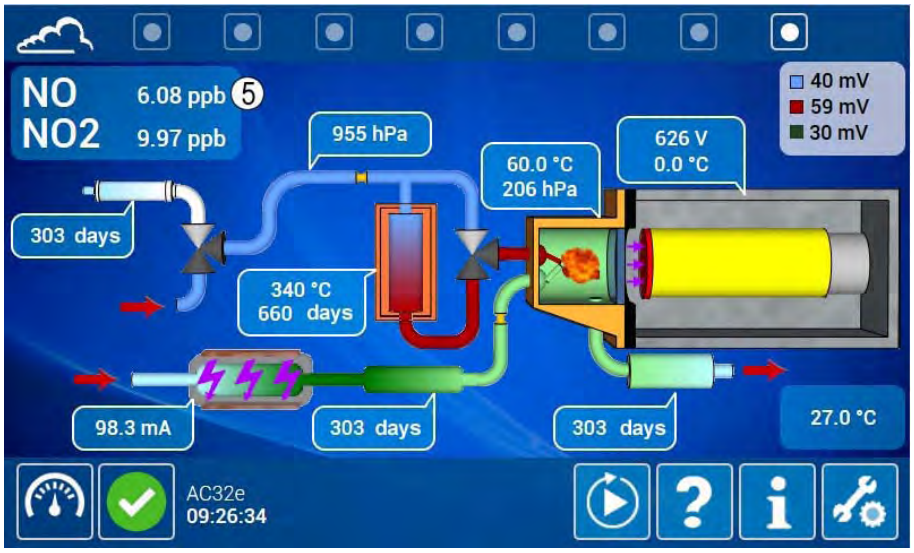
The gas inlet arrow on the synoptic screen moves in front of the zero filter (17), the fluid color changes from blue to white (18) and the zero inlet icon is displayed at the left bottom side of the screen (16).

A progress bar (19) is displayed on the screen.

The NO signal (20) decreases and stabilizes, and the black signal stores this value (21).



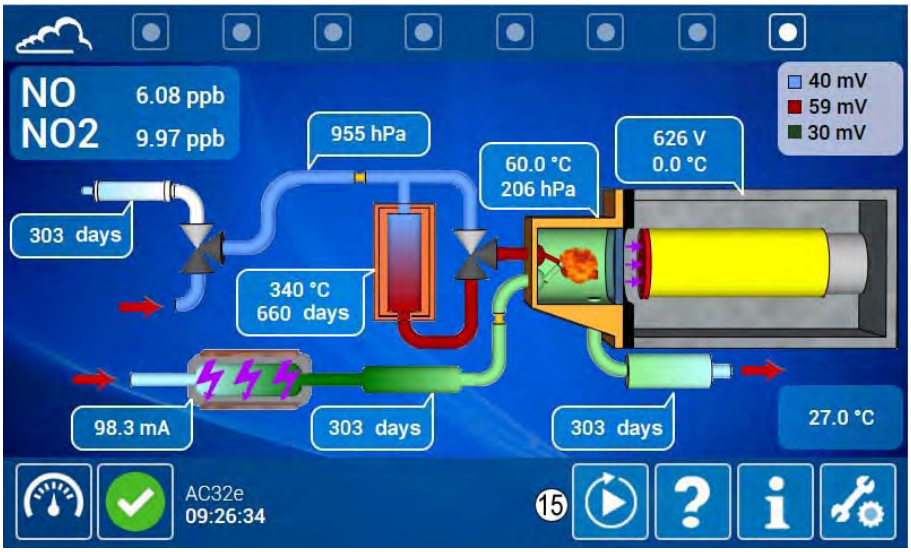
The NO measurement (5) must be within ± 0.5 ppb (taking offset into account, if programmed).
At the cycle end, the analyzer automatically returns to the initial measurement configuration.



– Scale point calibration.

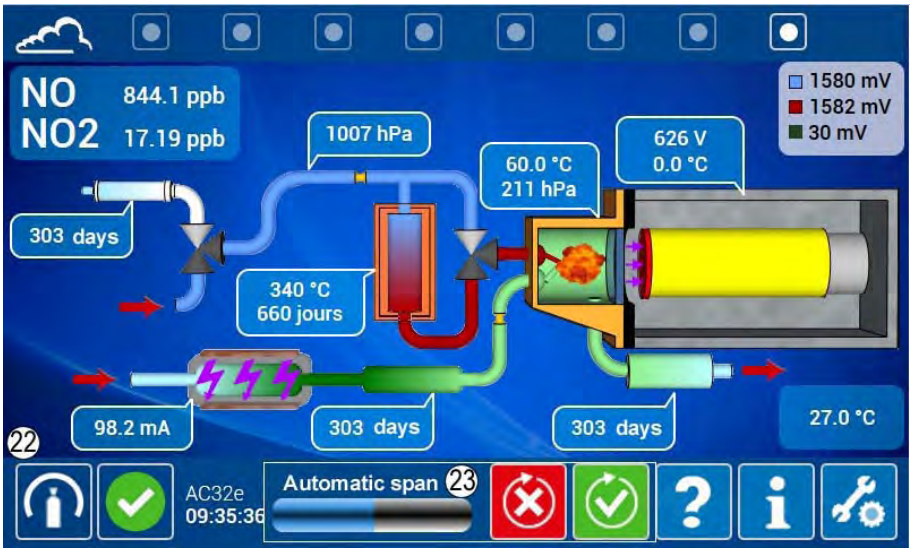
  Check that the span inlet is connected to the span gas supply. Touch/click on the button (15) to display the automatic cycle controls  and  .

  Use  to start a calibration cycle.



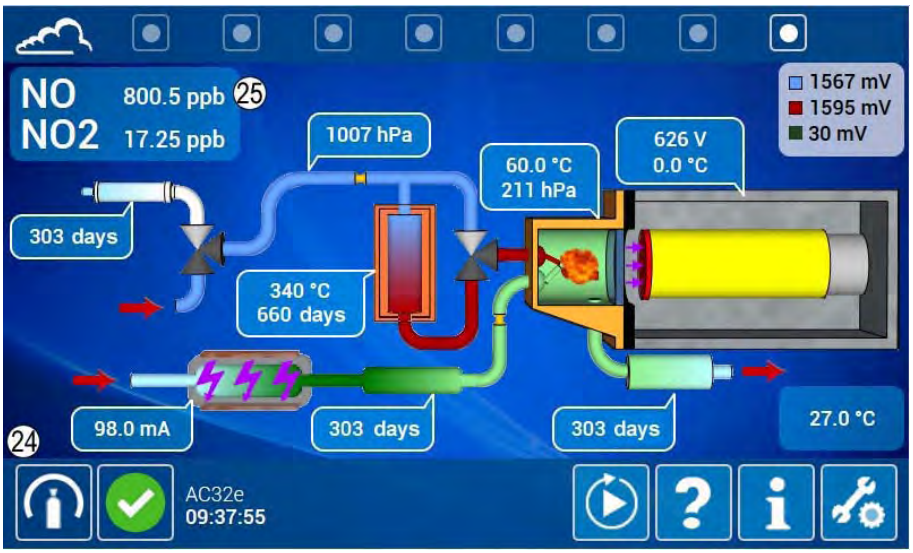
The span inlet icon is displayed at the left bottom side of the screen (22) according to the span configuration. A progress bar (23) is displayed on the screen.

At the cycle end, the analyzer automatically returns to the initial measurement configuration (sample inlet measurement in our example).



Calibration can be verified by selecting again the span inlet port (24).

Check that the NO measurement (25) corresponds to the injected concentration +/- 2 ppb.



This concentration is also the declared concentration (26) in the advanced analyzer configuration screen.

The new span coefficients for NO (27) and NOx (28) are displayed in this page, after the automatic calibration.

3.5.4. MULTI-POINT CALIBRATION

3.5.4.1. Presentation

An appropriate device consists of a diluter (MGC101 type), a certified span cylinder (NO) 1 % accuracy with NOx titration, and a zero air generator. Certified span cylinder calibration may be associated to reference materials of the National Institute of Standards and Technology (NIST) for calibration in the US EPA measurement field. Refer to Figure 3-4.

Gases will be applied at atmospheric pressure to the analyzer sample gas inlet. The outlet flow rate of dilutor must be at least twice the flow rate sampled by the analyzer.

Analyzer calibration requires gas generation of 7 points including zero (example: 0, 15, 30, 45, 60, 75 and 90% of the full scale of the measurement range used). The dilution gas must be the same as for zero measurement.

3.5.4.2. Procedure

Firstly, proceed to a two point calibration (see § 3.5.3) adjusting the diluter [NO] concentration output, [NO]gen, to 90% of the full scale of the used range.

NOTE : Verify that NOx (NO + NO_2 impurities) generated concentrations, plus an eventual programmed offset, does not exceed the NOx programmed full scale. If it is the case, decrease the NO concentration until to obtain a NOx concentration equal to 95% of the NOx programmed full scale.

Generate several additional concentrations (at least five evenly spaced points through the remaining scale are advised to verify linearity), wait for stabilization (10 min) between 2 points.

For each generated concentrations, record the (NO, NOx) values measured by the dilutor, and the (NO, NOx) corresponding measurements delivered by the analyzer.

Compare the analyzer's responses to the generated concentrations, verify that these responses are within the generated concentrations ±0.4ppb or the generated concentrations ±1% (taking into account the gas generator accuracy).

[NO]resp = [NO]gen ± 0.4 ppb	(for [NO]gen < 40 ppb)
[NO]resp = [NO]gen ± 1%	(for [NO]gen > 40 ppb)
[NOx]resp = [NOx]gen ± 0.4 ppb	(for [NOx]gen < 40 ppb)
[NOx]resp = [NOx]gen ± 1%	(for [NOx]gen > 40 ppb)

Where [NO]resp [NOx]resp are the analyzer's responses in ppb

[NO]gen [NOx]gen are the generated concentrations in ppb.

If analyzer's responses are out of limits, a complete maintenance must be performed.

NOTE : For more information about calibration procedure refer to EPA CFR40 Part 50 appendix F.

3.5.5. CHECKING CONVERSION EFFICIENCY OF MOLYBDENUM OVEN WITH G.P.T.

The gas phase titration (GPT) method with NO in excess allows to check the NO/NO_2 conversion efficiency from a NO concentration used as reference.

It uses the following reaction: $NO+O_3 \rightarrow NO_2+O_2$, allowing the NO_2 gas quantitative analysis as a function of NO variation concentration.

3.5.5.1. Device

- "Zero" air generator.
- NO in N_2 cylinder. The concentration is chosen in order to obtain, after dilution, a NO concentration of about 90% of the measurement full scale used.
- Diluter fitted with an O_3 generator using photolysis (MGC101), see Figure 3-4.
- Analyzer in operation for at least 2h.

3.5.5.2. Procedure

First, carry-out a 2-point calibration (see paragraph 3.5.3) by adjusting the [NO] generated concentration by the dilutor to 90% of the full scale of the ranges used.

Generate a [NO] concentration point at 80% of the NO_2 full scale (400 ppb for NO_2 full scale at 500 ppb). After stabilization, write down the concentrations read on the analyzer $[NO]_{initial}$ and $[NO_x]_{initial}$.

While keeping the same adjustments on the diluter (NO concentration and outlet flow rate), activate the ozone generator of the dilutor in order to generate an ozone concentration of about 80% of the [NO] previous concentration (320 ppb O3 for 400 ppb NO). After stabilization, write down the concentrations read on the analyzer, $[NO]_{final}$ and $[NO_x]_{final}$.

Check that $[NO]_{final}$ > 40 ppb (NO excess). If not, reduce the ozone concentration and repeat the operation.

Calculate the R converter efficiency as follows:

$R\ (\%) = 100 \times (1 - ([NO_x]_{initial} - [NO_x]_{final}) / ([NO]_{initial} - [NO]_{final}))$

Efficiency must be greater than 98%.

Remarks:

- Ozone generator activation does not change neither outlet flow rate nor the operating point of the mass flow controller (MFC).
- The NOx concentration (= NO + NO_2) remains constant during TPG, only the NO / NO_2 ratio is modified by the ozone addition.

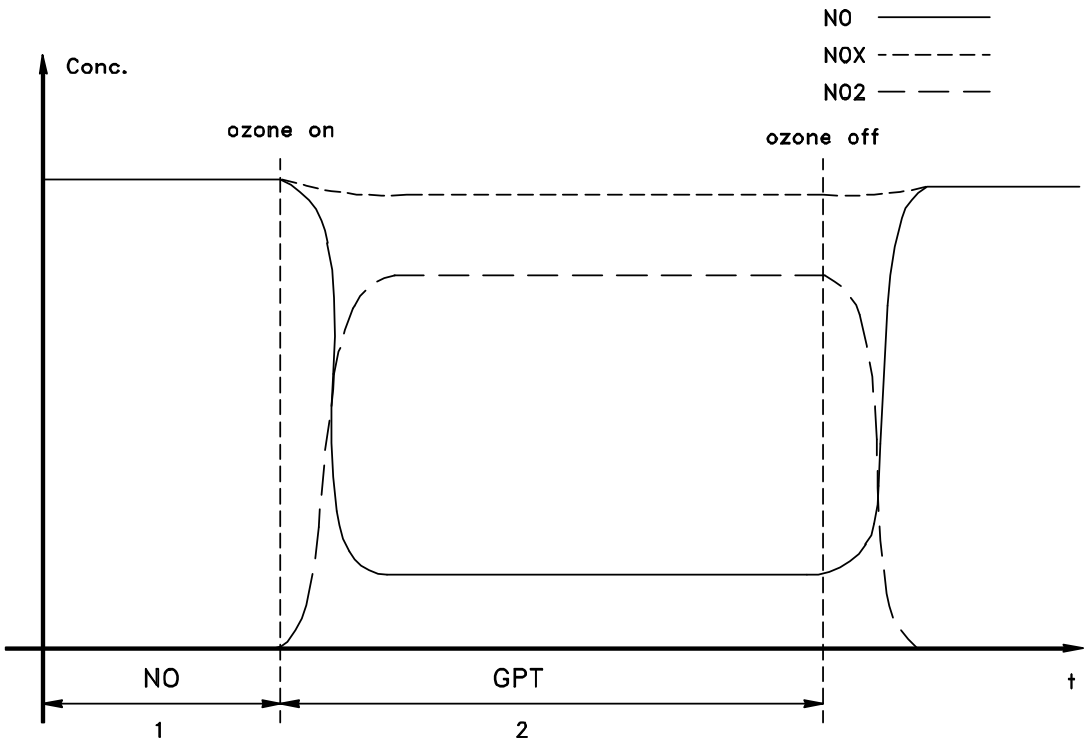


Figure 3-5 – Typical GTP diagram

The above curve shows the evolution of the various concentrations during the GPT.

An ideal converter (R = 100%) converts 100% of NO_2 to NO, resulting in $[NO_x]_{initial} = [NO_x]_{final}$ and thus a stable NOx measurement during TPG.

Inversely, a significant drop in the NOx measurement during the ozone generator activation of the dilutor indicates a converter efficiency fault.