

TÜV RHEINLAND ENERGY GMBH



Report on the performance test of the T200P air quality monitoring system manufactured by Teledyne API measuring components NO, NO₂ and NO_x

TÜV report: 936/21238687/A
Cologne, 12 September 2017

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Report on the performance test of the T200P air quality monitoring system
manufactured by Teledyne API measuring components NO, NO₂ and NO_x

AMS designation:	T200P
Manufacturer:	Teledyne API 9970 Carroll Canyon Rd San Diego, CA, 92131 USA
Test period:	April 2017 to September 2017
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1. Summary and certification proposal

1.1 Summary Overview

Teledyne API commissioned TÜV Rheinland Energy GmbH to carry out performance testing for the T200P air quality monitoring system measuring the components NO, NO₂ and NO_x.

The test was performed in respect of the following standards and requirements:

- VDI Guideline 4202 part 1: Performance criteria for performance tests of automated ambient air measuring systems – Point-related measurement methods for gaseous and particulate air pollutants, of September 2010
- VDI Guideline 4203 part 3: Testing of automated measuring systems - Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants
- EN 14211: Ambient air – Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence, of August 2012

The T200P analyser measures the components NO, NO₂ and NO_x by chemiluminescence. The measuring system thus corresponds to the EU reference method. The tests were performed in the laboratory and in a three-months field test in Cologne. The following measuring ranges were tested:

Table 1: Measuring ranges tested

Measured components:	measuring range in [$\mu\text{g}/\text{m}^3$] ¹	Measuring range in [ppb] or [nmol/mol]
NO ₂	0 – 500	0 – 261
NO	0 – 1200	0 – 962

¹ The specifications refer to 20 °C and 101.3 kPa

The minimum requirements were satisfied during the performance test.

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

1.2 Certification proposal

Based on the positive results obtained, the following recommendation on the announcement of the AMS as a certified system is put forward:

AMS designation:

T200P for NO, NO₂ and NO_x

Manufacturer:

Teledyne API, San Diego, USA

Field of application:

For the continuous measurement of nitrogen oxide concentrations from stationary sources in ambient air

Measurement ranges during performance testing:

Component	Certification range	Unit
Nitrogen monoxide	0 – 1200	µg/m ³
Nitrogen dioxide	0 – 500	µg/m ³

Software versions:

Package Version 1.1.5

Driver Version 1.0.15.22

Restriction:

None

Note:

This report on the performance test is available online at www.gal1.de.

Test Report:

TÜV Rheinland Energy GmbH, Cologne

Report no.: 936/21238687/A dated 12 September 2017

1.3 Summary report on test results

Performance criterion	Requirement	Test result	Satisfied	Page
4 Requirements on the instrument design				
4.1 General requirements				
4.1.1 Measured value display	Shall be fitted with.	The measuring system is fitted with a measured value display.	yes	33
4.1.2 Easy maintenance	Maintenance should be possible without larger effort, if possible from outside.	Maintenance takes reasonable effort and is possible with standard tools from the outside.	yes	34
4.1.3 Functional check	Particular instruments required to this effect shall be considered as part of the measuring system and be applied in the corresponding sub-tests and included in the assessment.	The tested measuring system does not have internal devices for operating the functional check.	not applicable	35
4.1.4 Set-up times and warm-up times	The instruction manual shall include specifications in this regard.	Set-up times and warm-up times have been determined.	yes	36
4.1.5 Instrument design	The instruction manual shall include specifications in this regard.	Specifications made in the instruction manual concerning instrument design are complete and correct.	yes	37
4.1.6 Unintended adjustment	Shall secure measuring system against that.	The measuring system is secured against unintended and unauthorised adjustment of instrument parameters by way of a password.	yes	38
4.1.7 Data output	The output signals shall be provided digitally and/or as analogue signals.	Measured signals are provided as analogue signals (0–20 mA, 4–20 mA and 0–1V, 0–5V and 0–10V) and digitally (via TCP/IP, RS 232, USB).	yes	39

Performance criterion	Requirement	Test result	Satisfied	Page
5. Performance requirements				
5.1 General requirements	The manufacturer's specifications in the instruction manual shall not contradict the results of the performance test.	There were no discrepancies between the instrument features and the instruction manuals.	yes	40
5.2 General requirements				
5.2.1 Certification range	Shall meet the requirements stipulated in Table 1 of VDI Guideline 4202 part 1.	It is possible to assess the measuring system in the range of the relevant limit values.	yes	41
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, the measuring range is set to 0–500 µg/m ³ for NO ₂ and 0–1200 µg/m ³ for NO. Supplementary measuring ranges up to 0–4 ppm are possible. Thus, the instrument's upper limit of measurement is larger or equal to the upper limit of the certification range.	yes	42
5.2.3 Negative output signals	May not be suppressed (life zero).	The measuring system also provides negative output signals.	yes	43
5.2.4 Failure in the mains voltage	Uncontrolled emission of operation and calibration gas shall be avoided; instrument parameters shall be secured by buffering against loss; when mains voltage returns, the instrument shall automatically reach the operation mode and start the measurement.	On return of mains voltage, the instrument returns to normal operating mode and automatically resumes measuring.	yes	44
5.2.5 Operating states	The measuring system shall allow their control by telemetrically transmitted status signals.	The measuring system provides various ports to ensure comprehensive monitoring and control via an external computer.	yes	45
5.2.6 Switch-over	Switch-over between measurement and functional check and/or calibration shall be possible telemetrically.	In principle, it is possible to monitor all tasks necessary for a functional check on the instrument itself or telemetrically.	yes	46
5.2.7 Maintenance interval	Ideally 3 months, at least 2 weeks.	The maintenance interval is determined by the necessary maintenance works. It is 4 weeks.	yes	47

Performance criterion	Requirement	Test result	Satisfied	Page
5.2.8 Availability	At least 95%.	Availability was 100% for both instruments including maintenance times required for testing.	yes	48
5.2.9 Instrument software	Shall be displayed when switched on. Changes affecting instrument functions shall be communicated to the test laboratory.	The instrument's software version is displayed. Software changes are communicated to the test laboratory.	yes	49
5.3 Requirements on measuring systems for gaseous air pollutants				
5.3.1 General requirements	Performance criterion specified in VDI Guideline 4202, part 1.	This test and its evaluation were performed on the basis of the requirement specified in VDI Guideline 4202, part 1 (September 2010) and EN 14211 (2012).	yes	50
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 Guideline 4202, part 1, in the certification range according to Table 1 of that Guideline.	See chapter 7.1 8.4.5 Repeatability standard deviation.	yes	51
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 Guideline 4202, part 1, in the certification range according to Table 1 of that Guideline.	See chapter 7.1 8.4.5 Repeatability standard deviation	yes	52
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.	See chapter 7.1 8.4.6 Lack of fit of linearity of the calibration function.	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).	See chapter 7.1 8.4.7 Sensitivity coefficient to sample gas pressure	yes	54

Performance criterion	Requirement	Test result	Satisfied	Page
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).	See chapter 8.4.8 Sensitivity coefficient to sample gas temperature	yes	55
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).	See chapter 7.1 8.4.9 Sensitivity coefficient to surrounding temperature	yes	56
5.3.8 Sensitivity coefficient of electrical voltage	The sensitivity coefficient of supply voltage shall not exceed the requirements of Table 2 of VDI 4202, part 1 (September 2010).	See chapter 7.1 8.4.10 Sensitivity coefficient to electrical voltage	yes	57
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, at zero and reference point.	See chapter 7.1 8.4.11 Interferents	yes	58

Performance criterion	Requirement	Test result	Satisfied	Page
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).	See chapter 7.1 8.4.12 Averaging test	yes	59
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 VDI 4202, part 1 (September 2010).	See chapter 7.1 8.5.5 Reproducibility standard deviation for NO ₂ under field conditions	yes	60
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, in the field test.	See chapter 7.1 8.5.4 Long-term drift.	yes	61
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, within 12 h (for benzene 24 h) in the laboratory test and within 24 h in the field test.	See chapter 7.1 8.4.4 Short-term drift	yes	62
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 chapter 7.1 8.4.3 Response time	yes	63

Performance criterion	Requirement	Test result	Satis- fied	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).	See chapter 7.1 8.4.13 Difference sample/calibration port	yes	64
5.3.16 Converter efficiency	In case of measuring systems with a converter, the converter efficiency shall be at least 98%.	See chapter 7.1 8.4.14 Converter efficiency	yes	65
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 VDI 4202, part 1 (September 2010).	See chapter 7.1 8.4.15 Residence time in the analyser	yes	66
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 performed in accordance with standard EN 14211 (2012) and is presented in chapter 7.1 8.6 Calculation of the total uncertainty in accordance with standard EN 14211 (2012) according to Annex E of EN 14211 (2012).	yes	67

Performance criterion	Requirement	Test result	Satisfied	Page
8.4 Requirements specified in standard EN 14211				
8.4.3 Response time	Rise and fall response time ≤ 180 s each. Difference between rise and fall response time ≤ 10 s.	The values determined remained considerably below the maximum permissible response time of 180 s at all times. The maximum response time determined for instrument 1 was 54 s for NO and 42.5 s for NO ₂ . For instrument 2 it was determined at 54 s for NO and 42 s for NO ₂ .	yes	68
8.4.4 Short-term drift	Short-term drift at zero shall not exceed 2.0 nmol/mol/12 h (corresponds to 2.50 µg/m ³ /12 h). The short-term drift at reference level shall not exceed 6.0 nmol/mol/12 h (corresponds to 7.50 µg/m ³ /12 h).	For instrument 1 the value for the short-term drift at zero point was 0.03 nmol/mol, for instrument 2 it was 0.03 nmol/mol. Short-term drift at reference point was 0.72 nmol/mol/12 h for instrument 1 and 0.86 nmol/mol/12 h for instrument 2.	yes	73
8.4.5 Repeatability standard deviation	The performance criteria are as follows: Repeatability standard deviation at zero shall not exceed 1.0 nmol/mol (corresponds to 1.25 µg/m ³). At a sample gas concentration at the reference point it shall not exceed 3.0 nmol/mol (corresponds to 3.75 µg/m ³)	For instrument 1 the value for the repeatability standard deviation at zero point was 0.00 nmol/mol, for instrument 2 it was 0.00 nmol/mol. Repeatability standard deviation at reference point was 1.23 nmol/mol for instrument 1 and 1.46 nmol/mol for instrument 2.	yes	77
8.4.6 Lack of fit of linearity of the calibration function	The deviation from the linearity of the calibration function at zero shall not exceed 5.0 nmol/mol (corresponds to 6.3 µg/m ³). At concentrations above zero, it shall not exceed 4% of the measured value.	The deviation from the linear regression line for instrument 1 is -0.94 nmol/mol at zero point and no more than 0.75% of the target value for concentrations above zero. The deviation from the linear regression line for instrument 2 is -0.94 nmol/mol at zero point and no more than 1.10% of the target value for concentrations above zero.	yes	79
8.4.7 Sensitivity coefficient to sample gas pressure	The sensitivity coefficient of the sample gas pressure shall be ≤ 8.0 nmol/mol/kPa (corresponds to 10 µg/m ³ /kPa).	For instrument 1, the sensitivity coefficient to sample gas pressure is 0.99 nmol/mol/kPa. For instrument 2, the sensitivity coefficient to sample gas pressure is 0.91 nmol/mol/kPa.	yes	84

Performance criterion	Requirement	Test result	Satisfied	Page
8.4.8 Sensitivity coefficient to sample gas temperature	The sensitivity coefficient to sample gas temperature shall not exceed 3.0 nmol/mol/K (corresponds to 3.75 µg/m ³ /K).	For instrument 1, the sensitivity coefficient to sample gas temperature is 0.15 nmol/mol/K. For instrument 2, the sensitivity coefficient to sample gas temperature is 0.13 nmol/mol/K.	yes	86
8.4.9 Sensitivity coefficient to surrounding temperature	The sensitivity coefficient to the surrounding temperature shall not exceed 3.0 nmol/mol/K (corresponds to 3.75 µg/m ³ /K).	The sensitivity coefficient to the surrounding temperature did not exceed the performance criterion specified at 3.0 nmol/mol/K. For the purpose of uncertainty calculation, the largest value is used for both instruments. This would be 0.410 nmol/mol/K for instrument 1 and 0.732 nmol/mol/K for instrument 2.	yes	88
8.4.10 Sensitivity coefficient to electrical voltage	The sensitivity coefficient to electrical voltage shall not exceed 0.30 nmol/mol/V (corresponds to 0.38 µg/m ³ /V).	At no test item did the sensitivity coefficient to electrical voltage exceed the value of 0.30 nmol/mol/V specified in standard EN 14211. For the purpose of uncertainty calculation, the largest value is used for both instruments. For instrument 1, this is 0.02 nmol/mol/V and for instrument 2 it is 0.02 nmol/mol/V.	yes	91
8.4.11 Interferents	Interferents at zero and at concentration c_t (at the level of the 1-hour limit value = 200 µg/m ³ for NO ₂). Deviations for interferents H ₂ O, CO ₂ and NH ₃ shall not exceed 5.0 nmol/mol (corresponds to 6.25 µg/m ³).	At zero point the result for the interference were -0.33 nmol/mol (AMS 1) and -0.60 nmol/mol (AMS 2) for H ₂ O, 1.10 nmol/mol (AMS 1) and 1.47 nmol/mol (AMS 2) for CO ₂ and finally 0.93 nmol/mol (AMS 1) and 0.83 nmol/mol (AMS 2) for NH ₃ . The following results were obtained for the cross-sensitivity at the limit value c_t : H ₂ O: -1.37 nmol/mol for instrument 1 and -0.07 nmol/mol for instrument 2; CO ₂ : -0.50 nmol/mol for instrument 1 and -1.30 nmol/mol for instrument 2; NH ₃ and 0.53 nmol/mol for instrument 1 and 0.97 nmol/mol.	yes	93
8.4.12 Averaging test	The averaging effect shall not exceed 7% of the measured value.	The performance criterion specified by standard EN 14211 is fully satisfied.	yes	96
8.4.13 Difference sample/calibration port	The difference between the sample and calibration ports shall not exceed 1%.	The performance criterion specified by standard EN 14211 is fully satisfied.	yes	99

Performance criterion	Requirement	Test result	Satisfied	Page
8.4.14 Converter efficiency	Converter efficiency shall be at least 98%.	The performance criterion specified by standard EN 14211 is fully satisfied.	yes	101
8.4.15 Residence time in the analyser	The residence time in the analyser shall not exceed 3.0 s.	Residence time in the analyser was 1.6 s.	yes	103
8.5.4 Long-term drift	Long-term drift at zero shall not exceed 5.0 nmol/mol (corresponds to 6.25 µg/m ³). Long-term drift at span level shall not exceed 5% of the certification range (corresponds to 13.05 µg/m ³ at a measuring range of 0–261 nmol/mol).	Maximum long-term drift at zero point DI _z was at -2.21 nmol/mol for instrument 1 and 1.15 nmol/mol for instrument 2. Maximum long-term drift at reference point DI _s was at -0.94 % for instrument 1 and -0.76 % for instrument 2.	yes	104
8.5.6 Maintenance interval	The period of unattended operation of the AMS shall be at least 2 weeks.	The period of unattended operation is determined by the necessary maintenance works. It is 4 weeks.	yes	110
8.5.5 Reproducibility standard deviation for NO ₂ under field conditions	Reproducibility standard deviation under field conditions shall not exceed 5% of the mean value over a period of three months.	The reproducibility standard deviation for NO ₂ under field conditions was 3.83% as a percentage of the mean value over the three-months field test period. Thus, the requirements of EN 14211 are satisfied.	yes	107
8.5.7 Period of availability of the analyser	Availability of the analyser shall be at least 90%.	The availability is 100%. Thus, the requirement of EN 14211 is satisfied.	yes	111

2. Task Definition

2.1 Nature of the test

Teledyne API commissioned TÜV Rheinland Energy GmbH to submit the T200P air quality monitor to performance testing. The test was carried out as a complete performance test.

2.2 Objectives

The AMS is designed to determine NO, NO₂ and NO_x concentrations in ambient air in the following concentration ranges:

Component	Certification range	Unit
Nitrogen monoxide	0 – 1200	µg/m ³
Nitrogen dioxide	0 – 500	µg/m ³

The T200P analyser measures the components NO, NO₂ and NO_x by chemiluminescence.

The task was to carry out performance testing in line with the applicable standards and taking into consideration the latest developments in the field.

The test was performed on the basis of the following standards:

- VDI Guideline 4202 part 1: Performance criteria for performance tests of automated ambient air measuring systems – Point-related measurement methods for gaseous and particulate air pollutants, of September 2010
- VDI Guideline 4203 part 3: Testing of automated measuring systems – Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants of September 2010
- EN 14211: Ambient air – Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence, of August 2012

3. Description of the AMS tested

The T200P air quality monitor is a continuous nitrogen oxide analyser. The instrument uses the chemiluminescence method as a measuring principle. It was designed for the continuous measurement of NO, NO₂ and NO_x in ambient air.

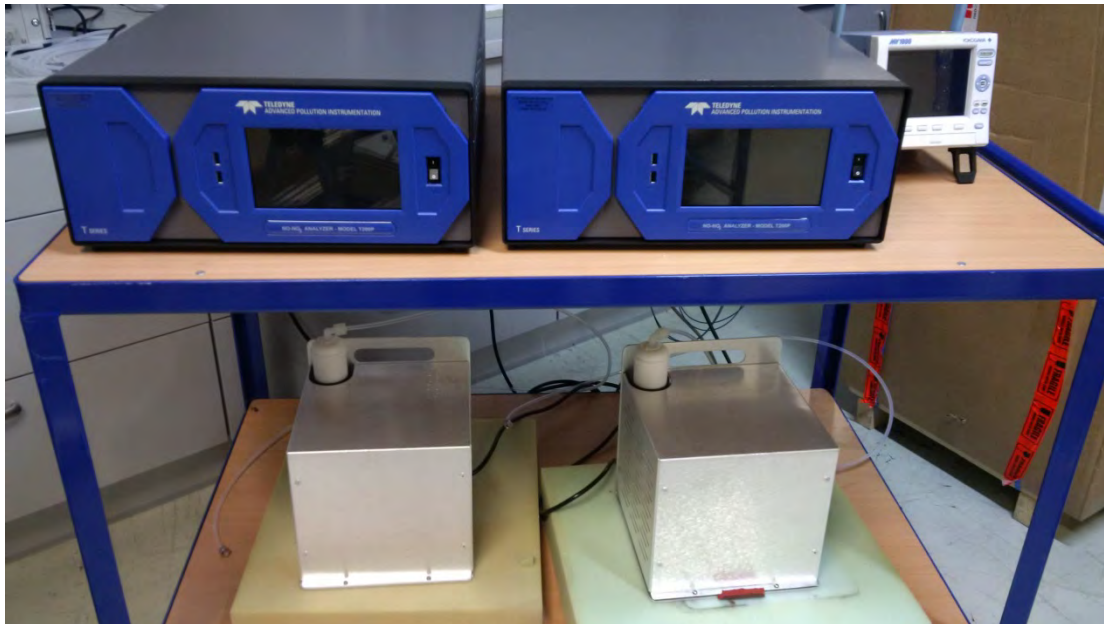
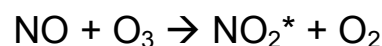


Figure 1: Presentation of the T200P analyser

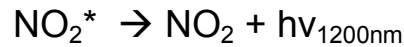
3.1 Measuring principle

The analyser measures the amount of NO present in a gas by detecting the chemiluminescence which occurs when nitrogen oxide (NO) is exposed to ozone (O₃). This reaction is a two-step process:

- In the first step, one molecule of NO and one molecule of O₃ collide and chemically react to produce one molecule of oxygen (O₂) and one molecule of nitrogen dioxide (NO₂). Some of the NO₂ molecules created by this reaction retain excess energy from the collision and exist in an excited state, where one of the electrons of the NO₂ molecule resides in a higher energy state than normal.



- The second step occurs because the laws of thermodynamics require that systems seek the lowest stable energy state available, therefore the excited NO₂ molecule quickly returns to its ground state, releasing the excess energy. This release takes the form of a quantum of light (h_v). The distribution of wavelengths for these quanta range between 600 and 3000 nm, with a peak at about 1200 nm.



- All things being constant (temperature, pressure, amount of ozone present, etc.), the relationship between the amount of NO present in the reaction cell and the amount of light emitted from the reaction is very linear. If more NO is present, more IR light is produced. By measuring the amount of IR light produced with a sensor sensitive in the near-infrared spectrum the amount of NO present can be determined.

3.2 AMS scope and set-up

Teledyne API's Model T200P is a photolytic NO/NO₂/NO_x Analyser that uses a patented high efficiency Blue Light Converter (BLC) coupled with state-of-the-art microprocessor technology to provide true measurement of ambient nitrogen dioxide (NO₂). The BLC includes the latest technology in high powered LEDs and a Teflon cell with reflective properties that increase the overall conversion efficiency, which allows for better speciation of lower NO₂ levels.

Sample gas to the solenoid valve unit through the inlet filter at the analyser. The inlet port (sample, zero gas, span gas) can be selected. The dryer situated between the dust filter and the solenoid valve unit allows to remove any adverse effect produced by moisture.

For the NO cycle, the sample is sucked into the reaction cell directly; for the NO_x cycle it is sucked in via the NO₂ → NO-BLC converter.

The ozoniser generates the ozone required for measurements from ambient air. First, dust is removed from the air sucked in before the latter is transported to the dryer. The ozone produced first passes through a cleaner at the outlet of the ozoniser before it is led to the reaction cell inside the measurement module. The ozoniser chip ensures voltage supply to the ozoniser.

Furthermore, the dryer supplies purge air for converting the photomultiplier tube after the purge dryer filter has been purged. The vacuum distributor connected to the external pump links all internal elements which need to operate under negative pressure.

The following main components are situated inside the analyser:

Blue light converter (BLC)

The analyser uses photolysis in its conversion process by flowing sample gas through the converter chamber where it is exposed to blue light from two high powered ultraviolet light-emitting diodes (LEDs) at very narrow wavelengths centred at ~ 395 nm (hashed region in graph). This blue spectral output includes the band where NO₂ is absorbed and where other interferences drop out, thereby selectively converting sample NO₂ to NO with negligible radiant heating or interference from other gases.

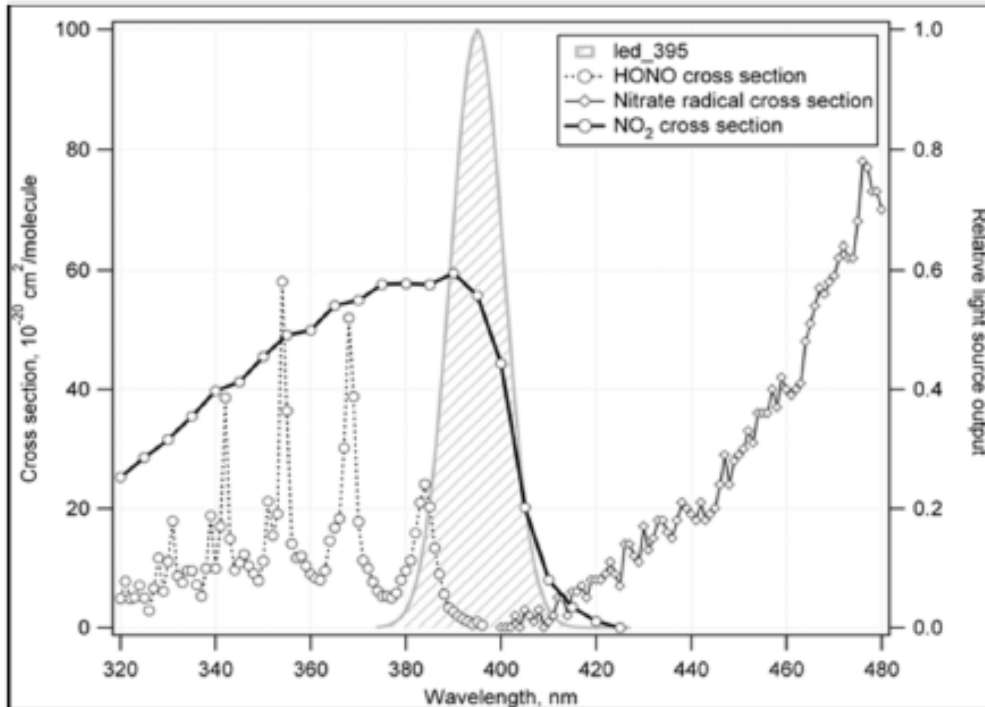


Figure 2: Blue Light Spectral Absorption Band

Photomultiplier Tube (PMT)

The analyser uses a special kind of vacuum tube, called a photo-multiplier tube (PMT), to detect the amount of light created by the NO and O₃ reaction in the reaction cell.

Photons enter the PMT and strike a negatively charged photo cathode causing it to emit electrons. These electrons are accelerated by an applied high voltage and multiplied through a sequence of similar acceleration steps (dynodes) until a useable current signal is generated (see Section 6.6 for a more detailed description). The more light present (in this case photons given off by the chemiluminescent reaction described above), the more current is produced. Therefore the more NO present in the reaction cell the more current is produced by the PMT.

The current produced by the PMT is converted to a voltage and amplified by the preamplifier board and then communicated to the analyser's CPU via the A-D converter circuitry on the analyser.

Optical Filter

A high pass optical filter, only transparent to wavelengths of light above 645 nm, placed between the reaction cell and the PMT (see Figure 6-2) in conjunction with the response characteristics of the PMT creates a very narrow window of wavelengths of light to which the analyser will respond. The narrowness of this band of sensitivity allows the analyser to ignore extraneous light and radiation that might interfere with the analyser's measurement.

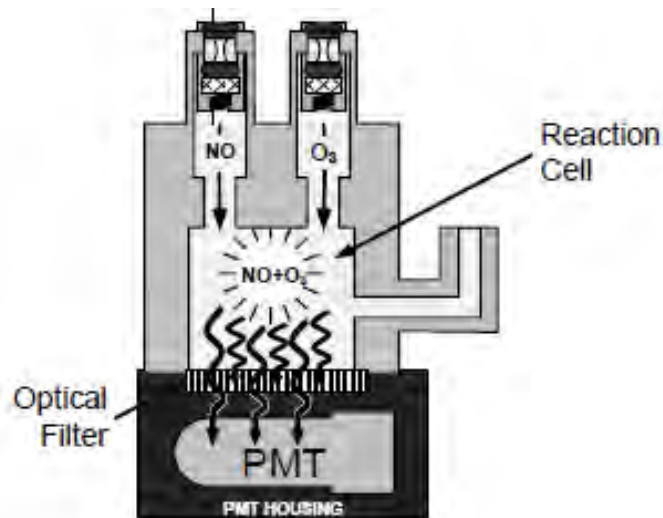


Figure 3: Reaction Cell with PMT Tube and Optical Filter

Ozone Dryer / Sample Dryer

Ambient air usually contains enough water vapour to greatly diminish the yield of ozone produced by the ozone generator. Water also reacts with chemicals inside the O₃ Generator to produce caustic substances such as ammonium sulphate or highly corrosive nitric acid that will damage the optical filter located in the reaction cell.

To prevent this, the air supply for the O₃ generator is dried using a special permeation dryer. The dryer consists of a single tube of Nafion[®] that is mounted within an outer, flexible plastic tube. Nafion[®] is a co-polymer that absorbs water very well but not most other chemicals. As gas flows through the inner Nafion[®] tube, water vapour is absorbed into the membrane walls. The absorbed water is transported through the membrane wall and evaporated into the dry purge gas flowing through the outer tube, countercurrent to the gas in the inner tube.

Because this chemical reaction is based on hydrogen bonds between the water molecule and the Nafion[®] material most other chemical components of the gas to be dried are usually unaffected. Specifically, the gases of interest for the T200, NO and NO₂, do not get absorbed and pass the dryer unaltered.

To provide a dry purge gas for the outer side of the Nafion[®] tube, the analyser returns some of the dried air from the inner tube to the outer tube. This means that any time the analyser is turned on after having been OFF for 30 minutes or more, the humidity gradient between the inner and outer tubes is not very large and the dryer's efficiency is low. It takes a certain amount of time for the humidity gradient to become large enough for the Sample Dryer operate efficiently, in such cold start cases the O₃ Generator is not turned on until 30 minutes has passed in order to ensure that it is not operating until its air supply is properly dry.

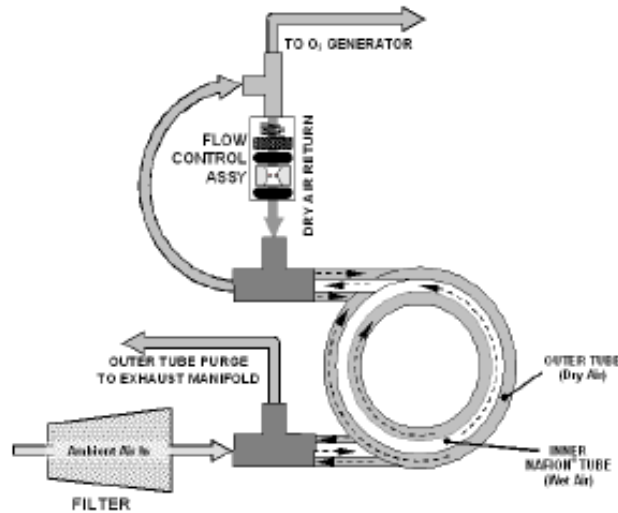


Figure 4: Sample Dryer

Ozone generator

The analyser uses a dual-dielectric, Corona Discharge (CD) tube for creating its O₃, which is capable of producing high concentrations of ozone efficiently and with low excess heat. The primary component of the generator is a glass tube with hollow walls of which the outermost and innermost surfaces are coated with electrically conductive material.

Air flows through the glass tube, between the two conductive coatings, in effect creating a capacitor with the air and glass acting as the dielectric. The layers of glass also separate the conductive surfaces from the air stream to prevent reaction with the O₃. As the capacitor charges and discharges, electrons are created and accelerated across the air gap and collide with the O₂ molecules in the air stream splitting them into elemental oxygen.

Some of these oxygen atoms recombine with O₂ to O₃. The quantity of ozone produced is dependent on factors such as the voltage and frequency of the alternating current applied to the CD cells. When enough high-energy electrons are produced to ionize the O₂ molecules, a light emitting, gaseous plasma is formed, which is commonly referred to as a corona.

Vacuum Pump

The sample gas flow is created by an external vacuum pump that is located pneumatically downstream from the rest of the instrument's components.

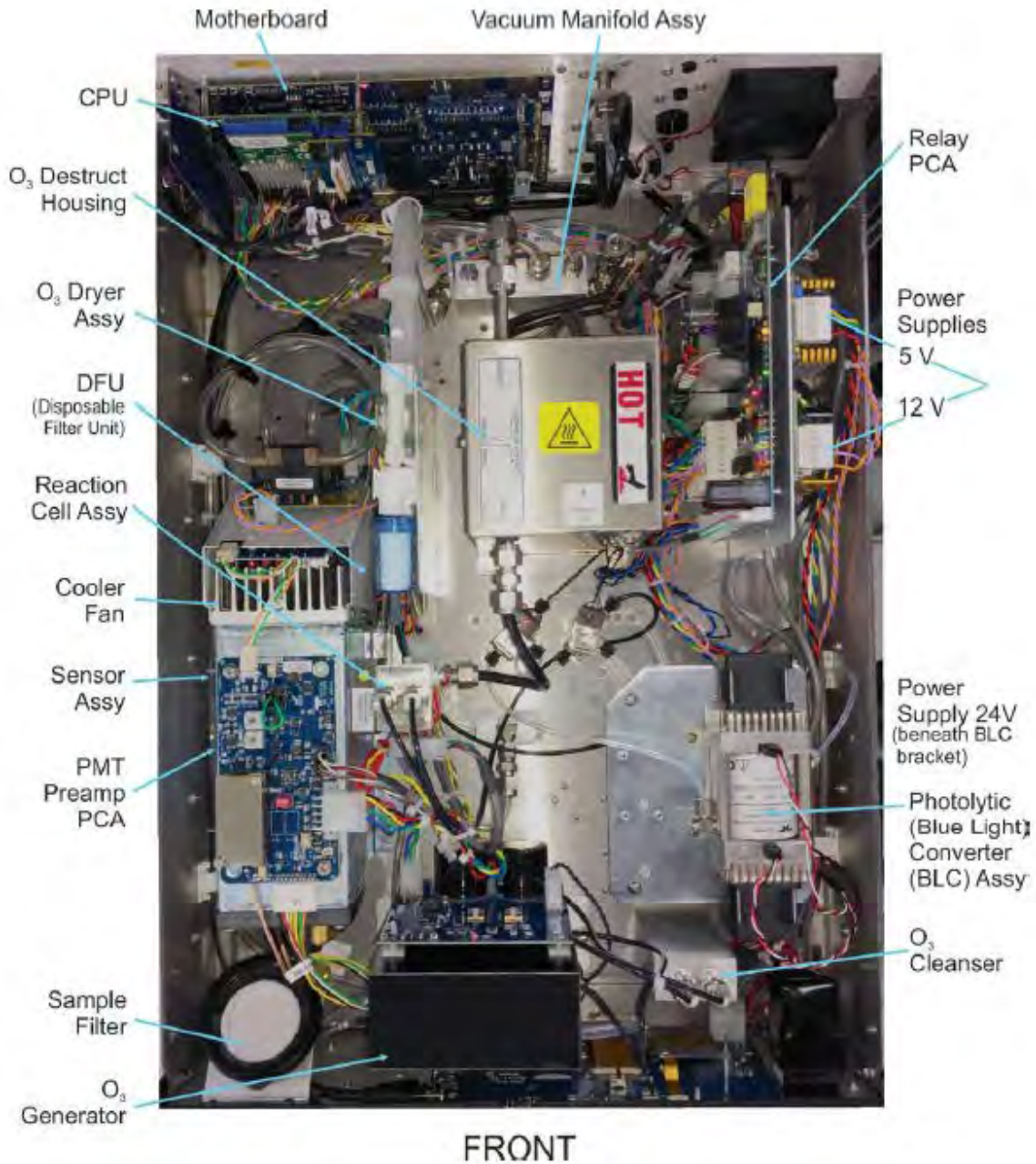


Figure 5: Internal set-up of the T200P

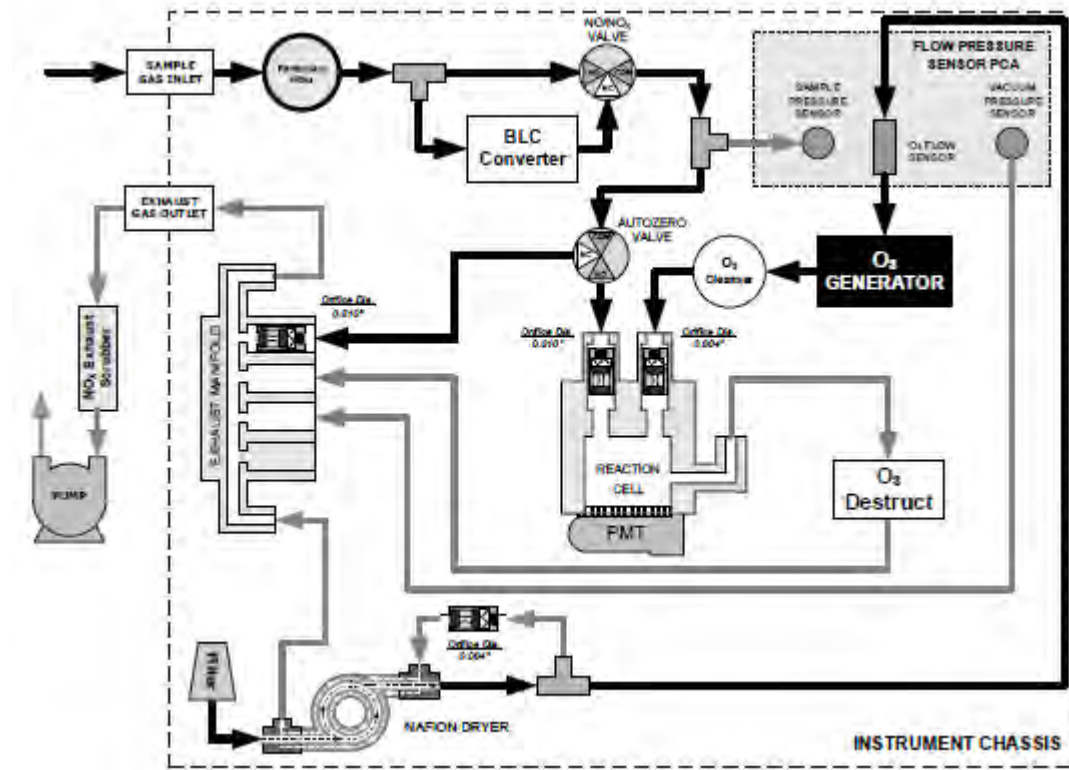


Figure 6: Pneumatic connections of the T200P

Table 2 lists a number of important instrument characteristics.

Table 2: Instrument characteristics T200P (manufacturer's specifications)

Measured range:	Max 0–4 ppm (selectable)
Units:	ppb, ppm, mg/m ³ or µg/m ³
Measured compounds:	NO, NO ₂ , NO _x
Sample flow rate	apx. 0.5 litre/min
Outputs:	<ul style="list-style-type: none"> • USB port • RS-232 • TCP/IP Ethernet connection • 8 digital outputs • 4 analogue outputs
Power supply	Voltage: 230 V or 115 V Frequency: 50Hz or 60 Hz
Power consumption:	~ 160 W
Dimension (l x w x h)	178 x 432 x 597 mm / 18 kg + 7 kg pump

4. Test programme

4.1 General remarks

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

Instrument 1: SN 59

Instrument 2: SN 60

The tests were performed with the following software version implemented:

Package Version 1.1.5

Driver Version 1.0.15.22

The test comprised a laboratory test to determine the performance characteristics as well as a field test over a period of several months.

In this report, the heading for each performance criterion cites the requirements according to the relevant standards ([1, 2, 3, 4]) including its chapter number and wording.

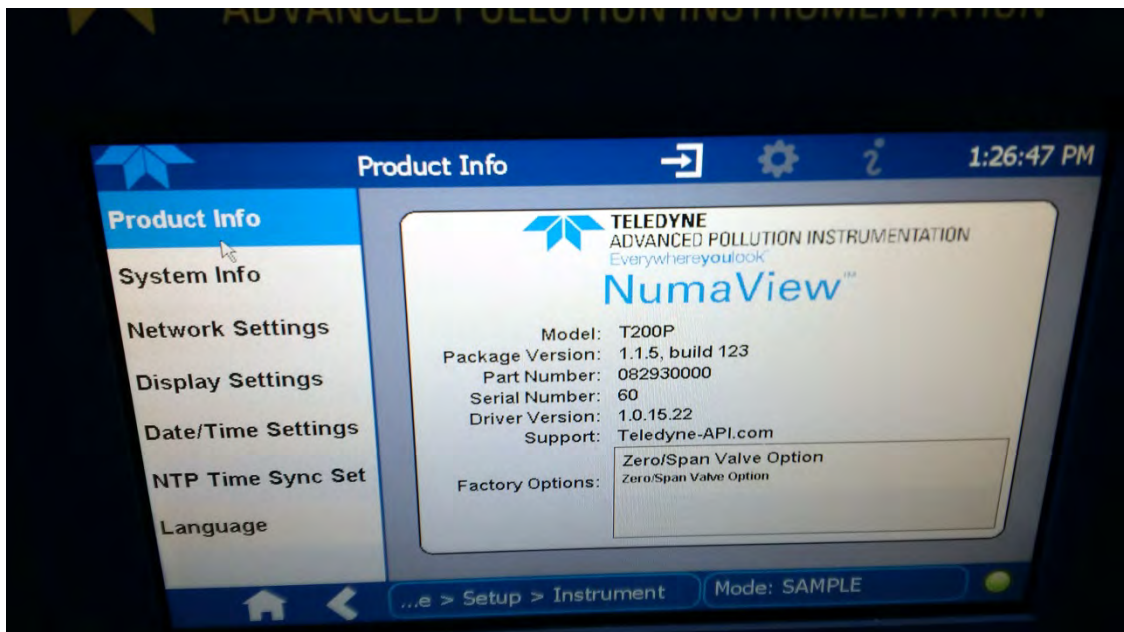


Figure 7: Software versions of the T200P test instruments

4.2 Laboratory test

The laboratory test was performed using two complete and identical systems type T200P, serial numbers 59 and SN: 60. Standards [2] and [3] specify the following test programme for the laboratory test:

- Description of instrument functions
- General requirements
- Deviation from the linearity of the calibration function
- Determination of response times
- Short-term drift
- Repeatability standard deviation
- Sensitivity to sample gas pressure
- Sensitivity to sample gas temperature
- Sensitivity to surrounding temperature
- Sensitivity to supply voltage
- Cross sensitivities
- Averaging test
- Difference sample/calibration ports
- Converter efficiency

Measured values were recorded using an external data logger.
Chapter 6 summarizes the results of the laboratory tests.

4.3 Field test

The field test was performed between 29/05/2017 and 11/09/2017 using two identical measuring systems. The instruments used were identical with those used for laboratory testing. The serial numbers were:

Instrument 1: SN 59
instrument 2: SN 60

The following test programme was determined for the field test:

- Long-term drift
- Period of unattended operation
- Availability
- Reproducibility standard deviation

5. Reference Measurement Method

Test gases used for adjustment purposes during the test (test samples and TÜV measuring systems):

(The specified test gases were used during the entire test and, where necessary, were diluted with the help of a sample splitter or a mass flow controller.)

Zero gas:	Synthetic air
Test gas NO:	2080 ppb in N₂
Number of test gas cylinder:	16296 / DI50364
Manufacturer / date of manufacture:	Praxair / 27/01/2017
Stability guarantee / certified:	24 months
Certificate checked by:	Own laboratory
Rel. uncertainty according to certificate:	5%
Test gas NO:	152.54 ppb in N₂
Number of test gas cylinder:	3920860
Manufacturer / date of manufacture:	Linde / 03/05/2017
Stability guarantee / certified:	6 months
Certificate checked by:	UBA
Rel. uncertainty according to certificate:	20%
Rel. Uncertainty according to UBA:	+/- 4.6 nmol/mol
Test gas NO₂:	0.39 ppm in air
Number of test gas cylinder:	16322 / DI50511
Manufacturer / date of manufacture:	Praxair / 18/07/2017
Stability guarantee / certified:	12 months
Certificate checked by:	Own laboratory
Rel. uncertainty according to certificate:	5%
Test gas NO₂:	9.86 ppm in air
Number of test gas cylinder:	16297
Manufacturer / date of manufacture:	Praxair / 22/02/2017
Stability guarantee / certified:	24 months
Certificate checked by:	Own laboratory
Rel. uncertainty according to certificate:	2%

6. Test results in accordance with 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 Testing

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

6.4 Evaluation

The measuring system is fitted with a measured value display.

6.5 Assessment

The measuring system is fitted with a measured value display.
Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

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 Testing

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

6.4 Evaluation

The user is advised to perform the following maintenance activities:

1. Checking the operational status
The operational status may be monitored and checked by visual inspections of the instrument's display.
2. Checking and replacement of the particle filter at the sample gas inlet The frequency at which the particle filter needs to be replaced depends on the dust concentrations in ambient air.

6.5 Assessment

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

Criterion satisfied? yes

6.6 Detailed presentation of test results

Maintenance was performed during the test in accordance with the activities and procedures described in the operation manual. Complying with the procedures described in the manual, no difficulties were identified. So far, all maintenance activities were possible without any difficulties using standard 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

Operation manual

6.3 Testing

The tested measuring system does not have internal devices for operating the functional check. The current operating status of the measuring system is continuously monitored and any issues will be flagged via a series of different error messages.

The functional check of the instruments was performed using external test gases.

6.4 Evaluation

The tested measuring system does not have internal devices for operating the functional check. The current operating status is continuously monitored and any issues will be flagged via a series of different error messages.

External monitoring of the zero and reference point using test gases is possible.

6.5 Assessment

The tested measuring system does not have internal devices for operating the functional check.

Criterion satisfied? not applicable

6.6 Detailed presentation of test results

Not applicable.

6.1 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

An additional watch was provided for testing this criterion.

6.3 Testing

The measuring systems were set up following the manufacturer's instructions. Set-up times and warm-up times were recorded separately.

Necessary constructional measures prior to the installation such as the installation of a sampling system in the analysis room were not taken into account.

6.4 Evaluation

The manual does not specify the set-up time. It will of course depend on the situation given at the site of installation as well as the local voltage supply. Since the T200P is a compact analyser, the set-up time is mainly determined by the following tasks:

- Connecting the AMS to supply voltage;
- Connecting the tubing (sampling, discharged air).

Changing positions in the laboratory on various occasions (installation in/removal from the climatic chamber) as well as the installation at the field test location resulted in a set-up time of ~30 minutes.

When switching the AMS on in a completely cold state, it takes about 30 minutes to reach a stable reading. This time is necessary mainly to heat up the in-built converter operating temperature.

The measuring system has to be installed at a location where it is protected from weather conditions, e.g. in an air-conditioned measurement container.

6.5 Assessment

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

It is possible to operate the measuring system at different locations with limited effort. Set-up time amounts to about 30 minutes. Depending on the stabilisation time needed under specific circumstances, warm-up time will also be about 30 minutes.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

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

For this test, a measuring device to determine energy consumption and scales are used.

6.3 Testing

The instrument design of the measuring systems handed over for testing was compared to the description provided in the manual. The energy consumption specified was verified during normal operation in the field test.

6.4 Evaluation

The measuring system is intended for horizontal mounting (e.g. on a table or in a rack) sheltered from weather conditions. The temperature at the site of installation must be between 0 °C and 30 °C.

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

Energy consumption according to manufacturer specifications is 160 VA. The average energy consumption of the measuring system was determined in a 24h test. During this test, the value specified at 160 VA was exceeded at no point in time.

6.5 Assessment

Specifications made in the instruction manual concerning instrument design are complete and correct.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 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

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

6.3 Testing

The measuring system can be operated via a display at its front with touch panel or via a PC directly connected to the RS232- or Ethernet interface.

The instrument provides an internal feature (password protection) to secure it against illicit or unintended adjustment. It is only possible to change parameters or adjust sensors after entering the password.

6.4 Evaluation

On entering the correct password, it is possible to change instrument parameters affecting measurement characteristics via the control panel and via an external computer.

6.5 Assessment

The measuring system is secured against unintended and unauthorised adjustment of instrument parameters by way of a password.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 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

PC with network connection

6.3 Testing

The measuring system provides the following transmission routes: RS232, USB, digital und analogue inputs and outputs (optional), TCP/IP network. Moreover, the measuring system also provides an option to output analogue signals (optional).

6.4 Evaluation

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

Analogue:	0–20, 2–20, 4–20 mA or 0–1/5/10 V, selectable concentration ranges
Digital	RS232, USB, digital inputs and outputs, TCP/IP network

6.5 Assessment

Measured signals are provided as analogue signals (0–20 mA, 4–20 mA and 0–1V, 0–5V and 0–10V) and digitally (via TCP/IP, RS 232, USB).

The instrument provides additional interfaces (e.g. analogue outputs) for connecting additional measuring or other peripheral instruments.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 5.1 General requirements

The manufacturer's specifications in the instruction manual shall not contradict the results of the performance test.

6.2 Equipment

Not required for this performance criterion.

6.3 Testing

Test results were compared to the specifications indicated in the manual.

6.4 Evaluation

The tested measuring systems correspond to the related and accompanying manual.

6.5 Assessment

There were no discrepancies between the instrument features and the instruction manuals.
Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 5.2.1 Certification range

The certification range intended for testing shall be determined.

6.2 Equipment

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

6.3 Testing

The certification range intended for testing shall be determined.

6.4 Evaluation

VDI Guideline 4202, part 1 and standard EN 14211 define the following minimum requirements for the certification ranges of continuous air quality monitoring systems for nitrogen oxide:

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

Measured components:	CR lower limit	CR upper limit	Limit value	Evaluation period
	in µg/m ³	in µg/m ³	in µg/m ³	
Nitrogen dioxide	0	500	200	1 h
Nitrogen monoxide	0	1200	631.3 ^{*)}	1 h

^{*)} No limit value is defined for NO. Standard EN 14211 recommends to use a value of 500 ± 50 nmol/mol instead.

6.5 Assessment

It is possible to assess the measuring system in the range of the relevant limit values.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

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

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

6.3 Testing

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

6.4 Evaluation

In theory, it is possible to set the measuring system to measuring ranges of up to 0–4 ppm.

Possible measuring range:	4 ppm
Upper limit of the certification range for NO:	1200 µg/m ³ (962 ppb or nmol/mol)
Upper limit of the certification range for NO ₂ :	500 µg/m ³ (261 ppb or nmol/mol)

6.5 Assessment

By default, the measuring range is set to 0 – 500 µg/m³ for NO₂ and 0 – 1200 µg/m³ for NO. Supplementary measuring ranges up to 0 – 4 ppm are possible.

Thus, the measuring system's upper limit of measurement is larger or equal to the upper limit of the certification range.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 5.2.3 Negative output signals

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

6.2 Equipment

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

6.3 Testing

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

6.4 Evaluation

The AMS displays negative values.

6.5 Assessment

The measuring system also provides negative output signals.
Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 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 measurement parameters shall be secured by buffering against loss caused by failure in the mains voltage. When mains voltage returns, the instrument shall automatically reach the operation mode and start the measurement according to the operating instructions.

6.2 Equipment

Not required for this performance criterion.

6.3 Testing

A simulated failure in the mains voltage served to test whether the instrument remained fully functional and reached operation mode on return of the mains voltage.

6.4 Evaluation

Since the measuring systems do not rely on operation and calibration gases, uncontrolled emission of gases is not possible.

Once the measuring system resumes operation after a power failure it is in warm-up mode until it reaches an appropriate operating temperature again. How long it will take up to fully warm up again will depend on the ambient conditions and the temperature of the system when switching it back on again. After completion of the warm-up phase, the measuring system will switch back automatically into the mode which had been active before the failure in mains voltage. The warm-up phase is indicated by a number of different error messages.

6.5 Assessment

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

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 5.2.5 Operating states

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

6.2 Equipment

Computer for data acquisition

6.3 Testing

The measuring system possesses various interfaces such as RS232, USB, digital and analogue inputs and outputs, TCP/IP network. A simple connection can be established between the analyser and an external computer via a web browser. This enables telemetrically transferring data, adjusting configurations and displaying the analyser reading on the computer screen. In this mode it is possible to access and operate all the information and features from the analyser display via the computer.

6.4 Evaluation

The measuring system allows for comprehensive monitoring and control via various connectors.

6.5 Assessment

The measuring system provides various ports to ensure comprehensive monitoring and control via an external computer.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 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

Not required for this performance criterion.

6.3 Testing

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

6.4 Evaluation

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

6.5 Assessment

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

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 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

Not required for this performance criterion.

6.3 Testing

With regard to this minimum requirement, the maintenance tasks required in a specific period and the length of that period for the correct functioning of the measuring system were identified. Furthermore, in determining the maintenance interval, the drift determined for zero and reference point in accordance with 7.1 8.5.4 Long-term drift have been taken into consideration.

6.4 Evaluation

Over the entire period of the field test, no unacceptable drift was observed. The maintenance interval is thus determined by the necessary maintenance works.

During operation times, maintenance is generally limited to contamination and plausibility checks and potential status/error messages.

6.5 Assessment

The maintenance interval is determined by the necessary maintenance works. It is 4 weeks.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

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

Not required for this performance criterion.

6.3 Testing

Start and end time of the availability are determined by the start and end time of the test at the field test location. To this effect, any interruption of the test, caused for example by malfunction or maintenance, was documented.

6.4 Evaluation

The field test took place between 29 May 2017 and 11 September 2017. Table 4 establishes the operation, maintenance and outage times.

The outage time of 151 was caused by a failure in mains voltage of the measurement container. On July 20, severe weather caused the measurement container's mains voltage to fail. The measurement container resumed operation on July 26, after repairs performed by a specialised company. The field test was extended by a week until September 11 in order to compensate for the missing time. The outage resulting from the failure in mains voltage was not taken into consideration when calculating availability. Maintenance times were caused by daily test gas feeding for the purpose of determining the drift behaviour and the maintenance interval and by times needed for replacing the Teflon filter built into the sample gas path.

No errors in functioning were observed.

6.5 Assessment

Availability was 100% for both instruments including maintenance times required for testing.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 4: Determination of availability

		System 1	System 2
Operation time	h	2366	2366
Outage time	h	151*	151*
Maintenance time	h	9	9
Actual operating time:	h	2357	2357
Actual operating time incl. maintenance times:	h	2366	2366
Availability	%	100	100

*Power outage in the measurement container used for field testing

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

Not required for this performance criterion.

6.3 Testing

It was tested whether the software version can be displayed on the instrument. The AMS manufacturer was informed of his obligation to communicate any changes to the instrument software to the test laboratory.

6.4 Evaluation

The current software version is displayed when switching on the instrument. Furthermore, it can be accessed via menu item "Information" at any time.

The tests were performed with the following software version implemented:

Package Version 1.1.5

Driver Version 1.0.15.22

6.5 Assessment

The instrument's software version is displayed. Software changes are communicated to the test laboratory.

Criterion satisfied? yes

6.6 Detailed presentation of test results

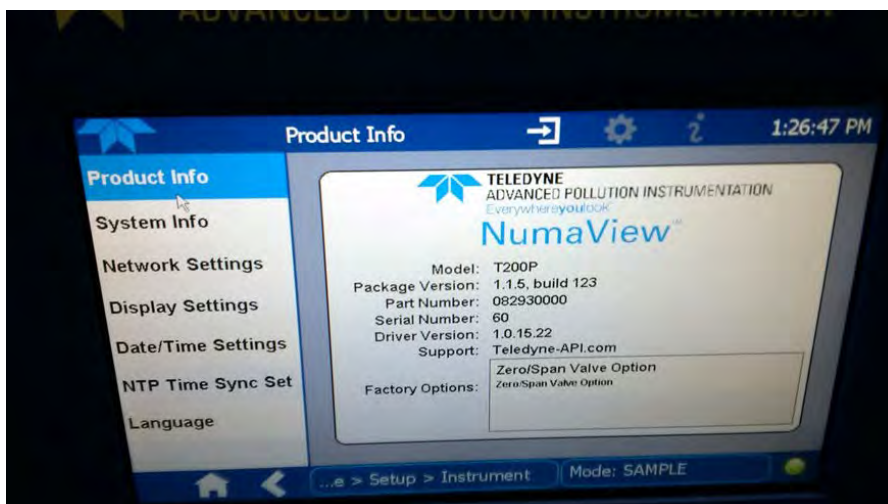


Figure 8: Display showing the software version

6.1 5.3.1 General requirements

This test was performed on the basis of the requirement specified in VDI Guideline 4202, part 1 (September 2010).

6.2 Equipment

Not required for this performance criterion.

6.3 Testing

This test was performed on the basis of the requirement specified in VDI Guideline 4202, part 1 (September 2012) and EN 14211 (2012).

6.4 Evaluation

VDI Guidelines 4202, part 1, and 4203, part 3, underwent a comprehensive revision and were then republished in September 2010. Criteria were assessed against the requirements specified in Table 2a/b of the mentioned guideline.

6.5 Assessment

This test and its evaluation were performed on the basis of the requirement specified in VDI Guideline 4202, part 1 (September 2010) and EN 14211 (2012).

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

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 VDI Guideline 4202, part 1, in the certification range according to Table 1 of that Guideline.

For alternative certification ranges, the repeatability standard deviation at zero point shall not exceed 2% of the upper limit of that certification range.

The repeatability standard deviation at zero point shall be ≤ 1.0 nmol/mol of the upper limit of the certification range.

6.2 Equipment

Not applicable

6.3 Testing

Performing and evaluating the repeatability standard deviation at zero point corresponds exactly to determining the repeatability standard deviation in accordance with standard EN 14211 (2012). The reader is therefore referred to chapter 7.1 8.4.5 Repeatability standard deviation.

6.4 Evaluation

See chapter 7.1 8.4.5 Repeatability standard deviation.

6.5 Assessment

See chapter 7.1 8.4.5 Repeatability standard deviation.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 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 Guideline 4202, part, in the certification range according to Table 1 of that Guideline. The limit value or the alert threshold shall be used as reference point.

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

The repeatability standard deviation at reference point shall not exceed 3 nmol/mol.

6.2 Equipment

Not applicable

6.3 Testing

Performing and evaluating the repeatability standard deviation at reference point corresponds exactly to determining the repeatability standard deviation in accordance with standard EN 14211 (2012). The reader is therefore referred to chapter 7.1 8.4.5 Repeatability standard deviation.

6.4 Evaluation

See chapter 7.1 8.4.5 Repeatability standard deviation.

6.5 Assessment

See chapter 7.1 8.4.5 Repeatability standard deviation
Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 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 VDI 4202, part 1, in the certification range according to Table 1, VDI 4202, part 1.

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

The deviations from the linear regression shall not exceed 4%.

6.2 Equipment

Not applicable

6.3 Testing

Performing and evaluating the lack of fit corresponds exactly to determining the lack of fit in accordance with standard EN 14211 (2012). The reader is therefore referred to chapter 7.1 8.4.6 Lack of fit of linearity of the calibration function.

6.4 Evaluation

See chapter 7.1 8.4.6 Lack of fit of linearity of the calibration function.

6.5 Assessment

See chapter 7.1 8.4.6 Lack of fit of linearity of the calibration function.
Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 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). A value c_t at 70% to 80% of the upper limit of the certification range shall be used as reference point.

The sensitivity coefficient of sample gas pressure at reference point shall not exceed 8 (nmol/mol)/kPA.

6.2 Equipment

Not applicable

6.3 Testing

Performing and evaluating the sensitivity coefficient of sample gas pressure corresponds exactly to determining the sensitivity coefficient to sample gas pressure in accordance with standard EN 14211 (2012). The reader is therefore referred to chapter 7.1 8.4.7 Sensitivity coefficient to sample gas pressure.

6.4 Evaluation

See chapter 7.1 8.4.7 Sensitivity coefficient to sample gas pressure

6.5 Assessment

See chapter 7.1 8.4.7 Sensitivity coefficient to sample gas pressure
Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 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). A value c_i at 70% to 80% of the upper limit of the certification range shall be used as reference point.

The sensitivity coefficient of sample gas temperature shall not exceed 3 (nmol/mol)/kPA.

6.2 Equipment

Not applicable

6.3 Testing

Performing and evaluating the sensitivity coefficient of sample gas temperature corresponds exactly to determining the sensitivity coefficient to sample gas temperature in accordance with standard EN 14211 (2012). The reader is therefore referred to chapter 8.4.8 Sensitivity coefficient to sample gas temperature.

6.4 Evaluation

See chapter 8.4.8 Sensitivity coefficient to sample gas temperature

6.5 Assessment

See chapter 8.4.8 Sensitivity coefficient to sample gas temperature
Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 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). A value c_t at 70% to 80% of the upper limit of the certification range shall be used as reference point.

The sensitivity coefficient of surrounding temperature shall not exceed 3 (nmol/mol)/kPA.

6.2 Equipment

Not applicable

6.3 Testing

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

6.4 Evaluation

See chapter 7.1 8.4.9 Sensitivity coefficient to surrounding temperature

6.5 Assessment

See chapter 7.1 8.4.9 Sensitivity coefficient to surrounding temperature
Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.3.8 Sensitivity coefficient of electrical voltage

The sensitivity coefficient of electrical voltage shall not exceed the requirements of Table 2 of 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.

The sensitivity coefficient of electrical voltage shall not exceed 0.3 (nmol/mol)/V.

6.2 Equipment

Not applicable

6.3 Testing

Performing and evaluating the sensitivity coefficient of electrical voltage corresponds exactly to determining the sensitivity coefficient to electrical voltage in accordance with standard EN 14211 (2012). The reader is therefore referred to chapter 7.1 8.4.10 Sensitivity coefficient to electrical voltage.

6.4 Evaluation

See chapter 7.1 8.4.10 Sensitivity coefficient to electrical voltage

6.5 Assessment

See chapter 7.1 8.4.10 Sensitivity coefficient to electrical voltage
Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 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, at zero and reference point. The limit value (1-h limit value for NO=631.3 µg/m³) 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 negative deviations caused by interfering components in the sample gas shall not exceed 3% of the upper limit of the certification range at zero and reference point. A value c_i at 70% to 80% of the upper limit of the certification range shall be used as reference point.

6.2 Equipment

Not applicable

6.3 Testing

Performing and evaluating cross sensitivity corresponds exactly to determining interferences in accordance with standard EN 14211 (2012). The reader is therefore referred to chapter 7.18.4.11 Interferences.

6.4 Evaluation

See chapter 7.1 8.4.11 Interferences

6.5 Assessment

See chapter 7.1 8.4.11 Interferences

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

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 VDI 4202, part 1 (September 2010).

The averaging effect shall not exceed 7% of the measured value.

6.2 Equipment

Not applicable

6.3 Testing

Performing and evaluating the averaging effect corresponds exactly to determining the averaging test in accordance with standard EN 14211 (2012). The reader is therefore referred to chapter 7.1 8.4.12 Averaging test.

6.4 Evaluation

See chapter 7.1 8.4.12 Averaging test

6.5 Assessment

See chapter 7.1 8.4.12 Averaging test

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

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 VDI 4202, part 1 (September 2010).

The standard deviation under field conditions shall not exceed 5% of the mean value over a period of three months.

6.2 Equipment

Not applicable

6.3 Testing

Performing and evaluating the standard deviation from paired measurements corresponds exactly to determining the reproducibility standard deviation in accordance with standard EN 14211 (2012). The reader is therefore referred to chapter 7.1 8.5.5 Reproducibility standard deviation for NO₂ under field conditions.

6.4 Evaluation

See chapter 7.1 8.5.5 Reproducibility standard deviation for NO₂ under field conditions

6.5 Assessment

See chapter 7.1 8.5.5 Reproducibility standard deviation for NO₂ under field conditions
Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

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 VDI 4202, part 1, 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.

The long-term drift at zero point shall not exceed 5 nmol/mol.

The long-term drift at reference point shall not exceed 5% of the upper limit of the certification range.

6.2 Equipment

Not applicable

6.3 Testing

Determination and evaluation of the long-term drift corresponds exactly to determining the long term drift in accordance with standard EN 14211 (2012). The reader is therefore referred to chapter 7.18.5.4 Long-term drift.

6.4 Evaluation

See chapter 7.1 8.5.4 Long-term drift

6.5 Assessment

See chapter 7.1 8.5.4 Long-term drift.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 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, 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.

The short-term drift at zero point shall not exceed 2 nmol/mol.

The short-term drift at reference point shall not exceed 6 nmol/mol.

6.2 Equipment

Not applicable

6.3 Testing

Determination and evaluation of the short-term drift corresponds exactly to determining the short term drift in accordance with standard EN 14211 (2012). The reader is therefore referred to chapter 7.1 8.4.4 Short-term drift.

6.4 Evaluation

See chapter 7.1 8.4.4 Short-term drift

6.5 Assessment

See chapter 7.1 8.4.4 Short-term drift

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 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

Not applicable

6.3 Testing

Determination and evaluation of the response time corresponds exactly to determining the response time in accordance with standard EN 14211 (2012). The reader is therefore referred to chapter 7.1 8.4.3 Response time.

6.4 Evaluation

See chapter 7.1 8.4.3 Response time

6.5 Assessment

See chapter 7.1 8.4.3 Response time

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 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). A value c_i at 70% to 80% of the upper limit of the certification range shall be used as reference point.

The difference between sample and calibration port shall not exceed 1%.

6.2 Equipment

Not applicable

6.3 Testing

Determination and evaluation of the difference between sample and calibration port corresponds exactly to determining the difference sample/calibration port in accordance with standard EN 14211 (2012). The reader is therefore referred to chapter 7.1 8.4.13 Difference sample/calibration port.

6.4 Evaluation

See chapter 7.1 8.4.13 Difference sample/calibration port

6.5 Assessment

See chapter 7.1 8.4.13 Difference sample/calibration port
Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

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

Not applicable

6.3 Testing

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

6.4 Evaluation

See chapter 7.1 8.4.14 Converter efficiency

6.5 Assessment

See chapter 7.1 8.4.14 Converter efficiency
Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 5.3.17 Increase of NO₂ concentration due to residence in the measuring system

In case of NO_x measuring systems the increase of NO₂ concentration due to residence in the measuring system shall not exceed the requirements of Table 2 of VDI 4202, part 1 (September 2010).

Requirements defined in Table 2 of VDI 4202, part 1, (September 2010) apply to the certification ranges specified in Table 1 of VDI 4202, part 1, (September 2010). For deviating certification ranges the requirements shall be proportionally converted.

6.2 Equipment

Not applicable

6.3 Testing

As part of the review of standard EN 14211 (2012), test item Increase of NO₂ concentration due to residence in the measuring system (2005 version) was replaced by "Residence time in the analyser" (2012 version). The reader is therefore referred to chapter

7.1 8.4.15 Residence time in the analyser.

6.4 Evaluation

See chapter 7.1 8.4.15 Residence time in the analyser

6.5 Assessment

See chapter 7.1 8.4.15 Residence time in the analyser

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

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 VDI 4202, part 1 (September 2010).

6.2 Equipment

Not applicable

6.3 Testing

The uncertainty calculation was performed in accordance with standard EN 14211 (2012) and is presented in chapter 7.1 8.6 Calculation of the total uncertainty in accordance with standard EN 14211 (2012).

6.4 Evaluation

The uncertainty calculation was performed in accordance with standard EN 14211 (2012) and is presented in chapter 7.1 8.6 Calculation of the total uncertainty in accordance with standard EN 14211 (2012).

6.5 Assessment

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

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

7. Test Results in accordance with Standard EN 14211 (2012)

7.1 8.4.3 Response time

Rise and fall response time ≤ 180 s each. Difference between rise and fall response time ≤ 10 s.

7.2 Test procedures

The determination of the response time shall be carried out by applying to the analyser a step function in the concentration from less than 20 % to about 80 % of the maximum of the certification range of NO and vice versa.

The change from zero gas to span gas and vice versa needs to be made almost instantaneously, with the use of a suitable valve. The valve outlet shall be mounted direct to the inlet of the analyser, and both zero gas and span gas shall have the same amount of gas in excess, which is vented by the use of a tee. The gas flows of both zero gas and span gas shall be chosen in such a way that the dead time in the valve and tee can be neglected compared to the lag time of the analyser system. The step change is made by switching the valve from zero gas to span gas. This event needs to be timed and is the start ($t = 0$) of the (rise) lag time according to Figure 13. When the reading shows 98% of the applied concentration, the span gas can be changed to zero gas again; this event is the start ($t = 0$) of the (fall) lag time. When the reading shows 2% of the applied concentration, the whole cycle as shown in Figure 9 is complete.

The elapsed time (response time) between the start of the step change and reaching 90% of the analyser final stable reading of the applied concentration shall be measured. The whole cycle shall be repeated four times. The average of the four response times (rise) and the average of the four response times (fall) shall be calculated.

The test shall then be repeated with NO₂ at levels from less than 20 % to about 80 % of the maximum of the certification range of NO₂ and vice versa.

The difference in response times shall be calculated according to: Where:

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

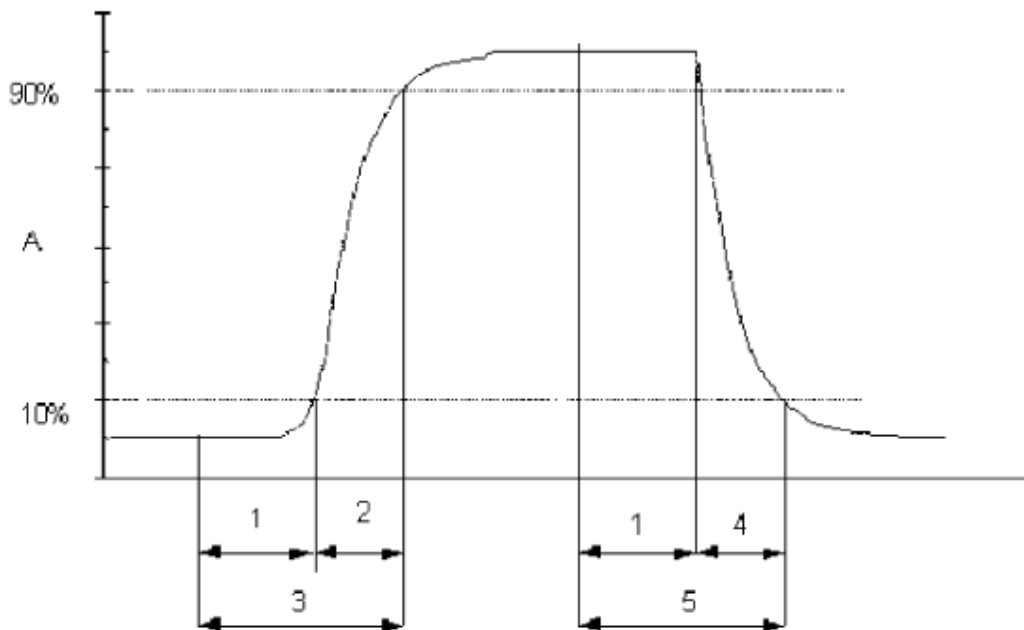
Where:

t_d is the difference between response time (rise) and response time (fall), in s;

\bar{t}_r is the response time (rise) (average of the four response times - rise), in s;

\bar{t}_f is the response time (fall) (average of the four response times - fall), in s.

t_r , t_f and t_d shall comply with the performance criteria indicated above.



Key

- A analyser response
- 1 lag time
- 2 rise time
- 3 response time (rise)
- 4 fall time
- 5 response time (fall)

Figure 9: Diagram illustrating the response time

7.3 Testing

The test was performed in line with the requirements of EN 14211 mentioned before. A Yokogawa data logger with the averaging time set to 1s was used to record data.

7.4 Evaluation

Table 5 Response time of the two T200P measuring systems for NO

	Anforderung	Gerät 1		Gerät 2	
Mittelwert Anstieg t_r [s]	≤ 180 s	52	✓	53	✓
Mittelwert Abfall t_f [s]	≤ 180 s	54	✓	54	✓
Differenz t_d [s]	≤ 10 s	-2	✓	-1	✓

For NO, system 1, the average t_r was 52s, the average t_f was 54s and t_d -2s.

For NO, system 2, the average t_r was 53s, the average t_f was 54s and t_d -1s.

Table 6 Response time of the two T200P measuring systems for NO₂

	requirements	device 1		device 2	
average rise t_r [s]	≤ 180 s	42	✓	42	✓
average fall t_f [s]	≤ 180 s	42.5	✓	41.5	✓
difference t_d [s]	≤ 10 s	-0.5	✓	0.5	✓

For NO₂, system 1, the average t_r was 42, the average t_f was 42.5 and t_d -0.5s.

For NO₂, system 2, the average t_r was 42, the average t_f was 41.5 and t_d 0.5s.

7.5 Assessment

The values determined remained considerably below the maximum permissible response time of 180 s at all times. The maximum response time determined for instrument 1 was 54 s for NO and 42.5 s for NO₂. For instrument 2 it was determined at 54 s for NO and 42 s for NO₂.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 7: Individual readings for the response time for component NO

80%		device 1					
measuring range	768.00	rise			fall		
	nmol/mol	0.0	0.9	1.0	1.0	0.1	0.0
		0.00	691.20	768.00	768.00	76.80	0.00
cycle 1	t = 0	12:05:00	12:05:55	12:07:00	12:12:00	12:12:55	12:14:00
	delta t		00:00:55			00:00:55	
	delta t [s]		55			55	
cycle 2	t = 0	12:19:00	12:19:52	12:20:00	12:25:00	12:25:52	12:26:00
	delta t		00:00:52			00:00:52	
	delta t [s]		52			52	
cycle 3	t = 0	12:31:00	12:31:51	12:33:00	12:45:00	12:45:53	12:46:00
	delta t		00:00:51			00:00:53	
	delta t [s]		51			53	
cycle 4	t = 0	12:51:00	12:51:50	12:53:00	12:57:00	12:57:56	12:58:00
	delta t		00:00:50			00:00:56	
	delta t [s]		50			56	

80%		device 2					
measuring range	768.00	rise			fall		
	nmol/mol	0.0	0.9	1.0	1.0	0.1	0.0
		0.00	691.20	768.00	768.00	76.80	0.00
cycle 1	t = 0	12:05:00	12:05:54	12:07:00	12:12:00	12:12:55	12:14:00
	delta t		00:00:54			00:00:55	
	delta t [s]		54			55	
cycle 2	t = 0	12:19:00	12:19:56	12:20:00	12:25:00	12:25:52	12:26:00
	delta t		00:00:56			00:00:52	
	delta t [s]		56			52	
cycle 3	t = 0	12:31:00	12:31:50	12:33:00	12:45:00	12:45:53	12:46:00
	delta t		00:00:50			00:00:53	
	delta t [s]		50			53	
cycle 4	t = 0	12:51:00	12:51:52	12:53:00	12:57:00	12:57:56	12:58:00
	delta t		00:00:52			00:00:56	
	delta t [s]		52			56	

Table 8: Individual readings for the response time for component NO₂

80%		device 1					
measuring range	209.21	rise			fall		
	nmol/mol	0.0	0.9	1.0	1.0	0.1	0.0
cycle 1	t = 0	09:17:00	09:17:42	09:19:00	09:24:00	09:24:44	09:26:00
	delta t	0.00	188.28	209.21	209.21	20.92	0.00
	delta t [s]		42			44	
cycle 2	t = 0	09:31:00	09:31:41	09:33:00	09:38:00	09:38:43	09:40:00
	delta t						
	delta t [s]		41			43	
cycle 3	t = 0	09:45:00	09:45:41	09:47:00	09:51:00	09:51:41	09:53:00
	delta t						
	delta t [s]		41			41	
cycle 4	t = 0	09:58:00	09:58:44	10:00:00	10:05:00	10:07:42	10:07:00
	delta t						
	delta t [s]		44			42	

80%		device 2					
measuring range	209.21	rise			fall		
	nmol/mol	0.0	0.9	1.0	1.0	0.1	0.0
cycle 1	t = 0	09:17:00	09:17:43	09:19:00	08:27:00	09:24:41	09:26:00
	delta t	0.00	188.28	209.21	209.21	20.92	0.00
	delta t [s]		43			41	
cycle 2	t = 0	09:31:00	09:31:42	09:33:00	09:38:00	09:38:40	09:40:00
	delta t						
	delta t [s]		42			40	
cycle 3	t = 0	09:45:00	09:45:39	09:47:00	09:51:00	09:51:41	09:53:00
	delta t						
	delta t [s]		39			41	
cycle 4	t = 0	09:58:00	09:58:44	10:00:00	10:05:00	10:07:44	10:07:00
	delta t						
	delta t [s]		44			44	

7.1 8.4.4 Short-term drift

Short-term drift at zero shall not exceed 2.0 nmol/mol/12 h.

The short-term drift at reference level shall not exceed 6.0 nmol/mol/12 h.

7.2 Test procedure

After the required stabilisation period, the analyser shall be adjusted at zero and span level (around 70% to 80% of the maximum of the certification range). Wait the time equivalent to one independent reading and then record 20 individual measurements, first at zero and then at span concentration. From these 20 measurements, the average is calculated for zero and span level.

The analyser shall be kept running under the laboratory conditions. After a period of 12 h, zero and span gas is fed to the analyser. Wait the time equivalent to one independent reading and then record 20 individual measurements, first at zero and then at span concentration. The averages for zero and span level shall be calculated.

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

$$D_{s,z} = (C_{z,2} - C_{z,1})$$

Where:

$D_{s,z}$ is the 12-hour drift at zero;

$C_{z,1}$ is the average concentration of the measurements at zero at the beginning of the drift period;

$C_{z,2}$ is the average concentration of the measurements at zero at the end of the drift period.

$D_{s,z}$ shall comply with the performance criterion indicated above.

$$D_{s,s} = (C_{s,2} - C_{s,1}) - D_{s,z}$$

Where:

$D_{s,s}$ is the 12-hour drift at span;

$C_{s,1}$ is the average concentration of the measurements at span level at the beginning of the drift period;

$C_{s,2}$ is the average concentration of the measurements at span level at the end of the drift period.

$D_{s,s}$ shall comply with the performance criterion indicated above.

7.3 Testing

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

7.4 Evaluation

Table 9 indicates the measured value determined for the short-term drift.

Table 9: Results for the short-term drift

	requirements	device 1		device 2	
average at zero at the beginning [nmol/mol]	-	0.12		0.11	
average at zero at the end [nmol/mol]	-	0.14		0.14	
average at span at the beginning [nmol/mol]	-	719.75		720.32	
average at span at the end [nmol/mol]	-	720.50		721.20	
12-hour drift at zero $D_{s,z}$ [nmol/mol]	≤ 2,0	0.03	✓	0.03	✓
12-hour drift at span $D_{s,s}$ [nmol/mol]	≤ 6,0	0.72	✓	0.86	✓

7.5 Assessment

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

Short-term drift at reference point was 0.72 nmol/mol/12 h for instrument 1 and 0.86 nmol/mol/12 h for instrument 2.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 10 and Table 11 present the individual test results.

Table10 Values at the start of the short-term drift test

at beginning			at beginning		
zero level			span level		
	device 1	device 2		device 1	device 2
time	[nmol/mol]	[nmol/mol]	time	[nmol/mol]	[nmol/mol]
19:00:00	0.1	0.1	19:30:00	719.8	720.5
19:01:00	0.1	0.1	19:31:00	719.8	720.5
19:02:00	0.1	0.1	19:32:00	719.8	720.5
19:03:00	0.1	0.1	19:33:00	719.8	720.5
19:04:00	0.1	0.1	19:34:00	719.8	720.5
19:05:00	0.1	0.1	19:35:00	719.8	720.5
19:06:00	0.1	0.1	19:36:00	719.8	720.5
19:07:00	0.1	0.1	19:37:00	719.8	720.5
19:08:00	0.1	0.1	19:38:00	719.8	720.5
19:09:00	0.1	0.1	19:39:00	719.8	720.5
19:10:00	0.1	0.1	19:40:00	719.8	720.5
19:11:00	0.1	0.1	19:41:00	719.8	720.5
19:12:00	0.1	0.1	19:42:00	719.8	720.5
19:13:00	0.1	0.1	19:43:00	719.8	720.5
19:14:00	0.1	0.1	19:44:00	719.8	720.5
19:15:00	0.1	0.1	19:45:00	719.8	719.8
19:16:00	0.1	0.1	19:46:00	719.8	719.8
19:17:00	0.1	0.1	19:47:00	719.8	719.8
19:18:00	0.1	0.1	19:48:00	719.8	719.8
19:19:00	0.1	0.1	19:49:00	719.8	719.8
average	0.1	0.1	average	719.8	720.3

Table 11 Values at the end of the short-term drift test

after 12h		
zero level		
	device 1	device 2
time	[nmol/mol]	[nmol/mol]
07:05:00	0.2	0.2
07:06:00	0.2	0.2
07:07:00	0.2	0.1
07:08:00	0.2	0.1
07:09:00	0.2	0.1
07:10:00	0.1	0.1
07:11:00	0.1	0.1
07:12:00	0.1	0.1
07:13:00	0.1	0.1
07:14:00	0.1	0.1
07:15:00	0.1	0.1
07:16:00	0.1	0.1
07:17:00	0.1	0.1
07:18:00	0.1	0.1
07:19:00	0.1	0.1
07:20:00	0.1	0.1
07:21:00	0.1	0.1
07:22:00	0.1	0.1
07:23:00	0.1	0.1
07:24:00	0.1	0.1
average	0.1	0.1

after 12h		
span level		
	device 1	device 2
time	[nmol/mol]	[nmol/mol]
07:35:00	720.5	721.3
07:36:00	720.5	721.0
07:37:00	720.5	721.0
07:38:00	720.5	721.3
07:39:00	720.5	721.3
07:40:00	720.5	721.3
07:41:00	720.5	721.3
07:42:00	720.5	721.3
07:43:00	720.5	721.3
07:44:00	720.5	721.0
07:45:00	720.5	721.0
07:46:00	720.5	721.3
07:47:00	720.5	721.3
07:48:00	720.5	721.3
07:49:00	720.5	721.3
07:50:00	720.5	721.3
07:51:00	720.5	721.3
07:52:00	720.5	721.3
07:53:00	720.5	721.3
07:54:00	720.5	721.3
average	720.5	721.2

7.1 8.4.5 Repeatability standard deviation

The performance criteria are as follows: Repeatability standard deviation at zero shall not exceed 1.0 nmol/mol. At a sample gas concentration at the reference point it shall not exceed 3 nmol/mol.

7.2 Test procedure

After waiting the time equivalent of one independent reading, 20 individual measurements both at zero concentration and at an NO test concentration (c_t) of (500 ± 50) nmol/mol shall be performed.

From these measurements, the repeatability standard deviation (s_r) at zero concentration and at concentration c_t shall be calculated according to:

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

Where:

- s_r the repeatability standard deviation;
- x_i the i th measurement;
- \bar{x} is the average of the 20 measurements;
- n is the number of measurements.

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

s_r shall comply with the performance criterion indicated above, both at zero and at the test gas concentration c_t .

7.3 Testing

The test was performed in line with the requirements of EN 14211 mentioned before. In compliance with the standard, the test has to be performed with the component NO. Pursuant to EN 14211, the test shall be performed at a concentration level of 500 nmol/mol NO. Pursuant to VDI Guideline 4202, part 1, the repeatability standard deviation at reference point shall be determined at the limit value.

7.4 Evaluation

Table 12 presents the results for the repeatability standard deviation.

Table 12: Repeatability standard deviation at zero and reference point

	requirements	device 1		device 2	
repeatability standard deviation $s_{r,z}$ at zero [nmol/mol]	≤ 1.0	0.00	✓	0.00	✓
repeatability standard deviation $s_{r,ct}$ at c_t [nmol/mol]	≤ 3.0	1.23	✓	1.46	✓
detection limit [nmol/mol]		0.00		0.00	

7.5 Assessment

For instrument 1 the value for the repeatability standard deviation at zero point was 0.00 nmol/mol, for instrument 2 it was 0.00 nmol/mol. Repeatability standard deviation at reference point was 1.23 nmol/mol for instrument 1 and 1.46 nmol/mol for instrument 2.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 13 lists the results of individual measurements.

Table 13: Individual test results obtained for the repeatability standard deviation

zero level			c_t level		
	device 1	device 2		device 1	device 2
time	[nmol/mol]	[nmol/mol]	time	[nmol/mol]	[nmol/mol]
13:43:00	-1.0	-1.0	14:17:00	505.0	504.3
13:44:00	-1.0	-1.0	14:18:00	505.0	504.3
13:45:00	-1.0	-1.0	14:19:00	506.9	504.3
13:46:00	-1.0	-1.0	14:20:00	506.9	504.3
13:47:00	-1.0	-1.0	14:21:00	506.9	504.3
13:48:00	-1.0	-1.0	14:22:00	506.9	506.2
13:49:00	-1.0	-1.0	14:23:00	506.9	506.2
13:50:00	-1.0	-1.0	14:24:00	506.9	506.2
13:51:00	-1.0	-1.0	14:25:00	506.9	506.2
13:52:00	-1.0	-1.0	14:26:00	506.9	506.2
13:53:00	-1.0	-1.0	14:27:00	506.9	506.2
13:54:00	-1.0	-1.0	14:28:00	506.9	506.2
13:55:00	-1.0	-1.0	14:29:00	506.9	506.2
13:56:00	-1.0	-1.0	14:30:00	508.8	506.2
13:57:00	-1.0	-1.0	14:31:00	508.8	508.1
13:58:00	-1.0	-1.0	14:32:00	508.8	508.1
13:59:00	-1.0	-1.0	14:33:00	508.8	508.1
14:00:00	-1.0	-1.0	14:34:00	508.8	508.1
14:01:00	-1.0	-1.0	14:35:00	508.8	508.1
14:02:00	-1.0	-1.0	14:36:00	508.8	508.1
average	-1.0	-1.0	average	507.4	506.3

7.1 8.4.6 Lack of fit of linearity of the calibration function

The deviation from the linearity of the calibration function at zero shall not exceed 5 nmol/mol. At concentrations above zero, it shall not exceed 4% of the measured value.

7.2 Test procedure

The lack of fit of linearity of the calibration function of the analyser shall be tested over the range of 0% to 95% of the maximum of the certification range of NO, using at least six concentrations (including the zero point). The analyser shall be adjusted at a concentration of about 80% of the maximum of the certification range. At each concentration (including zero) at least five single measurements shall be performed.

The concentrations shall be applied in the following sequence: 80%, 40%, 0%, 60%, 20% and 95%. After each change in concentration, at least four response times shall be taken into account before the next measurement is performed.

The regression function and the deviations shall be calculated in accordance with Annex A of standard EN 14211. The deviations from the linear regression function shall comply with the performance criterion specified above.

Establishment of the regression line:

A linear regression function in the form of $Y_i = A + B * X_i$ is made through calculation of the following formula:

$$Y_i = a + B(X_i - X_z)$$

For the regression calculation, all measuring points (including zero) are taken into account. The total number of measuring points is equal to the number of concentration levels (at least six including zero) times the number of repetitions (at least five) at a particular concentration level.

The coefficient a is obtained from:

$$a = \sum Y_i / n$$

Where:

- a is the average value of the Y-values;
- Y_i is the individual Y-value;
- N is the number of measuring points.

The coefficient B is obtained from:

$$B = \left(\sum Y_i (X_i - X_z) \right) / \sum (X_i - X_z)^2$$

Where:

X_z is the average of the x-values $(= \sum (X_i / n))$
 X_i is the individual x-value.

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

$$A = a - B * X_z$$

The residuals of the averages of each calibration point (including the zero point) are calculated as follows.

The average of each calibration point (including the zero point) at one and the same concentration c is calculated according to:

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

Where:

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

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

$$r_c = (Y_a)_c - (A + B \times c)$$

Each residual to a value relative to its own concentration level c is expressed in % as:

$$r_{c,rel} = \frac{r_c}{c} \times 100\%$$

7.3 Testing

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

7.4 Evaluation

The following linear regressions were established:

Figure 10 and Figure 11 summarise the results of the group averages.

Table 14: Deviations of the analyser function T200P

	requirements	device 1		device 2	
largest value of the relative residuals r_{max} [%]	≤ 4.0	0.75	✓	1.10	✓
residual at zero r_z [nmol/mol]	≤ 5.0	-0.94	✓	-0.94	✓

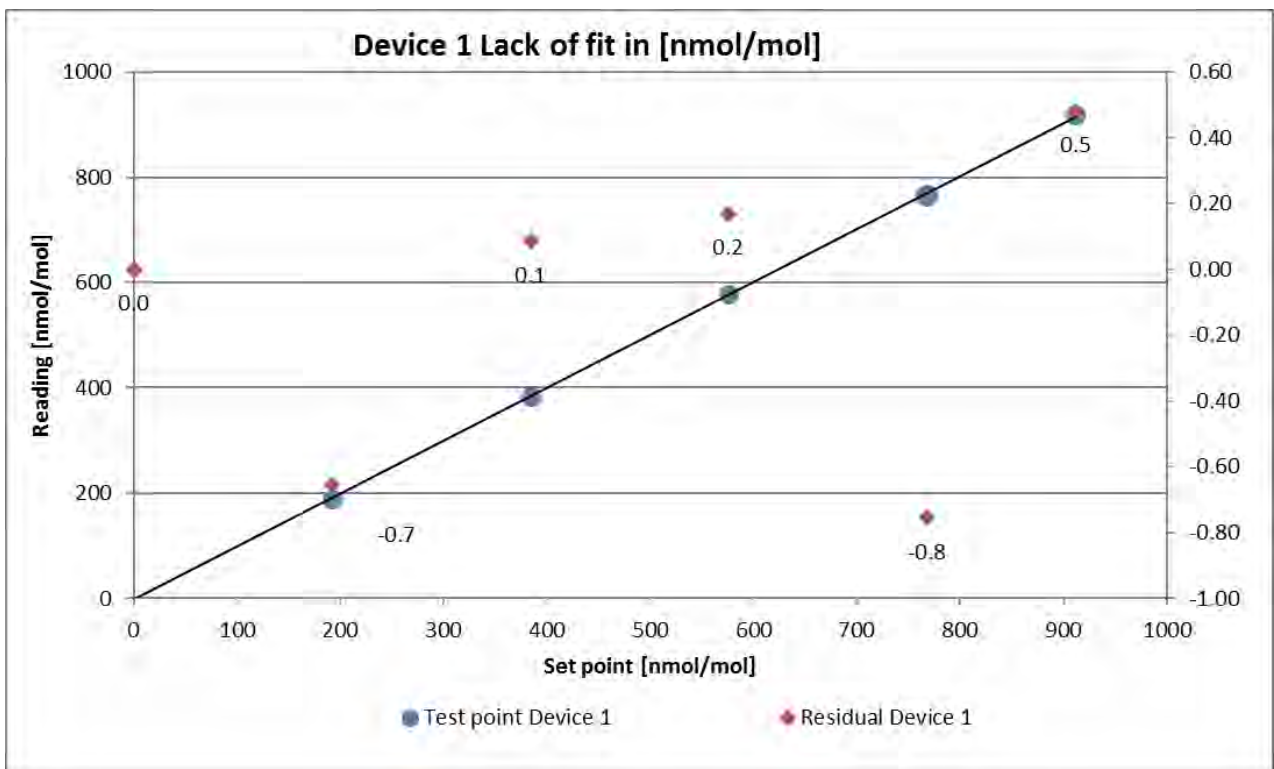


Figure 10: Analytical function obtained from the group averages for system 1, component NO

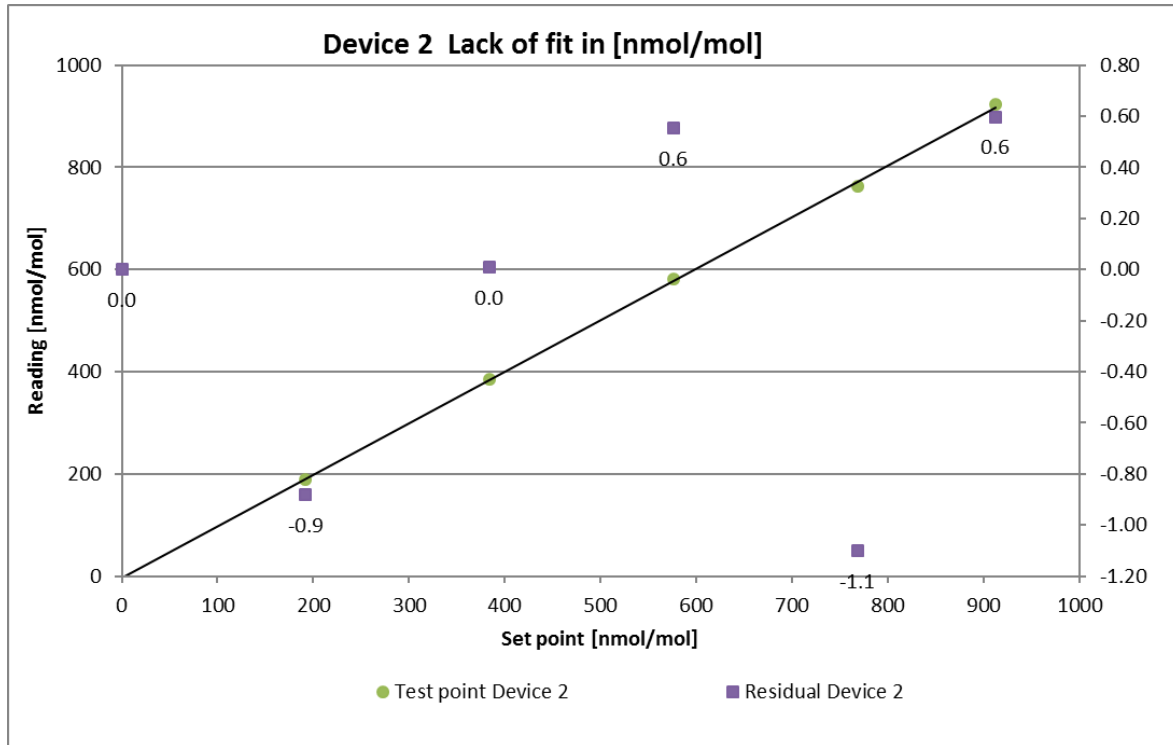


Figure 11: Analytical function obtained from the group averages for system 2, component NO

7.5 Assessment

The deviation from the linear regression line for instrument 1 is -0.94 nmol/mol at zero point and no more than 0.75% of the target value for concentrations above zero. The deviation from the linear regression line for instrument 2 is -0.94 nmol/mol at zero point and no more than 1.10% of the target value for concentrations above zero.

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

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 15 presents the individual test results.

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Table 15: Individual results of the lack-of-fit test

		device 1 [nmol/mol]		device 2 [nmol/mol]	
time	level [%]	actual value y _i	set value x _i	actual value y _i	set value x _i
10:13:00	80	762.50	768.00	762.20	768.00
10:14:00	80	762.80	768.00	762.30	768.00
10:15:00	80	763.00	768.00	763.10	768.00
10:16:00	80	764.10	768.00	764.20	768.00
10:17:00	80	765.40	768.00	765.30	768.00
average		763.56		763.42	
r _{c,rel}		-0.75		-1.10	
10:21:00	40	384.20	384.00	384.60	384.00
10:22:00	40	384.00	384.00	384.50	384.00
10:23:00	40	383.80	384.00	384.80	384.00
10:24:00	40	383.60	384.00	384.80	384.00
10:25:00	40	383.70	384.00	385.10	384.00
average		383.86		384.76	
r _{c,rel}		0.09		0.01	
10:29:00	0	-0.80	0.00	-0.90	0.00
10:30:00	0	-0.90	0.00	-0.90	0.00
10:31:00	0	-0.90	0.00	-0.90	0.00
10:32:00	0	-1.00	0.00	-1.00	0.00
10:33:00	0	-1.10	0.00	-1.00	0.00
average		-0.94		-0.94	
r _z					
10:37:00	60	576.80	576.00	582.00	576.00
10:38:00	60	577.00	576.00	581.90	576.00
10:39:00	60	577.40	576.00	581.40	576.00
10:40:00	60	577.80	576.00	581.20	576.00
10:41:00	60	578.10	576.00	581.00	576.00
average		577.42		581.50	
r _{c,rel}		0.17		0.55	
10:45:00	20	189.30	192.00	188.90	192.00
10:46:00	20	189.40	192.00	189.20	192.00
10:47:00	20	189.40	192.00	189.50	192.00
10:48:00	20	189.40	192.00	189.70	192.00
10:49:00	20	189.30	192.00	190.00	192.00
average		189.36		189.46	
r _{c,rel}		-0.65		-0.88	
10:53:00	95	918.10	912.00	922.50	912.00
10:54:00	95	918.20	912.00	922.50	912.00
10:55:00	95	918.40	912.00	922.60	912.00
10:56:00	95	918.40	912.00	922.40	912.00
10:57:00	95	919.00	912.00	922.60	912.00
average		918.42		922.52	
r _{c,rel}		0.48		0.60	

7.1 8.4.7 Sensitivity coefficient to sample gas pressure

The sensitivity coefficient to sample gas pressure shall be ≤ 8.0 nmol/mol/kPa.

7.2 Test procedures

Measurements are taken at a concentration of about 70% to 80% of the maximum of the certification range of NO at an absolute pressure of about (80 ± 0.2) kPa and at an absolute pressure of about (110 ± 0.2) kPa. At each pressure after waiting the time equivalent to one independent reading, three individual measurements are recorded. From these measurements, the averages at each pressure are calculated.

Measurements at different pressures shall be separated by at least four response times.

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

$$b_{sp} = \left| \frac{(C_{P2} - C_{P1})}{(P_2 - P_1)} \right|$$

Where:

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

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

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

P_1 is the minimum sampling gas pressure P_1 ;

P_2 is the maximum sampling gas pressure P_2 .

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

7.3 Testing

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

Negative pressure was produced by reducing the test gas volume fed by means of blocking the sample gas line. For the positive pressure test, the AMS was connected to a sample gas source. The test gas volume generated was set at a higher rate than the volume sucked in by the analyser. The excess supply was diverted via a tee. The positive pressure was produced by blocking the bypass line. The test gas pressure was determined with the help of a pressure sensor located in the sample gas path.

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

7.4 Evaluation

The following sensitivity coefficients to sample gas pressure were determined:

Table 16: Sensitivity coefficient to sample gas pressure

	requirements	device 1		device 2	
sensitivity coeff. sample gas pressure b_{gp} [nmol/mol/kPa]	≤ 8.0	0.99	✓	0.91	✓

7.5 Assessment

For instrument 1, the sensitivity coefficient to sample gas pressure is 0.99 nmol/mol/kPa.

For instrument 2, the sensitivity coefficient to sample gas pressure is 0.91 nmol/mol/kPa.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 17: Individual values obtained from testing the sensitivity to changes in the sample gas pressure

time	pressure [kPa]	concentration	device 1		device 2	
			[nmol/mol]	[nmol/mol]	[nmol/mol]	[nmol/mol]
13:28:00	80	720.00	738.80		736.10	
13:29:00	80	720.00	739.90		736.20	
13:30:00	80	720.00	739.10		737.50	
average C_{P1}			739.27		736.60	
13:14:00	110	720.00	710.10		709.20	
13:15:00	110	720.00	709.80		709.30	
13:16:00	110	720.00	709.00		709.50	
average C_{P2}			709.63		709.33	

8.4.8 Sensitivity coefficient to sample gas temperature

The sensitivity coefficient to sample gas temperature shall be $\leq 3.0 \mu\text{mol/mol/K}$.

7.2 Test procedures

Measurements shall be performed at sample gas temperatures of $T_{G,1} = 0 \text{ }^\circ\text{C}$ and $T_{G,2} = 30 \text{ }^\circ\text{C}$. The sensitivity coefficient to sample gas temperature is determined at a concentration of around 70% to 80% of the maximum certification range. Wait the time equivalent to one independent measurement and record three individual measurements at each temperature.

The sample gas temperature, measured at the inlet of the analyser, shall be held constant for at least 30 minutes.

The sensitivity coefficient to sample gas temperature is calculated as follows:

$$b_{gt} = \frac{(C_{GT,2} - C_{GT,1})}{(T_{G,2} - T_{G,1})}$$

Where:

- b_{gt} is the sample gas temperature sensitivity coefficient;
- $C_{GT,1}$ is the average concentration of the measurements at sample gas temperature $T_{G,1}$;
- $C_{GT,2}$ is the average concentration of the measurements at sample gas temperature $T_{G,2}$;
- $T_{G,1}$ is the minimum sample gas temperature;
- $T_{G,2}$ is the maximum sample gas temperature;
- b_{gt} shall comply with the performance criterion indicated above.

7.3 Testing

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

For the purpose of this test, the test gas mixture was led through a 50 m tube-bundle and a mixing container which were situated in a climatic chamber. The measuring systems were installed directly upstream of the climatic chamber. The end of the tube-bundle was led out of the climatic chamber and connected to the measuring systems. The feed line outside of the climatic chamber was isolated; a thermometer was used to monitor the temperature of the test gas directly upstream of the measuring system. The temperature of the climatic chamber was adjusted so that the gas temperature directly upstream of the analysers was exactly $0 \text{ }^\circ\text{C}$ or $30 \text{ }^\circ\text{C}$.

7.4 Evaluation

Table 18: Sensitivity coefficient to sample gas temperature

	requirements	device 1		device 2	
sensitivity coeff. sample gas temperature b_{gt} [nmol/mol/K]	≤ 3.0	0.15	✓	0.13	✓

7.5 Assessment

For instrument 1, the sensitivity coefficient to sample gas temperature is 0.15 nmol/mol/K.

For instrument 2, the sensitivity coefficient to sample gas temperature is 0.13 nmol/mol/K.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 19: Individual results obtained for the influence of sample gas temperature for NO

time	temp [°C]	concentration	device 1	device 2
			[nmol/mol]	[nmol/mol]
08:20:00	0	720.00	720.30	720.30
08:21:00	0	720.00	720.40	720.70
08:22:00	0	720.00	720.60	721.20
average $C_{GT,1}$			720.43	720.73
08:26:00	30	720.00	715.10	716.10
08:27:00	30	720.00	716.30	717.10
08:28:00	30	720.00	716.50	717.30
average $C_{GT,1}$			715.97	716.83

7.1 8.4.9 Sensitivity coefficient to surrounding temperature

The sensitivity coefficient to surrounding temperature shall be ≤ 3.0 $\mu\text{mol/mol/K}$.

7.2 Test procedures

The sensitivity of the analyser readings to the surrounding temperature shall be determined by performing measurements at the following temperatures within the specifications of the manufacturer:

- 1) at the minimum temperature $T_{\min} = 0$ °C;
- 2) at the temperature $T_1 = 20$ °C;
- 3) at the maximum temperature $T_{\max} = 30$ °C.

For these tests, a climate chamber is necessary.

The sensitivity coefficient to surrounding temperature is determined at a concentration of around 70% to 80% of the maximum certification range. At each temperature setting after waiting the time equivalent to one independent measurement, three individual measurements at zero and at span shall be recorded.

The sequence of test temperatures is as follows:

T_1, T_{\min}, T_1 and T_1, T_{\max}, T_1

At the first temperature (T_1), the analyser shall be adjusted at zero and at span level (70% to 80% of the maximum of the certification range). Then three individual measurements are recorded after waiting the time equivalent to one independent reading at T_1 , at T_{\min} and again at T_1 . This measurement procedure shall be repeated at the temperature sequence of T_1, T_{\max} and at T_1 .

In order to exclude any possible drift due to factors other than temperature, the measurements at T_1 are averaged, which is taken into account in the following formula for calculation of the sensitivity coefficient for temperature dependence:

$$b_{st} = \left| \frac{x_T - \frac{x_1 + x_2}{2}}{T_S - T_{S,0}} \right|$$

Where:

b_{st} is the surrounding temperature sensitivity coefficient;

x_T is the average of the measurements at T_{\min} or T_{\max} ;

x_1 is the first average of the measurements at T_1 ;

x_2 is the second average of the measurements at T_1 ;

T_S is the surrounding temperature in the laboratory;

$T_{S,0}$ is the average of the surrounding temperatures at set point.

For reporting the surrounding temperature dependence the higher value is taken of the two calculations of the temperature dependence at $T_{S,1}$ and $T_{S,2}$.

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

7.3 Testing

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

7.4 Evaluation

The following sensitivity coefficients to surrounding temperature have been determined:

Table 20: Sensitivity coefficients to surrounding temperature

	requirements	device 1		device 2	
sensitivity coefficient at 0 °C for zero level [nmol/mol/K]	≤ 3.0	0.015	✓	0.016	✓
sensitivity coefficient at 30 °C for zero level [nmol/mol/K]	≤ 3.0	0.027	✓	0.023	✓
sensitivity coefficient at 0 °C for span level [nmol/mol/K]	≤ 3.0	0.410	✓	0.342	✓
sensitivity coefficient at 30 °C for span level [nmol/mol/K]	≤ 3.0	0.297	✓	0.732	✓

As is evident from Table 20, the sensitivity coefficient to the surrounding temperature at zero and at reference point meets the performance criteria.

7.5 Assessment

The sensitivity coefficient to the surrounding temperature b_{st} did not exceed the performance criterion specified at 3.0 nmol/mol/K. For the purpose of uncertainty calculation, the largest value b_{st} is used for both instruments. This would be 0.410 nmol/mol/K for instrument 1 and 0.732 nmol/mol/K for instrument 2.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 21 presents the individual test results.

Table 21: Individual test results for the sensitivity coefficients

date	zero level				span level			
	time	temp [°C]	device 1 [nmol/mol]	device 2 [nmol/mol]	time	temp [°C]	device 1 [nmol/mol]	device 2 [nmol/mol]
09.05.2017	07:57:00	20	0.0	0.0	08:25:00	20	720.3	720.5
09.05.2017	07:58:00	20	0.0	0.1	08:26:00	20	720.5	720.6
09.05.2017	07:58:00	20	0.0	0.1	08:27:00	20	720.6	720.8
average (X _{1(TS1)})			0.0	0.1			720.5	720.6
09.05.2017	15:55:00	0	-0.3	-0.1	16:12:00	0	711.1	713.7
09.05.2017	15:56:00	0	-0.3	-0.3	16:13:00	0	711.2	714.0
09.05.2017	15:57:00	0	-0.3	-0.3	16:14:00	0	711.3	714.2
average(X _{TS1})			0	-0.2			711.2	714.0
10.05.2017	08:08:00	20	0.0	0.1	08:25:00	20	718.2	720.4
10.05.2017	08:09:00	20	0.0	0.1	08:26:00	20	718.2	721.4
10.05.2017	08:10:00	20	0.0	0.1	08:27:00	20	718.6	721.2
average (X _{2(TS1)}) = (X _{1(TS2)})			0.0	0.1			718.3	721.0
10.05.2017	14:49:00	30	0.3	0.3	15:06:00	30	722.4	728.6
10.05.2017	14:50:00	30	0.2	0.3	15:07:00	30	723.3	729.5
10.05.2017	14:51:00	30	0.3	0.3	15:08:00	30	723.5	729.7
average(X _{TS2})			0.3	0.3			723.1	729.3
11.05.2017	08:19:00	20	0.0	0.1	08:36:00	20	721.5	722.2
11.05.2017	08:20:00	20	0.0	0.0	08:37:00	20	722.0	723.0
11.05.2017	08:21:00	20	0.0	0.0	08:38:00	20	722.1	723.5
average (X _{2(TS2)})			0.0	0.0			721.9	722.9

7.1 8.4.10 Sensitivity coefficient to electrical voltage

The sensitivity coefficient to electrical voltage shall not exceed 0.30 nmol/mol/V.

7.2 Test procedures

The sensitivity coefficient of electrical voltage shall be determined at both ends of the voltage range specified by the manufacturer, V_1 and V_2 , at zero concentration and at a concentration around 70% to 80% of the maximum of the certification range of NO. After waiting the time equivalent to one independent measurement, three individual measurements at each voltage and concentration level shall be recorded.

The sensitivity coefficient to electrical voltage in accordance with EN 14211 is calculated as follows:

$$b_v = \left| \frac{(C_{V2} - C_{V1})}{(V_2 - V_1)} \right|$$

Where:

b_v is the voltage sensitivity coefficient,

C_{V1} is the average concentration reading of the measurements at voltage V_1

C_{V2} is the average concentration reading of the measurements at voltage V_2

V_1 is the minimum voltage V_{\min}

V_2 is the maximum voltage V_{\max}

For reporting the dependence on voltage, the higher value of the result at zero and span level shall be taken.

b_v shall comply with the performance criterion indicated above.

7.3 Testing

For the purpose of determining the sensitivity coefficient to electrical voltage, a transformer was looped into the measuring system's voltage supply. Test gases were applied to the zero and reference point at various voltages.

7.4 Evaluation

The following sensitivity coefficients to electrical voltage have been determined:

Table 22: Sensitivity coefficient to electrical voltage

	requirements	device 1		device 2	
sensitivity coeff. of voltage b_v at 0 level [nmol/mol/V]	≤ 0.3	0.00	✓	0.01	✓
sensitivity coeff. of voltage b_v at span level [nmol/mol/V]	≤ 0.3	0.02	✓	0.02	✓

7.5 Assessment

At no test item did the sensitivity coefficient to electrical voltage b_v exceed the value of 0.30 nmol/mol/V specified in standard EN 14211. For the purpose of uncertainty calculation, the largest b_v is used for both instruments. For instrument 1, this is 0.02 nmol/mol/V and for instrument 2 it is 0.02 nmol/mol/V.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 23: Individual results for the sensitivity coefficient to electrical voltage

time	voltage [V]	concentration	device 1	device 2
			[nmol/mol]	[nmol/mol]
14:38:00	207	0	-1.7	-1.2
14:39:00	207	0	-1.8	-0.9
14:40:00	207	0	-1.9	-1
average C_{V1} at 0			-1.80	-1.03
14:48:00	253	0	-2	-1.6
14:49:00	253	0	-1.9	-1.7
14:50:00	253	0	-1.8	-1.8
average C_{V2} at 0			-1.90	-1.70
15:05:00	207	720.00	722.3	724.2
15:06:00	207	720.00	722.8	724.3
15:07:00	207	720.00	722.9	724.3
average C_{V1} at Span			722.67	724.27
15:15:00	253	720.00	723.4	725.1
15:16:00	253	720.00	723.5	725.2
15:17:00	253	720.00	723.5	725.6
average C_{V2} at Span			723.47	725.30

7.1 8.4.11 Interferents

Interferents at zero and at concentration c_t for NO (500 ± 50 nmol/mol). Deviations for interferents H₂O, CO₂ and NH₃ shall not exceed 5.0 nmol/mol.

7.2 Test conditions

The analyser response to certain interferents shall be tested. The interferents can give a positive or negative response. The test shall be performed at zero and at an NO test concentration (c_t) of (500 ± 50) nmol/mol.

The concentration of the mixtures of the test gases with the interferent shall have an expanded uncertainty of $\leq 5\%$ and shall be traceable to nationally accepted standards. The interferents to be tested and their respective concentrations are given in Table 24. The influence of each interferent shall be determined separately. A correction on the concentration of the measurand shall be made for the dilution effect due to addition of an interferent (e.g. water vapour).

After adjustment of the analyser at zero and span level, the analyser shall be fed with a mixture of zero gas and the interferent to be investigated with the concentration as given in Table 24. With this mixture, one independent measurement of NO followed by two individual measurements of NO shall be carried out. This procedure shall be repeated with a mixture of the measurand at concentration c_t and the interferent to be investigated. The influence quantities at zero and concentration c_t are calculated from:

$$X_{\text{int},z} = x_z$$

$$X_{\text{int},ct} = x_{ct} - c_t$$

Where:

$X_{\text{int},z}$ is the influence quantity of the interferent at zero;

x_z is the average of the measurements of NO at zero;

$X_{\text{int},ct}$ is the influence quantity of the interferent at concentration c_t ;

x_{ct} is the average of the measurements of NO at concentration c_t

c_t is the applied concentration at the one-hour limit value.

The influence quantities of the interferents shall comply with the performance criteria indicated above, both at zero and at concentration c_t .

7.3 Testing

The test was performed in line with the requirements of EN 14211 mentioned before. The instruments are adjusted at zero and at the concentration c_t . Zero and test gas with the various interfering components were then applied. The interferents listed in Table 24 were applied in the concentrations indicated.

As required by standard EN 14211, the measured NO_x concentration shall be used instead of the NO concentration when testing the interferent NH₃.

Table 24: Interferents in accordance with EN 14211

Interferent	Value
H ₂ O	19 mmol/mol
CO ₂	500 µmol/mol
NH ₃	200 nmol/mol

7.4 Evaluation

The following overview presents the influence quantities of each interfering substance.

Table 25: Influence of the tested interferent ($c_i = 500 \pm 50$ nmol/mol) for the two T200P instruments measuring NO

	requirements	device 1		device 2	
influence quantity interferent H ₂ O at zero [nmol/mol/V]	≤ 5.0 nmol/mol	-0.33	✓	-0.60	✓
influence quantity interferent H ₂ O at c_i [nmol/mol/V]	≤ 5.0 nmol/mol	-1.37	✓	-0.07	✓
influence quantity interferent CO ₂ at zero [nmol/mol/V]	≤ 5.0 nmol/mol	1.10	✓	1.47	✓
influence quantity interferent CO ₂ at c_i [nmol/mol/V]	≤ 5.0 nmol/mol	-0.50	✓	-1.30	✓
influence quantity interferent NH ₃ at zero [nmol/mol/V]	≤ 5.0 nmol/mol	0.93	✓	0.83	✓
influence quantity interferent NH ₃ at c_i [nmol/mol/V]	≤ 5.0 nmol/mol	0.53	✓	0.97	✓

7.5 Assessment

At zero point the result for the interference were -0.33 nmol/mol (AMS 1) and -0.60 nmol/mol (AMS 2) for H₂O, 1.10 nmol/mol (AMS 1) and 1.47 nmol/mol (AMS 2) for CO₂ and finally 0.93 nmol/mol (AMS 1) and 0.83 nmol/mol (AMS 2) for NH₃.

The following results were obtained for the cross-sensitivity at the limit value c_i : H₂O: -1.37 nmol/mol for instrument 1 and -0.07 nmol/mol for instrument 2; CO₂: -0.50 nmol/mol for instrument 1 and -1.30 nmol/mol for instrument 2; NH₃ and 0.53 nmol/mol for instrument 1 and 0.97 nmol/mol.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Tabell 26 presents the individual test results.

Tabell 26: Individual test results for the interferents for NO

	without interferents			with interferents		
	time	device 1	device 2	time	device 1	device 2
zero gas + H ₂ O (19 mmol/mol)	13:34:00	-0.20	-0.20	13:44:00	-0.60	-0.90
	13:35:00	-0.30	-0.30	13:45:00	-0.60	-0.80
	13:36:00	-0.30	-0.30	13:46:00	-0.60	-0.90
	average x _z	-0.27	-0.27	average x _z	-0.60	-0.87
test gas c _t + H ₂ O (19 mmol/mol)	13:54:00	498.70	499.60	14:04:00	497.70	499.90
	13:55:00	498.80	499.50	14:05:00	497.40	499.60
	13:56:00	498.80	499.90	14:06:00	497.10	499.30
	average x _{ct}	498.77	499.67	average x _{ct}	497.40	499.60
zero gas + CO ₂ (500 µmol/mol)	14:17:00	-0.50	-0.80	14:27:00	0.90	0.70
	14:18:00	-0.50	-0.80	14:28:00	0.40	0.50
	14:19:00	-0.60	-0.90	14:29:00	0.40	0.70
	average x _z	-0.53	-0.83	average x _z	0.57	0.63
test gas c _t + CO ₂ (500 µmol/mol)	14:39:00	501.10	502.30	14:49:00	500.30	500.60
	14:40:00	501.00	502.30	14:50:00	500.70	501.00
	14:41:00	501.00	502.10	14:51:00	500.60	501.20
	average x _{ct}	501.03	502.23	average x _{ct}	500.53	500.93
zero gas + NH ₃ (200 nmol/mol)	15:01:00	-1.10	-1.70	15:11:00	-0.40	-1.10
	15:02:00	-1.10	-1.70	15:12:00	-0.30	-0.90
	15:03:00	-1.30	-1.80	15:13:00	0.00	-0.70
	average x _z	-1.17	-1.73	average x _z	-0.23	-0.90
test gas c _t + NH ₃ (200 nmol/mol)	15:21:00	501.80	502.70	15:31:00	502.40	504.00
	15:22:00	501.90	503.00	15:32:00	502.50	503.60
	15:23:00	502.10	502.80	15:33:00	502.50	503.7
	average x _{ct}	502.47	502.83	average x _{ct}	502.47	503.80

7.1 8.4.12 Averaging test

The averaging effect shall not exceed 7% of the measured value.

7.2 Test conditions

The averaging test gives a measure of the uncertainty in the averaged values caused by short-term concentration variations in the sampled air shorter than the time scale of the measurement process in the analyser. In general, the output of an analyser is a result of the determination of a reference concentration (normally zero) and the actual concentration which takes a certain time.

For the determination of the uncertainty due to the averaging, the following concentrations are applied to the analyser and readings are taken at each concentration:

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

The time period (t_c) of the constant NO concentration shall be at least equal to a period necessary to obtain four independent readings (which is equal to at least sixteen response times). The time period (t_v) of the varying NO concentration shall be at least equal to a period to obtain four independent readings. The time period (t_{NO}) for the NO concentration shall be 45 s followed by a period (t_{zero}) of 45 s of zero concentration. Further:

c_t is the test concentration;

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

The change from t_{NO} to t_{zero} shall be within 0.5 s. The change from t_c to t_v shall be within one response time of the analyser under test.

The averaging effect (E_{av}) is calculated according to:

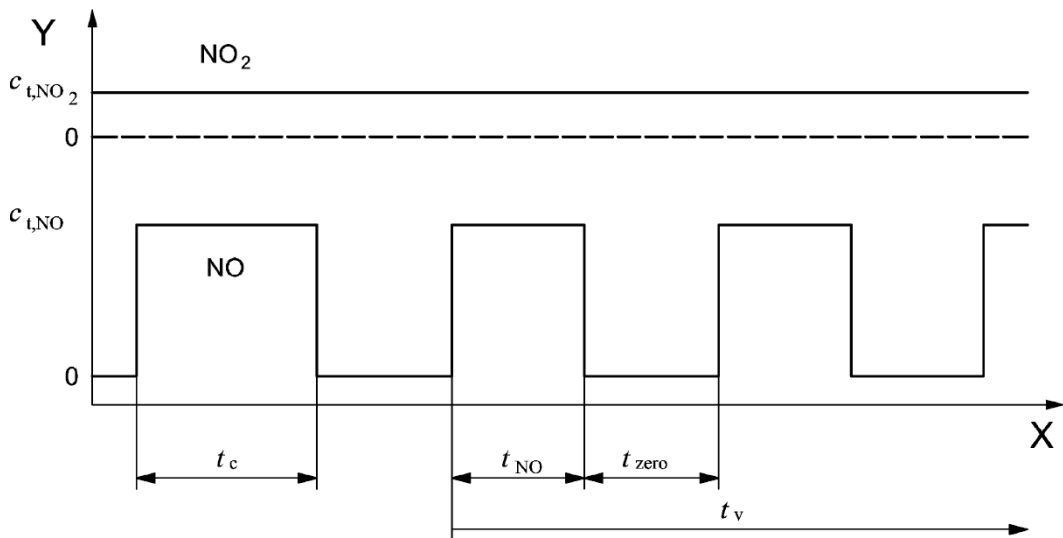
$$E_{av} = \frac{C_{const}^{av} - 2C_{var}^{av}}{C_{const}^{av}} * 100$$

Where:

E_{av} is the averaging effect (%);

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

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



Legende

Y Konzentration (nmol/mol)
X Zeit

Figure 12: Changes in concentration for the determination of the averaging effect ($t_{NO} = t_{zero} = 45$ s)

7.3 Testing

The averaging test was performed in compliance with the requirements specified in EN 14211. With the help of a mass flow controller we applied a step change of the NO concentration between zero and 600 nmol/mol and, at the same time, a constant NO₂ concentration c_{t,NO_2} of roughly twice the hourly limit value. First, the average was calculated at a constant test gas concentration. Then, a three-way valve served to switch between zero and test gas every 45 s. During that period of alternating test gas application the average was calculated again.

7.4 Evaluation

During the test, the following averages were determined for the two T200P measuring systems.

	requirements	device 1	device 2
averaging effect E_{av} [%]	$\leq 7\%$	-2.46 ✓	-3.72 ✓

This results in the following averaging effects:

AMS 1: -2.46%

AMS 2: -3.72%

7.5 Assessment

The performance criterion specified by standard EN 14211 is fully satisfied.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 27 presents the individual results of the averaging test:

Table 27: Individual results of the averaging test

		device 1	device 2
	time	[nmol/mol]	[nmol/mol]
average constant concentration $C_{av,c}$	09:05:00	597.5	596.7
	till		
	09:25:00		
average variable concentration $C_{av,c}$	09:26:00	302.9	305.8
	till		
	09:46:00		

		device 1	device 2
	time	[nmol/mol]	[nmol/mol]
average constant concentration $C_{av,c}$	09:57:00	577.7	578.6
	till		
	10:17:00		
average variable concentration $C_{av,c}$	10:18:00	303.6	305.9
	till		
	10:38:00		

		device 1	device 2
	time	[nmol/mol]	[nmol/mol]
average constant concentration $C_{av,c}$	10:39:00	579.2	578.6
	till		
	10:59:00		
average variable concentration $C_{av,c}$	11:00:00	292.2	297.8
	till		
	11:20:00		

7.1 8.4.13 Difference sample/calibration port

The difference between sample and calibration port shall not exceed 1.0%.

7.2 Test procedures

If the analyser has different ports for feeding sample gas and calibration gas, the difference in response of the analyser to feeding through the sample or calibration port shall be tested. The test shall be carried out by feeding the analyser with a test gas with a concentration of 70% to 80% of the maximum of the certification range of NO through the sample port. The test shall consist of one independent measurement followed by two individual measurements. After a period of at least four response times, the test shall be repeated using the calibration port. The difference shall be calculated according to:

$$\Delta_{SC} = \frac{x_{sam} - x_{cal}}{C_t} \times 100$$

Where:

Δ_{SC} is the difference sample/calibration port;

x_{sam} is the average of the measured concentration using the sample port;

x_{cal} is the average of the measured concentration using the calibration port;

C_t is the concentration of the test gas;

Δ_{SC} shall comply with the performance criterion indicated above.

7.3 Testing

The test was performed in compliance with the requirements specified in EN 14211. During the test, the gas path was switched between sample gas and span gas inlet using a three-way valve.

7.4 Evaluation

During the test, the following differences between sample and calibration port were determined for the two T200P measuring systems.

	requirements	device 1		device 2	
difference sample/calibration port Δx_{cs} [%]	$\leq 1\%$	-0.24	✓	-0.13	✓

AMS 1: -0.24%

AMS 2: -0.13%

7.5 Assessment

The performance criterion specified by standard EN 14211 is fully satisfied.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 28 presents the individual results.

Table 28: Individual results for testing the difference between sample and calibration port

		device 1	device 2
	time	[nmol/mol]	[nmol/mol]
calibration port	11:17:00	721.5	723.5
	11:18:00	721.4	723.3
	11:19:00	721.4	723.4
sample port	11:24:00	723.3	724.5
	11:25:00	723.3	724.2
	11:26:00	722.8	724.3

7.1 8.4.14 Converter efficiency

The converter efficiency should be at least 98%.

7.2 Test procedures

The converter efficiency is determined by measurements with calculated amounts of NO₂. This can be achieved by means of gas-phase titration of NO to NO₂ with ozone.

The test shall be performed at two concentration levels: at about 50% and about 95% of the maximum of the certification range of NO₂.

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

A known NO concentration at 50% of the NO certification range is applied to the measuring system until a stable signal is obtained. This stable period shall be at least as long as four response times. Four individual readings each are performed at the NO and the NO_x channel. Then, NO is brought to react with O₃ to produce NO₂. This mixture containing a constant NO_x concentration is applied to the measuring system until the output signal has stabilised. This stable period shall be at least four response times of the measuring system under test; the NO concentration after gas-phase titration shall be between 10% and 20% of the original NO concentration. Then, four individual readings each are performed at the NO and the NO_x channel. Then, the O₃ supply is cut and only NO is applied to the measuring system until the output signal has stabilised again. This stable period shall be at least as long as four response times of the measuring system. After that the average of the four individual measurements at the NO and the NO_x channel is calculated.

The converter efficiency is calculated as follows:

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

Where:

E_{conv} is the converter efficiency in %;

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

$(NO_x)_f$ is the average of the four individual measurements at the NO_x channel at the resulting NO_x concentration after applying O₃;

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

$(NO)_f$ is the average of the four individual measurements at the NO channel at the resulting NO concentration after applying O₃;

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

7.3 Testing

The test was performed in compliance with the requirements specified in EN 14211. When applying test gas two NO₂ concentrations in the range of 50% to 95% of the certification range for NO₂ were adjusted by means of gas-phase titration.

7.4 Evaluation

During the test, the following converter efficiencies were determined for the two T200P measuring systems. The lowest value of the two NO₂ concentration is reported below.

	requirements	device 1		device 2	
converter efficiency E _c [%]	≥ 98%	99.6	✓	99.4	✓

7.5 Assessment

The performance criterion specified by standard EN 14211 is fully satisfied.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 29 presents the individual values.

Table 29: Individual results for the converter efficiency

	time	O ₃ [nmol/mol]	NO ₂ [nmol/mol]	device 1		device 2	
				NO [nmol/mol]	NO _x [nmol/mol]	NO [nmol/mol]	NO _x [nmol/mol]
	10:25:00			start			
O ₃ =0, NO=50%	10:37:00	0.0	0.2	480.8	481.1	481.5	481.7
	10:41:00	0.0	-0.1	480.4	481.3	481.6	481.2
	10:45:00	0.0	0.4	480.7	481.1	481.8	481.9
	10:49:00	0.0	-0.5	480.9	481.4	401.2	481.5
average		0.0	0.0	480.7	481.2	461.5	481.6
NO ₂ = 50% 130.75	11:05:00	131.0	147.3	333.8	480.8	331.6	480.5
	11:09:00	131.0	147.4	333.4	480.8	332.4	480.7
	11:13:00	131.0	148.1	333.2	480.7	331.8	480.9
	11:17:00	131.0	148.1	333.6	480.5	331.0	481.1
average		131.0	147.7	333.5	480.7	331.7	480.8
O ₃ =0, NO=50%	12:24:00	0.0	-0.8	483.5	482.5	485.2	482.8
	12:28:00	0.0	-0.7	483.6	482.9	485.2	482.9
	12:32:00	0.0	-1.1	483.8	482.8	485.3	483.1
	12:36:00	0.0	-0.7	483.8	483.1	485.4	483.0
average		0.0	-0.8	483.7	482.8	485.3	483.0
NO ₂ = 95% 248.43	12:52:00	248.4	245.8	238.0	483.0	235.6	481.4
	12:56:00	248.4	244.8	237.3	482.3	236.7	481.5
	13:00:00	248.4	244.7	237.8	482.4	236.8	481.5
	13:04:00	248.4	245.8	237.6	482.3	236.0	481.8
average		248.4	245.3	237.7	482.5	236.3	481.6
O ₃ =0, NO=50%	13:16:00	0.0	0.0	481.2	481.0	481.5	481.1

7.1 8.4.15 Residence time in the analyser

The residence time in the analyser shall be ≤ 3.0 s.

7.2 Test procedures

The residence time inside the analyser shall be calculated on the basis of the flow and the volumes of the tubing and other relevant components inside the analyser.

7.3 Testing

Upstream of the inlet to the measuring cell, the T200P analysers volume merely consists of internal tubing and the permeation dryer. The length of the sampling lines leading from the sampling port to the inlet of the measurement cell is 0.5 m at an inner diameter of 4mm, the permeation dryer not included. The length in the permeation dryer is at 2 m at an inner diameter of 4 mm. This results in a volume of 12.8 ml in the analyser upstream of the measuring cell. The typical sample gas flow is at 0.5 l/min. This results in a residence time in the analyser upstream of the measuring cell of 1.6 s.

7.4 Evaluation

Not applicable.

7.5 Assessment

Residence time in the analyser was 1.6 s.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Not applicable.

7.1 8.5.4 Long-term drift

*The long-term drift at zero point shall not exceed ≤ 5.0 nmol/mol.
Long-term drift at span level shall not exceed 5% of the certification range.*

7.2 Test procedures

After each bi-weekly zero and span check, the drift of the analysers under test shall be calculated at zero and at span following the procedures as given below. If the drift compared to the initial calibration exceeds one of the performance criteria for drift at zero or span level, the “period of unattended operation” equals the number of weeks until the observation of the infringement, minus two weeks. For further (uncertainty) calculations, the values for “long term drift” are the values for zero and span drift over the period of unattended operation.

At the beginning of the drift period, five individual measurements were performed at zero and span level following the calibration (after waiting the time equivalent to a single independent reading).

The long-term drift is calculated as follows:

$$D_{L,Z} = (C_{Z,1} - C_{Z,0})$$

Where:

$D_{L,Z}$ is the drift at zero;

$C_{Z,0}$ is the average concentration of the measurements at zero at the beginning of the drift period;

$C_{Z,1}$ is the average concentration of the measurements at zero at the end of the drift period;

$D_{L,Z}$ shall comply with the performance criterion indicated above.

$$D_{L,S} = \frac{(C_{S,1} - C_{S,0}) - D_{L,Z}}{C_{S,1}} \times 100$$

Where:

$D_{L,S}$ is the drift at span concentration c_i ;

$C_{S,0}$ is the average concentration of the measurements at span level at the beginning of the drift period;

$C_{S,1}$ is the average concentration of the measurements at span level at the end of the drift period;

$D_{L,S}$ shall comply with the performance criterion indicated above.

7.3 Testing

For the purpose of this test, test gas was applied every other week. Table 30 and Table 31 report the measured values for bi-weekly test gas applications.

On July 20, severe weather caused the measurement container's mains voltage to fail. The measurement container resumed operation on July 26, after repairs performed by a specialised company. Once the power supply was re-established, the tested AMS resumed regular operation after a certain warm-up period. The bi-weekly test gas application scheduled for July 24 was postponed to July 27. Test gas applications after the power outage remained within the limits of the specifications. The measured values did not have to be adjusted. The field test was extended for a week.

7.4 Evaluation

Table 30: Results for the long-term drift at zero point, component NO

		Anforderung	Device 1		Device 2	
average start Cz ₁ at zero [nmol/mol]	29.05.2017	≤ 5,0	0,15	✓	0,17	✓
long term drift DL _z at zero [nmol/mol]	12.06.2017	≤ 5,0	-0,15	✓	0,07	✓
long term drift DL _z at zero [nmol/mol]	26.06.2017	≤ 5,0	0,24	✓	0,43	✓
long term drift DL _z at zero [nmol/mol]	10.07.2017	≤ 5,0	-0,01	✓	0,27	✓
long term drift DL _z at zero [nmol/mol]	*27.07.2017	≤ 5,0	0,23	✓	0,61	✓
long term drift DL _z at zero [nmol/mol]	07.08.2017	≤ 5,0	0,23	✓	0,35	✓
long term drift DL _z at zero [nmol/mol]	21.08.2017	≤ 5,0	-2,21	✓	-0,07	✓
long term drift DL _z at zero [nmol/mol]	04.09.2017	≤ 5,0	-1,17	✓	1,15	✓
long term drift DL _z at zero [nmol/mol]	11.09.2017	≤ 5,0	-1,37	✓	0,99	✓

* Failure of mains voltage of the measurement container from 20–26 July. That's why the drift check took place on July 27.

Table 31: Results for the long-term drift at reference point, component NO

		requierment	Device 2 1		Device 2	
average start Cs ₁ at span [nmol/mol]	29.05.2017	≤ 5 %	--	✓	--	✓
long term drift DL _s at span [nmol/mol]	12.06.2017	≤ 5 %	-0,04	✓	-0,04	✓
long term drift DL _s at span [nmol/mol]	26.06.2017	≤ 5 %	-0,22	✓	-0,32	✓
long term drift DL _s at span [nmol/mol]	10.07.2017	≤ 5 %	-0,37	✓	-0,54	✓
long term drift DL _s at span [nmol/mol]	*27.07.2017	≤ 5 %	-0,94	✓	0,19	✓
long term drift DL _s at span [nmol/mol]	07.08.2017	≤ 5 %	-0,50	✓	-0,61	✓
long term drift DL _s at span [nmol/mol]	21.08.2017	≤ 5 %	-0,43	✓	-0,76	✓
long term drift DL _s at span [nmol/mol]	04.09.2017	≤ 5 %	-0,16	✓	-0,09	✓
long term drift DL _s at span [nmol/mol]	11.09.2017	≤ 5 %	-0,60	✓	-0,51	✓

* Failure of mains voltage of the measurement container from 20–26 July. That's why the drift check took place on July 27.

7.5 Assessment

Maximum long-term drift at zero point D_{l,z} was at -2.21 nmol/mol for instrument 1 and 1.15 nmol/mol for instrument 2. Maximum long-term drift at reference point D_{l,s} was at -0.94 % for instrument 1 and -0.76 % for instrument 2.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 32 presents the individual values obtained for the determination of the long-term drift.

Table 32: Individual results of the drift test

Zero Concentration			
Date	Time	Device 1	Device 2
		nmol/mol	nmol/mol
29.05.2017	08:19:00	0,00	0,00
	08:20:00	0,00	0,00
	08:21:00	0,10	0,10
	Mittel	0,03	0,03
	08:25:00	0,10	0,10
	08:26:00	0,10	0,10
	08:27:00	0,10	0,10
	Mittel	0,10	0,10
	08:31:00	0,20	0,20
	08:32:00	0,20	0,20
	08:33:00	0,20	0,20
	Mittel	0,20	0,20
	08:37:00	0,20	0,20
	08:38:00	0,20	0,30
	08:39:00	0,20	0,20
	Mittel	0,20	0,23
	08:43:00	0,20	0,30
08:44:00	0,20	0,30	
08:45:00	0,20	0,30	
		0,20	0,30
Average field start cz,0		0,15	0,17
12.06.2017	08:30:00	0,00	0,20
	08:31:00	0,00	0,20
	08:21:00	0,00	0,30
	08:33:00	0,00	0,30
	08:34:00	0,00	0,20
	Aver. cz,1	0,00	0,24
26.06.2017	12:36:00	0,50	0,60
	12:37:00	0,50	0,60
	12:38:00	0,05	0,60
	12:39:00	0,40	0,60
	12:40:00	0,50	0,60
	Aver. cz,1	0,39	0,60
10.07.2017	10:22:00	0,20	0,40
	10:23:00	0,20	0,40
	10:24:00	0,10	0,40
	10:25:00	0,10	0,40
	10:26:00	0,10	0,60
	Aver. cz,1	0,14	0,44
*27.07.2017	08:33:00	0,40	0,90
	09:34:00	0,40	0,90
	09:35:00	0,40	0,90
	09:36:00	0,30	0,60
	09:37:00	0,40	0,60
	Aver. cz,1	0,38	0,78
07.08.2017	08:08:00	0,40	0,60
	08:09:00	0,50	0,50
	08:10:00	0,20	0,60
	08:11:00	0,10	0,60
	08:12:00	0,70	0,30
	Aver. cz,1	0,38	0,52
21.08.2017	13:36:00	-2,10	0,10
	13:37:00	-2,10	0,10
	13:38:00	-2,10	0,10
	13:39:00	-2,00	0,10
	13:40:00	-2,00	0,10
	Aver. cz,1	-2,06	0,10
04.09.2017	13:58:00	-1,00	1,40
	13:59:00	-1,00	1,40
	14:00:00	-1,00	1,40
	14:01:00	-1,00	1,30
	14:02:00	-1,10	1,10
	Aver. cz,1	-1,02	1,32
11.09.2017	08:50:00	-1,20	1,20
	08:51:00	-1,20	1,20
	08:52:00	-1,20	1,20
	08:53:00	-1,20	1,20
	08:54:00	-1,30	1,00
	Aver. cz,1	-1,22	1,16

C _i -Concentration			
Date	Time	Device 1	Device 2
		nmol/mol	nmol/mol
29.05.2017	09:04:00	719,60	721,30
	09:05:00	719,50	721,20
	09:06:00	719,60	721,00
	Mittel	719,57	721,17
	09:10:00	719,40	720,90
	09:11:00	719,20	721,00
	09:12:00	719,60	721,30
	Mittel	719,40	721,07
	09:16:00	719,40	721,10
	09:17:00	720,10	721,00
	09:18:00	719,90	721,10
	Mittel	719,80	721,07
	09:22:00	720,20	721,50
	09:23:00	720,30	721,60
	09:24:00	720,40	721,40
	Mittel	720,30	721,50
	09:28:00	720,80	721,30
	09:29:00	720,50	721,20
	09:30:00	720,70	721,20
			720,67
Average field start cs,0		719,95	721,21
12.06.2017	08:45:00	719,20	720,80
	08:46:00	719,50	720,90
	08:47:00	719,50	721,00
	08:49:00	719,60	721,00
	08:50:00	719,60	721,10
	Aver. cs,1	719,48	720,96
26.06.2017	12:44:00	718,90	719,40
	12:45:00	718,40	719,40
	12:46:00	718,90	719,40
	12:47:00	718,40	719,30
	12:48:00	718,40	719,20
	Aver. cs,1	718,60	719,34
10.07.2017	10:35:00	716,40	717,00
	10:36:00	716,60	717,20
	10:37:00	716,70	717,20
	10:38:00	718,20	718,10
	10:39:00	718,40	718,60
	Aver. cs,1	717,26	717,62
*27.07.2017	09:46:00	713,10	723,00
	09:47:00	713,10	723,10
	09:48:00	713,40	723,10
	09:49:00	713,90	723,40
	09:50:00	714,00	723,50
	Aver. cs,1	713,50	723,22
07.08.2017	08:17:00	716,40	716,80
	08:18:00	716,40	717,00
	08:19:00	716,40	717,00
	09:20:00	716,80	717,50
	09:21:00	717,10	717,60
	Aver. cs,1	716,62	717,18
21.08.2017	13:46:00	714,00	715,00
	13:47:00	714,20	715,00
	13:48:00	714,40	715,20
	13:49:00	715,20	716,60
	13:50:00	715,70	716,60
	Aver. cs,1	714,70	715,68
04.09.2017	14:08:00	717,50	721,40
	14:09:00	717,50	721,50
	14:10:00	717,60	721,50
	14:11:00	717,80	722,00
	14:12:00	717,70	722,10
	Aver. cs,1	717,62	721,70
11.09.2017	09:00:00	714,20	718,40
	09:01:00	714,20	718,40
	09:02:00	714,20	718,40
	09:03:00	714,50	718,90
	09:04:00	714,50	718,50
	Aver. cs,1	714,32	718,52

* Failure of mains voltage of the measurement container from 20–26 July. That's why the drift check took place on July 27.

7.1 8.5.5 Reproducibility standard deviation for NO₂ under field conditions

Reproducibility standard deviation under field conditions shall not exceed 5% of the mean value over a period of three months.

7.2 Test procedures

The reproducibility standard deviation under field conditions is calculated from the measured hourly averaged data during the three-month period.

The difference $\Delta x_{f,i}$ for each (ith) parallel measurement is calculated from:

$$\Delta x_{f,i} = x_{f,1,i} - x_{f,2,i}$$

Where:

$\Delta x_{f,i}$ is the ith difference in a parallel measurement;

$x_{f,1,i}$ is the ith measurement result of analyser 1;

$x_{f,2,i}$ is the ith measurement result of analyser 2;

The reproducibility standard deviation under field conditions is calculated according to:

$$s_{r,f} = \frac{\left(\sqrt{\frac{\sum_{i=1}^n \Delta x_{f,i}^2}{2 * n}} \right)}{c_f} \times 100$$

Where:

$s_{r,f}$ is the reproducibility standard deviation for NO₂ under field conditions (%);

n is the number of parallel measurements;

c_f is the average concentration of nitrogen dioxide measured during the field test;

The reproducibility standard deviation under field conditions, $s_{r,f}$, shall comply with the performance criterion indicated above.

7.3 Testing

The reproducibility standard deviation under field conditions was calculated from the hourly averages over the field test period according to the equation stated above.

Occasionally, NO₂ was added to the sample air to demonstrate that the measuring systems continue to operate in the same manner at higher concentrations, too.

On July 20, severe weather caused the measurement container's mains voltage to fail. The measurement container resumed operation on July 26, after repairs performed by a special-

ised company. The field test was extended by a week until September 11, in order to compensate for the missing measured values.

7.4 Evaluation

Table 33: Determination of the reproducibility standard deviation on the basis of complete field test data

Reproducibility standard deviation in the field test				
Number of measurements	n	=	2366	
Averages of both analysers		=	11.05	nmol/mol
Standard deviation from paired measurements	s _d	=	0.423	nmol/mol
Reproducibility standard deviation (%)	Sr,f	=	3.83	%

The reproducibility standard deviation under field conditions is at 3.83% of the average.

7.5 Assessment

The reproducibility standard deviation for NO₂ under field conditions was 3.83% as a percentage of the mean value over the three-months field test period. Thus, the requirements of EN 14211 are satisfied.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Figure 13 provides an illustration of the reproducibility standard deviation under field conditions.

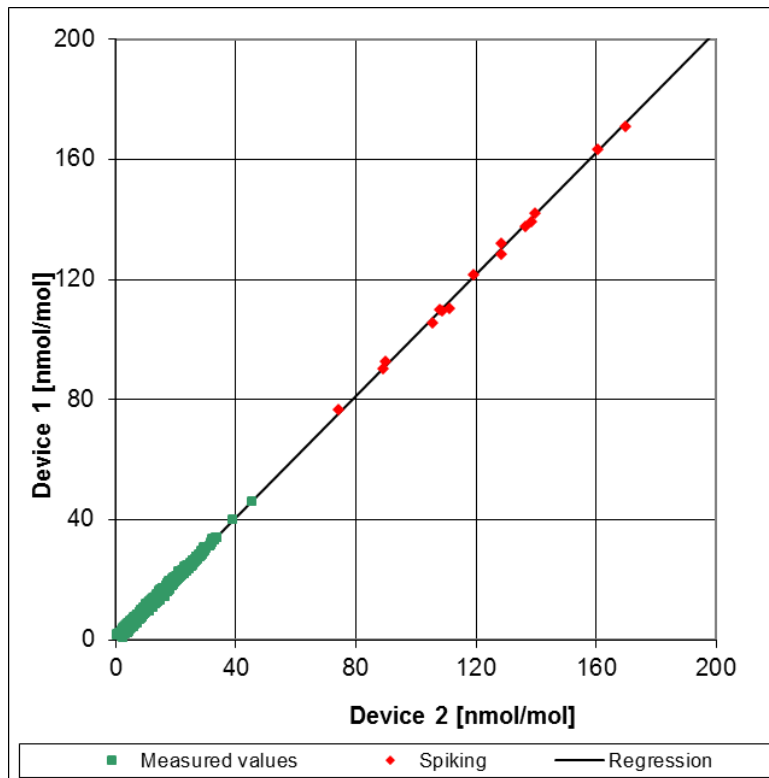


Figure 13: Diagram illustrating the reproducibility standard deviation under field conditions

7.1 8.5.6 Maintenance interval

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

7.2 Equipment

Not required for this performance criterion.

7.3 Testing

With regard to this minimum requirement, the maintenance tasks required in a specific period and the length of that period for the correct functioning of the measuring system were identified. Furthermore, in determining the maintenance interval, the drift determined for zero and reference point in accordance with 7.1 8.5.4 Long-term drift have been taken into consideration.

7.4 Evaluation

Over the entire period of the field test, no unacceptable drift was observed. The maintenance interval is thus determined by the necessary maintenance works.

During operation times, maintenance is generally limited to contamination and plausibility checks and potential status/error messages.

7.5 Assessment

The period of unattended operation is determined by the necessary maintenance works. It is 4 weeks.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Not applicable in this instance.

7.1 8.5.7 Period of availability of the analyser

Availability of the analyser shall be at least 90%.

7.2 Test procedures

The correct operation of the analysers shall be checked at least every fourteen days. It is recommended to perform this check every day during the first fourteen days. These checks consist of plausibility checks on the measured values, as well as, when available, on status signals and other relevant parameters. Time, duration and nature of any malfunctioning shall be logged.

The total time period with useable measuring data is the period during the field test during which valid measuring data of the ambient air concentrations are obtained. In this time period, the time needed for calibrations, conditioning of sample systems and filters and maintenance shall not be included.

The availability of the analyser is calculated as:

$$A_a = \frac{t_u}{t_t} * 100$$

Where:

A_a is the availability of the analyser (%);

t_u is the total time period with validated measuring data;

t_t is the time period of the field test minus the time for calibration, conditioning and maintenance.

t_u and t_t shall be expressed in the same units.

The availability shall comply with the performance criterion indicated above.

7.3 Testing

Using the equation given above, the availability was calculated from the total period of the field test and the outage times which have occurred during this period.

7.4 Evaluation

Outage times which have occurred during the field test are listed in Table 34.

Table 34: Availability of the T200P measuring system

		System 1	System 2
Operation time	h	2366	2366
Outage time	h	151*	151*
Maintenance time	h	9	9
Actual operating time:	h	2357	2357
Actual operating time incl. maintenance times:	h	2366	2366
Availability	%	100	100

The outage time of 151 hours was caused by a failure in mains voltage of the measurement container. On July 20, severe weather caused the measurement container's mains voltage to fail. The measurement container resumed operation on July 26, after repairs performed by a specialised company. The field test was extended by a week until September 11, in order to compensate for the missing measured values. The outage resulting from the failure in mains voltage was not taken into consideration when calculating availability.

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

7.5 Assessment

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

Criterion satisfied? yes

7.6 Detailed presentation of test results

Not applicable.

7.1 8.6 Calculation of the total uncertainty in accordance with standard EN 14211 (2012)

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

- 1) The value of each individual performance characteristic tested in the laboratory shall fulfil the criterion stated in Table E.1 of standard EN 14211.*
- 2) The expanded uncertainty calculated from the standard uncertainties due to the values of the specific performance characteristics obtained in the laboratory tests shall fulfil the criterion as stated in Annex I of Directive 2008/50/EC (15% for fixed measurements or 25% for indicative measurements). This criterion is the maximum uncertainty of individual measurements for continuous measurements at the 1-hour limit value. The relevant specific performance characteristics and the calculation procedure are given in Annex E of standard EN 14211.*
- 3) The value of each of the individual performance characteristics tested in the field shall fulfil the criterion stated in Table E.1 of EN 14211.*
- 4) The expanded uncertainty calculated from the standard uncertainties due to the values of the specific performance characteristics obtained in the laboratory and field tests shall fulfil the criterion as stated in Annex I of Directive 2008/50/EC (15% for fixed measurements or 25% for indicative measurements). This criterion is the maximum uncertainty of individual measurements for continuous measurements at the 1-hour limit value. The relevant specific performance characteristics and the calculation procedure are given in Annex E of standard EN 14211.*

7.2 Equipment

Calculation of the total uncertainty in accordance with standard EN 14211 (2012), Annex E

7.3 Testing

At the end of the performance test, the total uncertainties were calculated from the values obtained during the test.

7.4 Evaluation

Regarding 1) The value of each performance characteristic tested in the laboratory tests fulfils the criterion stated in Table E.1 of EN 14211.

Regarding 2) The expanded uncertainty calculated from the standard uncertainties due to the values of the specific performance characteristics obtained in the laboratory tests fulfils the criterion as stated.

Regarding 3) The value of each performance characteristic tested in the field tests fulfils the criterion stated in Table E.1 of EN 14211.

Regarding 4) The expanded uncertainty calculated from the standard uncertainties due to the values of the specific performance characteristics obtained in the laboratory and field tests fulfils the criterion as stated.

7.5 Assessment

The requirement regarding the expanded uncertainty of the measuring system is complied with.

Criterion satisfied? yes

Table 35: Relevant performance characteristics and criteria according to EN 14211

Performance characteristic	Performance criterion	Test result	Satisfied	Page
8.4.5 Repeatability standard deviation at zero	≤ 1.0 nmol/mol	S _r system 1: 0.00 nmol/mol S _r system 2: 0.00 nmol/mol	yes	77
8.4.5 Repeatability standard deviation at concentration level c _t	≤ 3.0 nmol/mol	S _r system 1: 1.23 nmol/mol S _r system 2: 1.46 nmol/mol	yes	77
8.4.6 "Lack of fit" (deviation from the linear regression)	Largest deviation from the linear regression function > 0, ≤ 4.0% of the reading Residual at zero: ≤ 5 nmol/mol	X _{l,z} Analyser 1: ZP -0.94 nmol/mol X _l Analyser 1: RP 0.75% X _{l,z} Analyser 2: ZP -0.94 nmol/mol X _l Analyser 2: RP 1.10%	yes	79
8.4.7 Sensitivity coefficient of sample gas pressure	≤ 8.0 nmol/mol/kPa	b _{gp} Analyser 1: 0.99 nmol/mol/kPa b _{gp} Analyser 2: 0.91 nmol/mol/kPa	yes	84
8.4.8 Sensitivity coefficient of sample gas temperature	≤ 3.0 nmol/mol/K	b _{gt} Analyser 1: 0.15 nmol/mol/K b _{gt} Analyser 2: 0.13 nmol/mol/K	yes	86
8.4.9 Sensitivity coefficient of surrounding temperature	≤ 3.0 nmol/mol/K	b _{st} Analyser 1: 0.410 nmol/mol/K b _{st} Analyser 2: 0.732 nmol/mol/K	yes	88
8.4.10 Sensitivity coefficient of electrical voltage	≤ 0.3 nmol/mol/V	b _v Analyser 1: RP 0.02 nmol/mol/V b _v Analyser 2: RP 0.02 nmol/mol/V	yes	91
8.4.11 Interferent at zero and at concentration level c _t	H ₂ O ≤ 5.0 nmol/mol CO ₂ ≤ 5.0 nmol/mol NH ₃ ≤ 5.0 nmol/mol	H ₂ O System 1 ZP -0.33 nmol/mol / RP -1.37 nmol/mol System 2 ZP -0.60 nmol/mol / RP -0.07 nmol/mol CO ₂ System 1 ZP 1.10 nmol/mol / RP -0.50 nmol/mol System 2 ZP 1.47 nmol/mol / RP -1.30 nmol/mol NH ₃ System 1 ZP 0.93 nmol/mol / RP 0.53 nmol/mol System 2 ZP 0.83 nmol/mol / RP 0.97 nmol/mol	yes	93

Performance characteristic	Performance criterion	Test result	Satisfied	Page
8.4.12 Averaging effect	≤ 7.0% of the measured value	E _{av} analyser 1: -2.46% E _{av} analyser 2: -3.72%	yes	93
8.4.13 Difference sample/calibration port	≤ 1.0%	Δ _{SC} analyser 1: -0.24% Δ _{SC} analyser 2: -0.13%	yes	99
8.4.3 Response time (rise)	≤ 180 s	t _r system 1: 52 s (NO) t _r system 2: 53 s (NO) t _r system 1: 42 s (NO ₂) t _r system 2: 42.5 s (NO ₂)	yes	68
8.4.3 Response time (fall)	≤ 180 s	t _f system 1: 54 s (NO) t _f system 2: 54 s (NO) t _f system 1: 42.5 s (NO ₂) t _f system 2: 41.5 s (NO ₂)	yes	68
8.4.3 Difference between the rise and fall response time	≤ 10% relative difference or 10s, whichever value is larger	t _d analyser 1: -2s (NO) t _d analyser 2: -1s (NO) t _d analyser 1: -0.5s (NO ₂) t _d Analyser 2: 0.5 s (NO ₂)	yes	68
8.4.14 Converter efficiency	≥ 98%	E _{conv} Analyser 1: 99.6% E _{conv} Analyser 2: 99.4%	yes	101
8.4.15 Residence time	≤ 3.0 s	System 1 1.6 s System 2 1.6 s	yes	103
8.5.6 Period of unattended operation	3 months or less if the manufacturer indicates a shorter period; no less than 2 weeks	System 1 4 weeks System 2 4 weeks	yes	110
8.5.7 Availability of the analyser	> 90%	A _a Analyser 1: 100% A _a Analyser 2: 100%	yes	111
8.5.5 Reproducibility standard deviation under field conditions	≤ 5.0% of the average over a period of 3 months	S _{r,f} Analyser 1: 3.83% S _{r,f} Analyser 2: 3.83%	yes	107
8.5.4 Long-term drift at zero point	≤ 5.0 nmol/mol	C _z Analyser 1: -2.21 nmol/mol C _z Analyser 2: 1.15 nmol/mol	yes	104
8.5.4 Long-term drift at span level	≤ 5.0% of the upper limit of the certification range	C _s Analyser 1: max. - 0.94% C _s Analyser 2: max. - 0.76%	yes	104
8.4.4 Short-term drift at zero	≤ 2.0 nmol/mol over 12 h	D _{s,z} Analyser 1: 0.03 nmol/mol D _{s,z} Analyser 2: 0.03 nmol/mol	yes	73
8.4.4 Short-term drift at span level	≤ 6.0 nmol/mol over 12 h	D _{s,s} Analyser 1: 0.72 nmol/mol D _{s,s} Analyser 2: 0.86 nmol/mol	yes	73

Table 36: Expanded uncertainty from the results obtained in the laboratory for analyser 1

Measuring device:		T200P		Serial-No.:		SN: 59	
Measured component:		NO		1h-limit value:		104,6 nmol/mol	
No.	Performance characteristic	Performance criterion	Result	Partial uncertainty		Square of partial uncertainty	
1	Repeatability standard deviation at zero	≤ 1.0 nmol/mol	0,000	$u_{r,z}$	0,00	0,0000	
2	Repeatability standard deviation at 1h-limit value	≤ 3.0 nmol/mol	1,230	$u_{r,h}$	0,06	0,0038	
3	"lack of fit" at 1h-limit value	≤ 4.0% of measured value	0,750	$u_{l,h}$	0,45	0,2051	
4	Sensitivity coefficient of sample gas pressure at 1h-limit value	≤ 8.0 nmol/mol/kPa	0,990	u_{sp}	2,49	6,2057	
5	Sensitivity coefficient of sample gas temperature at 1h-limit value	≤ 3.0 nmol/mol/K	0,150	u_{gt}	0,38	0,1425	
6	Sensitivity coefficient of surrounding temperature at 1h-limit value	≤ 3.0 nmol/mol/K	0,410	u_{st}	1,03	1,0644	
7	Sensitivity coefficient of electrical voltage at 1h-limit value	≤ 0.30 nmol/mol/V	0,020	u_v	0,06	0,0034	
8a	Interferent H ₂ O with 21 mmol/mol	≤ 10 nmol/mol (Zero)	-0,330	u_{H_2O}	-0,41	0,1673	
		≤ 10 nmol/mol (Span)	-1,370				
8b	Interferent CO ₂ with 500 µmol/mol	≤ 5.0 nmol/mol (Zero)	1,100	$u_{int,pos}$	0,93	0,8668	
		≤ 5.0 nmol/mol (Span)	-0,500				
8c	Interferent NH ₃ mit 200 nmol/mol	≤ 5.0 nmol/mol (Zero)	0,930	or	0,93	0,8668	
		≤ 5.0 nmol/mol (Span)	0,530				
9	Averaging effect	≤ 7.0% of measured value	-2,460	u_{av}	-1,49	2,2071	
18	Difference sample/calibration port	≤ 1.0%	-0,240	u_{18c}	-0,25	0,0630	
21	Converter efficiency	≥ 98	99,600	u_{EC}	0,42	0,1751	
23	Uncertainty of test gas	≤ 3.0%	2,000	u_{cg}	1,05	1,0941	
Combined standard uncertainty				u_c		3,4931	nmol/mol
Expanded uncertainty				U		6,9863	nmol/mol
Relative expanded uncertainty				W		6,68	%
Maximum allowed expanded uncertainty				W_{req}		15	%

Table 37: Expanded uncertainty from the results obtained in the laboratory and field for analyser 1

Measuring device:		T200P		Serial-No.:		SN: 59	
Measured component:		NO		1h-limit value:		104,6 nmol/mol	
No.	Performance characteristic	Performance criterion	Result	Partial uncertainty		Square of partial uncertainty	
1	Repeatability standard deviation at zero	≤ 1.0 nmol/mol	0,000	$u_{r,z}$	0,00	0,0000	
2	Repeatability standard deviation at 1h-limit value	≤ 3.0 nmol/mol	1,230	$u_{r,h}$	not considered, as $\sqrt{2} \cdot u_{r,h} = 0,08 < u_{r,f}$		-
3	"lack of fit" at 1h-limit value	≤ 4.0% of measured value	0,750	$u_{l,h}$	0,45	0,2051	
4	Sensitivity coefficient of sample gas pressure at 1h-limit value	≤ 8.0 nmol/mol/kPa	0,990	u_{sp}	2,49	6,2057	
5	Sensitivity coefficient of sample gas temperature at 1h-limit value	≤ 3.0 nmol/mol/K	0,150	u_{gt}	0,38	0,1425	
6	Sensitivity coefficient of surrounding temperature at 1h-limit value	≤ 3.0 nmol/mol/K	0,410	u_{st}	1,03	1,0644	
7	Sensitivity coefficient of electrical voltage at 1h-limit value	≤ 0.30 nmol/mol/V	0,020	u_v	0,06	0,0034	
8a	Interferent H ₂ O with 21 mmol/mol	≤ 10 nmol/mol (Zero)	-0,330	u_{H_2O}	-0,41	0,1673	
		≤ 10 nmol/mol (Span)	-1,370				
8b	Interferent CO ₂ with 500 µmol/mol	≤ 5.0 nmol/mol (Zero)	1,100	$u_{int,pos}$	0,93	0,8668	
		≤ 5.0 nmol/mol (Span)	-0,500				
8c	Interferent NH ₃ mit 200 nmol/mol	≤ 5.0 nmol/mol (Zero)	0,930	or	0,93	0,8668	
		≤ 5.0 nmol/mol (Span)	0,530				
9	Averaging effect	≤ 7.0% of measured value	-2,460	u_{av}	-1,49	2,2071	
10	Reproducibility standard deviation under field conditions	≤ 5.0% of average over 3 months	3,830	$u_{r,f}$	4,01	16,0495	
11	Long term drift at zero level	≤ 5.0 nmol/mol	-2,210	$u_{d,l,z}$	-1,28	1,6280	
12	Long term drift at span level	≤ 5.0% of max. of certification range	-0,940	$u_{d,l,h}$	-0,57	0,3223	
18	Difference sample/calibration port	≤ 1.0%	-0,240	u_{18c}	-0,25	0,0630	
21	Converter efficiency	≥ 98	99,600	u_{EC}	0,42	0,1751	
23	Uncertainty of test gas	≤ 3.0%	2,000	u_{cg}	1,05	1,0941	
Combined standard uncertainty				u_c		5,4949	nmol/mol
Expanded uncertainty				U		10,9898	nmol/mol
Relative expanded uncertainty				W		10,51	%
Maximum allowed expanded uncertainty				W_{req}		15	%

Report on the performance test of the T200P air quality monitoring system
manufactured by Teledyne API measuring components NO, NO₂ and NO_x
Report no.: 936/21238687/A

Table 38: Expanded uncertainty from the results obtained in the laboratory for analyser 2

Measuring device:		T200P		Serial-No.:		SN: 60	
Measured component:		NO		1h-limit value:		104,6 nmol/mol	
No.	Performance characteristic	Performance criterion	Result	Partial uncertainty		Square of partial uncertainty	
1	Repeatability standard deviation at zero	≤ 1.0 nmol/mol	0,000	u _{r,z}	0,00	0,0000	
2	Repeatability standard deviation at 1h-limit value	≤ 3.0 nmol/mol	1,460	u _{r,1h}	0,07	0,0054	
3	"lack of fit" at 1h-limit value	≤ 4.0% of measured value	1,100	u _{l,1h}	0,66	0,4413	
4	Sensitivity coefficient of sample gas pressure at 1h-limit value	≤ 8.0 nmol/mol/kPa	0,910	u _{sp}	2,29	5,2433	
5	Sensitivity coefficient of sample gas temperature at 1h-limit value	≤ 3.0 nmol/mol/K	0,130	u _{gt}	0,33	0,1070	
6	Sensitivity coefficient of surrounding temperature at 1h-limit value	≤ 3.0 nmol/mol/K	0,732	u _{st}	1,84	3,3927	
7	Sensitivity coefficient of electrical voltage at 1h-limit value	≤ 0.30 nmol/mol/V	0,020	u _v	0,06	0,0034	
8a	Interferent H ₂ O with 21 mmol/mol	≤ 10 nmol/mol (Zero)	-0,600	u _{H2O}	-0,36	0,1332	
		≤ 10 nmol/mol (Span)	-0,070				
8b	Interferent CO ₂ with 500 µmol/mol	≤ 5.0 nmol/mol (Zero)	1,470	u _{int,pos}	1,00	1,0063	
		≤ 5.0 nmol/mol (Span)	-1,300				
8c	Interferent NH ₃ mit 200 nmol/mol	≤ 5.0 nmol/mol (Zero)	0,830	or			
		≤ 5.0 nmol/mol (Span)	0,970				
9	Averaging effect	≤ 7.0% of measured value	-3,720	u _{av}	-2,25	5,0469	
18	Difference sample/calibration port	≤ 1.0%	-0,130	u _{asc}	-0,14	0,0185	
21	Converter efficiency	≥ 98	99,40	u _{ec}	0,63	0,3939	
23	Uncertainty of test gas	≤ 3.0%	2,000	u _{cg}	1,05	1,0941	
Combined standard uncertainty				u _c	4,1099	nmol/mol	
Expanded uncertainty				U	8,2198	nmol/mol	
Relative expanded uncertainty				W	7,86	%	
Maximum allowed expanded uncertainty				W _{req}	15	%	

Table 39: Expanded uncertainty from the results obtained in the laboratory and field for analyser 2

Measuring device:		T200P		Serial-No.:		SN: 60	
Measured component:		NO		1h-limit value:		104,6 nmol/mol	
No.	Performance characteristic	Performance criterion	Result	Partial uncertainty		Square of partial uncertainty	
1	Repeatability standard deviation at zero	≤ 1.0 nmol/mol	0,000	u _{r,z}	0,00	0,0000	
2	Repeatability standard deviation at 1h-limit value	≤ 3.0 nmol/mol	1,460	u _{r,1h}	not considered, as √2*ur,1h = 0,1 < ur,f	-	
3	"lack of fit" at 1h-limit value	≤ 4.0% of measured value	1,100	u _{l,1h}	0,66	0,4413	
4	Sensitivity coefficient of sample gas pressure at 1h-limit value	≤ 8.0 nmol/mol/kPa	0,910	u _{sp}	2,29	5,2433	
5	Sensitivity coefficient of sample gas temperature at 1h-limit value	≤ 3.0 nmol/mol/K	0,130	u _{gt}	0,33	0,1070	
6	Sensitivity coefficient of surrounding temperature at 1h-limit value	≤ 3.0 nmol/mol/K	0,732	u _{st}	1,84	3,3927	
7	Sensitivity coefficient of electrical voltage at 1h-limit value	≤ 0.30 nmol/mol/V	0,020	u _v	0,06	0,0034	
8a	Interferent H ₂ O with 21 mmol/mol	≤ 10 nmol/mol (Zero)	-0,600	u _{H2O}	-0,36	0,1332	
		≤ 10 nmol/mol (Span)	-0,070				
8b	Interferent CO ₂ with 500 µmol/mol	≤ 5.0 nmol/mol (Zero)	1,470	u _{int,pos}	1,00	1,0063	
		≤ 5.0 nmol/mol (Span)	-1,300				
8c	Interferent NH ₃ mit 200 nmol/mol	≤ 5.0 nmol/mol (Zero)	0,830	or			
		≤ 5.0 nmol/mol (Span)	0,970				
9	Averaging effect	≤ 7.0% of measured value	-3,720	u _{av}	-2,25	5,0469	
10	Reproducibility standard deviation under field conditions	≤ 5.0% of average over 3 months	3,830	u _{r,f}	4,01	16,0495	
11	Long term drift at zero level	≤ 5.0 nmol/mol	1,150	u _{d,l,z}	0,66	0,4408	
12	Long term drift at span level	≤ 5.0% of max. of certification range	-0,760	u _{d,l,1h}	-0,46	0,2107	
18	Difference sample/calibration port	≤ 1.0%	-0,130	u _{asc}	-0,14	0,0185	
21	Converter efficiency	≥ 98	99,400	u _{ec}	0,63	0,3939	
23	Uncertainty of test gas	≤ 3.0%	2,000	u _{cg}	1,05	1,0941	
Combined standard uncertainty				u _c	5,7950	nmol/mol	
Expanded uncertainty				U	11,5899	nmol/mol	
Relative expanded uncertainty				W	11,08	%	
Maximum allowed expanded uncertainty				W _{req}	15	%	

8. Recommendations for use in practice

Tasks to be performed in the maintenance interval (4 weeks)

The tested measuring systems require regular performance of the following tasks:

- Regular visual inspections/telemetric inspections
- Instrument status ok
- No error messages
- Replacement of the Teflon filter in the sample gas inlet
- Zero and reference point checks using appropriate test gases

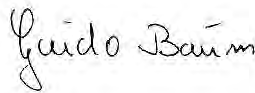
Apart from that please consider the manufacturer's instructions.

Further details are provided in the operation manual.

Environmental Protection/Air Pollution Control



Dipl.-Ing. Martin Schneider



Dipl.-Ing. Guido Baum

Cologne, 12 September 2017
936/21238687/A

9. Bibliography

- [1] VDI Guideline 4202, Part 1 – “Performance criteria for performance tests of automated ambient air measuring systems – Point-related measurement methods for gaseous and particulate air pollutants,” dated September 2010.
- [2] VDI Guideline 4203, part 3 – “Testing of automated measuring systems – Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants”, dated September 2010 or August 2010 respectively.
- [3] European standard EN 14211 Ambient air - Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence, August 2012
- [4] Directive 2008/50/EG of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe.

10. Annexes

Annex 1: Weather data for the field test

Table 40: Meteorological data (daily averages), May 2017

May 2017	Date	Air pressure [hPa]	Avg. air temperature [°C]	Rel. moisture [%]
29	29.05.2017	1004	27	58
30	30.05.2017	1006	23	65
31	31.05.2017	1009	21	62

Table 41: Meteorological data (daily averages), June 2017

June 2017	Date	Air pressure [hPa]	Avg. air temperature [°C]	Rel. moisture [%]
1	01.06.2017	1006	22	67
2	02.06.2017	1007	25	60
3	03.06.2017	1005	22	70
4	04.06.2017	1007	18	70
5	05.06.2017	1006	19	55
6	06.06.2017	995	17	59
7	07.06.2017	1004	15	61
8	08.06.2017	1008	20	57
9	09.06.2017	1005	19	65
10	10.06.2017	1012	20	58
11	11.06.2017	1008	24	56
12	12.06.2017	1008	20	57
13	13.06.2017	1011	19	60
14	14.06.2017	1010	20	58
15	15.06.2017	1006	24	58
16	16.06.2017	1012	19	60
17	17.06.2017	1018	19	66
18	18.06.2017	1016	23	61
19	19.06.2017	1012	25	52
20	20.06.2017	1008	26	52
21	21.06.2017	1008	27	54
22	22.06.2017	1003	28	52
23	23.06.2017	1007	24	56
24	24.06.2017	1008	21	59
25	25.06.2017	1004	22	61
26	26.06.2017	1005	21	59
27	27.06.2017	1000	20	65
28	28.06.2017	990	20	81
29	29.06.2017	989	20	73
30	30.06.2017	996	19	69

Table 42: Meteorological data (daily averages), July 2017

July 2017	Date	Air pressure [hPa]	Avg. air temperature [°C]	Rel. moisture [%]
1	01.07.2017	1001	17	84
2	02.07.2017	1010	17	82
3	03.07.2017	1012	24	52
4	04.07.2017	1009	24	58
5	05.07.2017	1009	23	67
6	06.07.2017	1006	26	60
7	07.07.2017	1008	25	59
8	08.07.2017	1005	24	61
9	09.07.2017	1000	22	71
10	10.07.2017	1001	17	84
11	11.07.2017	1009	17	69
12	12.07.2017	1008	18	66
13	13.07.2017	1011	19	69
14	14.07.2017	1012	19	66
15	15.07.2017	1011	21	64
16	16.07.2017	1017	20	71
17	17.07.2017	1009	22	72
18	18.07.2017	1008	23	64
19	19.07.2017	1009	21	71
20	20.07.2017*	--	--	--
21	21.07.2017*	--	--	--
22	22.07.2017*	--	--	--
23	23.07.2017*	--	--	--
24	24.07.2017*	--	--	--
25	25.07.2017*	--	--	--
26	26.07.2017*	--	--	--
27	27.07.2017	1002	21	65
28	28.07.2017	1000	20	70
29	29.07.2017	1004	19	62
30	30.07.2017	1004	23	64
31	31.07.2017	1001	25	55

* Power outage in the measurement container

Table 43: *Meteorological data (daily averages), August 2017*

August 2017	Date	Air pressure [hPa]	avg. air temperature [°C]	Rel. moisture [%]
1	01.08.2017	1007	21	77
2	02.08.2017	1009	21	73
3	03.08.2017	1003	22	72
4	04.08.2017	1005	22	61
5	05.08.2017	1007	18	78
6	06.08.2017	1014	18	67
7	07.08.2017	1011	19	59
8	08.08.2017	1008	21	57
9	09.08.2017	1008	21	59
10	10.08.2017	1011	19	59
11	11.08.2017	1012	18	69
12	12.08.2017	1010	18	66
13	13.08.2017	1009	20	66
14	14.08.2017	1009	19	71
15	15.08.2017	1011	19	69
16	16.08.2017	1010	19	66
17	17.08.2017	1007	21	69
18	18.08.2017	1005	18	86
19	19.08.2017	1009	16	76
20	20.08.2017	1015	16	74
21	21.08.2017	1015	18	67
22	22.08.2017	1013	18	66
23	23.08.2017	1008	21	62
24	24.08.2017	1008	21	65
25	25.08.2017	1010	19	74
26	26.08.2017	1007	22	77
27	27.08.2017	1010	21	69
28	28.08.2017	1010	22	66
29	29.08.2017	1007	25	63
30	30.08.2017	1018	23	76
31	31.08.2017	1019	21	74

Table 44: *Meteorological data (daily averages), September 2017*

September 2017	Date	Air pressure [hPa]	avg. air temperature [°C]	Rel. moisture [%]
1	01.09.2017	1006	18	71
2	02.09.2017	1007	18	72
3	03.09.2017	1004	19	78
4	04.09.2017	1005	23	60
5	05.09.2017	1009	20	71
6	06.09.2017	1001	19	75
7	07.09.2017	1000	19	69
8	08.09.2017	1000	16	73
9	09.09.2017	997	15	78
10	10.09.2017	997	14	81
11	11.09.2017	995	15	78

Annex 1 Manual

Annex 1:

Manual



TELEDYNE API
Everywhereyoulook™



User Manual

MODELS T200P and T200UP
Photolytic NO/NO₂/NO_x Analyzer

with NumaView™ software

© TELEDYNE API (TAPI)
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TRADEMARKS

All trademarks, registered trademarks, brand names or product names appearing in this document are the property of their respective owners and are used herein for identification purposes only.

SAFETY MESSAGES

Important safety messages are provided throughout this manual for the purpose of avoiding personal injury or instrument damage. Please read these messages carefully. Each safety message is associated with a safety alert symbol and is placed throughout this manual; the safety symbols are also located inside the instrument. It is imperative that you pay close attention to these messages, the descriptions of which are as follows:



WARNING: Electrical Shock Hazard



HAZARD: Strong oxidizer



GENERAL WARNING/CAUTION: Read the accompanying message for specific information.



CAUTION: Hot Surface Warning



Do Not Touch: Touching some parts of the instrument without protection or proper tools could result in damage to the part(s) and/or the instrument.



Technician Symbol: All operations marked with this symbol are to be performed by qualified maintenance personnel only.



Electrical Ground: This symbol inside the instrument marks the central safety grounding point for the instrument.

CAUTION



This instrument should only be used for the purpose and in the manner described in this manual. If you use this instrument in a manner other than that for which it was intended, unpredictable behavior could ensue with possible hazardous consequences.

NEVER use any gas analyzer to sample combustible gas(es)!

For Technical Assistance regarding the use and maintenance of this instrument or any other Teledyne API product, contact Teledyne API's Technical Support Department:

Telephone: 800-324-5190

Email: sda_techsupport@teledyne.com

or access any of the service options on our website at <http://www.teledyne-api.com/>

CONSIGNES DE SÉCURITÉ

Des consignes de sécurité importantes sont fournies tout au long du présent manuel dans le but d'éviter des blessures corporelles ou d'endommager les instruments. Veuillez lire attentivement ces consignes. Chaque consigne de sécurité est représentée par un pictogramme d'alerte de sécurité; ces pictogrammes se retrouvent dans ce manuel et à l'intérieur des instruments. Les symboles correspondent aux consignes suivantes :



AVERTISSEMENT : Risque de choc électrique



DANGER : Oxydant puissant



AVERTISSEMENT GÉNÉRAL / MISE EN GARDE : Lire la consigne complémentaire pour des renseignements spécifiques



MISE EN GARDE : Surface chaude



Ne pas toucher : Toucher à certaines parties de l'instrument sans protection ou sans les outils appropriés pourrait entraîner des dommages aux pièces ou à l'instrument.



Pictogramme « technicien » : Toutes les opérations portant ce symbole doivent être effectuées uniquement par du personnel de maintenance qualifié.



Mise à la terre : Ce symbole à l'intérieur de l'instrument détermine le point central de la mise à la terre sécuritaire de l'instrument.

MISE EN GARDE



Cet instrument doit être utilisé aux fins décrites et de la manière décrite dans ce manuel. Si vous utilisez cet instrument d'une autre manière que celle pour laquelle il a été prévu, l'instrument pourrait se comporter de façon imprévisible et entraîner des conséquences dangereuses.

NE JAMAIS utiliser un analyseur de gaz pour échantillonner des gaz combustibles!

WARRANTY

WARRANTY POLICY (02024J)

Teledyne API (TAPI), a business unit of Teledyne Instruments, Inc., provides that: Prior to shipment, TAPI equipment is thoroughly inspected and tested. Should equipment failure occur, TAPI assures its customers that prompt service and support will be available. (For the instrument-specific warranty period, please refer to the “Limited Warranty” section in the Terms and Conditions of Sale on our website at the following link: http://www.teledyne-api.com/terms_and_conditions.asp).

COVERAGE

After the warranty period and throughout the equipment lifetime, TAPI stands ready to provide on-site or in-plant service at reasonable rates similar to those of other manufacturers in the industry. All maintenance and the first level of field troubleshooting are to be performed by the customer.

NON-TAPI MANUFACTURED EQUIPMENT

Equipment provided but not manufactured by TAPI is warranted and will be repaired to the extent and according to the current terms and conditions of the respective equipment manufacturer’s warranty.

PRODUCT RETURN

All units or components returned to Teledyne API should be properly packed for handling and returned freight prepaid to the nearest designated Service Center. After the repair, the equipment will be returned, freight prepaid.

The complete Terms and Conditions of Sale can be reviewed at http://www.teledyne-api.com/terms_and_conditions.asp

CAUTION – Avoid Warranty Invalidation



Failure to comply with proper anti-Electro-Static Discharge (ESD) handling and packing instructions and Return Merchandise Authorization (RMA) procedures when returning parts for repair or calibration may void your warranty. For anti-ESD handling and packing instructions please refer to the manual, Fundamentals of ESD, PN 04786, in its “Packing Components for Return to Teledyne API’s Customer Service” section. The manual can be downloaded from our website at <http://www.teledyne-api.com>. RMA procedures can also be found on our website.

ABOUT THIS MANUAL

This manual is comprised of multiple documents, in PDF format, as listed below.

Part No.	Name/Description
083730229	T200P/T200UP User Manual with NumaView™ Software (this manual)
n/a	MODBUS Registers, Appendix A
084440000	T200P Interconnect Diagram, Appendix B
074570000	T200UP Interconnect Diagram, Appendix B

Support manuals, such as electrostatic discharge (ESD) prevention, are available on the TAPI website <http://www.teledyne-api.com> under Product Manuals in the Special Manuals section.

Note

We recommend that all users read this manual in its entirety before operating the instrument.

CONVENTIONS USED

In addition to the safety symbols as presented in the *Safety Messages* page, this manual provides *special notices* related to the careful and effective use of the instrument and related, pertinent information.

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY
This special notice provides information to avoid damage to your instrument and possibly invalidate the warranty.

Important

IMPACT ON READINGS OR DATA
Provides information about that which could either affect accuracy of instrument readings or cause loss of data.

Note

Provides information pertinent to the proper care, operation or maintenance of the instrument or its parts.

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Appendix A – MODBUS Registers

Appendix B – Interconnect Wiring Diagram

1. INTRODUCTION, SPECIFICATIONS, APPROVALS, & COMPLIANCE

Teledyne API’s Model T200P and Model T200UP are both Photolytic NO/NO₂/NO_x Analyzers that use a patented high efficiency Blue Light Converter (BLC) coupled with state-of-the-art microprocessor technology to provide true measurement of ambient nitrogen dioxide (NO₂). The BLC includes the latest technology in high powered LEDs and a Teflon cell with reflective properties that increase the overall conversion efficiency, which allows for better speciation of lower NO₂ levels.

While both analyzers operate the same way, some of their specifications and components differ wherein the T200UP’s “ultra-sensitive” capability allows it to provide trace level measurements due to higher reflectivity, decreased interferents, and greater chemiluminescent reaction. For example, the reaction cell in the T200UP is gold-plated to create even greater reflectivity; the pre-reactor chamber mitigates hydrocarbon interferents, and the sample flow rate being twice the mass flow rate generates more light and therefore a much lower detectable limit (LDL). Also, the T200UP’s high performance vacuum pump decreases pressure in the reaction cell to less than 5 in-Hg-A, thereby increasing chemiluminescent reaction.

Along with providing high accuracy and dependability, these analyzers track operational parameters and will issue warnings if those parameters fall outside diagnostic limits, as well as store easily retrievable data.

1.1. SPECIFICATIONS

Table 1-1. Specifications

PARAMETER	SPECIFICATION	
	T200P	T200UP
Min/Max Range (Physical Analog Output) selectable, dual ranges supported	Min: 0-50 ppb Full Scale Max: 0-4,000 ppb Full Scale	Min: 0-5 ppb Full Scale Max: 0-2,000 ppb Full Scale
Measurement Units (selectable)	ppb, ppm, µg/m ³ , mg/m ³	ppb, µg/m ³
Zero Noise ¹	< 0.2 ppb (RMS)	< 25 ppt (RMS)
Span Noise ¹	< 0.5% of reading (RMS) above 50 ppb or 0.2 ppb, whichever is greater	< 0.5% of reading (RMS) above 5 ppb
Lower Detectable Limit ²	0.4 ppb	< 50 ppt
Zero Drift (at constant temperature and voltage) /24 hours	< 0.5 ppb	< 0.1 ppb
Span Drift (at constant temperature and voltage) /24 hours	< 0.5% of full scale	< 0.5% of reading
Lag Time ¹	20 seconds	20 seconds
Rise/Fall Time ¹	< 60 seconds to 95%	< 50 seconds to 95%

PARAMETER	SPECIFICATION	
Linearity	1% of full scale	1% of full scale
Precision	0.5% of reading above 50 ppb	0.5% of reading above 5 ppb
Sample Flow Rate	500 cc/min ± 10%	1100 cc/min ± 10%
AC Power	Rating (T200P, T200UP) 110-120 V~, 60 Hz, 3.0 A 220-240 V~, 50/60 Hz, 3.0 A	Typical Power Consumption 160 W (T200P) 165 W (T200UP) 160 W (T200P) 165 W (T200UP)
Analog Output Ranges	10V, 5V, 1V, 0.1V (selectable) All Ranges with 5% Under/Over Range	
Analog Output Resolution	1 part in 4096 of selected full-scale voltage	
Recorder Offset	± 10%	
Standard I/O	1 Ethernet: 10/100Base-T 2 RS-232 (300 – 115,200 baud) 2 USB device ports 8 opto-isolated digital status outputs (user-configurable) 6 opto-isolated digital control inputs (user-configurable) 4 analog outputs (user-configurable)	
Optional I/O	1 USB com port 1 RS485 8 analog inputs (0-10V, 12-bit) (user-configurable) 4 digital alarm outputs (user-configurable) Multidrop RS232 3 4-20mA current outputs (T200P); 2 4-20mA current outputs (T200UP)	
Dimensions H x W x D	7" x 17" x 23.5" (178mm x 432 mm x 597 mm)	
Weight	Analyzer: 40 lbs (18 kg) External Pump Pack: 15 lbs (7 kg)	
Operating Temperature Range	5 - 40 °C	
Humidity Range	0-95% RH non-condensing	
Environmental Conditions	Installation Category (Over voltage Category) II Pollution Degree 2 Intended for Indoor Use Only at Altitudes ≤ 2000m	
¹ As defined by the US EPA. ² Defined as twice the zero noise level by the US EPA. All specifications are based on constant conditions.		

1.2. EPA DESIGNATION

The official List of Designated Reference and Equivalent Methods is published in the U.S. Federal Register – <http://www3.epa.gov/ttn/amtic/criteria.html>.

1.2.1. MODEL T200P

The Teledyne API Model T200P nitrogen oxides analyzer is officially designated as US EPA Federal Equivalent Method (FEM), Designation Number EQNA-1016-241.

1.2.2. MODEL T200UP

The Teledyne API Model T200UP trace level nitrogen oxides analyzer is officially designated as US EPA Federal Equivalent Method (FEM), Designation Number EQNA-0512-200.

1.3. SAFETY

IEC/EN 61010-1:2010 (3rd Edition), Safety requirements for electrical equipment for measurement, control, and laboratory use.

CE: 2006/95/EC, Low-Voltage Directive

1.4. EMC

IEC/EN 61326-1, Class A Emissions/Industrial Immunity

EN55011 (CISPR 11), Group 1, Class A Emissions

FCC 47 CFR Part 15B, Class A Emissions

CE: 2004/108/EC, Electromagnetic Compatibility Directive

1.5. OTHER CERTIFICATIONS

Please call the Technical Support Department for information on other certifications.

2. GETTING STARTED

This section addresses unpacking, connecting, and initializing the instrument, getting an overview of the menu system, and setting up/configuring the functions.

2.1. UNPACKING



CAUTION - GENERAL SAFETY HAZARD

To avoid personal injury, always use two persons to lift and carry the analyzer.

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Printed Circuit Assemblies (PCAs) are sensitive to electro-static discharges too small to be felt by the human nervous system. Failure to use Electro-Static Discharge (ESD) protection when working with electronic assemblies will void the instrument warranty. Refer to the manual, Fundamentals of ESD, PN 04786, which can be downloaded from our website at <http://www.teledyne-api.com>.

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Do not operate this instrument without first removing dust plugs from SAMPLE and EXHAUST ports on the rear panel.

Note

Teledyne API recommends that you store shipping containers and materials for future use if/when the instrument should be returned to the factory for repair and/or calibration service. See Warranty statement in this manual and Return Merchandise Authorization (RMA) on our Website at <http://www.teledyne-api.com>.

Verify that there is no apparent external shipping damage. If damage has occurred, please advise the shipper first, then Teledyne API.

Included with your instrument is a printed record of the final performance characterization performed on your instrument at the factory. This record, titled Final Test and Validation Data Sheet, is an important quality assurance and calibration record and should be placed in the quality records file for this instrument.

With no power to the unit, carefully remove the top cover of the instrument and check for internal shipping damage by carrying out the following steps:

1. Carefully remove the top cover and check for internal shipping damage.
 - a. Remove the setscrew located in the top, center of the front panel.
 - b. Slide the cover backward until it clears the instrument's front bezel.
 - c. Lift the cover straight up.
2. Inspect the interior of the instrument to ensure all circuit boards and other components are intact and securely seated.
3. Check the connectors of the various internal wiring harnesses and pneumatic hoses to ensure they are firmly and securely seated.
4. Verify that all of the optional hardware ordered with the unit has been installed. These are listed on the paperwork accompanying the instrument.



WARNING – ELECTRICAL SHOCK HAZARD

Never disconnect PCAs, wiring harnesses or electronic subassemblies while under power.

2.1.1. VENTILATION CLEARANCE

Whether the instrument is set up on a bench or installed in a rack, be sure to leave sufficient ventilation clearance.

Table 2-1. Ventilation Clearance

AREA	MINIMUM REQUIRED CLEARANCE
Back of the instrument	10 cm / 4 in
Sides of the instrument	2.5 cm / 1 in
Above and below the instrument	2.5 cm / 1 in

2.2. INSTRUMENT LAYOUT

This section illustrates the front and rear panels and the internal chassis layout.

2.2.1. FRONT PANEL

The front panel (Figure 2-1) includes two USB ports for peripheral device connections, which can be used with mouse and keyboard as alternatives to the touchscreen interface, or with flash drive for uploads/downloads (devices not included).

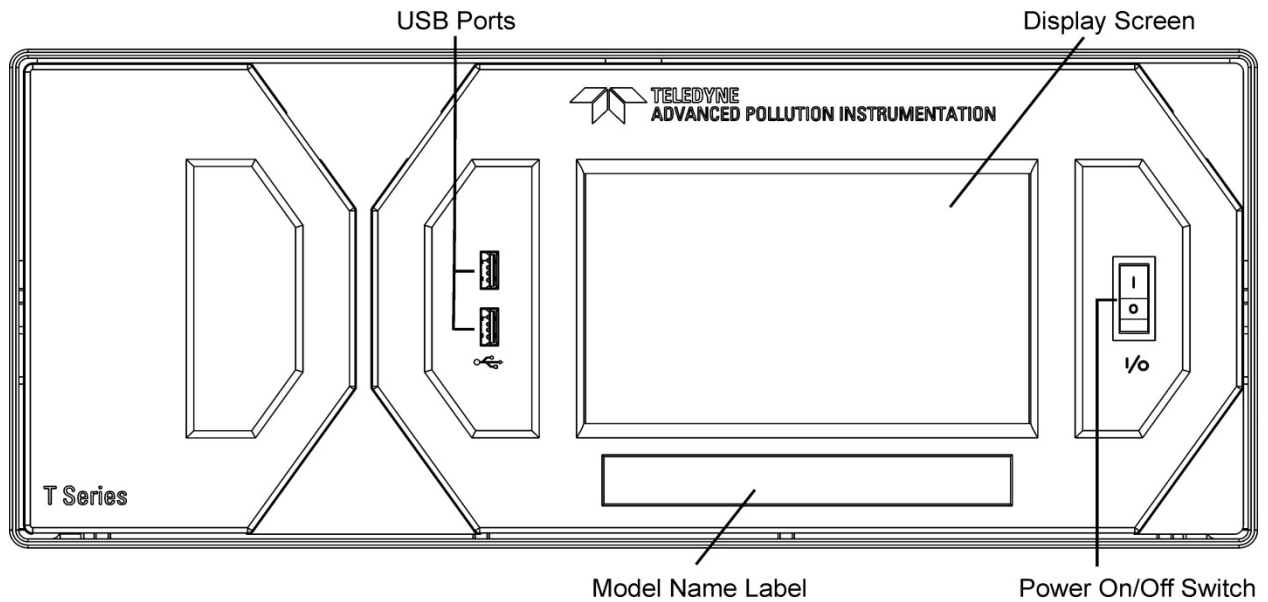


Figure 2-1. Front Panel Layout

2.2.2. REAR PANEL

Figure 2-2 shows the layout of the rear panel.

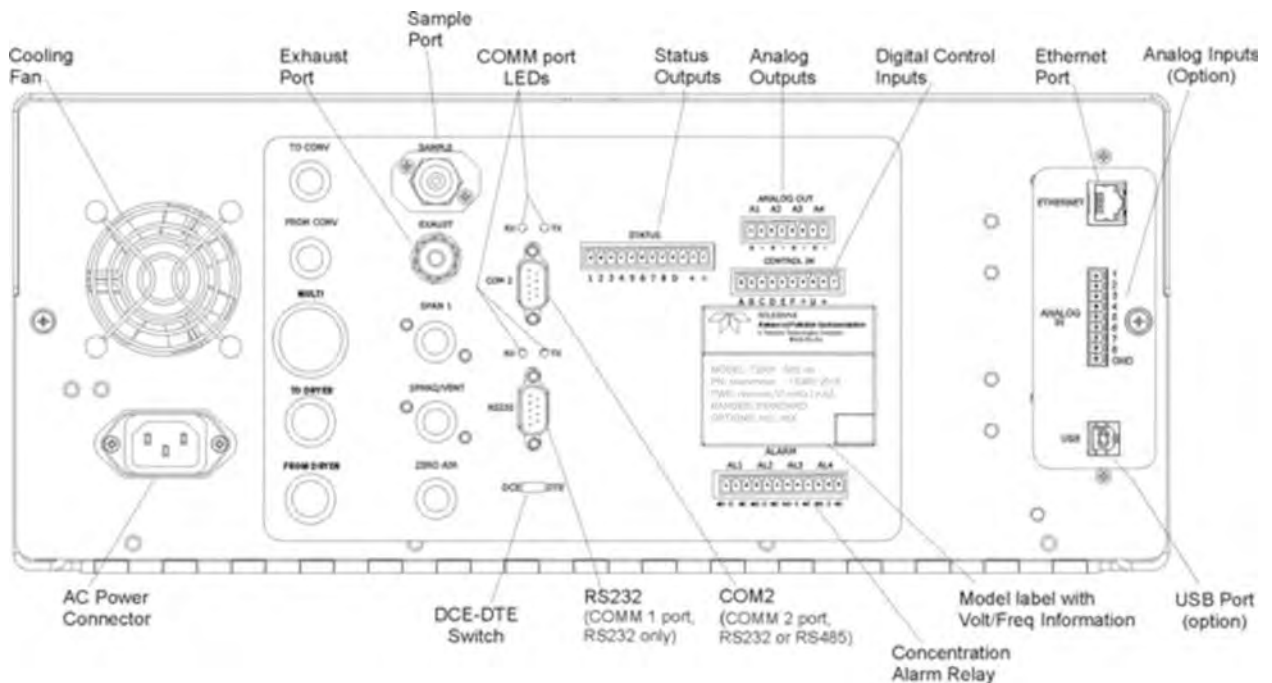



Figure 2-2. Rear Panel Layout, Base Unit (options include additional pneumatic ports)

Table 2-2. Rear Panel Description

COMPONENT	FUNCTION
cooling fan	Pulls ambient air into chassis through side vents and exhausts through rear.
 AC power connector	Connector for three-prong cord to apply AC power to the analyzer. CAUTION! The cord's power specifications (specs) MUST comply with the power specs on the analyzer's rear panel Model number label
Model/specs label	Identifies the analyzer model number and provides power specs
TO CONV	(not used)
FROM CONV	(not used)
MULTI	(not used)
TO DRYER	(not used)
FROM DRYER	Outlet for internal sample gas dryer; connect to external zero air scrubber (for IZS options only).
SAMPLE	Connect a gas line from the source of sample gas here. Calibration gases can also enter here on units without zero/span/shutoff valve options installed.
EXHAUST	Connect an exhaust gas line of not more than 10 meters long here that leads outside the shelter or immediate area surrounding the instrument. The line must be ¼" tubing or greater.
SPAN 1	On units with zero/span/shutoff valves option installed, connect a gas line to the source of calibrated span gas here.
SPAN2/VENT	On units with pressurized span valve option, used for venting.
ZERO AIR	Internal Zero Air: On units with zero/span/shutoff valves option installed but no internal zero air scrubber attach a gas line to the source of zero air here.
RX TX	LEDs indicate receive (RX) and transmit (TX) activity on the when blinking.
COM 2	Serial communications port for RS-232 or RS-485.
RS-232	Serial communications port for RS-232 only.
DCE DTE	Switch to select either data terminal equipment or data communication equipment during RS-232 communication.
STATUS	For outputs to devices such as Programmable Logic Controllers (PLCs).
ANALOG OUT	For voltage or current loop outputs to a strip chart recorder and/or a data logger.
CONTROL IN	For remotely activating the zero and span calibration modes.
ALARM	Option for concentration alarms and system warnings.
ETHERNET	Connector for network or Internet remote communication, using Ethernet cable
ANALOG IN	Option for external voltage signals from other instrumentation and for logging these signals
USB	Connector for direct connection to laptop computer, using USB cable.
Model Label	Includes voltage and frequency specifications

2.2.3. INTERNAL CHASSIS

The T200P internal chassis layout is shown in Figure 2-3; T200UP is shown in Figure 2-4.

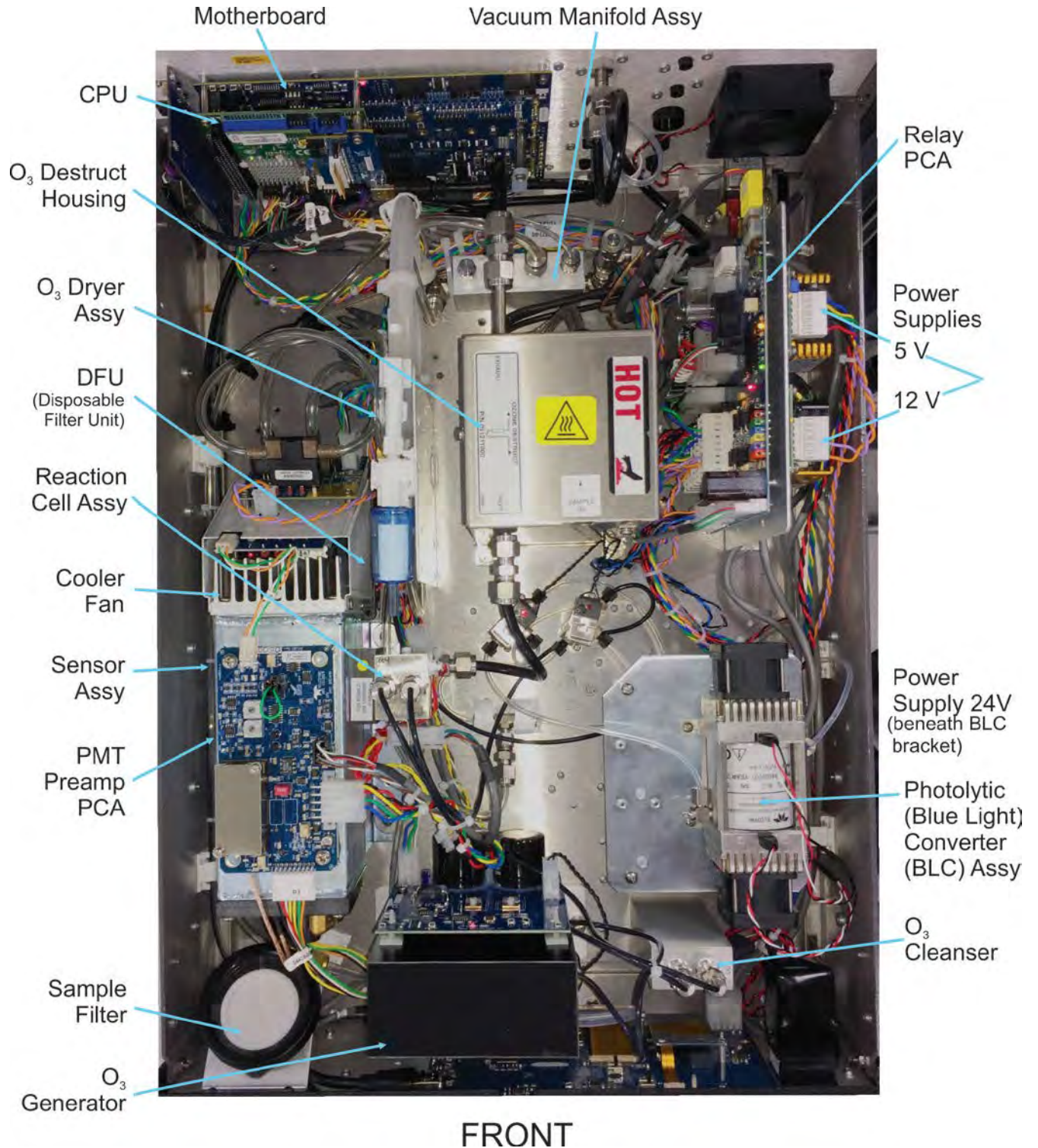


Figure 2-3. T200P Internal Chassis Layout

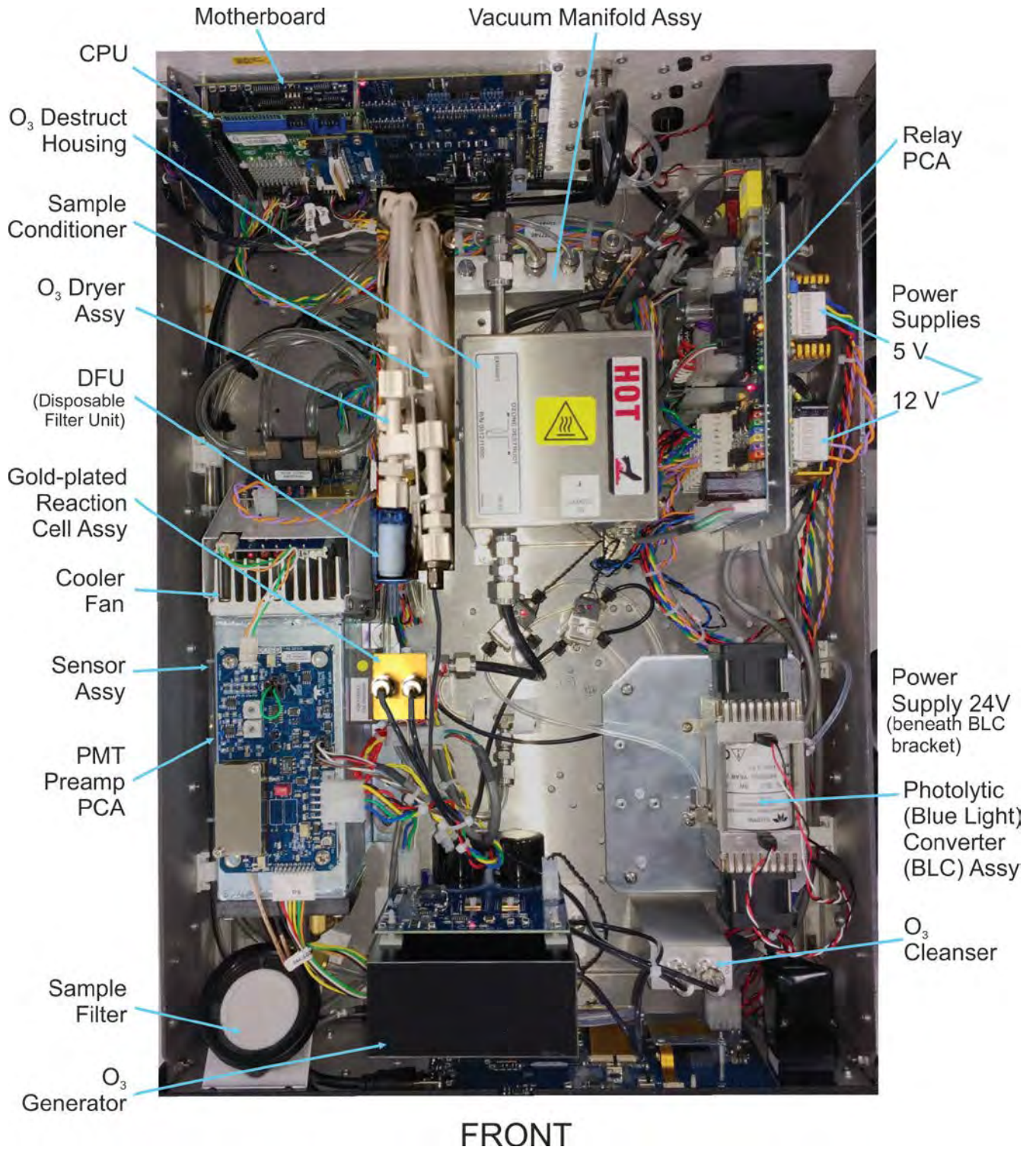


Figure 2-4. T200UP Internal Chassis Layout

2.3. CONNECTIONS AND STARTUP

This section presents the electrical (Section 2.3.1) and pneumatic (Section 2.3.2) connections for setting up and preparing the instrument for operation (Section 2.3.3).

2.3.1. ELECTRICAL CONNECTIONS

Note

Teledyne API recommends that you store shipping containers and materials for future use if/when the instrument should be returned to the factory for repair and/or calibration service.



WARNING – Electrical Shock Hazard

- High Voltages are present inside the instrument's case.
- Power connection must have functioning ground connection.
- Do not defeat the ground wire on power plug.
- Turn off instrument power before disconnecting or connecting electrical subassemblies.
- Do not operate with cover off.



CAUTION – Avoid Damage to the Instrument

Ensure that the AC power voltage matches the voltage indicated on the instrument's model/specs label before plugging it into line power.

2.3.1.1. CONNECTING POWER

Attach the power cord between the instrument's AC power connector and a power outlet capable of carrying at least the rated current at your AC voltage range. It is important to adhere to all safety and cautionary messages, and ensure that the outlet is equipped with a functioning earth ground.

2.3.1.2. CONNECTING ANALOG INPUTS (OPTION)

The Analog In connector option is used for measuring external voltage signals from other instrumentation (such as meteorological instruments) and for logging these signals in the analyzer's internal data acquisition system, the Data Logger (Section 2.5.1). The input voltage range for each analog input is 0-10 VDC and input impedance is nominally 20k Ω in parallel with 0.1 μ F.

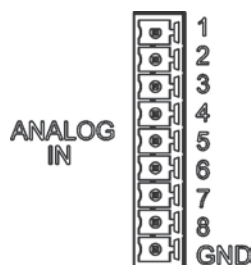


Figure 2-5. Analog In Connector

Assignments for the Analog In connector pins 1 through 8 (Table 2-3) are configurable through the Setup>Ext Analog Inputs menu (visible with installed option).

Table 2-3. Analog Input Pin Assignments

PIN	DESCRIPTION	DAS/DATA LOGGER PARAMETER ¹
1	Analog input # 1	Channel 1
2	Analog input # 2	Channel 2
3	Analog input # 3	Channel 3
4	Analog input # 4	Channel 4
5	Analog input # 5	Channel 5
6	Analog input # 6	Channel 6
7	Analog input # 7	Channel 7
8	Analog input # 8	Channel 8
GND	Analog input Ground	N/A

¹ See Section 2.5.1 for details on setting up the Data Logger.

2.3.1.3. CONNECTING ANALOG OUTPUTS

The rear panel Analog Output channels A1 through A4 can be mapped to reflect various operating values in the analyzer, including concentration values, temperatures, pressures, etc. These mappings are not configured by default and must be set by the user.

An optional Current Loop output (Section 2.3.1.4) is available for A1, A2 and A3 only.

To access these signals attach a strip chart recorder and/or data-logger to the appropriate analog output connections on the rear panel of the analyzer.

Configure through the Setup>Analog Outputs menu (Section 2.5.8)

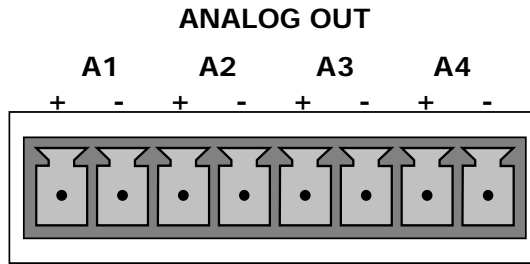


Figure 2-6. Analog Output Connector


Table 2-4. Analog Output Pin Assignments

PIN	ANALOG OUTPUT	SIGNAL OUT	STANDARD VOLTAGE OUTPUT	CURRENT LOOP OPTION
1	A1	User-selected through the Setup>Analog Outputs menu.	V +	I Out +
2			Ground	I Out -
3	A2		V +	I Out +
4			Ground	I Out -
3	A3		V +	I Out +
4			Ground	I Out -
7	A4		V +	Not Available
8			Ground	Not Available

2.3.1.4. CURRENT LOOP ANALOG OUTPUTS (OPTION 41) SETUP

If your analyzer had this option installed at the factory, there are no further connections to be made. Otherwise, it can be installed as a retrofit for each of the analog outputs. This option converts the DC voltage analog output to a current signal with 0-20 mA output current, which can be scaled to any set of limits within that 0-20 mA range. However, most current loop applications call for either 2-20 mA or 4-20 mA range. All current loop outputs have a +5% over-range. Ranges with the lower limit set to more than 1 mA (e.g., 2-20 or 4-20 mA) also have a -5% under-range.

Figure 2-7 provides installation instructions and illustrates a sample configuration of one current output combined with two voltage outputs. Next are instructions for converting current loop analog outputs to standard 0-to-5 VDC outputs. To calibrate or adjust these outputs use the Setup>Analog Outputs menu (Section 2.5.8).

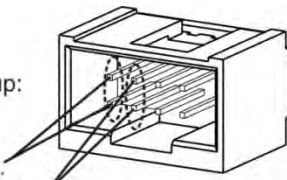


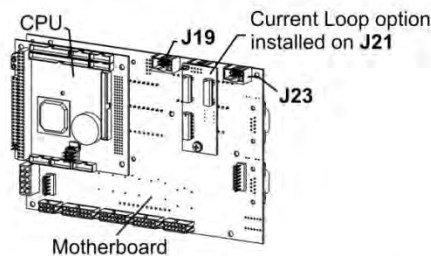
CAUTION – Avoid Invalidating Warranty

Servicing or handling of circuit components requires electrostatic discharge protection, i.e. ESD grounding straps, mats and containers. Failure to use ESD protection when working with electronic assemblies will void the instrument warranty. For information on preventing ESD damage, refer to the manual, Fundamentals of ESD, PN 04786, which can be downloaded from our website at <http://www.teledyne-api.com> under Help Center > Product Manuals in the Special Manuals section..

J19, J21, J23 Analog Output Setup:

- For **voltage** output of any one, two, or all:
 1. Jumper two leftmost pins.
 2. Jumper next two leftmost pins.
 3. Calibrate per Analog I/O Configuration menu.
- For **current** output of any one, two, or all:
 1. Remove jumper shunts.
 2. Install Current Loop option.
 3. Calibrate per Analog I/O Configuration menu.





Example setup: install jumper shunts for voltage output on J19 and J23; remove jumper shunts and install Current Loop option for current output on J21.

Figure 2-7. Current Loop Option Installed on the Motherboard

CONVERTING CURRENT LOOP ANALOG OUTPUTS TO STANDARD VOLTAGE OUTPUTS

To convert an output configured for current loop operation to the standard 0 to 5 VDC output operation:

1. Turn off power to the analyzer.
2. If a recording device is connected to the output being modified, disconnect it.
3. Remove the top cover.
 - Remove the set screw located in the top, center of the rear panel.
 - Remove the screws fastening the top cover to the unit (one per side).
 - Slide the cover back and lift the cover straight up.
4. Remove the screw holding the current loop option to the motherboard.
5. Disconnect the current loop option PCA from the appropriate connector on the motherboard (see Figure 2-7).
6. Each connector, J19 and J23, requires two shunts. Place one shunt on the two left most pins and the second shunt on the two adjacent pins (see Figure 2-7).
7. Return the top cover to the analyzer and secure.

The analyzer is now ready to have a voltage-sensing recording device attached to that output.

2.3.1.5. CONNECTING THE STATUS OUTPUTS (DIGITAL OUTPUTS)

The 12-pin STATUS connector allows the digital status outputs to report analyzer conditions (configured through the Setup>Digital Outputs menu) via optically isolated NPN transistors that sink up to 50 mA of DC current. These outputs can be used to interface with devices that accept logic-level digital inputs, such as Programmable Logic Controllers (PLCs). Each status bit is an open collector output that can withstand up to 40 VDC. All of the emitters of these transistors are tied together and available at pin D (see Figure 2-8).

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Most PLC's have internal provisions for limiting the current that the input will draw from an external device. When connecting to a unit that does not have this feature, an external dropping resistor must be used to limit the current through the transistor output to less than 50 mA. At 50 mA, the transistor will drop approximately 1.2V from its collector to emitter.

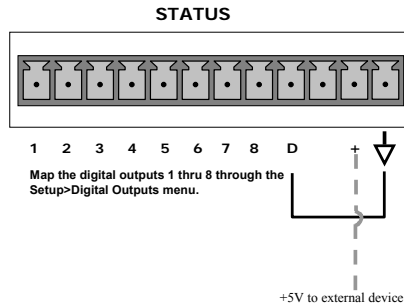


Figure 2-8. Status Output Connector for Digital Outputs

Table 2-5. Status Output Pin Assignments

PIN	STATUS DEFINITION	CONDITION
1-8	Configurable through the Setup>Digital Outputs menu	Collector side of individual status output opto-isolators.
D	Emitter BUS	The emitters of the transistors on pins 1 to 8 are bussed together.
Blank	NO CONNECTION	
+	DC Power	+ 5 VDC, 300 mA source maximum
↓	Digital Ground	The ground level from the analyzer's internal DC power supplies. This connection should be used as the ground return when +5VDC power is used.

2.3.1.6. CONNECTING THE CONTROL INPUTS (DIGITAL INPUTS)

With zero and span valves option installed, two digital control inputs in the rear panel CONTROL IN connector, can be used to remotely activate the zero and span calibration modes (see Section 4.2.2.1).

Energize the Control Inputs either by the internal +5V available from the pin labeled “+” (more convenient), or by a separate external 5 VDC power supply (ensures that these inputs are truly isolated). Refer to Figure 2-9.

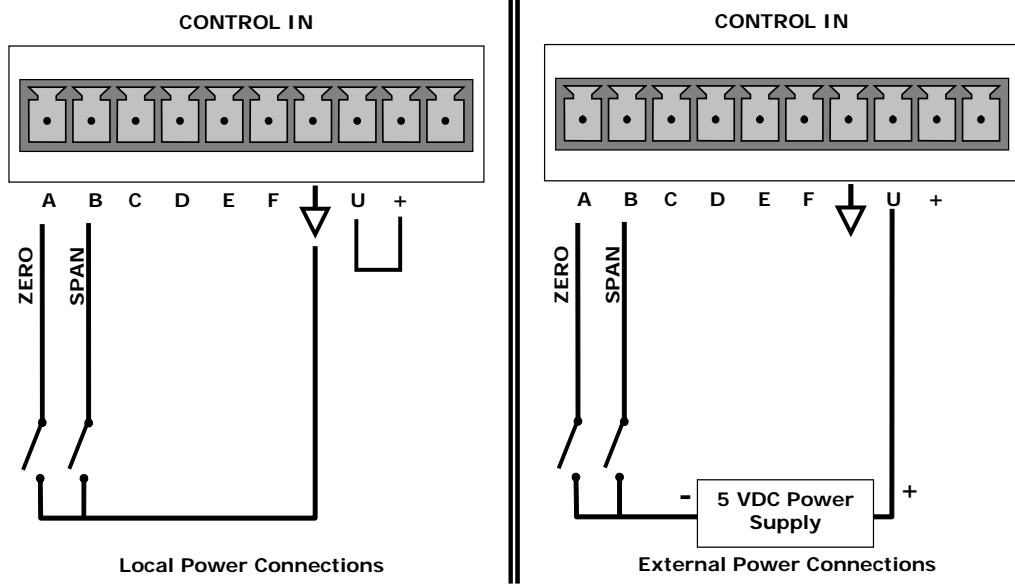



Figure 2-9. Energizing the Control Inputs

Table 2-6. Control Input Pin Assignments

INPUT #	STATUS DEFINITION	ON CONDITION
A	Remote Zero Cal	The analyzer is placed in Zero Calibration mode.
B	Remote Span Cal	The analyzer is placed in Lo Span Calibration mode.
C, D, E & F	Spare	
	Digital Ground	The ground level from the analyzer's internal DC Power Supplies (same as chassis ground).
U	External Power input	Input pin for +5 VDC is required to activate pins A – F.
+	5 VDC output	Internally generated 5V DC power. To activate inputs A – F, place a jumper between this pin and the “U” pin. The maximum amperage through this port is 300 mA (combined with the analog output supply, if used).

2.3.1.7. CONCENTRATION ALARM RELAY (OPTION 61)

The concentration relay option provides four (4) “dry contact” relays on the rear panel (Figure 2-10), each with 3 pins: Common (C), Normally Open (NO), and Normally Closed (NC). The Relays can be mapped to reflect various internal instrument conditions and states. Configure these outputs through the Setup>Digital Outputs menu (Section 2.5.7) under MB Relay [1 thru 4].

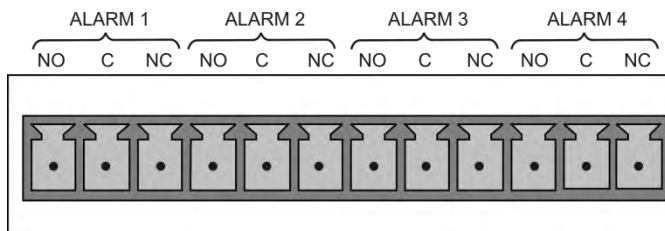


Figure 2-10. Concentration Alarm Relay

2.3.1.8. CONNECTING COMMUNICATIONS INTERFACES

ETHERNET CONNECTION

For network or Internet communication with the analyzer, connect an Ethernet cable from the analyzer’s rear panel Ethernet interface connector to an Ethernet port. Although the analyzer is shipped with DHCP enabled by default, it should be manually configured with a static IP address.

Configuration: Section 2.5.10.4

USB (OPTION) CONNECTION

The rear panel USB option is for direct communication between the analyzer and a PC. Connect a USB cable between the analyzer and a computer USB port. Computer and instrument baud rates must match.

Note If this option is installed, the rear panel RS232 (COM2) port cannot be used for anything other than RS-232 Multidrop communication.

RS-232 CONNECTION

For RS-232 communications with data terminal equipment (DTE) or with data communication equipment (DCE) connect either a DB9-female-to-DB9-female cable (Teledyne API part number WR000077) or a DB9-female-to-DB25-male cable (Option 60A), as applicable, from the analyzer's RS-232 port (see Figure 2-11 for connector pin assignments) to the device. Adjust the rear panel DCE-DTE switch to select DTE or DCE as appropriate (Section 3.1).

Configuration: Section 3.2.1 and Section 3.4.2 (for Hessen protocol)

Important

IMPACT ON READINGS OR DATA

Cables that appear to be compatible because of matching connectors may incorporate internal wiring that makes the link inoperable. Check cables acquired from sources other than Teledyne API for pin assignments (Figure 2-11) before using.

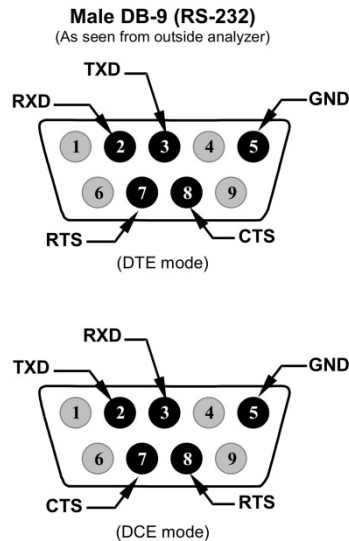


Figure 2-11. Rear Panel Connector Pin-Outs for RS-232 Mode

The signals from these two connectors are routed from the motherboard via a wiring harness to two 10-pin connectors on the CPU card, J11 and J12 (Figure 2-12).

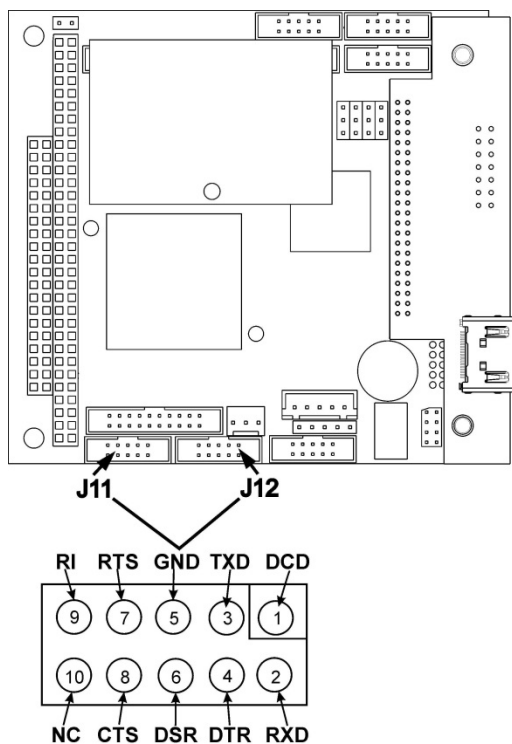


Figure 2-12. Default Pin Assignments for CPU COM Port Connector (RS-232)

Teledyne API offers two mating cables, one of which should be applicable for your use.

- P/N WR000077, a DB-9 female to DB-9 female cable, 6 feet long. Allows connection of the serial ports of most personal computers.
- P/N WR000024, a DB-9 female to DB-25 male cable. Allows connection to the most common styles of modems (e.g. Hayes-compatible) and code activated switches.

Both cables are configured with straight-through wiring and should require no additional adapters.

Note **Cables that appear to be compatible because of matching connectors may incorporate internal wiring that makes the link inoperable. Check cables acquired from sources other than Teledyne API for pin assignments before using.**

To assist in properly connecting the serial ports to either a computer or a modem, there are activity indicators just above the RS-232 port. Once a cable is connected between the analyzer and a computer or modem, both the red and green LEDs should be on.

- If the lights are not lit, locate the small switch on the rear panel to switch it between DTE and DCE modes.
- If both LEDs are still not illuminated, ensure that the cable properly constructed.

Received from the factory, the analyzer is set up to emulate an RS-232 DCE device. (View these parameters in the Setup>Comm>COM1[COM2] menu).

RS-232 (COM1): RS-232 (fixed) DB-9 male connector

- **Baud rate:** 115200 bits per second (baud)
- **Data Bits:** 8 data bits with 1 stop bit
- **Parity:** None

COM2: RS-232 (configurable to RS 485), DB-9 female connector

- **Baud rate:** 19200 bits per second (baud)
- **Data Bits:** 8 data bits with 1 stop bit
- **Parity:** None

RS-232 MULTIDROP (OPTION 62) CONNECTION

When the RS-232 Multidrop option is installed, connection adjustments and configuration through the menu system are required. This section provides instructions for the internal connection adjustments, then for external connections, and ends with instructions for menu-driven configuration.

Note

Because the RS-232 Multidrop option uses both the RS232 and COM2 DB9 connectors on the analyzer's rear panel to connect the chain of instruments, COM2 port is no longer available for separate RS-232 or RS-485 operation.

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Printed Circuit Assemblies (PCAs) are sensitive to electro-static discharges too small to be felt by the human nervous system. Failure to use ESD protection when working with electronic assemblies will void the instrument warranty. For information on preventing ESD damage, refer to the manual, Fundamentals of ESD, PN 04786, which can be downloaded from our website at <http://www.teledyne-api.com> under Help Center > Product Manuals in the Special Manuals section.

In each instrument with the Multidrop option there is a shunt jumpering two pins on the serial Multidrop and LVDS printed circuit assembly (PCA), as shown in Figure 2-13. This shunt must be removed from all instruments except that designated as last in the multidrop chain, which must remain terminated. This requires powering off and opening each instrument and making the following adjustments:

1. With **NO power** to the instrument, remove its top cover and lay the rear panel open for access to the Multidrop/LVDS PCA, which is seated on the CPU.
2. On the Multidrop/LVDS PCA's JP2 connector, remove the shunt that jumpers Pins 21 ↔ 22 as indicated in. (Do this for all but the last instrument in the chain where the shunt should remain at Pins 21 ↔ 22).

3. Check that the following cable connections are made in *all* instruments (again refer to Figure 2-13):
 - J3 on the Multidrop/LVDS PCA to the CPU's COM1 connector
(Be aware that the CPU's COM2 connector is not used in Multidrop)
 - J4 on the Multidrop/LVDS PCA to J12 on the motherboard
 - J1 on the Multidrop/LVDS PCS to the front panel LCD

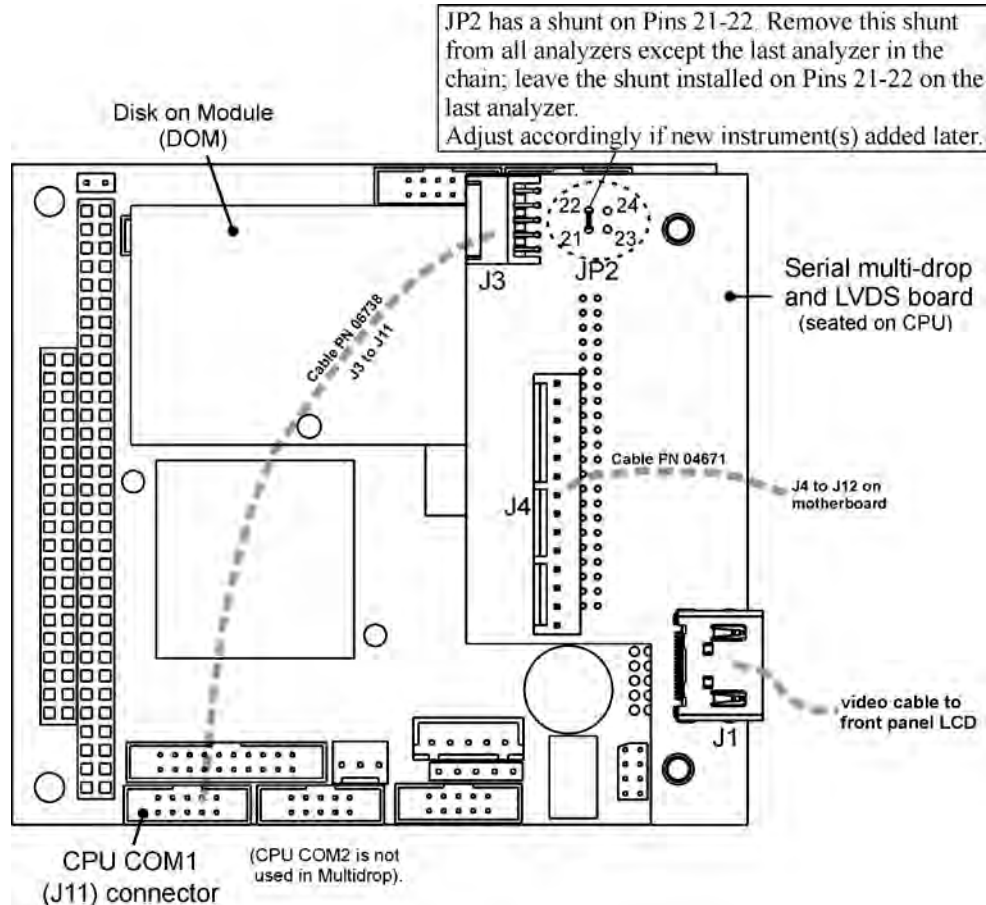


Figure 2-13. Jumper and Cables for Multidrop Mode

Note

If you are adding an instrument to the end of a previously configured chain, remove the shunt between Pins 21 on the Multidrop/LVDS PCA in the instrument that was previously the last instrument in the chain.

4. Close the instrument.
5. Referring to Figure 2-14 use straight-through DB9 male → DB9 female cables to interconnect the host RS232 port to the first analyzer's RS232 port; then from the first analyzer's COM2 port to the second analyzer's RS232 port; from the second analyzer's COM2 port to the third analyzer's RS232 port, etc., connecting in this fashion up to eight analyzers, subject to the distance limitations of the RS-232 standard.

6. On the rear panel of each analyzer, adjust the DCE DTE switch so that the green and the red LEDs (RX and TX) of the COM1 connector (labeled RS232) are both lit. (Ensure you are using the correct RS-232 cables internally wired specifically for RS-232 communication; see Figure 2-12).

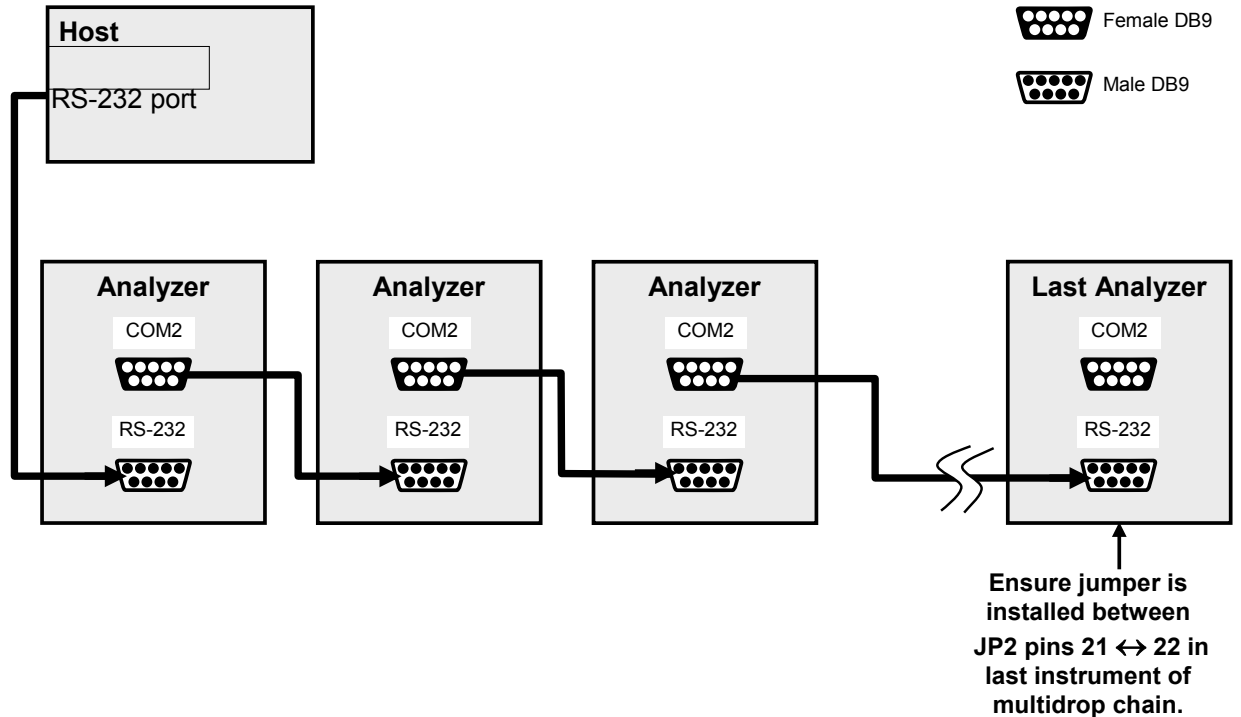


Figure 2-14. RS-232 Multidrop PCA Option Host/Analyzer Interconnect Diagram

7. BEFORE communicating from the host, power on the instruments and check that the user-selectable Instrument ID is unique for each: in the Setup>Vars menu, check Instrument ID in the list of variables. To change, select the variable and press the Edit button; once changed, press the Enter button.
8. Next, in the Setup>Comm>COM1 menu (do not use the COM2 menu for multidrop), use the Edit button to set COM1 Quiet Mode and COM1 Multidrop to ENABLED; then press the Accept button.
9. Also check the COM1 Baud Rate to ensure it reads the same for all instruments (edit if needed and press the Accept button).

Note The (communication) Host instrument can address only one instrument at a time, each by its unique ID (see step 7 above).

Note Teledyne API recommends setting up the first link, between the Host and the first analyzer, and testing it before setting up the rest of the chain.

2.3.2. PNEUMATIC CONNECTIONS

This section provides pneumatic connection and setup instructions for basic and optional configurations. Pneumatic flow diagrams are shown in Section 2.3.3. Calibration instructions are provided in Section 4.

Before making the pneumatic connections, carefully note the following cautionary and special messages:



CAUTION – General Safety Hazard

Do not vent calibration gas or sample gas into enclosed areas.



CAUTION – General Safety Hazard

In units with a permeation tube option installed, vacuum pump must be connected and powered on to maintain constant gas flow though the analyzer at all times. Insufficient gas flow allows gas to build up to levels that will contaminate the instrument or present a safety hazard to personnel.

Remove the permeation tube when taking the analyzer out of operation and store in sealed container (use the original shipping packaging).

(See Figure 2-4 for location (“Sample Gas Conditioner Option”) and Section 5.4.5 for instructions on how to remove the permeation tube when the unit is not in operation).

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Vent Pressurized Gas:

When any gas (span, zero air, sample) is received from a pressurized manifold, always provide a vent to equalize the pressure with the ambient atmosphere before it enters the instrument to ensure that the gases input do not exceed the instrument’s maximum inlet pressure, as well as to prevent back diffusion and pressure effects

Remove Dust Plugs:

Remove dust plugs from rear panel exhaust and supply line fittings before powering on the instrument.

Keep dust plugs for reuse in future storage or shipping to prevent debris from entering the pneumatics.

Important

IMPACT ON READINGS OR DATA

Sample and calibration gases should only come into contact with PTFE tubing.

Run a leak check once the appropriate pneumatic connections have been made; check all pneumatic fittings for leaks per Section 5.4.12.1 (or Section 5.4.12.2 for detailed check if any leaking is suspected).

2.3.2.1. CRITICAL TUBING, PRESSURE, VENTING AND EXHAUST REQUIREMENTS

The requirements presented in this section apply to all pneumatic connection instructions. All other connection instructions are provided with their respective instrument configurations in Sections 2.3.2.2 through 2.3.2.5.

Tubing:

- PTFE material
- Outer diameter (OD) minimum ¼" .
- Min/max length 2 meters to 10 meters.

Pressure:

- All Sample gas pressure must be at ambient atmospheric pressure, no greater than 1.0 psig.

Venting (to prevent back diffusion and pressure effects):

- Run tubing outside the enclosure or at least away from immediate area surrounding the instrument.

Exhaust Outlet:

- Run tubing outside the enclosure.

2.3.2.2. BASIC CONNECTIONS FROM CALIBRATOR

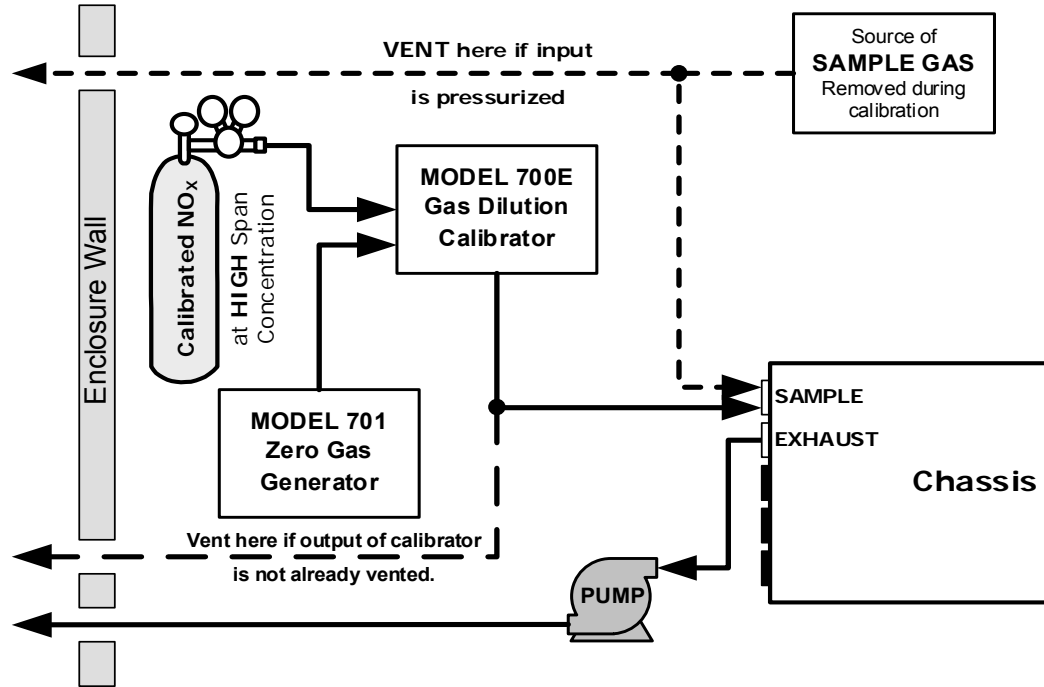


Figure 2-15. Gas Line Connections from Calibrator – Basic Configuration

For the analyzer’s basic configuration, in addition to tubing, pressure, venting, and exhaust requirements set out in Section 2.3.2.1, attach the following pneumatic lines:

SAMPLE GAS SOURCE

Connect a sample gas line to the SAMPLE inlet.

CALIBRATION GAS SOURCES

CAL GAS & ZERO AIR SOURCES: The source of calibration gas is attached to the SAMPLE inlet.

VENTING

Vent the output of the calibrator if calibrator not already vented.

2.3.2.3. CONNECTIONS W/AMBIENT ZERO/AMBIENT SPAN (Z/S) VALVES (OPT 50A)

This valve package is available for both the T200P and the T200UP; it includes:

- two solenoid valves located inside the analyzer that allow the user to switch either zero, span or sample gas to the instrument's sensor
- two additional gas inlet ports (ZERO AIR and SPAN1)

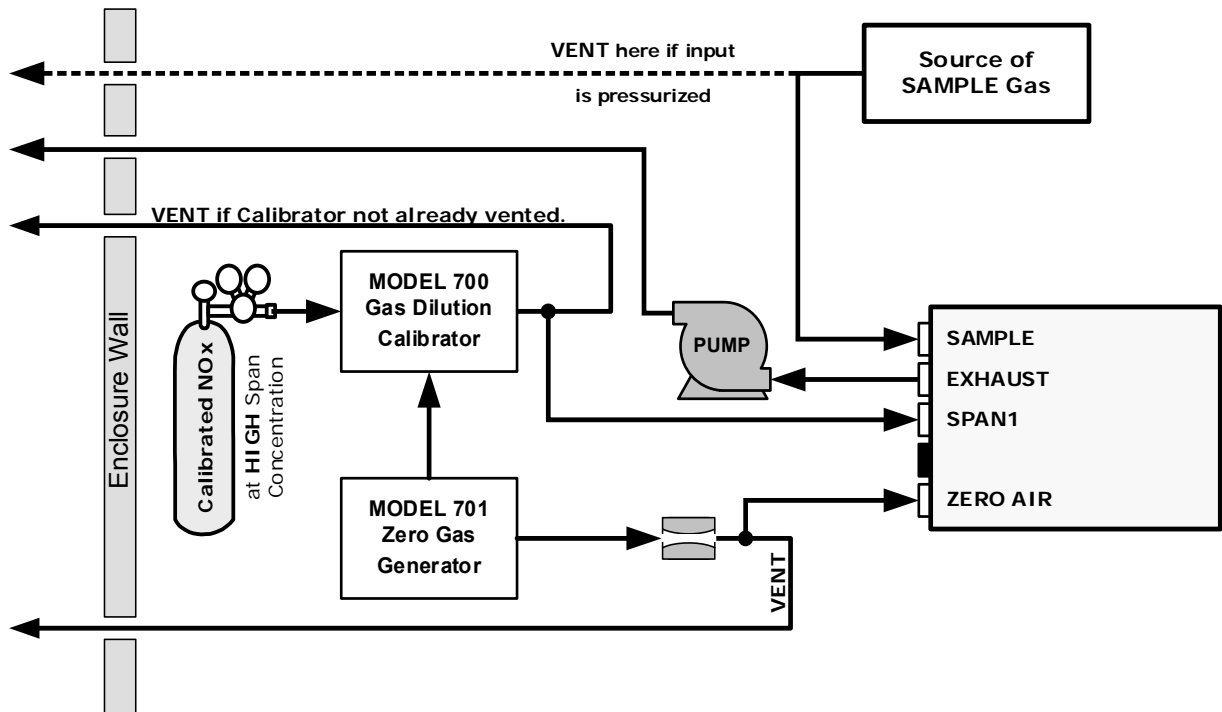


Figure 2-16. Gas Line Connections with Z/S Valves Option (OPT 50A)

In addition to tubing, pressure, venting, and exhaust requirements set out in Section 2.3.2.1, attach the following pneumatic lines:

SAMPLE GAS SOURCE

Attach a sample inlet line to the SAMPLE inlet fitting.

- In applications where the sample gas is received from a pressurized manifold, vent the sample gas line.

CALIBRATION GAS SOURCES

SPAN GAS Attach a gas line from the source of calibration gas (e.g. a Teledyne API's T700 Dynamic Dilution Calibrator) to the SPAN1 inlet.

ZERO AIR Zero air is supplied by the zero air generator such as a Teledyne API's M701. Attach a gas line from the source of zero air to the ZERO AIR inlet.

VENTING

Vent both the span gas and zero air supply lines.

2.3.2.4. CONNECTIONS W/AMBIENT ZERO/PRESSURIZED SPAN VALVES (OPT 50B)

This option is available for the T200P only. This calibration valve package is appropriate for applications where span gas is being supplied from a pressurized source such as bottled NIST SRM gases. This option includes:

- a critical flow orifice and vent to maintain the span gas supply at 1 ATM
- a shutoff valve to preserve the span gas source when it is not in use
- two solenoid valves for the user to switch either zero, span or sample gas to the instrument's sensor
- three additional gas inlet ports (ZERO AIR, SPAN and VENT)

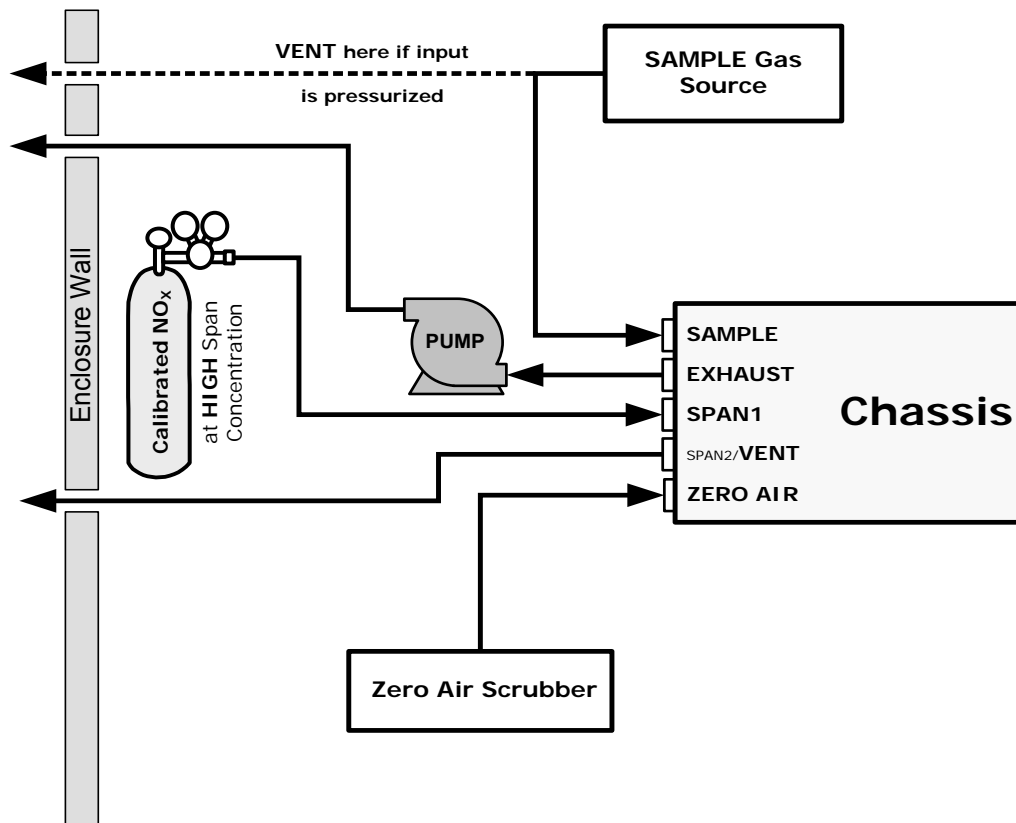


Figure 2-17. Gas Line Connection w/Ambient Zero/Pressurized Span Valves Option (OPT 50B)

In addition to tubing, pressure, venting, and exhaust requirements set out in Section 2.3.2.1, attach the following pneumatic lines:

SAMPLE GAS SOURCE

Attach a sample inlet line to the SAMPLE inlet fitting.

- In applications where the sample gas is received from a pressurized manifold, vent the sample gas line.

CALIBRATION GAS SOURCES

SPAN GAS Attach a gas line from the pressurized source of calibration gas (e.g. a bottle of NISTSRM gas) to the SPAN1 inlet. Use PTFE tubing, minimum O.D ¼”.

ZERO AIR (the dual-stage zero Air Scrubber makes zero air)

VENTING

Vent the SPAN2/VENT outlet.

2.3.2.5. ZERO SCRUBBER AND INTERNAL SPAN SOURCE (IZS) (OPT 50G)

This option is available for the T200P only. The internal NO₂ span gas generator and calibration valve option is intended for applications where there is a need for frequent automated calibration checks without access to an external source of span gas. (See the end of this subsection for important information about “Internal Span Gas Generation”).

Note

Check your regulations regarding the use of IZS with calibration.

This valve package includes:

- a 2-stage external scrubber for producing zero air
 - 50% Purafil Chemisorbant[®] (for conversion of NO → NO₂)
 - 50% charcoal (for removal of the NO₂)
- a heated enclosure for a NO₂ permeation tube
 - This option package DOES NOT contain an actual permeation tube. (Contact Sales for assistance in specifying the correct permeation tube for each application).
- a special desorber that removes all HNO₃ from the calibration gas stream
- one additional gas inlet port (ZERO AIR)
- one additional gas outlet port (FROM DRYER)
- two internal valves for switching between the sample gas inlet and the output of the zero/span subsystem

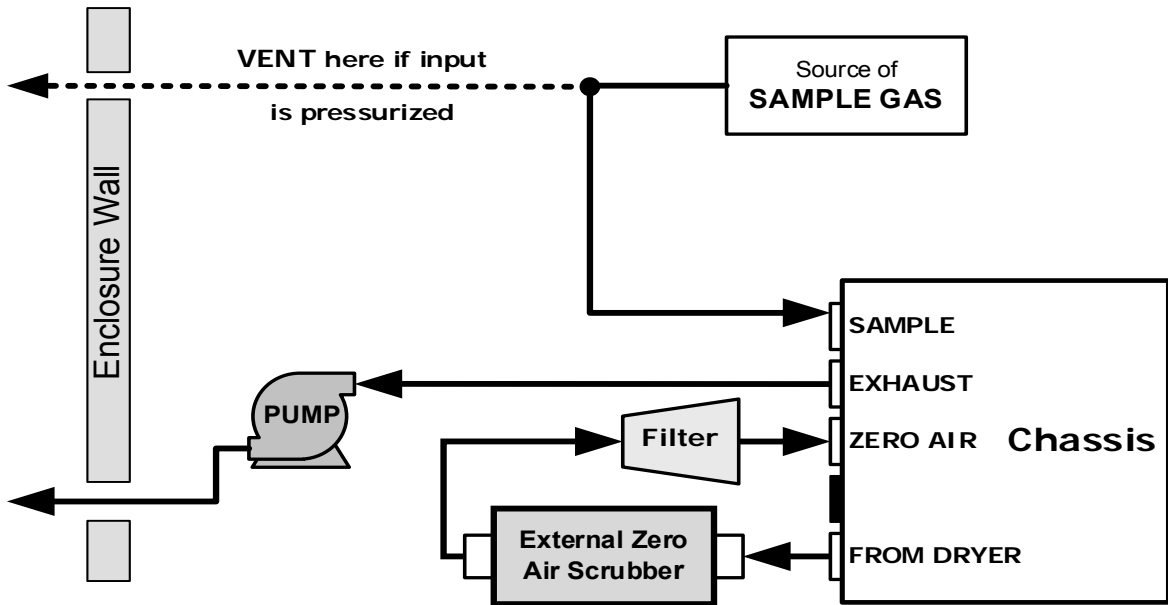


Figure 2-18. Gas Line Connection w/Zero Scrubber and Internal Span Source (IZS) Option (OPT 50G)

The internal span gas generator utilizes an NO₂ permeation tube as a span gas source (see the section on “Internal Span Gas Generation” that follows). The accuracy of these devices is only about ±5%. Whereas this may be sufficient for quick, daily calibration checks (Figure 2-18), we recommend using certified NO gases for precise calibration (Figure 2-19).

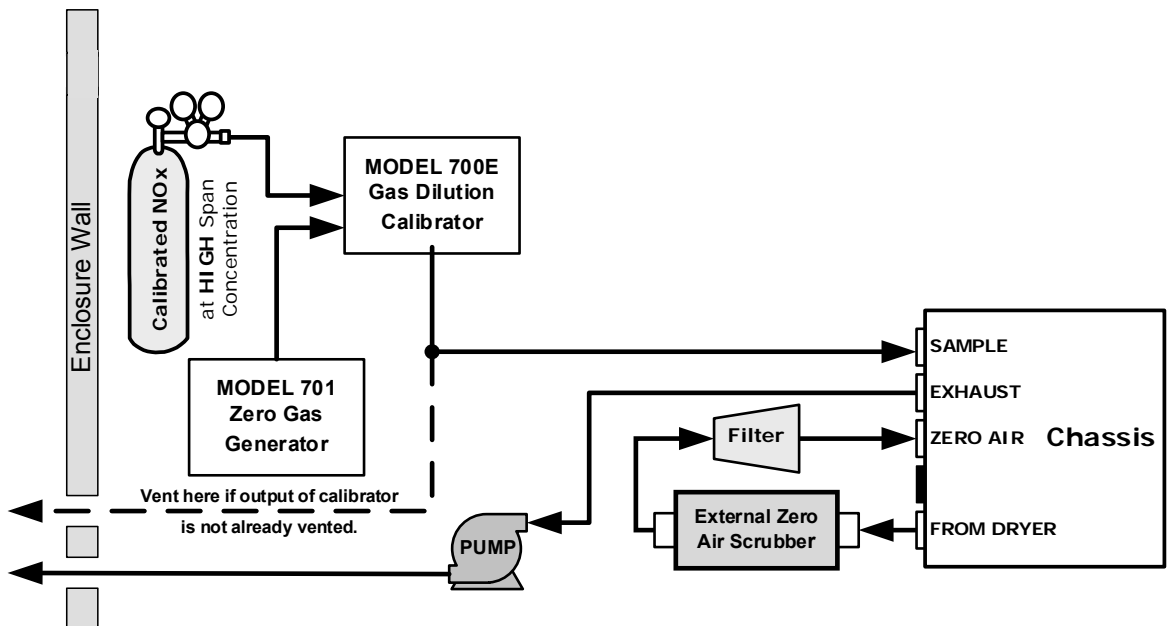


Figure 2-19. Pneumatic Connections for Precision Calibration when IZS Generator Present

In addition to tubing, pressure, venting, and exhaust requirements set out in Section 2.3.2.1, attach the following pneumatic lines:

SAMPLE GAS SOURCE

Connect a sample gas line to the SAMPLE inlet, and:

- In applications where the sample gas is received from a pressurized manifold and the analyzer is not equipped with one of the T200's pressurized span options, a vent must be placed on the sample gas line.

CALIBRATION GAS SOURCES

- Internal:
 - Uses the IZS generator.
- External (for precision calibration):
 - CAL GAS & ZERO AIR SOURCES: The source of calibration gas is attached to the SAMPLE inlet.

VENTING

Vent the Sample line if input is pressurized.

INTERNAL SPAN GAS GENERATION

The primary component of the internal span option is a permeation tube containing liquid NO₂. As zero air is passed over a permeable membrane on the end of the tube, molecules of NO₂ slowly pass through the membrane mixing with the zero air.

The resulting concentration of the NO₂ span gas is determined by three factors:

- size of the membrane (the larger the area of the membrane, the more permeation occurs)
- temperature of the NO₂ (increasing the temperature of the permeation tube increases the pressure inside the tube, thereby increasing the rate of permeation)
- flow rate of the zero air (if the previous two variables are constant, the permeation rate of the NO₂ into the zero air stream will be constant; therefore, a lower flow rate of zero air produces higher concentrations of NO₂)

The permeation tube enclosure is heated to a constant 50° C (10° above the maximum operating temperature of the instrument) in order to keep the permeation rate constant. A thermistor measures the actual temperature and reports it to the CPU for control feedback.

The flow rate of zero air across the permeation tube is maintained at 50 ± 10 cc/min by a critical flow orifice located in the analyzer's exhaust manifold.

2.3.2.6. GAS CONDITIONER OPTIONS

AMMONIA REMOVAL SAMPLE CONDITIONER OPTION (OPT 86A)

The sample conditioner (option in the T200P, standard in the T200UP as shown in Figure 2-4) is comprised of a permeation gas exchange tube to remove H₂O from the sample gas stream to a dewpoint of about -20° C (~600 ppm H₂O) and effectively remove concentrations of ammonia (NH₃) up to about 1 ppm.

2.3.3. PNEUMATIC FLOW DIAGRAMS

Figure 2-20 and Figure 2-21 show the basic pneumatic flows for the T200P and the T200UP, respectively. The remaining pneumatic flow diagrams shown are for the T200P.

PNEUMATIC FLOW FOR BASIC CONFIGURATION

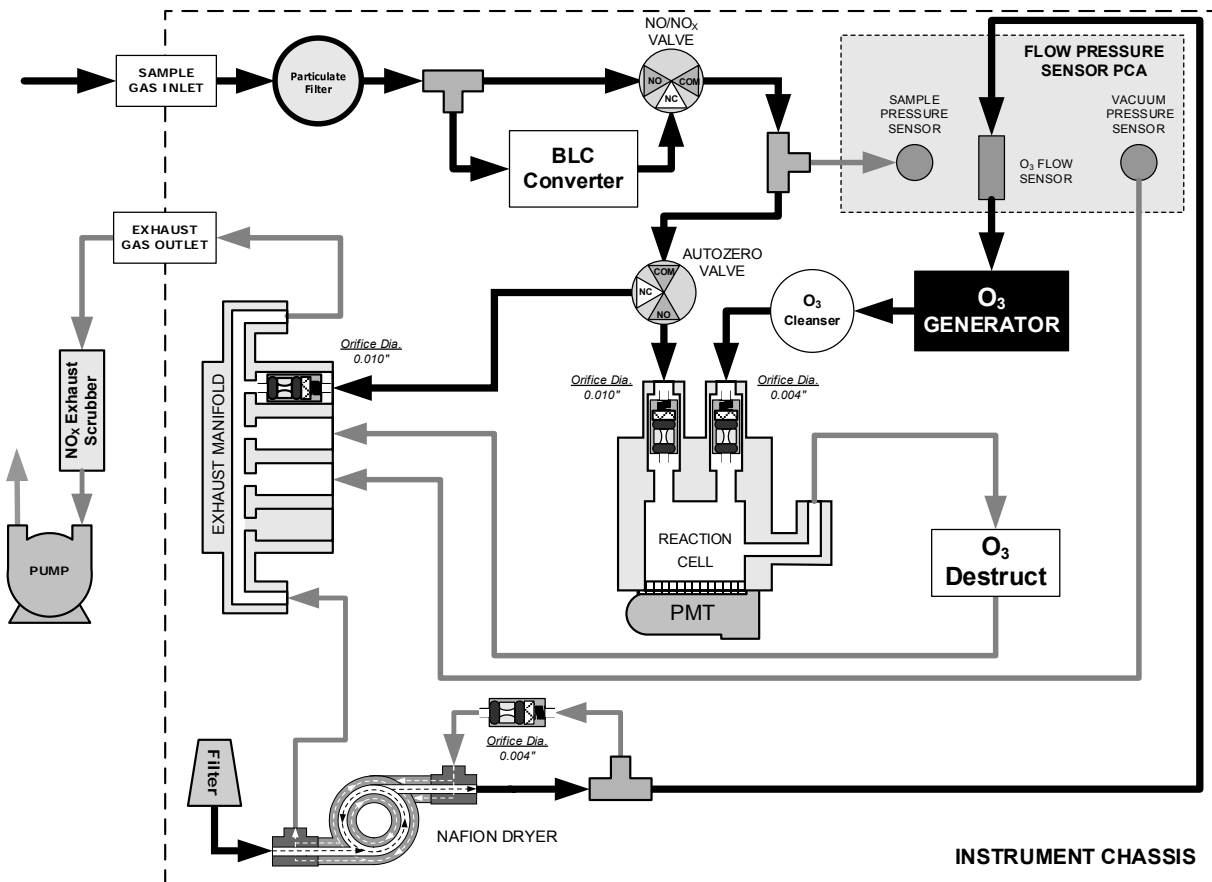


Figure 2-20. T200P Pneumatics, Basic Configuration

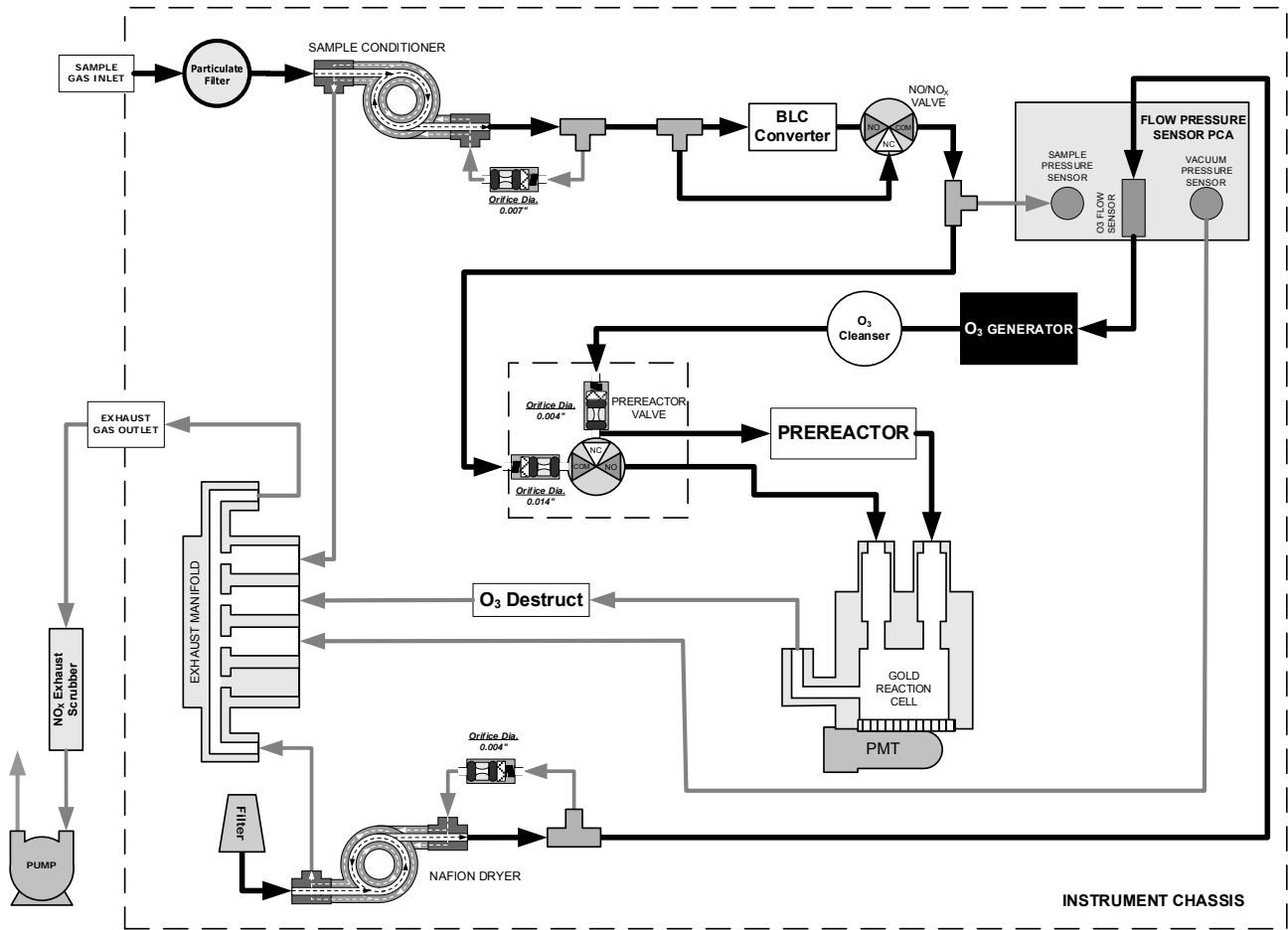


Figure 2-21. T200UP Pneumatics, Basic Configuration

PNEUMATIC FLOW FOR AMBIENT ZERO/AMBIENT SPAN VALVES (OPT 50A)

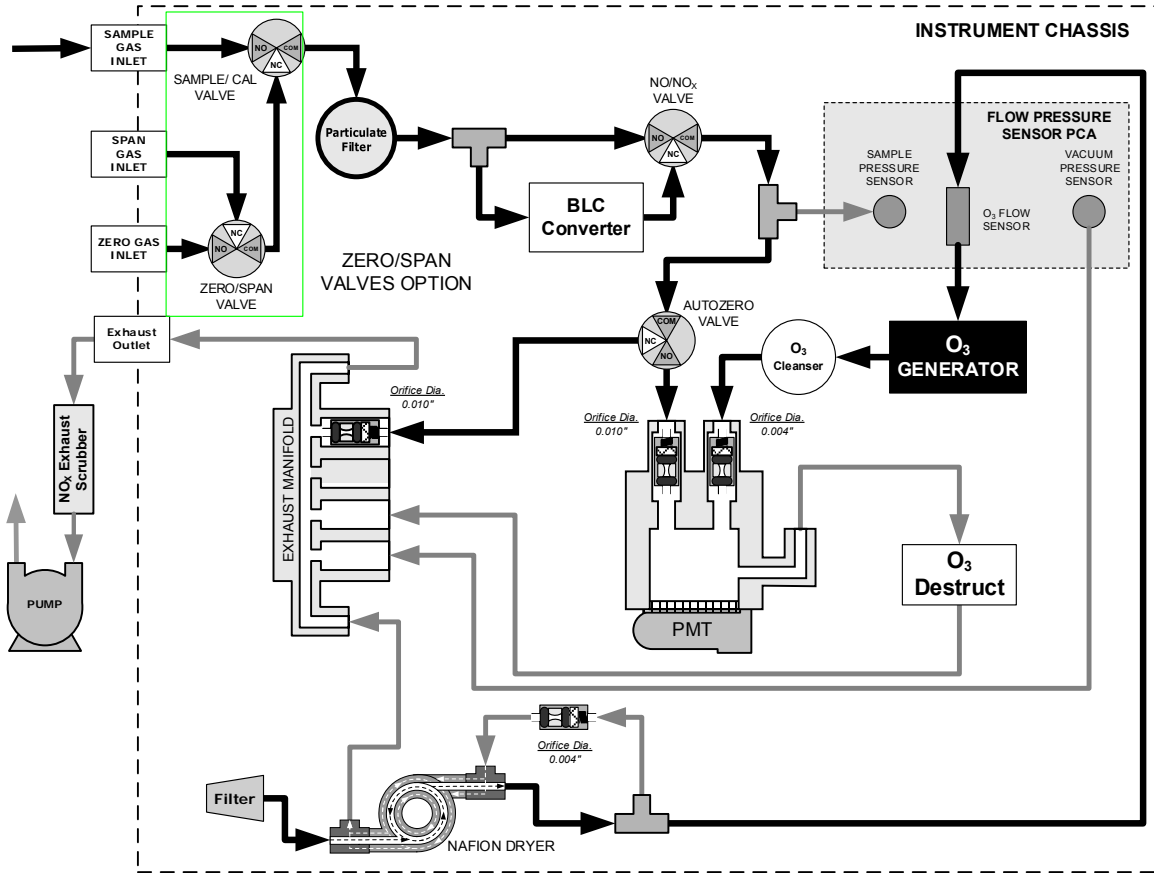


Figure 2-22. T200P Pneumatics with Zero/Span Valves Option (OPT 50A)

Table 2-7. Zero/Span Valves Operating States OPT 50A

MODE	VALVE	CONDITION	VALVE PORT STATUS
SAMPLE	Sample/Cal	Open to SAMPLE inlet	NO → COM
	Zero/Span	Open to ZERO AIR inlet	NO → COM
ZERO CAL	Sample/Cal	Open to ZERO/SPAN Valve	NC → COM
	Zero/Span	Open to ZERO AIR inlet	NO → COM
SPAN CAL	Sample/Cal	Open to ZERO/SPAN Valve	NC → COM
	Zero/Span	Open to SPAN inlet	NC → COM

PNEUMATIC FLOW FOR ZERO SCRUBBER AND IZS (OPT 50G)

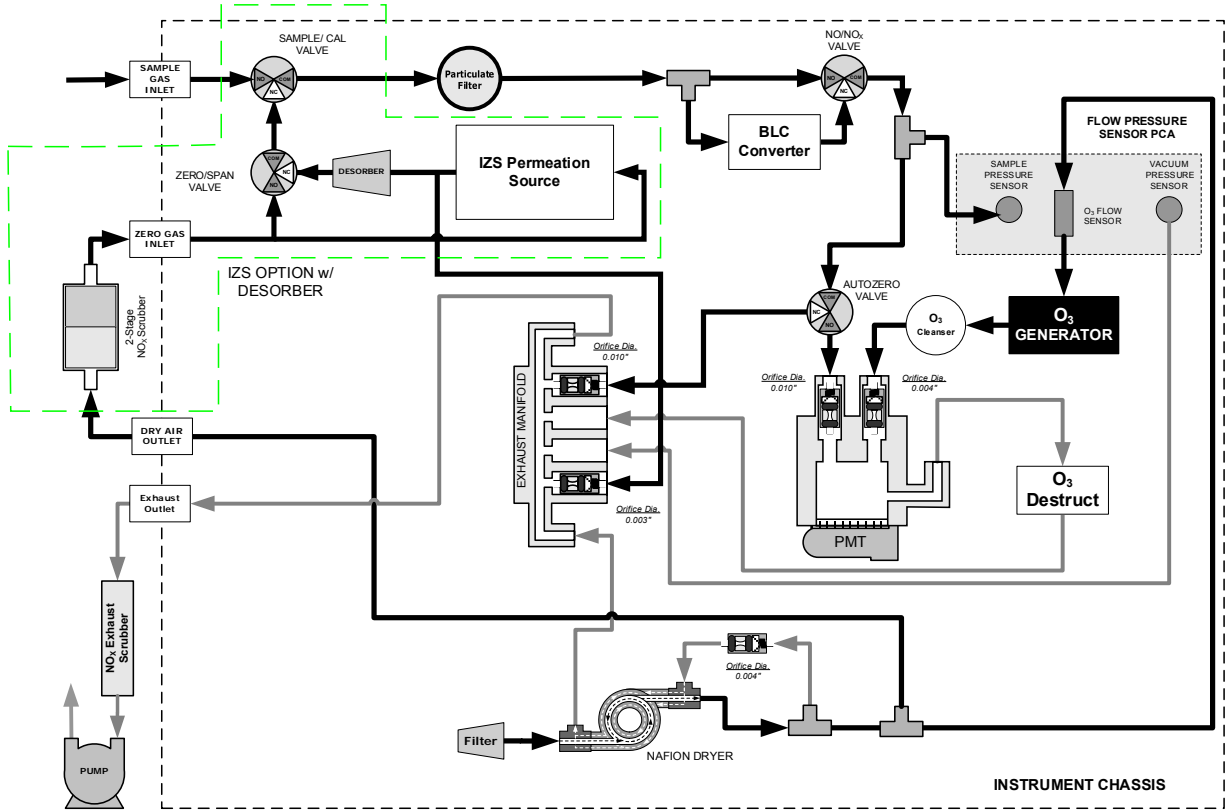


Figure 2-23. T200P Pneumatics with the Internal Span Gas Generator Option (OPT 50G)

Table 2-8. IZS Valve Option Operating States OPT 50G

MODE	VALVE	CONDITION	VALVE PORT STATUS
SAMPLE	Sample/Cal	Open to SAMPLE inlet	NO → COM
	Zero/Span	Open to ZERO AIR inlet	NO → COM
ZERO CAL	Sample/Cal	Open to ZERO/SPAN valve	NC → COM
	Zero/Span	Open to ZERO AIR inlet	NO → COM
SPAN CAL	Sample/Cal	Open to ZERO/SPAN valve	NC → COM
	Zero/Span	Open to SPAN inlet	NC → COM

PNEUMATIC FLOW FOR AMMONIA REMOVAL SAMPLE CONDITIONER (OPT 86A)

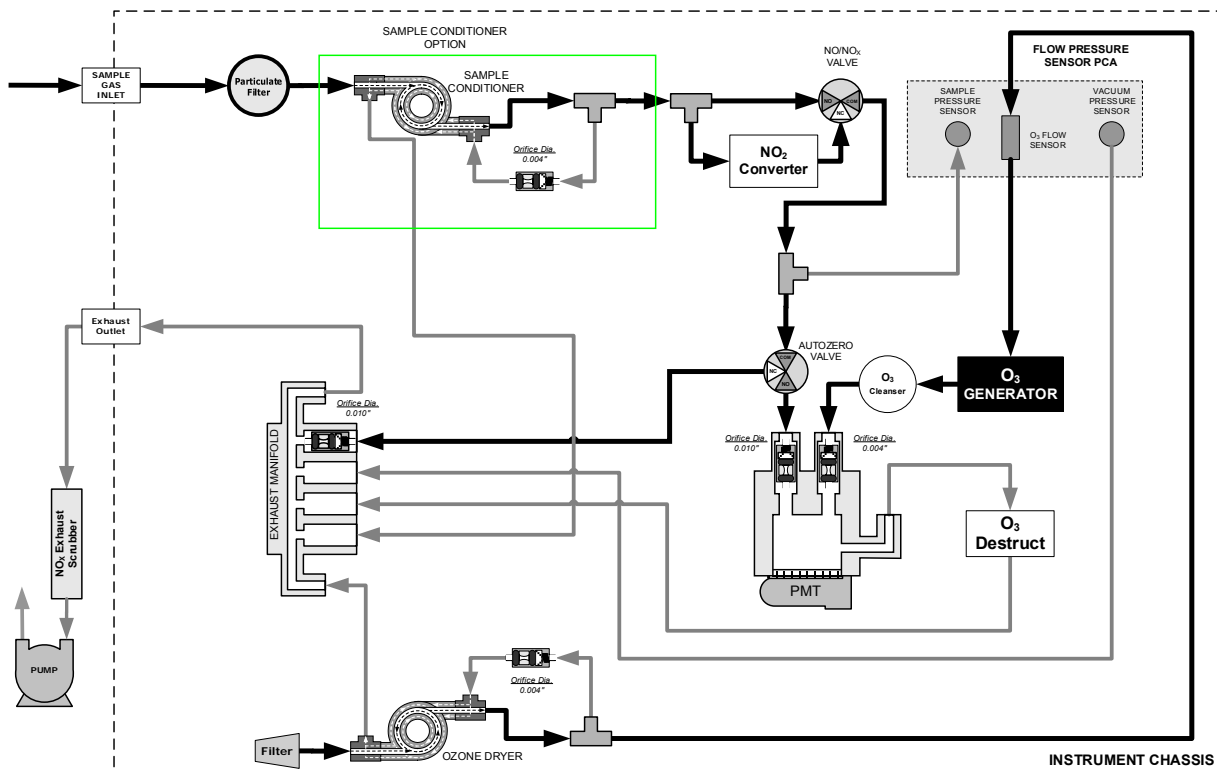


Figure 2-24. T200P Pneumatics for Sample Conditioner Option (OPT 86A)

2.3.4. STARTUP, FUNCTIONAL CHECKS AND CALIBRATION

We recommend reading Section 6 to become familiar with the principles of operation.

When the instrument is first started (Section 2.3.4.1), check its functionality (Section 2.3.4.3) and run an initial calibration (Section 2.3.4.4). Section 2.4 introduces the menu system, and Section 2.5 provides setup/customization instructions.

CAUTION!



If the presence of ozone is detected at any time, power down the instrument and contact Teledyne API Technical Support as soon as possible:

800-324-5190 or email: sda_techsupport@teledyne.com

2.3.4.1. STARTUP

Upon initial startup, a sequence of status screens (Figure 2-25) appear prior to the Home page (Figure 2-26).

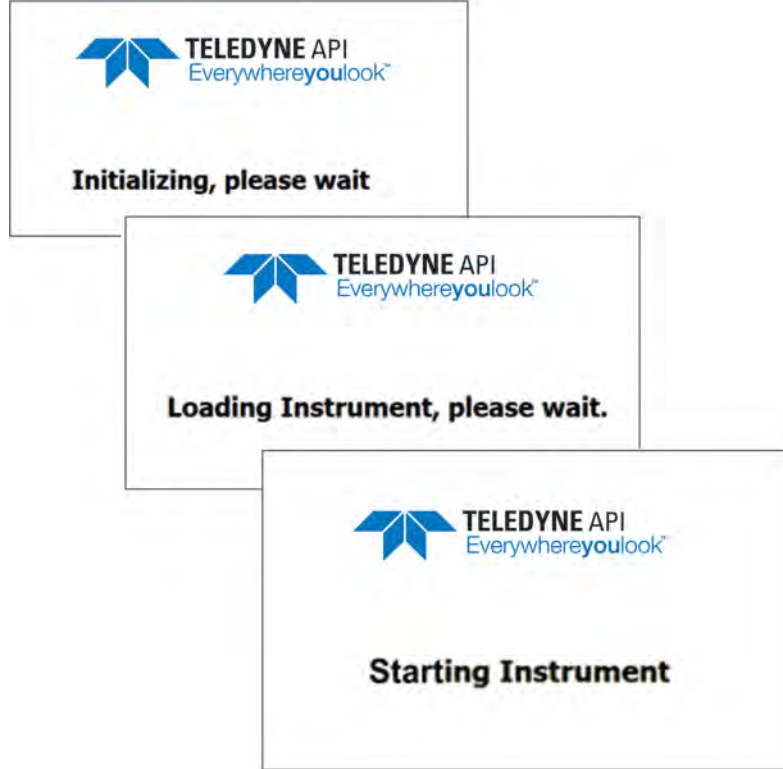


Figure 2-25. Status Screens at Startup

Upon any startup, this instrument should warm up for approximately one hour before reliable measurements can be taken.

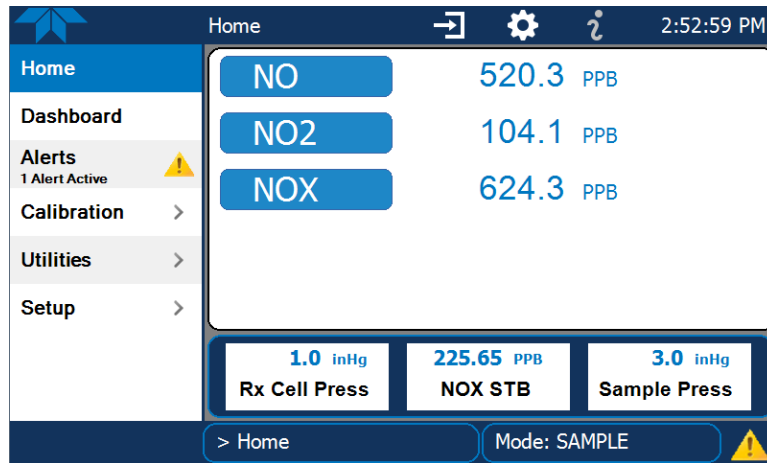


Figure 2-26. Home Page Example

2.3.4.2. ALERTS: WARNINGS AND OTHER MESSAGES

Because internal temperatures and other conditions may be outside the specified limits during the warm-up period, the software will suppress most Alerts for 30 minutes after power up. The Alerts page (Figure 2-27) shows the status of any active warning conditions or user-configured Events. (Section 2.4.3 provides more detailed information about Alerts, and Section 2.5.2 addresses Events).

Alerts can be viewed and cleared via either the Alerts menu or the Alerts shortcut (Caution symbol, bottom right corner of the screen). Although these alerts can be cleared from the Active Alerts page, a history of all alerts remains in the Utilities>Alerts Log page.

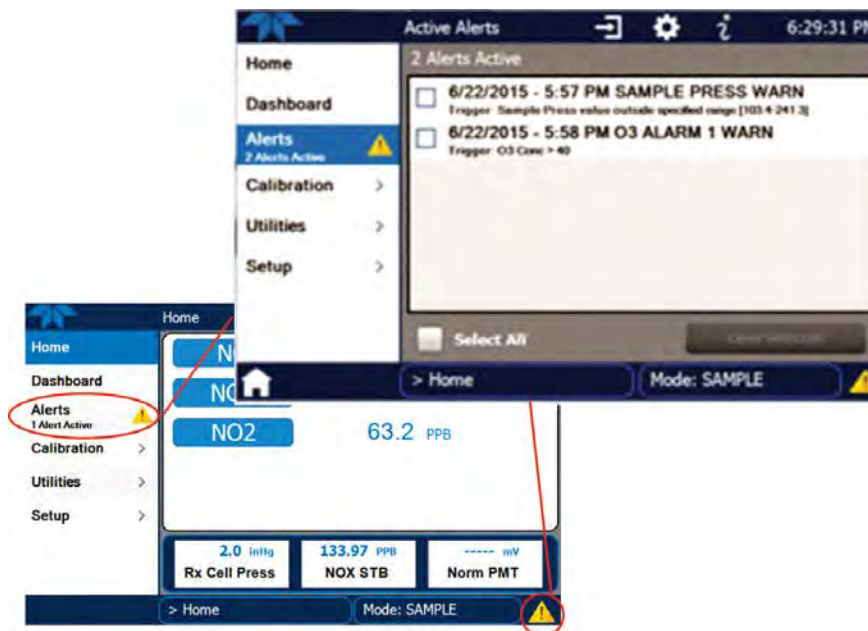


Figure 2-27. Viewing Active Alerts Page

If alerts of warning conditions persist after the warm up period or after being cleared, investigate their cause using the troubleshooting guidelines in Section 5.5.

2.3.4.3. FUNCTIONAL CHECKS

After warm-up, verify that the software properly supports any hardware options that are installed (Setup>Instrument menu), and that the instrument is functioning within allowable operating parameters. Check the Dashboard page against the instrument’s *Final Test and Validation Data sheet*, which lists these values as they appeared before the instrument left the factory. (If any functional parameters are not displayed, configure the Dashboard through the Setup>Dashboard menu to add them; see Section 2.4.2).

These functions are also useful tools for diagnosing problems (information provided in Section 5.5.2).

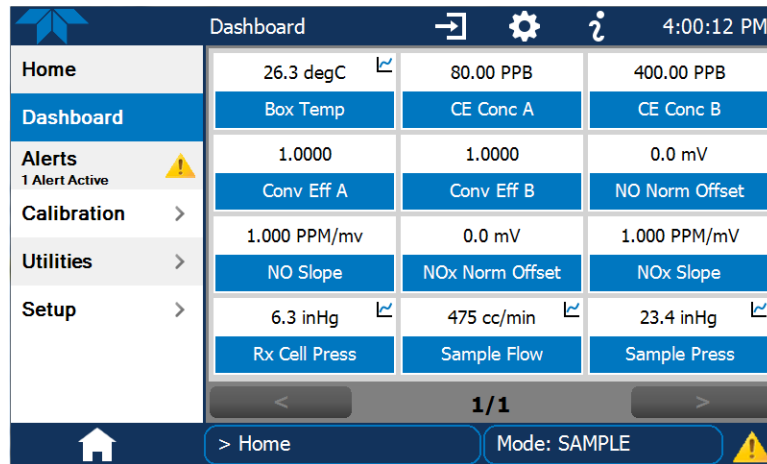


Figure 2-28. Sample Dashboard Page

2.3.4.4. CALIBRATION

Before operation begins, the analyzer requires zero and span calibrations, and possibly HVPS adjustment, followed by calibration of the converter efficiency (CE) points. Also, any time an analyzer is moved or its configuration changed, it must be calibrated. The method for performing a calibration differs slightly depending on whether or not any of the available internal zero air or valve options are installed. Follow the appropriate calibration instructions presented in Section 4.

2.4. MENU OVERVIEW

Table 2-9 describes the main menus and provides cross-references to the respective sections with configuration details.

Table 2-9. Menu Overview

MENU	DESCRIPTION	LOCATION
Home	View and plot concentration readings and other selectable parameter values (Figure 2-30).	Section 2.4.1
Dashboard	View user-selected parameters and their values, some of which can be displayed in a live-plot graph (Figure 2-31).	Section 2.4.2
Alerts	View and clear active Alerts that were triggered by factory-defined Events as well as user-defined Events. (Active and past Alerts are recorded in the Utilities>Alerts Log).	Section 2.4.3
Calibration	Run calibrations on the NO and NO _x channels and calibrate converter efficiency points.	Sections 2.4.4 and 4
Utilities	View logs, download data and firmware updates, copy configurations between instruments, and run diagnostics.	Section 2.4.5
Setup	Configure a variety of features and functions through these submenus for customized operation.	Section 2.5
Datalogging	Track and record concentration and calibration data and selectable diagnostic parameters, the reports for which can be viewed in the Utilities>Datalog View menu (Section 2.4.5) and downloaded to a flash drive via the Utilities>USB Utilities menu (Section 2.4.5). Also, select configured Events (Section 2.5.2) and create customized triggers for data logging functions.	Section 2.5.1
Events	Select parameters and define the conditions by which they are to be flagged and recorded in the Alerts log (Section 2.4.3) when they are triggered. Once configured, Events can be used to trigger Datalogs. (Section 2.5.1).	Section 2.5.2
Dashboard	Monitor instrument functionality (Figure 2-28) via selectable parameters.	Section 2.5.3
Auto Cal (with valve options)	When zero/span valve options installed, configure sequences for automatic calibration functions.	Section 4.3
Vars	Manually adjust several software variables that define specific operational parameters.	Section 2.5.5
Homescreen	Configure the parameters to be displayed in the three meters (Figure 2-29).	Section 2.5.6
Digital Outputs	Map the rear-panel digital outputs to a variety of signals present in the instrument to monitor the status of operating conditions, or custom events. (See Setup>Events.)	Section 2.5.7
Analog Outputs	Send user-selected parameter readings in the form of user-defined voltage or current loop signals as outputs to a strip chart recorder and/or the data logger.	Section 2.5.8
Instrument	View product and system information, including list of options, if any; view network settings; calibrate touchscreen; view/adjust Date and Time settings; and check for firmware updates when connected to a network that is connected to the Internet.	Section 2.5.9
Comm	View and configure network and serial communications.	Section 2.5.10

2.4.1. HOME PAGE

Figure 2-29 presents an orientation to the main display screen; Section 2.5.6 provides configuration instructions. Figure 2-30 shows that pressing the gas name or its concentration value or a meter below displays a live plot of their respective readings.

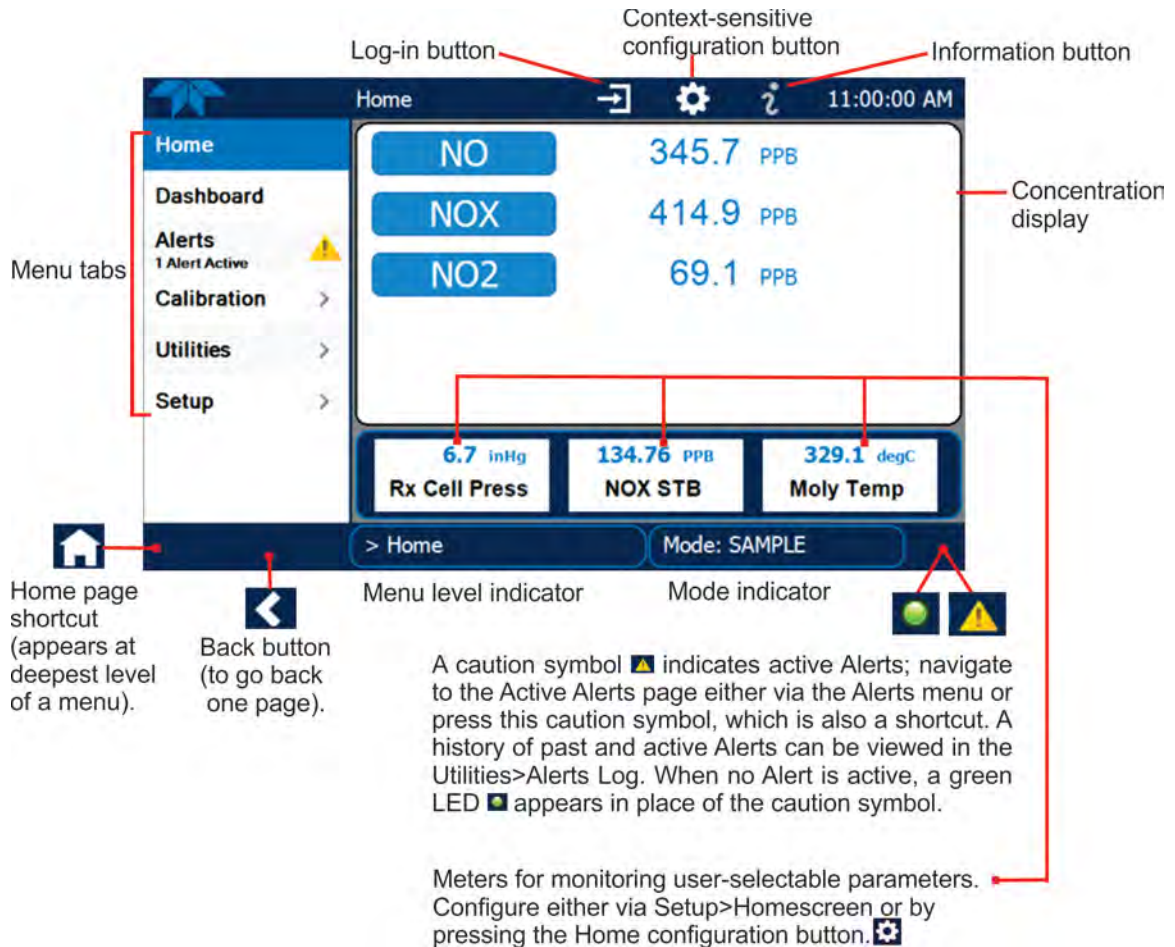


Figure 2-29. User Interface Orientation

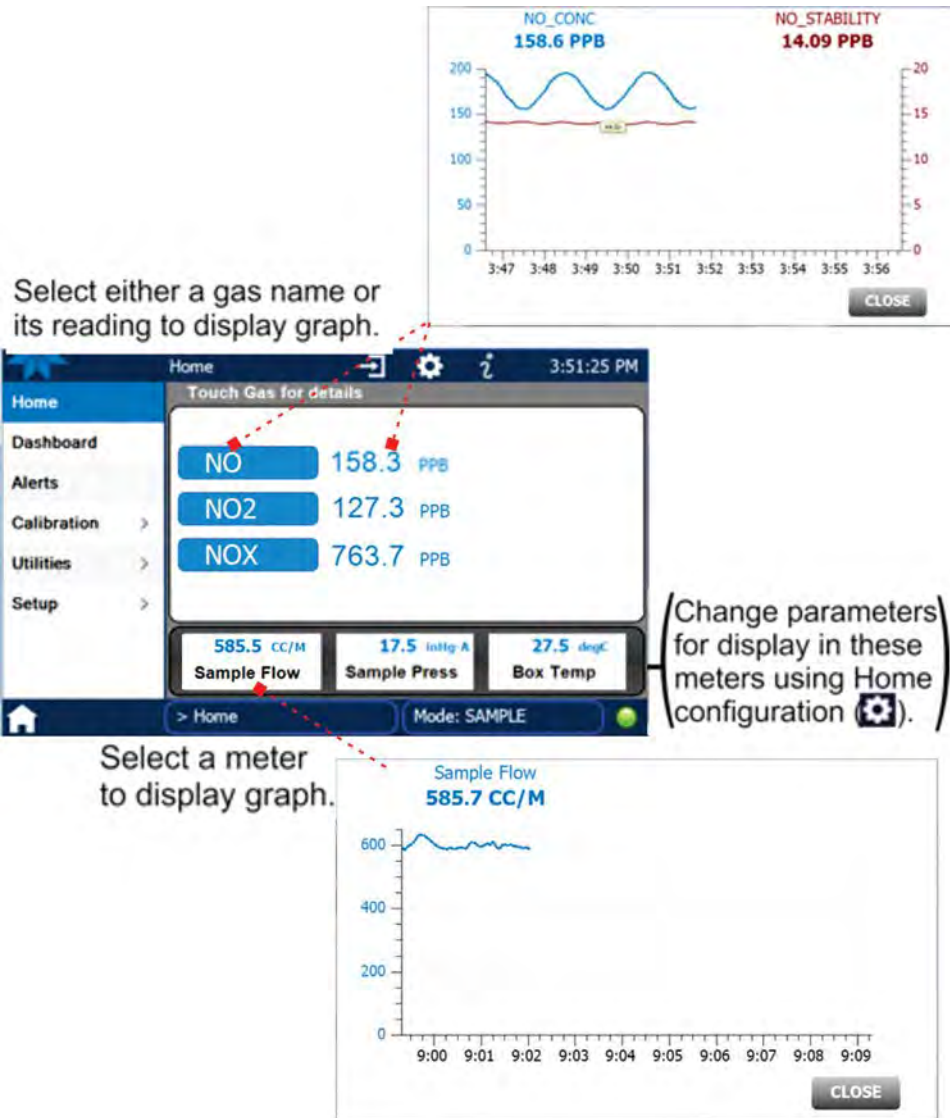
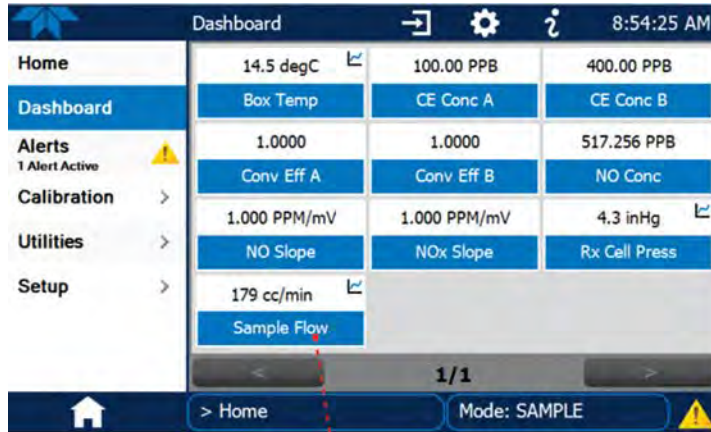


Figure 2-30. Concentration and Stability Graph (top) and Meter Graph (bottom)

2.4.2. DASHBOARD

The Dashboard displays an array of user-selectable parameters and their values (Section 2.5.3 provides configuration instructions). If there is a graphing icon in the upper right corner of a parameter, pressing that parameter displays a live plot of its readings as in Figure 2-31.



Select a graphable parameter in the Dashboard page to view a live plot.

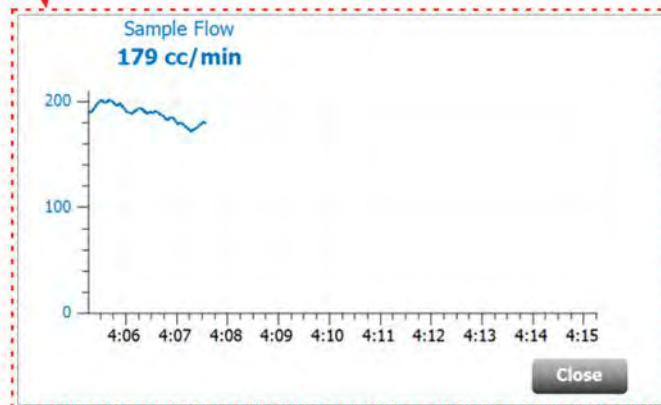


Figure 2-31. Dashboard Page

2.4.3. ALERTS

Alerts are notifications triggered by specific criteria having been met by either factory-defined conditions (standard and not editable) or user-defined Events (Section 2.5.2). The Active Alerts page shows the status of any active warning conditions or Events that have been triggered.

When Alerts are triggered, a caution symbol appears in both the Alerts menu tab and in the bottom right corner of the software interface, which serves as a shortcut to the Alerts page from any other page. View a list of currently active Alerts by pressing either the Alerts menu on the Home screen or by pressing the Alerts shortcut (Figure 2-32).

While Alerts can be cleared from the Active Alerts page, they remain recorded in the Utilities>Alerts Log menu.

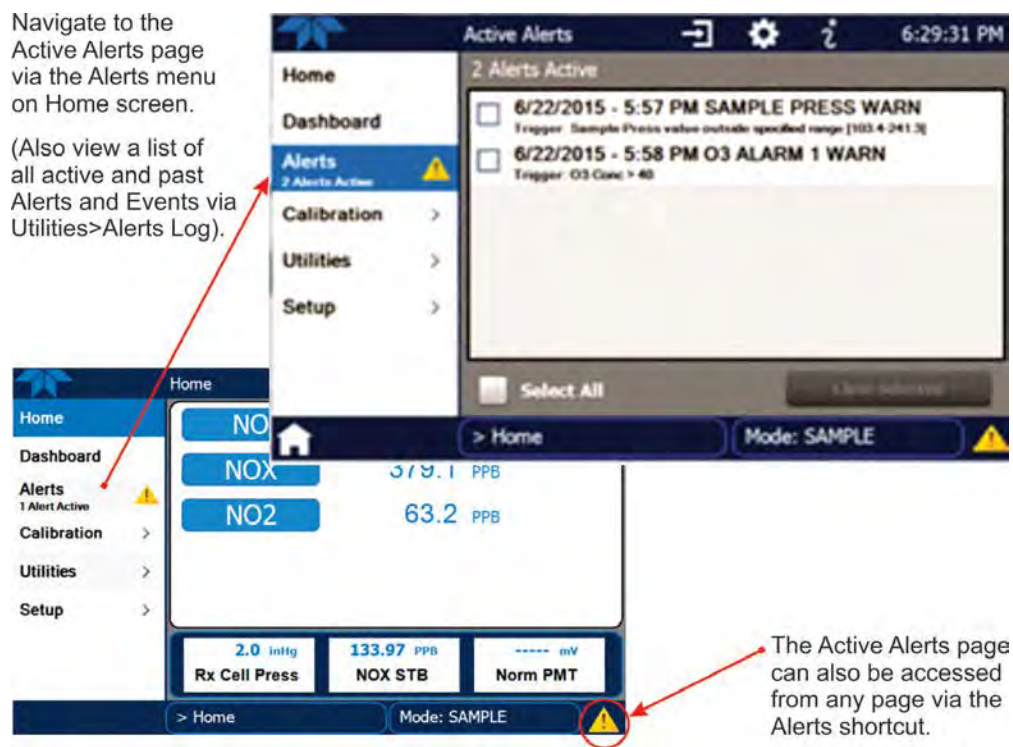


Figure 2-32. Navigating to the Active Alerts Page

Alerts can be configured as either latching (appears in Active Alerts screen when Event is triggered and must be cleared by the user) or non-latching (Active Alerts screen continuously updates based on the Event criteria, clearing on its own). See Section 2.5.2.

To clear Alerts from the Active Alerts page, either check individual boxes to choose specific Alerts, or check the Select All box to choose all Alerts, then press the Clear Selected button.

When all Alerts are cleared, the Alerts menu tab no longer shows the caution symbol, and a green LED replaces the caution symbol in the bottom right corner of the interface (Figure 2-33). However, Alerts can reappear if the conditions causing them are not resolved. For troubleshooting guidance, refer to Section 5.5.

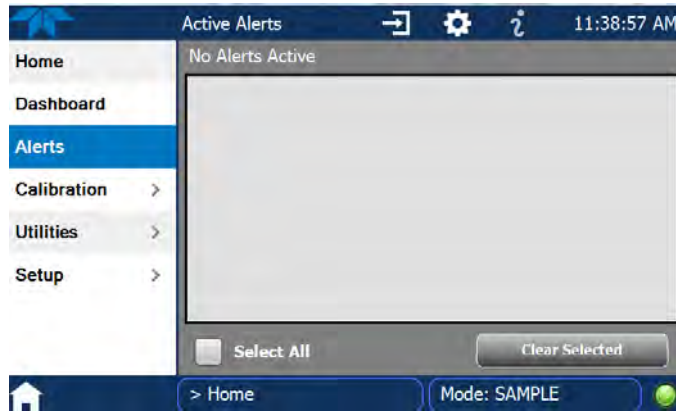


Figure 2-33. Active Alerts Cleared

Alerts and Events remain recorded in the Utilities>Alerts Log (Figure 2-34).

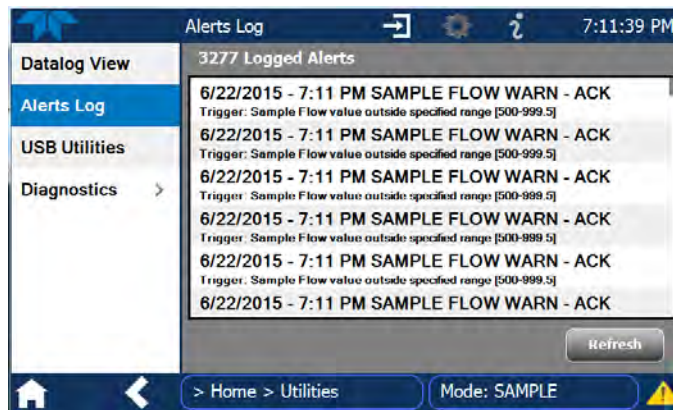


Figure 2-34. Utilities>Alerts Log of Active and Past Alerts and Events

2.4.4. CALIBRATION

The Calibration menu is used for zero/span/multipoint/CE calibrations and for external calibration with valve options installed. Calibration procedures are presented in Section 4.

2.4.5. UTILITIES

The Utilities menu has a variety of functions as described next in Table 2-10.

Table 2-10. Utilities Submenu Descriptions

UTILITIES MENU	DESCRIPTION
Datalog View	Displays the data logs that were configured via the Setup>Data Logging menu. From this list a log can be selected and filters applied to view the desired data. (For details on setting up and running the Data Logger, see Section 2.5.1).
Alerts Log	Displays a history of alerts that are triggered by factory-defined and user-defined Events, such as warnings and alarms (See Section 2.5.2 for Events configuration).
USB Utilities	Serves multiple purposes using a flash drive connected to the instrument's front panel USB port: <ul style="list-style-type: none"> • download data from the instrument's Data Acquisition System (DAS), the Data Logger, to a flash drive (Section 2.5.1.3) • update firmware (Section 5.3) • transfer instrument configuration from/to other instruments (Section 2.6)
Diagnostics	Provides access to various pages that facilitate troubleshooting.
Analog Inputs	Measure voltage signals of several analog input parameters, including those from other instrumentation when the External Analog Inputs Option (Section 2.3.1.2) is installed. These can be logged in the internal data acquisition system (DAS), by configuring the Data Logger in the Setup>Data Logging menu (Section 2.5.1).
Analog Outputs	Show the voltage signals for the functions selected and configured in the Setup>Analog Outputs menu (Section 2.5.8). Rear panel connections were presented in Section 2.3.1.3.
Digital Inputs	Show whether specific available features are turned ON or OFF; for example, whether or not Maintenance Mode input or Language selection can be controlled through the front panel, or whether a zero or span calibration can be activated remotely when an external source is connected to the rear panel Control In connector (Section 2.3.1.6).
Digital Outputs	Show the function of user-specified parameters configured in the Setup>Digital Outputs menu (Section 2.5.7).
Flow Cal	Used to calibrate the sample gas flow reading with actual flow measured by an external device. (Section 5.4.11.34.5).
OE Test	Used to run either an electrical test (ETest) or an optics test (OTest) (Section 5.5.9.11).
O3 Gen Override	Used to override the Ozone Generator state when needed, such as for service (Section 5.5.9.14).

2.4.6. SETUP

The Setup menu is used to configure the instrument's software features, gather information on the instrument's performance, and configure and access data from the Datalogger, the instrument's internal data acquisition system (DAS). Section 2.5 provides details for the menus under Setup.

2.5. SETUP MENU: SOFTWARE CONFIGURATION

This section provides instructions for configuring the instrument. Once setup is complete, the saved configurations can be downloaded to a USB drive through the Utilities>USB Utilities menu and uploaded to other instruments through that menu as well (Section 2.6).

2.5.1. SETUP>DATA LOGGING (DATA ACQUISITION SYSTEM, DAS)

The Datalogger can be configured to capture and store user-defined data, which then can be viewed in the Alerts page, if elected, as well as downloaded from the instrument to a USB flash drive for examination and analysis.

Figure 2-35 shows a new log; Figure 2-36 shows a sample existing log, which can be edited or deleted, and Figure 2-37 provides illustrated instructions for setting up a new log, with Sections 2.5.1.1 and 2.5.1.2 providing additional details.

To transfer captured instrument data to a flash drive see Section 2.5.1.3.

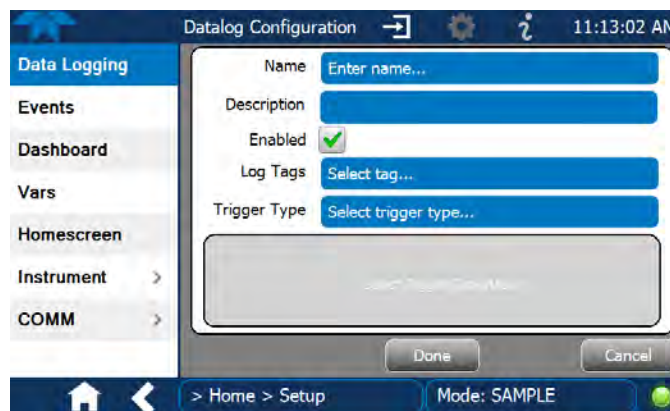


Figure 2-35. Datalog Configuration, New Log Page

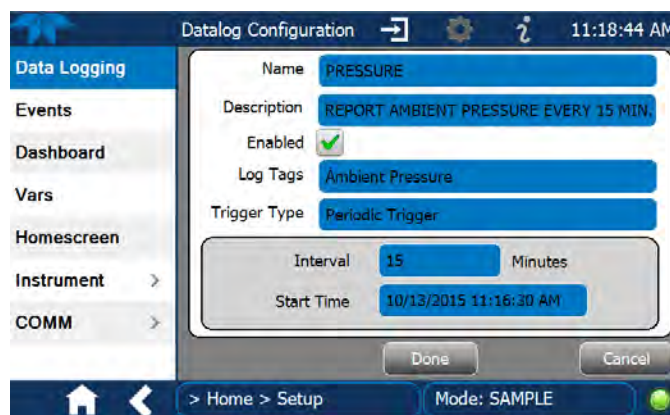
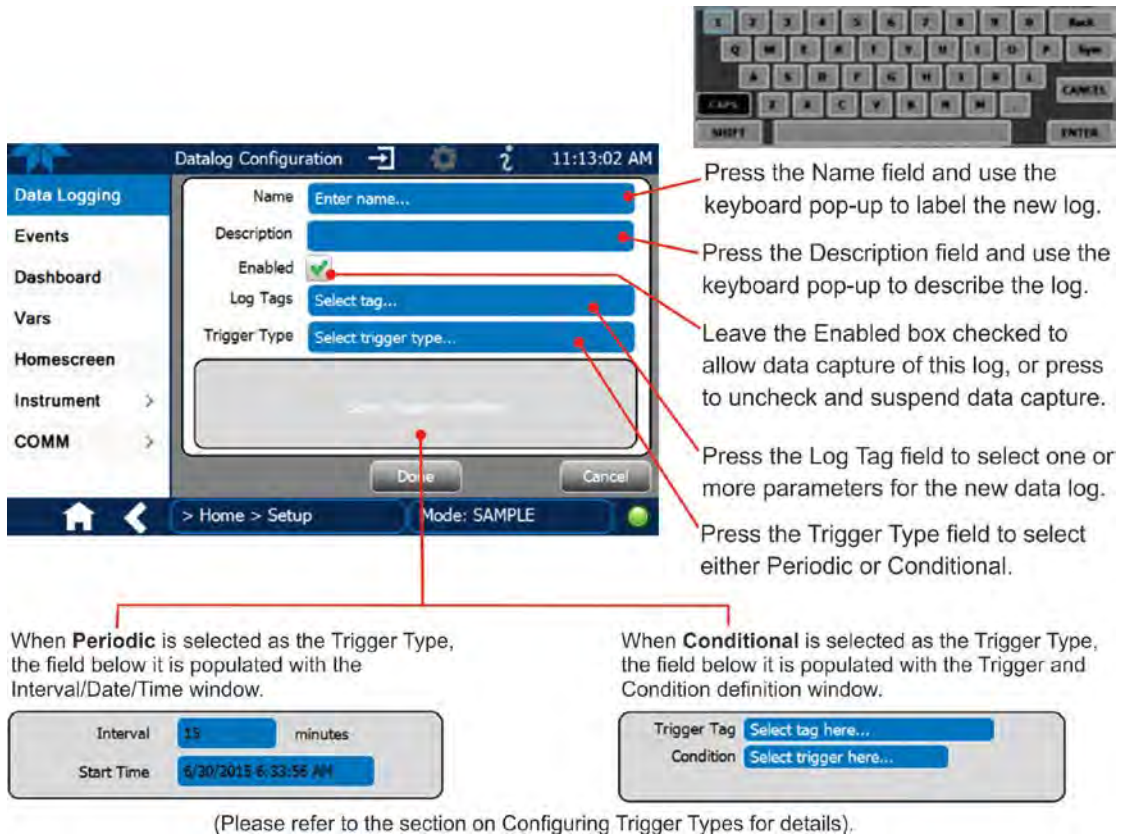


Figure 2-36. Datalog Configuration, Existing Log



Press the Name field and use the keyboard pop-up to label the new log.

Press the Description field and use the keyboard pop-up to describe the log.

Leave the Enabled box checked to allow data capture of this log, or press to uncheck and suspend data capture.

Press the Log Tag field to select one or more parameters for the new data log.

Press the Trigger Type field to select either Periodic or Conditional.

When **Periodic** is selected as the Trigger Type, the field below it is populated with the Interval/Date/Time window.

When **Conditional** is selected as the Trigger Type, the field below it is populated with the Trigger and Condition definition window.

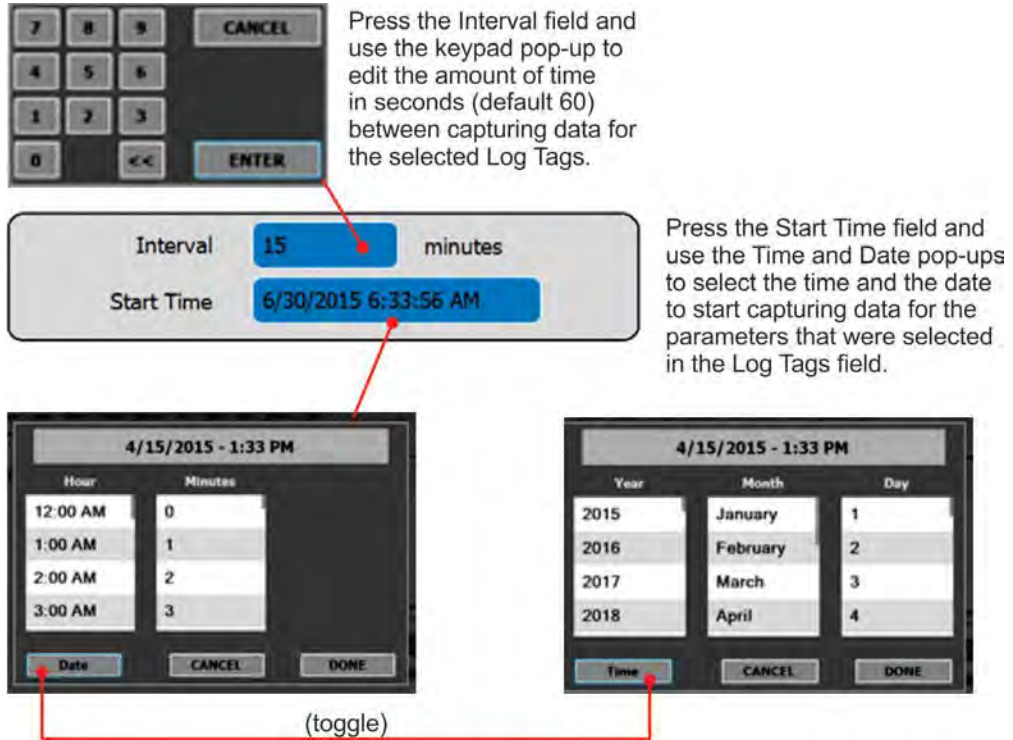
(Please refer to the section on Configuring Trigger Types for details).

Figure 2-37. Creating a New Data Log

The parameters available in the list of Log Tags include the names of Events configured in the Events page (Section 2.5.2).

2.5.1.1. CONFIGURING TRIGGER TYPES: PERIODIC

The Periodic trigger is a timer-based trigger that is used to log data at a specific time interval. Periodic Trigger requires an interval that is set to number of minutes and a start time that is set to date and clock time.



Press the Interval field and use the keypad pop-up to edit the amount of time in seconds (default 60) between capturing data for the selected Log Tags.

Press the Start Time field and use the Time and Date pop-ups to select the time and the date to start capturing data for the parameters that were selected in the Log Tags field.

(toggle)

Figure 2-38. Datalog Periodic Trigger Configuration

2.5.1.2. CONFIGURING TRIGGER TYPES: CONDITIONAL

Conditional Trigger tracks/records data for user-selected parameters that meet specified conditions.

Press the Trigger Tag field and select a parameter to be tracked/logged. A default Condition associated with the selected Tag will populate the Condition field.

Press the Condition field to select a different choice from the condition list.

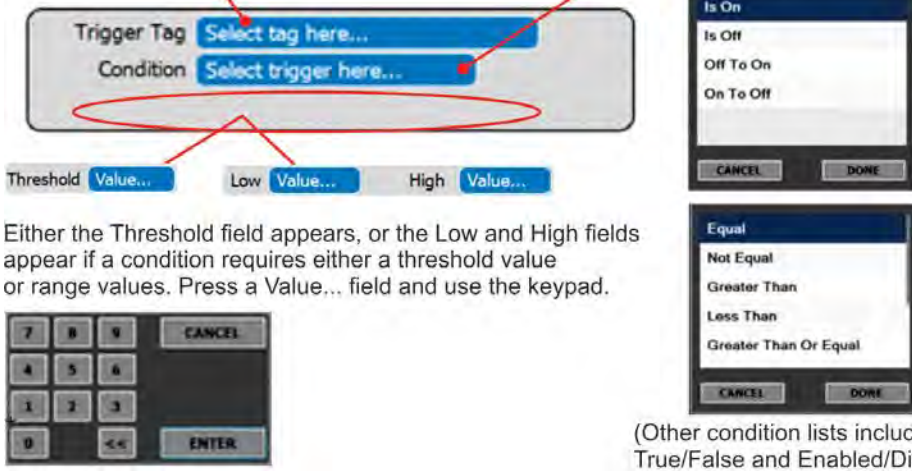


Figure 2-39. Datalog - Conditional Trigger Configuration

2.5.1.3. DOWNLOADING DAS (DATA ACQUISITION SYSTEM) DATA

In the Utilities>USB Utilities menu, instrument data can be downloaded to a flash drive, as presented here.

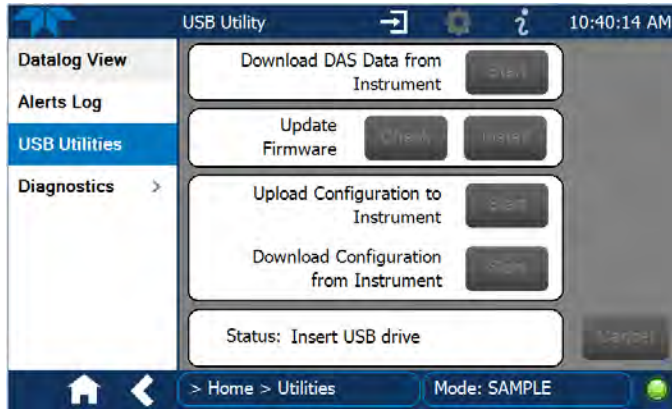


Figure 2-40. USB Utility Page

1. Press USB Utilities menu to open the utility page (Figure 2-40).
2. Insert a flash drive into a front panel USB port and wait for the Status field to indicate that the drive has been detected and available buttons are enabled (Figure 2-41).



Figure 2-41. DAS Data Download

3. To copy the data to the flash drive, press the Start button next to “Download DAS Data from Instrument.” (The Cancel button will be enabled).
4. Wait for the Status field to indicate that the transfer is complete and the Cancel button becomes the Done button.
5. Press the Done button; then remove the flash drive.

(The Update Firmware field is for checking for and installing firmware updates when the instrument is connected to the Internet, and is presented in Section 5.3. The Upload/Download Configuration field is for transferring instrument configuration from/to other instruments, and is presented in Section 2.6).

2.5.2. SETUP>EVENTS

Events are occurrences that relate to any operating function, and will trigger Alerts (notifications), (Section 2.4.3). Events can provide diagnostic information about the instrument, typically referred to as “Warnings”, or they can provide additional instrument functionality, such as concentration alarms. The instrument comes from the factory with a number of pre-defined warning Events, and the Setup>Events Configuration page provides the capability to create additional, user-defined Events. Existing Events are listed in the Events page (Figure 2-42) under the Setup menu.

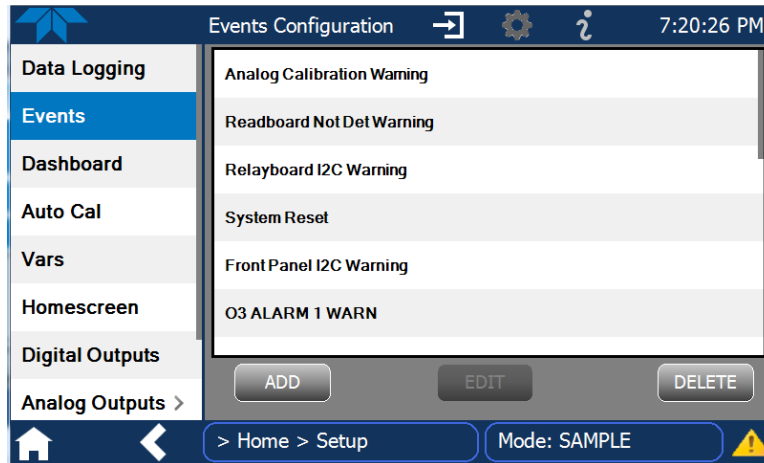


Figure 2-42. Events List

Access the Events Configuration page either from the Active Alerts page (Alerts Menu) by pressing the configuration button, or through the Home>Setup>Events menu (Figure 2-42). Press ADD to create a new Event (refer to Figure 2-43 for details), or select an existing Event to either Edit or Delete it (instructions presented in Figure 2-45).

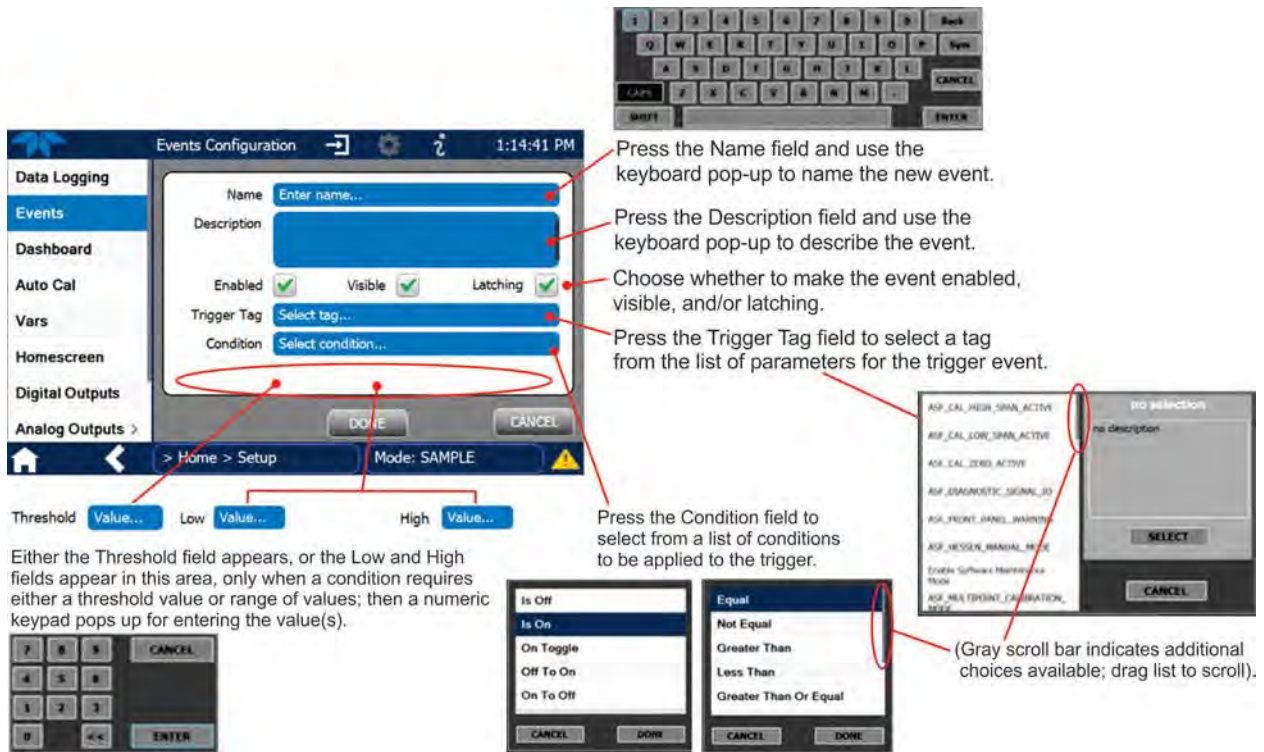


Figure 2-43. Event Configuration

- Enabled allows the choice of whether to track and record the Event (uncheck this box to “turn off” or deactivate the Event without deleting it). An Event must be enabled in order to use the Visible and the Latching options.
- Visible allows the choice of whether or not to display the Event in the Alerts page when it is triggered (it will still be recorded and can be viewed in the Utilities>Alerts Log). To use this option, the Event must be enabled.
- Latching allows the choice of whether or not to keep an Event visible even if the conditions that triggered it were to correct themselves. (Latching requires that the user interact with the Active Alerts screen to manually clear the Alert and internal Event state. Non-latching allows the entry in the Active Alerts screen and the internal Event state to continuously update based on the Event criteria, requiring no user interaction to clear the Alert or Event state).

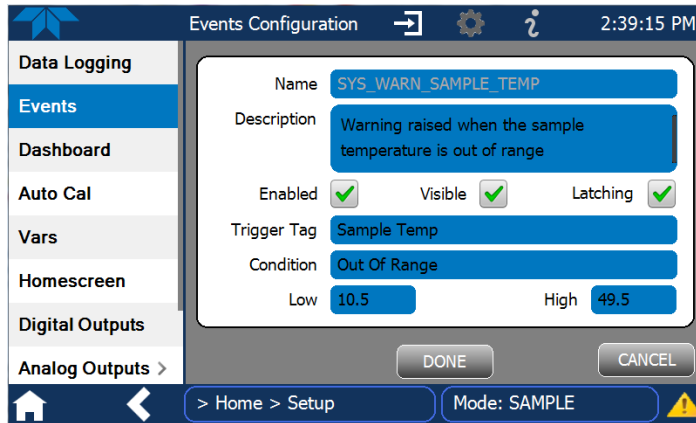


Figure 2-44. Configured Event Sample

2.5.2.1. EDITING OR DELETING EVENTS

Select an Event from the list (Figure 2-42) and press the Edit button to view or edit the details (Figure 2-44), or press the Delete button to delete the Event.

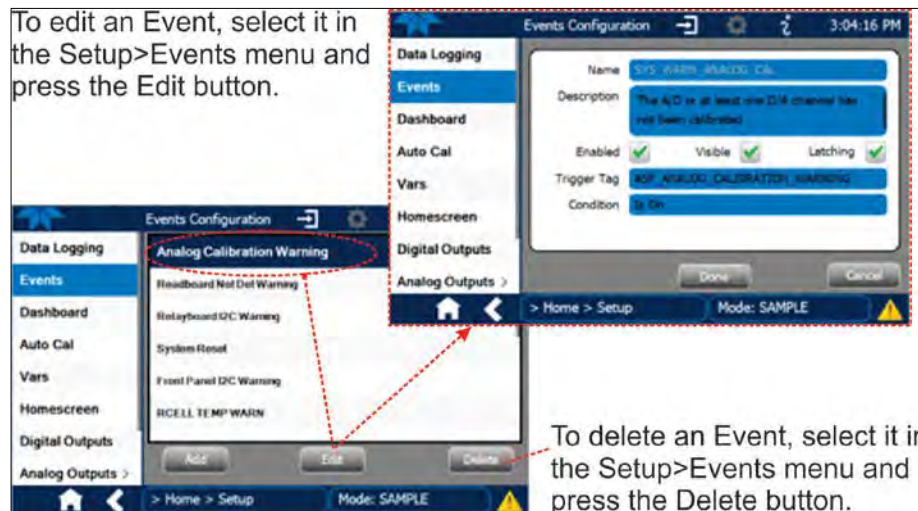


Figure 2-45. Edit or Delete an Event

2.5.2.2. USING EVENTS AS TRIGGERS FOR DATA LOGGING

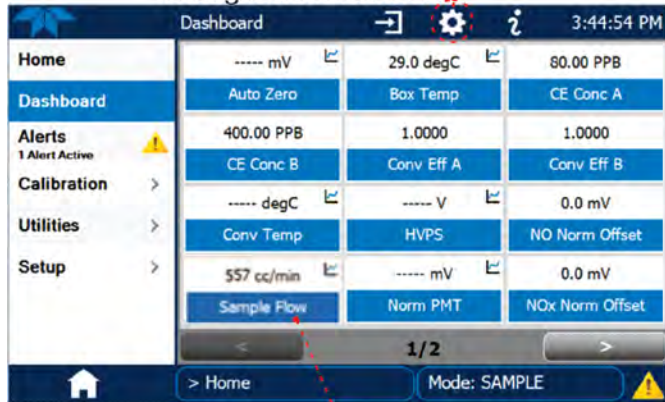
Events can also be used to create customized triggers for data logging functions. The name entered in the Name field of the Events Configuration page will appear in the list of Log Tags of the Datalog Configuration page. The Data Logger is presented in Section 2.5.1.

2.5.3. SETUP>DASHBOARD

To navigate to Dashboard Configuration, either press the configuration shortcut in the Dashboard page, or use the Setup>Dashboard menu.



Configuration Shortcut



Configuration editing:

To add a parameter to the Dashboard, select it in the "Available Tags" list and press the right-pointing arrows button. (Checkmarks in the "Available Tags" list indicate parameters that are currently in the Dashboard).

To remove a parameter from the Dashboard, select it from the "Dashboard" list and press the left-pointing arrows button.

Select a graphable parameter in the Dashboard page to view a live plot.

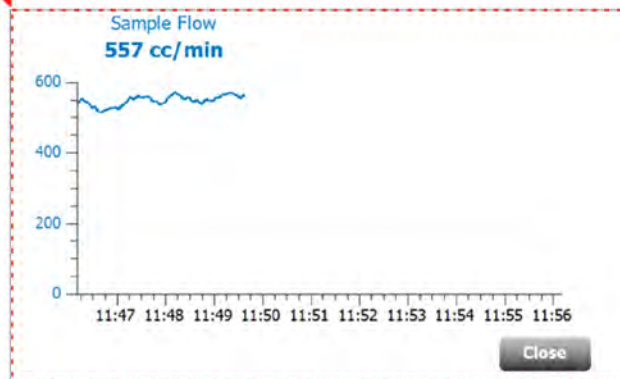


Figure 2-46. Dashboard Display and Configuration

2.5.4. SETUP>AUTO CAL (WITH VALVE OPTION)

Auto Cal is available with installed valve options (see Section 4.3).

2.5.5. SETUP>VARS

Vars are software variables that define operational parameters automatically set by the instrument's firmware, and are user-adjustable through this menu. Access the menu to see the list of variables; select a variable to view its description; touch the Edit button to change its setting(s).

Table 2-11. List of Variables with Descriptions

VARIABLE	DESCRIPTION
<i>(This list includes common Vars; depending on options, other variables may also appear in your Vars menu).</i>	
Conc Precision	Sets the number of significant digits to the right of the decimal point display of concentration and stability values.
Daylight Savings Enable	Enable or disable Daylight Savings Time (also see Setup>Instrument>Date/Time Settings)
Dilution Factor Option	<p>Sets the instrument to compensate for diluted sample gas, such as in continuous emission monitoring (CEM) where the quality of gas in a smoke stack is being tested and the sampling method used to remove the gas from the stack dilutes the gas. Once the degree of dilution is known, this feature allows the user to add an appropriate scaling factor to the analyzer's NO, NO₂ and NO_x concentration calculations so that the undiluted values for measurement range and concentration are shown on the instrument's front panel display and reported via the instrument's various outputs.</p> <ol style="list-style-type: none"> 1. Set the appropriate units of measure (Setup>Vars>User Units). 2. Select the reporting range mode (Setup>Vars>Range Mode) and set the reporting range upper limit (Setup>Analog Output). Ensure that the upper span limit entered for the reporting range is the maximum expected concentration of the undiluted gas. 3. Set the dilution factor as a gain, e.g., a value of 20 means 20 parts diluent and 1 part sample gas (Setup>Vars>Dilution Factor). 4. Calibrate the analyzer; ensure that the calibration span gas is either supplied through the same dilution system as the sample gas or has an appropriately lower actual concentration.
Dyn Zero Enable	Dynamic zero automatically adjusts offset and slope of the NO and NO _x response when performing a zero point calibration during an AutoCal (Section 4.3).
Dynamic Span Enable	Dynamic span automatically adjusts the offsets and slopes of the NO and NO _x response when performing a span point calibration during an AutoCal (Section 4.3).
Enable Software Maintenance Mode	Set instrument to continue sampling, while ignoring calibration, diagnostic, and reset instrument commands. This feature is of particular use for instruments connected to Multidrop (2.3.1.8) or Hessen protocol networks.
Instrument ID	Set unique identifier number for the instrument when it is connected with other instruments in multidrop configuration or on the same Ethernet LAN, or when applying MODBUS or Hessen protocols. (Setup>Vars>Instrument ID)
Max Concentration Range (T200P Only)	Set the highest concentration expected, as this is used by the CPU to adjust Preamp physical ranges. (Section 4.1.5 provides more information).

VARIABLE	DESCRIPTION
Measure Mode	Selects the gas measurement mode in which the instrument is to operate: NO _x only, NO only, or NO _x and NO simultaneously.
Range Mode	Controls range mode, single (SNGL) or dual (DUAL). (When set to DUAL, ensure that Max Concentration Range has been set).
System Hours	Total system runtime hours
TPC Enable	Enables or disables the Temperature and Pressure Compensation (TPC) feature (For information on TPC, see Section 6.10.2).
User Units	Change the concentration units of measure.

2.5.6. SETUP>HOMESCREEN

To select a parameter (“tag”) for display in each of the three meters at the bottom of the Home page, navigate to the Homescreen configuration page through either the Setup>Homescreen menu or from Home page using the configuration icon (Figure 2-47).

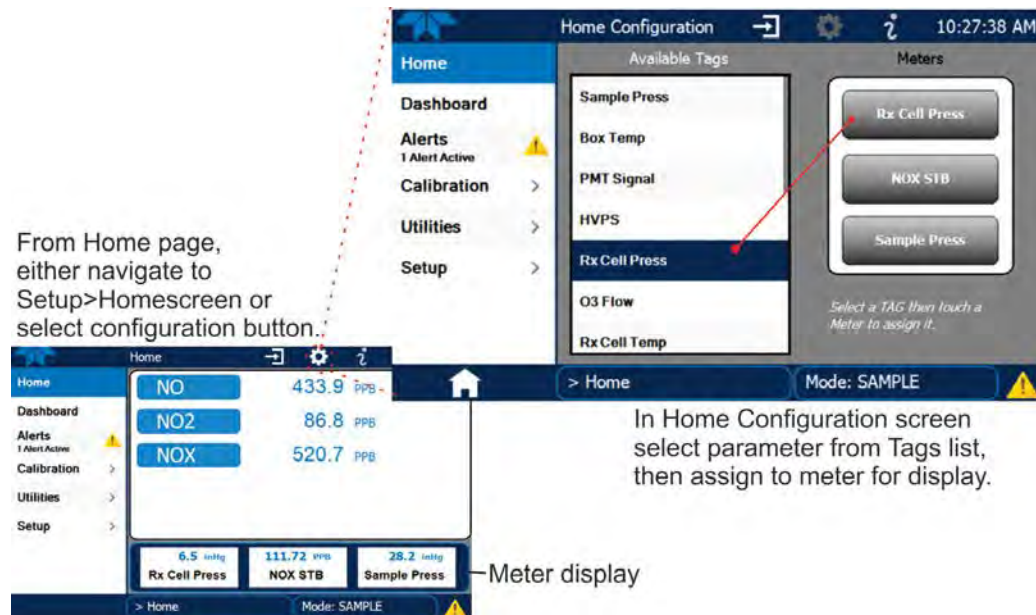


Figure 2-47. Homescreen Configuration

An orientation to the Homescreen was presented in Section 2.4.1, including Figure 2-29 and Figure 2-30.

2.5.7. SETUP>DIGITAL OUTPUTS

Specify the function of each digital output (connected through the rear panel STATUS connector) by mapping the output to a selection of “Signals” present in the instrument. Create custom “Signals” in the Setup>Events menu (Section 2.5.2). (If the Motherboard Relay Option was installed, the four additional relays can also be mapped).

To map Digital Outputs to Signals, select a pin in the Outputs list, then make a selection from the Signals list and press the Map button; if/as needed, change the polarity by pressing the Polarity button. Save any changes by pressing the Apply button, or discard the changes by pressing the Home or the back button (a pop-up provides a warning that the changes will be lost, and will prompt for confirmation to apply changes or not).

Go to the Utilities>Diagnostics>Digital Outputs menu to change the state (ON/OFF) of individual digital outputs.

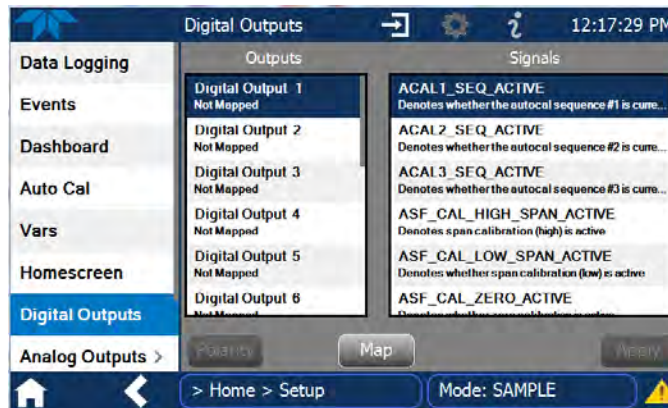


Figure 2-48. Digital Outputs Setup

2.5.8. SETUP>ANALOG OUTPUTS

Map the four user-configurable Analog Outputs to any of a wide variety of “Signals” present in the instrument and customize their respective configurations.

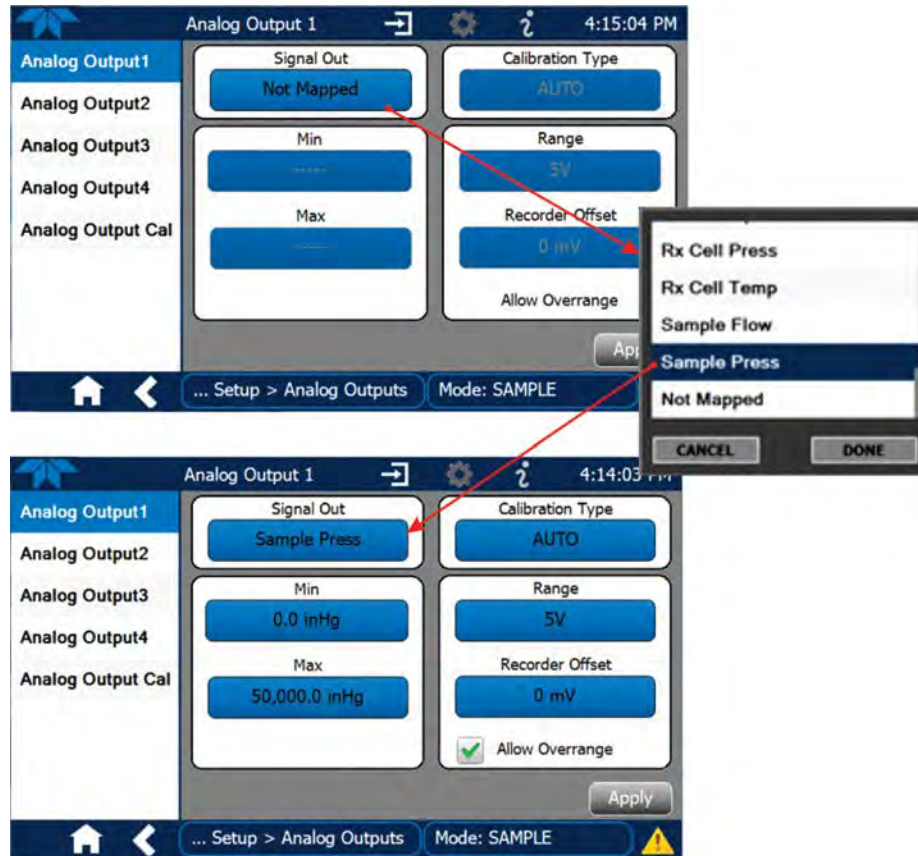


Figure 2-49. Analog Output Configuration Example

Refer to Figure 2-49 for the following:

- Signal Out: select a Signal for the output.
- Min/Max: edit minimum and maximum values associated with the selected Signal.
- Calibration Type:
 - AUTO for group calibration (Figure 2-50) of the analog outputs (cannot be selected when Current is selected for the Range)
 - MANUAL for individual calibration (Figure 2-51) of analog outputs where manual adjustments can be made (the only calibration type allowed when Current is selected for the Range). See Sections 2.5.8.1 and 2.5.8.2 .
- Range: assign a voltage or select Current (refer to Table 2-12).
- Recorder Offset: add a zero offset for recording slightly negative readings from noise around the zero point.
- Allow Overrange: check to allow a $\pm 5\%$ over-range; uncheck to disable over-range if the recording device is sensitive to excess voltage or current.

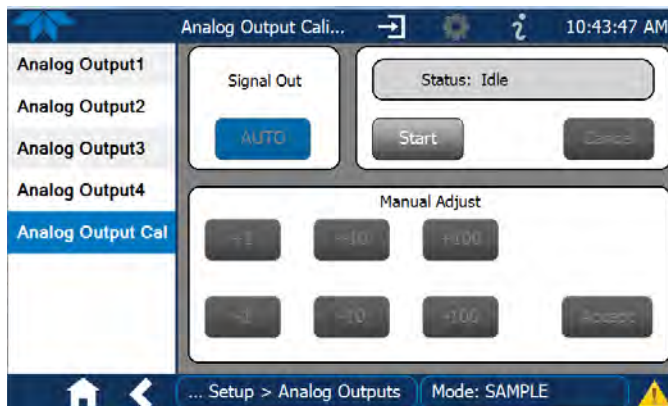


Figure 2-50. Analog Outputs Group Calibration Screen



Figure 2-51. Analog Outputs Manual Calibration Screen (AO2 Example)

Table 2-12. Analog Output Voltage/Current Range

RANGE¹	RANGE SPAN	MINIMUM OUTPUT	MAXIMUM OUTPUT
100mV	0-100 mVDC	-5 mVDC	105 mVDC
1V	0-1 VDC	-0.05 VDC	1.05 VDC
5V	0-5 VDC	-0.25 VDC	5.25 VDC
10V	0-10 VDC	-0.5 VDC	10.5 VDC
Current²	0-20 mA	0 mA	20 mA

¹ Each range is usable from -5% to +5% of the rated span.

² While these are the physical limits of the current loop modules, typical applications use 2-20 mA or 4-20 mA for the lower and upper limits.

For manual calibration adjustments, see Section 2.5.8.1 for voltage and Section 2.5.8.2 for current.

2.5.8.1. MANUAL CALIBRATION OF VOLTAGE RANGE ANALOG OUTPUTS

It is possible to manually calibrate the voltages by using a voltmeter connected across the output terminals (Figure 2-52) and changing the output signal level in the Manual Adjust field of the Analog Outputs Calibration screen (Figure 2-51). Refer to Table 2-13 for voltage tolerances.

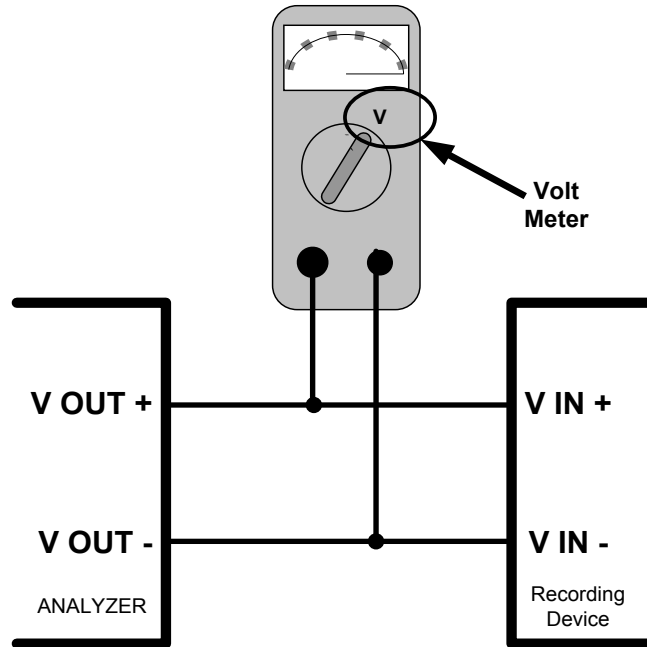


Figure 2-52. Setup for Checking / Calibrating DCV Analog Output Signal Levels

Table 2-13. Voltage Tolerances

FULL SCALE	ZERO TOLERANCE	SPAN VOLTAGE	SPAN TOLERANCE	MINIMUM ADJUSTMENT (1 count)
0.1 VDC	±0.0005V	90 mV	±0.001V	0.02 mV
1 VDC	±0.001V	900 mV	±0.001V	0.24 mV
5 VDC	±0.002V	4500 mV	±0.003V	1.22 mV
10 VDC	±0.004V	4500 mV	±0.006V	2.44 mV

2.5.8.2. MANUAL ADJUSTMENT OF CURRENT RANGE ANALOG OUTPUTS

These instructions assume that the Current Loop Option is installed (Section 2.3.1.4).

This option places circuitry in series with the output of the D-to-A converter on the motherboard that changes the normal DC voltage output to a 0-20 milliamp signal.

Adjusting the signal zero and span levels of the current loop output is done by raising or lowering the voltage output of the D-to-A converter circuitry on the analyzer's motherboard. This raises or lowers the signal level produced by the current loop option circuitry.

The software allows this adjustment to be made in 100, 10 or 1 count increments. Since the exact amount by which the current signal is changed per D-to-A count varies from output-to-output and instrument-to-instrument, you will need to measure the change in the signal levels with a separate, current meter placed in series with the output circuit. See Figure 2-6 for pin assignments and diagram of the analog output connector.



CAUTION!

Do not exceed 60 V peak voltage between current loop outputs and instrument ground.

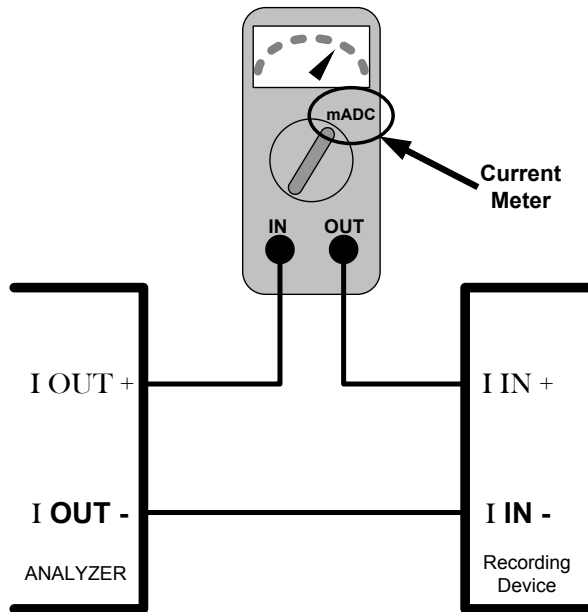


Figure 2-53. Setup for Checking / Calibration Current Output Signal Levels

An alternate method for measuring the output of the Current Loop converter is to connect a 250 ohm $\pm 1\%$ resistor across the current loop output in lieu of the current meter (see Figure 2-6 for pin assignments and diagram of the analog output connector). This allows the use of a voltmeter connected across the resistor to measure converter output as VDC or mVDC.

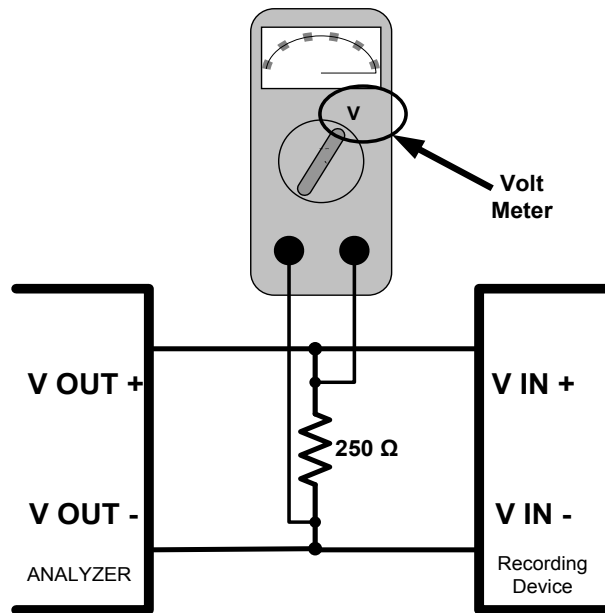


Figure 2-54. Alternative Setup Using 250Ω Resistor for Checking Current Output Signal Levels

In this case, follow the procedure above but adjust the output for the following values:

Table 2-14. Current Loop Output Check

% FS	Voltage across Resistor for 2-20 mA	Voltage across Resistor for 4-20 mA
0	500 mVDC	1000 mVDC
100	5000 mVDC	5000 mVDC

2.5.9. SETUP>INSTRUMENT

As presented in Table 2-15, view product and system information and network settings, edit network settings, and perform certain maintenance tasks.

Table 2-15. Setup>Instrument Menu

MENU	DESCRIPTION
Product Info	View Model, Part, and Serial Numbers and Package and Driver Versions, and options information.
System Info	View Windows and RAM information.
Network Settings	View the network settings (configurable through the Setup>Comm>Network Settings menu).
Display Settings	Adjust the touchscreen's response. (Instructions provided in Maintenance, Section 5.3.3).
Date/Time Settings	Adjust date, hour, and minutes, select a time zone, and set the system clock to automatically adjust for Daylight Savings Time or not. (Also see Setup>Vars>Daylight Savings Enable).
Remote Update	When an instrument is connected to a network that is connected to the Internet, follow the instructions on this Remote Update page to check for and activate software/firmware updates. (Also refer to Section 5.3).

2.5.10. SETUP>COMM

This menu is for specifying the various communications configurations.

2.5.10.1. COM1/COM2

Configure the instrument's COM1 or COM2 ports to operate in modes listed in Table 2-16.

Table 2-16. COM1/COM2 Configuration

MODE	DESCRIPTION
Baud Rate	Set the baud rate for the COM1 or COM2 port being configured.
Command Prompt Display	Enable/disable a command prompt to be displayed when in terminal mode.
Data Bits	Set the data bits to 7 or 8 (typically set in conjunction with Parity and Stop bits).
Echo and Line Editing	Enable/disable character echoing and line editing.
Handshaking Mode	Choose SOFTWARE handshaking for data flow control (do NOT use SOFTWARE handshaking mode when using MODBUS RTU for Protocol mode; select only HARDWARE or OFF for MODBUS RTU), or HARDWARE for CTS/RTS style hardwired transmission handshaking. (This style of data transmission handshaking is commonly used with modems or terminal emulation protocols). Or choose to turn OFF handshaking.
Hardware Error Checking	Enable/disable hardware error checking.
Hardware FIFO	Enable/disable the hardware First In – First Out (FIFO) for improving data transfer rate for that COM port.
Modem Connection	Select either a modem connection or a direct cable connection.
Modem Init String	Input an initialization string to enable the modem to communicate.
Multidrop	Enable/disable multidrop mode for multi-instrument configuration on a single communications channel. Multidrop requires a unique ID for each instrument in the chain (Setup>Vars>Instrument ID).
Parity	Select odd, or even, or no parity (typically set in conjunction with Data Bits and Stop Bits).
Protocol	Select among the communications protocols: TAPI, Hessen, MODBUS RTU, or MODBUS ASCII (MODBUS: Section 3.4.1; Hessen: Section 3.4.2).
Quiet Mode	Enable/disable Quiet mode, which suppresses any feedback from the analyzer (such as warning messages) to the remote device and is typically used when the port is communicating with a computer program where such intermittent messages might cause communication problems. Such feedback is still available, but a command must be issued to receive them.
RS-485	Enable/disable the rear panel COM2 Port for RS-485 communication. RS-485 mode has precedence over Multidrop mode if both are enabled. Also, RS-485 configuration disables the rear panel USB port.
Security	Enable/disable the requirement for a password for this serial port to respond. The only command that is active is the request-for-help command (? CR).
Stop bits	Select either 0 or 1 stop bit (typically set in conjunction with Parity and Data bits).

2.5.10.2. TCP PORT1

TCP Port1 allows choosing whether or not to display the command prompt, editing the Port 1 number for defining the terminal control port by which terminal emulation software addresses the instrument, such as Internet or NumaView™ Remote software, and enabling or disabling security on this port.

2.5.10.3. TCP PORT2

TCP Port2 is configured with the port number for MODBUS.

2.5.10.4. NETWORK SETTINGS

The Setup>Comm>Network Settings menu is for Ethernet configuration. The address settings default to automatic configuration by Dynamic Host Configuration Protocol (DHCP). Most users will want to configure the instrument with a static IP address: click the Static radio button to manually assign a static IP address (consult your network administrator, and see Table 2-17 for information).

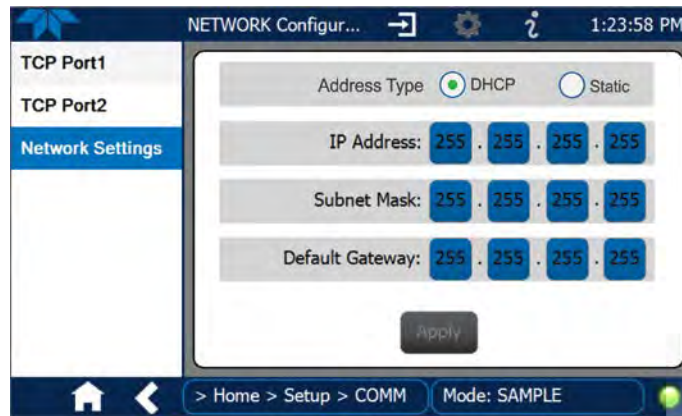


Figure 2-55. Communications Configuration, Network Settings

Table 2-17. LAN/Ethernet Configuration Properties

IP address	A string of four packets of 1 to 3 numbers each (e.g. 192.168.76.55.) is the internet protocol address of the instrument itself.
Subnet Mask	A string of four packets of 1 to 3 numbers each (e.g. 255.255.252.0) number that masks an IP address, and divides the IP address into network address and host address and identifies the LAN to which the device is connected. All addressable devices and computers on a LAN must have the same subnet mask. Any transmissions sent to devices with different subnets are assumed to be outside of the LAN and are routed through the gateway computer onto the Internet.
Default Gateway	A string of numbers very similar to the Instrument IP address (e.g. 192.168.76.1.) that is the address of the computer used by your LAN and serves as a router to access the Internet or another network.

2.6. TRANSFERRING CONFIGURATION TO OTHER INSTRUMENTS

Once an instrument is configured, the same configuration can be copied to other instruments of the same Model. This encompasses essentially anything the user can configure and does not apply to instrument-specific settings such as those that are configured at the factory for calibration.

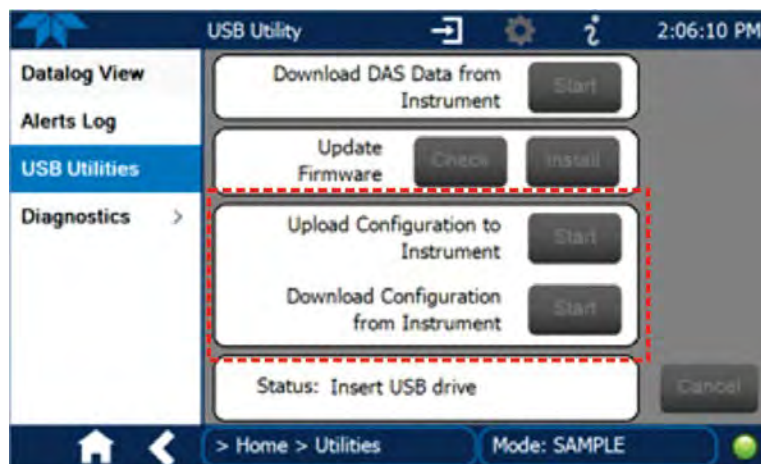


Figure 2-56. Configuration Transfer

1. In the source instrument, go to the Home>Utilities>USB Utilities page.
2. Insert a flash drive into either of the two front panel USB ports.
3. When the Status field indicates that the USB drive has been detected, press the “Download Configuration from Instrument” Start button.
4. When the Status field indicates that the download is complete, remove the flash drive.
5. In the target instrument, go to the Home>Utilities>USB Utilities page.
6. Insert a flash drive into either of the two front panel USB ports.
7. When the Status field indicates that the USB drive has been detected, press the “Upload Configuration to Instrument” Start button.
8. When the Status field indicates that the upload is complete, remove the flash drive.

3. COMMUNICATIONS AND REMOTE OPERATION

This instrument's rear panel connections include an Ethernet port, a USB port (option) and two serial communications ports labeled RS232, which is the COM1 port in the software menu, and COM2 (refer to Figure 2-2). These ports allow the ability to communicate with, issue commands to, and receive data from the analyzer through an external computer system or terminal. Connection instructions were provided in Section 2.3.1.8. Configuration information was provided in Section 2.5.10.

This section provides pertinent information regarding communication equipment, the communications ports, and communications protocol. Data acquisition is set up through the Datalogger (Section 2.5.1).

3.1. DATA TERMINAL / COMMUNICATION EQUIPMENT (DTE DCE)

RS-232 was developed for allowing communications between data terminal equipment (DTE) and data communication equipment (DCE). Basic terminals always fall into the DTE category whereas modems are always considered DCE devices. The difference between the two is the pin assignment of the Data Receive and Data Transmit functions.

- DTE devices receive data on pin 2 and transmit data on pin 3.
- DCE devices receive data on pin 3 and transmit data on pin 2.

To allow the analyzer to be used with terminals (DTE), modems (DCE) and computers (which can be either), a switch mounted below the serial ports on the rear panel, labeled DCE DTE (Figure 2-2), allows the user to set the RS-232 configuration for one of these two data devices. This switch exchanges the Receive and Transmit lines on RS-232 emulating a cross-over or null-modem cable. The switch has no effect on COM2.

3.2. MODES, BAUD RATE AND SERIAL COMMUNICATION

Referring to Table 2-16, use the SETUP>COMM menu to configure COM1 (labeled RS232 on instrument rear panel) and/or COM2 (labeled COM2 on instrument rear panel) for communication modes, baud rate and serial communications. If using a USB option communication connection, setup requires that the instrument's baud rate and personal computer baud rate match.

3.2.1. SERIAL COMMUNICATION: RS-232

The RS232 and COM2 communications ports operate on the RS-232 protocol (default configuration). Configurations possible for these two ports are:

- RS232 port can also be configured to operate in single or RS-232 Multidrop mode (Option 62); refer to Section 2.3.1.8.
- COM2 port can be left in its default configuration for standard RS-232 operation including multidrop, or it can be reconfigured for half-duplex RS-485 operation (please contact the factory for this configuration).

Note

When the rear panel COM2 port is in use, except for multidrop communication, the rear panel USB port cannot be used. (Alternatively, when the USB port is enabled, COM2 port cannot be used except for multidrop).

A code-activated switch (CAS), can also be used on either port to connect typically between 2 and 16 send/receive instruments (host computer(s) printers, data loggers, analyzers, monitors, calibrators, etc.) into one communications hub. Contact Teledyne API Sales (front cover, this manual) for more information on CAS systems.

3.2.2. SERIAL COMMUNICATION: RS-485 (OPTION)

The COM2 port of the instrument’s rear panel is set up for RS-232 communication but can be reconfigured for RS-485 communication. Contact Technical Support for reconfiguration unless this option was elected at the time of purchase, then the rear panel was preconfigured at the factory.

3.3. ETHERNET

When using the Ethernet interface, the analyzer can be connected to any standard 10BaseT or 100BaseT Ethernet network via low-cost network hubs, switches or routers. The interface operates as a standard TCP/IP device on port 3000. This allows a remote computer to connect through the network to the analyzer using NumaView™ Remote, terminal emulators or other programs.

The Ethernet connector has two LEDs that are on the connector itself, indicating its current operating status.

Table 3-1. Ethernet Status Indicators

LED	FUNCTION
amber (link)	On when connection to the LAN is valid.
green (activity)	Flickers during any activity on the LAN.

The analyzer is shipped with DHCP enabled by default. This allows the instrument to be connected to a network or router with a DHCP server; however, it should be configured with a Static IP address as soon as practical. See Section 2.5.10.4 for configuration details.

3.4. COMMUNICATIONS PROTOCOLS

Two communications protocols available with the analyzer are MODBUS (Section 3.4.1) and Hessen (Section 3.4.2). MODBUS registers are provided in Appendix A.

3.4.1. MODBUS

The following set of instructions assumes that the user is familiar with MODBUS communications, and provides minimal information to get started. For additional instruction, please refer to the Teledyne API MODBUS manual, PN 06276. Also refer to www.modbus.org for MODBUS communication protocols.

Minimum Requirements

- Instrument firmware with MODBUS capabilities installed
- MODBUS-compatible software (TAPI uses MODBUS Poll for testing; see www.modbustools.com)
- Personal computer
- Communications cable (Ethernet or USB or RS232)
- Possibly a null modem adapter or cable

3.4.1.1. MODBUS COM PORT CONFIGURATION

MODBUS communications can be configured for transmission over Ethernet or serial COM port through the Setup>Comm menu. Make the appropriate cable connections (Ethernet or COM port) between the instrument and a PC.

Ethernet: MODBUS is available on TCP port 502. By default, port 502 is assigned to the instrument’s TCP Port 2. In the Setup>Comm> TCP Port menu, check to see that it is set to “502” (Figure 3-1).

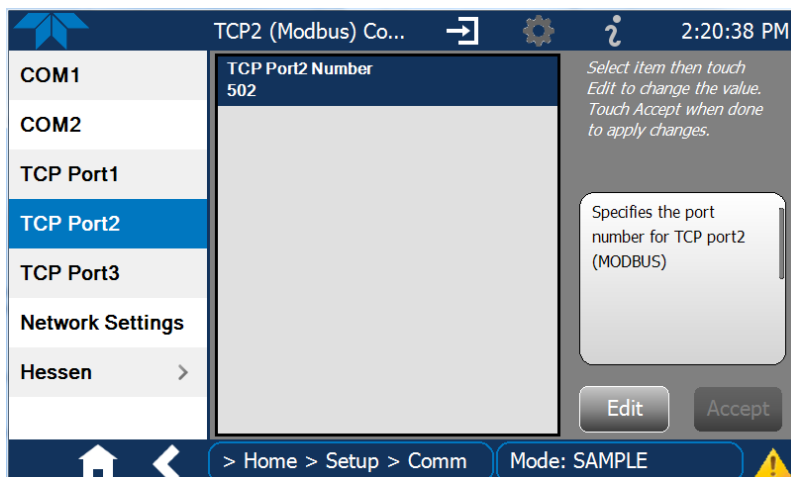


Figure 3-1. MODBUS via Ethernet

Serial COM: Both COM1 (labeled “RS232” on the instrument’s rear panel) and COM2 are configurable for RS-232 or RS-485 communication with either MODBUS RTU or MODBUS ASCII transmission modes. In the

Setup>Comm COM1[COM2] menu, edit the Protocol parameter to select a MODBUS transmission mode; edit Baud Rate, Parity, Data Bits, etc., if necessary (see descriptions in Table 2-16).

Important

When using MODBUS RTU, ensure that the COM1[COM2] Handshaking Mode is set to either Hardware or OFF. Do NOT set it to Software.

Press the Accept button to apply the settings. (Figure 3-2 shows an example for MODBUS RTU).

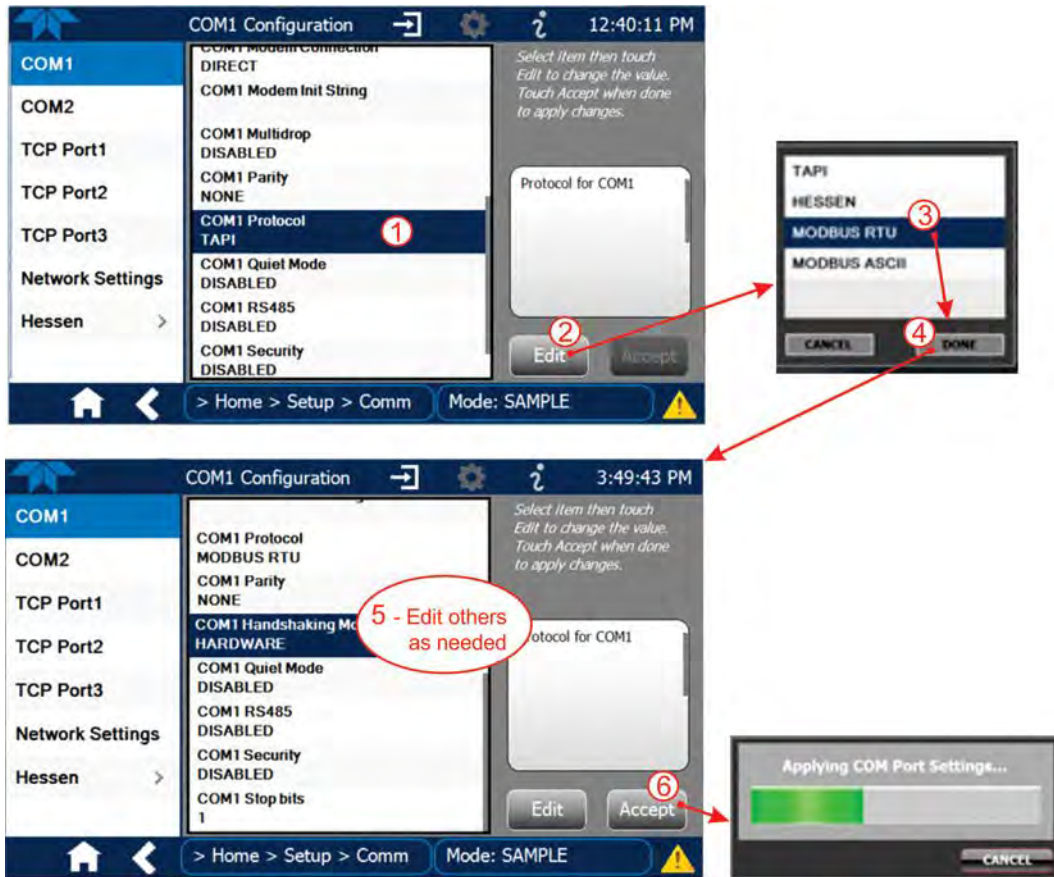


Figure 3-2. MODBUS via Serial Communication (example)

Important

When more than one analyzer is connected to the network, create a unique identification number for each in the Setup>Vars>Instrument ID menu.

Next, for the settings to take effect, power off the analyzer, wait 5 seconds, and power it on again.

3.4.2. HESSEN

Hessen is a multidrop protocol, in which several remote instruments (slaves) are connected via a common communications channel to a host computer. Slaves respond only to commands sent by the host using their unique identification.

Important Create a unique identification number for each instrument in the multidrop chain via the Setup>Vars>Instrument ID menu.

The Hessen protocol is not strictly defined; therefore, while Teledyne API's application is completely compatible with the protocol itself, it may be different from implementations by other companies.

3.4.2.1. HESSEN COM PORT CONFIGURATION

Configure the COM1/COM2 port for Hessen protocol through the Setup>Comm>COM1[COM2] menu: select COM1[COM2] Protocol and press Edit to select HESSEN, then press Accept.

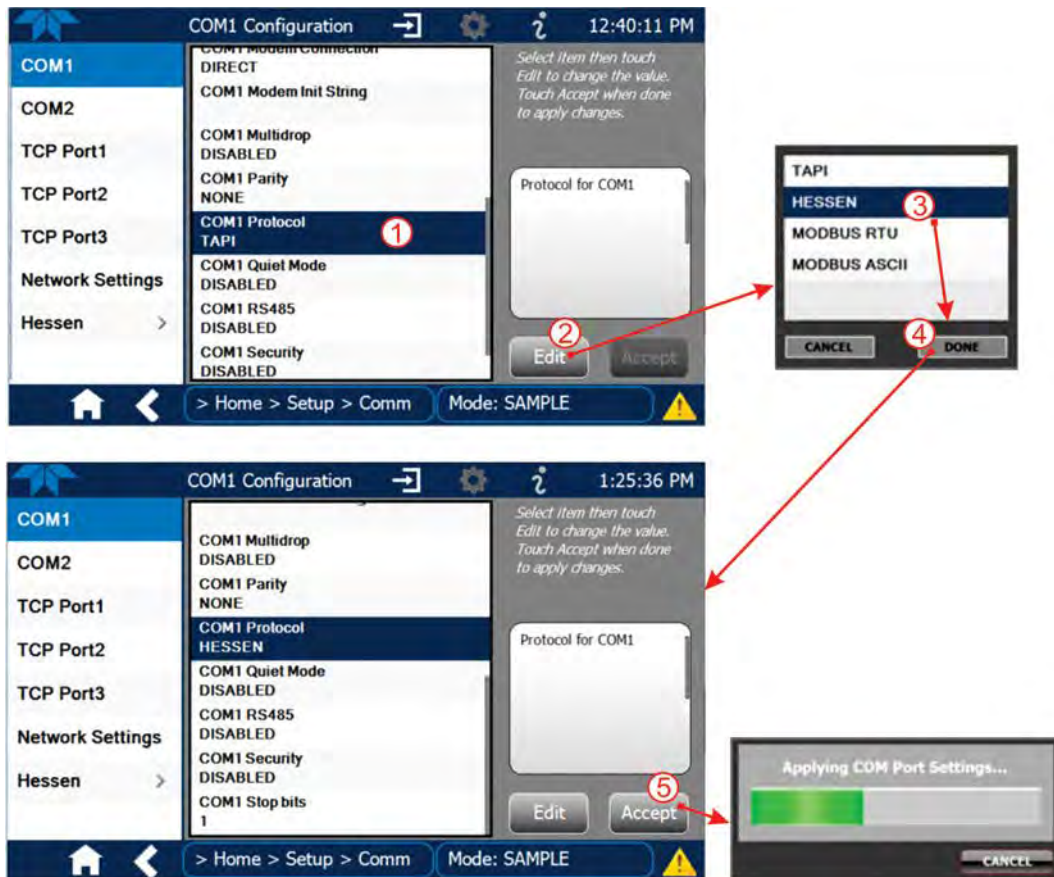


Figure 3-3. Serial Communication, Setting Hessen Protocol

Note

Ensure that the communication parameters of the host computer are also properly set.

Note that the instrument software has a 200 ms latency period before it responds to commands issued by the host computer. This latency should present no problems, but be mindful of issuing commands to the instrument too frequently.

3.4.2.2. HESSEN SETTINGS CONFIGURATION

Hessen configuration includes settings for alarms, version, response mode, status flags and gas list. Locate the alarms in the Hessen Settings list (Setup>Comm>Hessen>Hessen Settings) and edit as desired.

HESSEN VARIATION

For the Hessen Variation setting, there are two versions.

- TYPE 1 is the original implementation.
- TYPE 2 has more flexibility when operating with instruments that can measure more than one type of gas. For more specific information about the difference between the two versions, download the *Manual Addendum for Hessen Protocol* from the Teledyne API's web site: <http://www.teledyne-api.com/manuals/>.

HESSEN PROTOCOL RESPONSE MODE

Set the response mode under Hessen Response Mode, referring to Table 3-2 for descriptions.

Table 3-2. Teledyne API's Hessen Protocol Response Modes

MODE ID	MODE DESCRIPTION
CMD	This is the default setting. Responses from the instrument are encoded as the traditional command format. Style and format of responses depend on exact coding of the initiating command.
BCC	Responses from the instrument are always delimited with <STX> (at the beginning of the response, <ETX> (at the end of the response followed by a 2 digit Block Check Code (checksum), regardless of the command encoding.
TEXT	Responses from the instrument are always delimited with <CR> at the beginning and the end of the string, regardless of the command encoding.

HESSEN STATUS FLAGS

Locate the various status flags in the Hessen Settings list and edit as needed. They are listed by status flag name with their default bit assignments. (Those with unassigned flags are listed as "0x0000").

- The status bits are included in the instrument's responses to inform the host computer of its condition. Each bit can be assigned to one operational and warning message flag.
- It is possible to assign more than one flag to the same Hessen status bit. This allows the grouping of similar flags, such as all temperature warnings, under the same status bit.

- Assigning conflicting flags to the same bit will cause each status bit to be triggered if any of the assigned flags is active.

Table 3-3. Hessen Status Flags and Default Bit Assignments

STATUS FLAG NAME ³	DEFAULT BIT ASSIGNMENT (USER EDITABLE; ALSO SEE NOTE ³)
WARNING FLAGS	
SAMPLE FLOW WARNING	0001
OZONE FLOW WARNING	0002
RCEL PRESS WARNING	0004
BOX TEMP WARNING	0008
RCELL TEMP WARNING	0010
IZS TEMP WARNING ¹	0020
PMT TEMP WARN	0040
CONV TEMP WARNING	0080
INVALID CONC	8000
OPERATIONAL FLAGS	
In MANUAL Calibration Mode	0200
In ZERO Calibration Mode	0400
In SPAN Calibration Mode	0800
In WARMUP Mode	1000
UNITS OF MEASURE FLAGS	
UGM	0000
MGM	2000
PPB	4000
PPM	6000
SPARE/UNUSED BITS	0100
UNASSIGNED FLAGS (0000)	
MANIFOLD TEMPERATURE ²	HVPS WARNING
OZONE GEN OFF	FRONT PANEL WARN
SYSTEM RESET	ANALOG CAL WARNING
RELAY BOARD WARNING	CANNOT DYN ZERO
REAR BOARD NOT DETECTED	CANNOT DYN SPAN
AUTOZERO WARNING	Instrument is in MP CAL mode

¹ Only applicable if the optional internal span gas generator is installed.

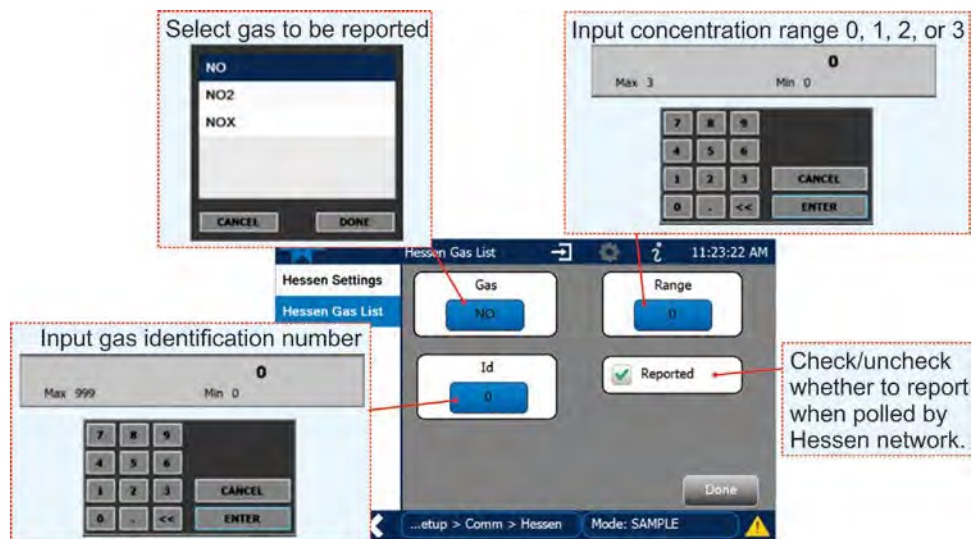
² Only applicable if the analyzer is equipped with an oxygenator option.

³ It is possible to assign more than one flag to the same Hessen status bit. This allows the grouping of similar flags, such as all temperature warnings, under the same status bit.

Be careful not to assign conflicting flags to the same bit as each status bit will be triggered if any of the assigned flags is active.

3.4.2.3. HESSEN GAS LIST CONFIGURATION

Configure the Hessen Gas List in the Setup>Comm>Hessen>Hessen Gas List page. Choose the Gas, the concentration Range, and enter the gas ID. Refer to and to the table below.



Menu: Setup>Comm>Hessen>Hessen Gas List

Figure 3-4. Hessen Gas List Configuration

Table 3-4. Hessen Gas List Definitions

PARAMETER	DEFINITION
Gas	type of gas to be reported
Range	concentration range to be reported (when Reported box is checked)
0	currently active range
1	only when range 1 or low range is active
2	only when range 2 or high range is active
3	Not Applicable
Id	specific gas identification
211	NO _x
212	NO
213	NO ₂
Reported	choice of whether to report when polled by the Hessen network

4. CALIBRATION

This section is organized into subsections as follows:

SECTION 4.1 – Important Precalibration Information

: contains important information you should know before calibrating the instrument.

SECTION 4.2 – Calibration Procedures: describes the procedure for manually checking calibration and performing actual calibration of the instrument.

SECTION 4.3 – Automatic Zero/Span Cal/Check (Auto Cal): describes the procedure for using the AutoCal feature to check calibration or to calibrate the instrument. (The AutoCal feature requires that either the zero/span valve option or the internal span gas generator option be installed and operating).

SECTION 4.4 – Calibration Quality Analysis: describes how to evaluate quality of each calibration.

SECTION 4.5 – Conversion Efficiency (CE) Calibration: provides information on monitoring and calibrating the efficiency of the photolytic converter.

SECTION 4.6 – EPA Protocol Calibration: provides links to the US EPA website for references regarding calibration with EPA protocols.

4.1. IMPORTANT PRECALIBRATION INFORMATION

Note

A start-up period of 4-5 hours is recommended prior to calibrating the analyzer.

4.1.1. CALIBRATION REQUIREMENTS

The following equipment, supplies, and expendables are required for calibration:

- Zero-air source
- Span gas source
- Gas lines - all gas line materials should be stainless steel or Teflon-type (PTFE or FEP).
- High-concentration NO gas transported over long distances may require stainless steel lines to avoid oxidation of NO due to the possibility of O₂ diffusing into the tubing.

Optional equipment: A recording device such as a strip-chart recorder and/or data logger.

For electronic documentation, the internal data acquisition system (DAS) can be used by configuring the Datalogger through the Setup>Data Logging menu; Section 2.5.1).

The method for performing an initial calibration for the analyzer differs between the standard instrument and those with options.

- See Section 4.2.1 for instructions for initial calibration of the analyzer in its base configuration.
- See Section 4.2.2 for information regarding setup and calibration of the analyzer with Z/S Valve options.

Note

Zero air and span gases must be supplied at twice the instrument's specified gas flow rate. Therefore, the zero and span gases should be supplied to their respective inlets in excess of 1000 cc/min (500 cc/min x 2) for the T200P and in excess of 2000 cc/min (1000 cc/min x2) for the T200UP.

4.1.2. ZERO AIR

Zero air or zero calibration gas is similar in chemical composition to the measured medium but without the gas to be measured by the analyzer. For the T200P/UP, this means zero air should be devoid of NO, NO₂, CO₂, NH₃ or H₂O vapor.

Note

Moderate amounts of NH₃ and H₂O can be removed from the sample gas stream by installing the optional sample gas dryer/scrubber (see Section 2.3.2.6).

- If your application is not a measurement in ambient air, the zero calibration gas should be matched to the composition of the gas being measured.
- Pure nitrogen (N₂) could be used as a zero gas for applications where NO_x is measured in nitrogen.
- If your analyzer is equipped with an external zero air scrubber option, it is capable of creating zero air from ambient air.
- For analyzers without the external zero air scrubber, a zero air generator such as the Teledyne API's Model T701 can be used. Please visit the company website for more information.

4.1.3. CALIBRATION (SPAN) GAS

Calibration gas is specifically mixed to match the chemical composition of the type of gas being measured at near full scale of the desired reporting range. To measure NO_x with the analyzer, it is recommended that you use a span gas with an NO concentration equal to 80% of the measurement range for your application.

EXAMPLE:

- If the application is to measure NO_x in ambient air between 0 ppb and 500 ppb, an appropriate span gas would be 400 ppb.
- If the application is to measure NO_x in ambient air between 0 ppb and 1000 ppb, an appropriate span gas would be 800 ppb.

4.1.4. SPAN GAS FOR MULTIPOINT CALIBRATION

Some applications, such as EPA monitoring, require a multipoint calibration where span gases of different concentrations are needed. We recommend using an NO gas of higher concentration combined with a gas dilution calibrator such as the Teledyne API T700/T700U Models. Calibrators mix high concentration gas with zero air to accurately produce span gas of the desired concentration. Linearity profiles can be automated with these models and run unattended overnight.

If a dynamic dilution system is used to dilute high concentration gas standards to low, ambient concentrations, ensure that the NO concentration of the reference gas matches the dilution range of the calibrator. (Section 2.5.5 contains information about the dilution option).

Choose the NO gas concentration so that the dynamic dilution system operates in its mid-range and not at the extremes of its dilution capabilities.

EXAMPLE:

- A dilution calibrator with 10-10000 dilution ratio will not be able to accurately dilute a 5000 ppm NO gas to a final concentration of 500 ppb, as this would operate at the very extreme dilution setting.
- A 100 ppm NO gas in nitrogen is much more suitable to calibrate the analyzer (dilution ratio of 222, in the mid-range of the system's capabilities).

4.1.5. PHYSICAL RANGE MEASUREMENTS

The T200P measurement physical ranges for NO_x, NO and NO₂ concentrations are 0-2000 ppb or 0-20,000 ppb.

The T200UP measurement physical range for NO_x, NO and NO₂ concentrations is 0-2000 ppb (low range only).

Electronically the T200P analyzer converts the 0-5 volt analog signal output from the PMT to a digital signal with 4096 counts of resolution. Since its measurement range is 0 ppb to 20,000 ppb, this only allows about 3 ppb per count. While this might be acceptable for high concentration measurements made in parts per million units (ppm), it is not useful enough for lower level NO_x measurements. To overcome this limitation the T200P is designed with two physical measurement ranges:

- LOW range to measure concentration from 0 ppb to 2,000 ppb with a resolution of 0.27 ppb per count
- HIGH range to measure the full 20,000 ppb range of the analyzer

The analyzer's CPU chooses the appropriate physical range, by adjusting the hardware gain on the preamp PCA, based on the configuration of the Max Concentration Range variable in the Setup>Vars menu (see Table 2-11).

4.1.6. INTERFERENTS

The chemiluminescence method for detecting NO_x , coupled with a photolytic converter, is subject to interference from a number of sources including water vapor (H_2O), sulfur dioxide (SO_2), and carbon dioxide (CO_2); however, the analyzer has been designed to reject most of these interferences.

- Unlike the heated catalytic converter where Ammonia is the most common Interferent, whereby NH_3 is converted to NO , the photolytic converter doesn't exhibit this issue. However, high ambient concentrations of NH_3 can form white salts inside the cell, which can cause drift.
- Teledyne API offers a sample gas conditioning option (Section 2.3.2.6) to remove ammonia and water vapor for the T200P (standard in the T200UP).
- Carbon dioxide (CO_2) diminishes the NO_x signal when present in high concentrations.
 - If the analyzer is used in an application with excess CO_2 , contact Teledyne API's Technical Support Department (see Section 5.7) for possible solutions.
- Excess water vapor can be removed with one of the dryer options described in Section 2.3.2.6. In ambient air applications, SO_2 interference is usually negligible.

For more detailed information regarding interferents for NO_x , NO and NO_2 measurement, see Section 6.2.4.

4.1.7. NO_2 PERMEATION TUBES

For the T200P only, Teledyne API offers an optional internal span gas generator that utilizes an NO_2 permeation tube as a span gas source (see Section 2.3.2.5). The accuracy of these devices is only about $\pm 5\%$. Whereas this may be sufficient for quick, daily calibration checks, we recommend using certified NO gases for accurate calibration.

CAUTION!



Insufficient gas flow allows gas to build up to levels that will contaminate the instrument or present a safety hazard to personnel.

In units with a permeation tube installed, either the tube must be removed and stored in a sealed container (use original container that tube was shipped in) during periods of non-operation, or vacuum pump must be connected and powered on to maintain constant gas flow through the analyzer at all times.

(See Figure 2-4 for location and Section 5.4.5 for instructions).

4.1.8. DATA RECORDING DEVICES

A strip chart recorder, data acquisition system or digital data acquisition system should be used to record data from either the Ethernet, serial or analog outputs.

- If analog readings are used, the response of the recording system should be checked against a NIST traceable voltage source or meter.
- Data recording devices should be capable of bi-polar operation so that negative readings can be recorded.

For electronic data recording, the analyzers provide an internal data logger, which is configured through the Setup>Data Logger menu (Section 2.5.1).

NumaView™ Remote is a remote control program, which is also available as a convenient and powerful tool for data handling, download, storage, quick check and plotting.

4.1.9. NO₂ CONVERSION EFFICIENCY (CE)

The photolytic converter, internal to the analyzer, represents the latest in high intensity LED technology. The converter is capable of producing NO₂-to-NO conversion efficiency values similar to catalytic converter technologies, for ambient levels of NO₂. However, at higher concentrations of NO₂ the conversion efficiency decreases, with a linear relationship. For this reason the converter requires calibration at two distinct NO₂ concentrations. The concentrations are typically at 80% and 20% of the expected NO₂ range of measurement.

To ensure accurate performance of the analyzer, it is important to check the NO₂ conversion efficiency (CE) periodically and to update these values as necessary. Procedures for CE calibration are presented in Section 4.5.

4.2. CALIBRATION PROCEDURES

Check that the pneumatic connections for the specific instrument configuration are as instructed in Section 2.3.2. Calibration procedures include setting the expected span gas concentration (see Note below).

Verify/change (if needed) the settings in the Setup>Vars menu as follows:

- User Units (unit of Measure): PPB
- Max Concentration Range (highest concentration expected to measure)
- Range Mode: SNGL

Then perform the calibration:

- Perform a Zero calibration using zero air.
- Perform a span calibration on both the NO & NO_x channels using a known concentration of NO span gas.

- Perform the two point Converter efficiency, CEA and CEB, calibration using a known concentration of NO₂ span gas.

Note

Tips for Setting the Expected Span Gas Concentration:

- The expected concentrations for both NO and NO_x are usually set to the same value.
- When setting expected concentration values, consider impurities in your span gas source (e.g. NO often contains 1-3% NO₂ and vice versa).
- The NO and NO_x span gas concentrations should be 80% to 90% of range of concentration values likely to be encountered in your application.

To calibrate or to perform a calibration check for basic configuration instruments, see Section 4.2.1.

To calibrate or to perform a calibration check for instruments with valve options, see Section 4.2.2.

To perform a calibration check for instruments with the internal span gas generator, see Section 4.3.

To calibrate Conversion Efficiency, see Section 4.5.

4.2.1. CALIBRATION AND CHECK PROCEDURES FOR BASIC CONFIGURATION

Although this section uses the Calibration menu for both check and actual calibration, a check does not require the Calibration menu. Instead, while in Home page, simply flow the zero air or the NO span gas through the Sample port, and check the reading after the Stability (either in the gas graph or in the Dashboard) falls below 1.0 PPB.

Otherwise, follow the steps presented in Sections 4.2.1.1 and 4.2.1.2.

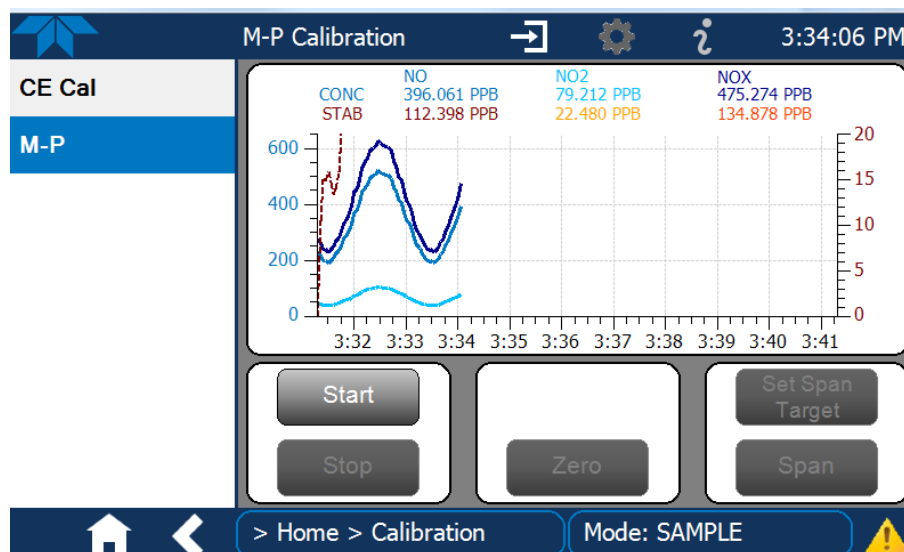


Figure 4-1. Multi-Point Calibration Page

4.2.1.1. ZERO CALIBRATION CHECK AND ACTUAL CALIBRATION

1. Go to the Calibration>M-P menu.
2. Input Zero air through the Sample port and press the Start button.
3. Either check or calibrate as follows:

CHECK ONLY:	ACTUAL CALIBRATION:
<ol style="list-style-type: none">a. Wait for reading to stabilize.b. Press Stop and check the reading.	<ol style="list-style-type: none">a. Press the Zero button.b. Press Stop and check the reading.

4.2.1.2. SPAN CALIBRATION CHECK AND ACTUAL CALIBRATION

1. While still in the Calibration>M-P menu, input NO Span gas through the Sample port and press the Start button.
2. Either check or calibrate as follows:

CHECK ONLY:	ACTUAL CALIBRATION:
<ol style="list-style-type: none">a. Wait to reach stability, then press Stop.b. Record the reading(s).	<ol style="list-style-type: none">a. Press the Set Span Target button and enter the NO and NO_x concentrations.b. Verify the concentration reading is the same as the NO concentration being supplied.c. If correct, wait to reach stability, then press the Span button.d. In the Cal Result window, press OK.
3. Press the Stop button and return to Home screen.
4. In the Dashboard, check and record the Slope(s) and the Offset(s). (See Table 4-4 in Section 4.4, Calibration Quality Analysis, for expected/acceptable values).

4.2.2. CALIBRATION AND CHECK PROCEDURES WITH VALVE OPTIONS INSTALLED



Figure 4-2. Zero and Span Calibration Screens

Follow the instructions in Section 4.2.1, except instead of the M-P menu, go to the Calibration>Zero menu for Zero cal and to the Calibration>Span menu for NO Span cal.

4.2.2.1. USE OF ZERO/SPAN VALVE WITH REMOTE CONTACT CLOSURE

Contact closures for controlling calibration and calibration checks are located on the rear panel CONTROL IN connector. Instructions for setup and use of these contacts are in Section 2.3.1.6.

When the contacts are closed for at least 5 seconds, the instrument switches into zero, low span or high span mode and the internal zero/span valves will be automatically switched to the appropriate configuration.

- The remote calibration contact closures may be activated in any order.

- It is recommended that contact closures remain closed for at least 10 minutes to establish a reliable reading.
- The instrument will stay in the selected mode for as long as the contacts remain closed.

If contact closures are being used in conjunction with the analyzer’s AutoCal (see Section 4.3) feature and the AutoCal attribute “Calibrate” is enabled (selection box is checked), the analyzer will not recalibrate the analyzer UNTIL the contact is opened. At this point, the new calibration values will be recorded before the instrument returns to SAMPLE mode.

If the AutoCal attribute “Calibrate” is disabled (selection box is unchecked), the instrument will return to SAMPLE mode, leaving the instrument’s internal calibration variables unchanged.

4.3. AUTOMATIC ZERO/SPAN CAL/CHECK (AUTO CAL)

The Auto Cal feature allows unattended periodic operation of the ZERO/SPAN valve options by using the instrument’s internal time of day clock. Auto Cal operates by executing preprogrammed calibrations or calibration checks set up by the user to initiate the various calibration states of the analyzer and to open and close valves appropriately. It is possible to set up and run up to three separate preprogrammed calibrations or calibration checks (labeled # 1, 2 and 3). Each calibration or check can operate in one of three modes (Zero, Low or High), or be disabled.

Table 4-1 and Table 4-2 show how to set up the operating states of each calibration or check, and Table 4-3 shows how to program the execution of each.

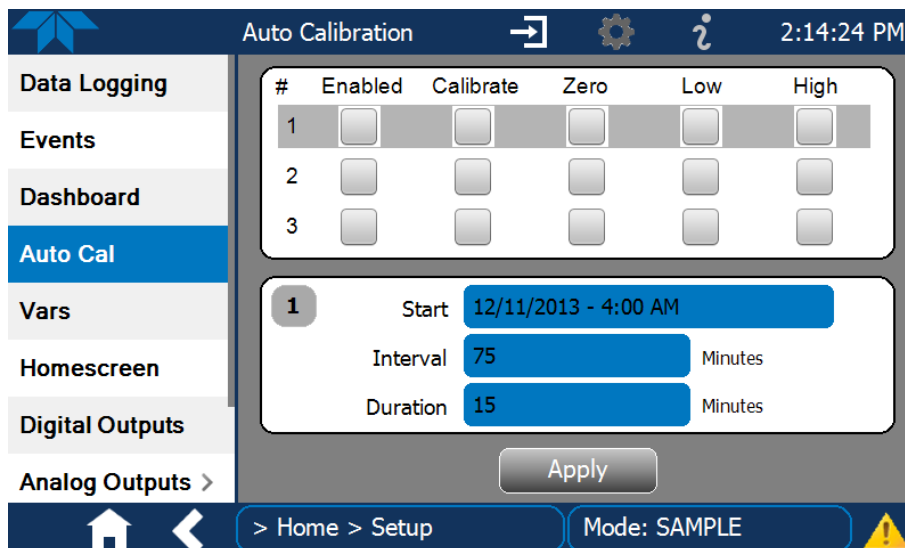


Figure 4-3. Auto Cal Page

Table 4-1. AUTO CAL States

MODE NAME	ACTION
Enabled	<input checked="" type="checkbox"/> enables the sequence; <input type="checkbox"/> disables the sequence.
Calibrate	<input checked="" type="checkbox"/> enables an actual calibration when the Enabled box is also <input checked="" type="checkbox"/> <input type="checkbox"/> allows a calibration check when the Enabled box is also <input checked="" type="checkbox"/> .
Zero	<input checked="" type="checkbox"/> causes the sequence to perform a Zero calibration when both the Calibrate and Enabled boxes are also <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> causes a Zero check when the Enabled box is also <input checked="" type="checkbox"/> and the Calibrate box is unchecked (<input type="checkbox"/>). <input type="checkbox"/> disables Zero calibration and check
Low	<input checked="" type="checkbox"/> causes the sequence to perform a Low Span calibration when both the Calibrate and Enabled boxes are also <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> causes a Low Span check when the Enabled box is also <input checked="" type="checkbox"/> and the Calibrate box is unchecked (<input type="checkbox"/>). <input type="checkbox"/> disables Low Span calibration and check
High	<input checked="" type="checkbox"/> causes the sequence to perform a High Span concentration calibration when both the Calibrate and Enabled boxes are also <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> causes a High Span check when the Enabled box is also <input checked="" type="checkbox"/> and the Calibrate box is unchecked (<input type="checkbox"/>). <input type="checkbox"/> disables the High Span calibration and check.

Table 4-2 shows how the selection boxes would be enabled/disabled for calibration checks and calibrations.

Table 4-2. Auto Cal Setup Combinations

MODE	ACTION	STATE				
		Enabled	Calibrate	Zero	Low	High
Zero	Check	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Calibrate	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Low	Check	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
	Calibrate	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
High	Check	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
	Calibrate	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Zero Low High	Check	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
	Calibrate	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

For each sequence, there are four parameters that control operational details: Date, Time (both in the Start field), Interval, and Duration, as presented in Table 4-3.

Table 4-3. Auto Cal Programming Sequence Execution

ATTRIBUTE	ACTION
Start	When the Enabled box is “on” <input checked="" type="checkbox"/> , the Sequence (identified by its number) begins on the date and time shown in the configurable Start field. (Click the field for the pop-up window and toggle between the Time (Hour/Minutes) and the Date (Year/Month/Day) attributes to edit as needed).
Interval	Number of minutes to skip between each Sequence execution. (Click the field to input the number of minutes in the pop-up window).
Duration	Number of minutes that each Sequence execution is to run. (Click the field to input the number of minutes in the pop-up window).

Important

IMPACT ON READINGS OR DATA

- The programmed **STARTING_TIME** must be a minimum of 5 minutes later than the real time clock for setting real time clock (Setup>Instrument, Section 2.5.9).
- Avoid setting two or more sequences at the same time of the day.
- Any new sequence that is initiated whether from a timer, the COM ports or the contact closure inputs will override any sequence that is in progress.
- The **CALIBRATE** attribute must always be set to **OFF** on analyzers with IZS Options installed and functioning.
- Calibrations should **ONLY** be performed using external sources of Zero Air and Span Gas whose accuracy is traceable to EPA standards.

4.4. CALIBRATION QUALITY ANALYSIS

It is important to evaluate the analyzer’s calibration **SLOPE** and **OFFSET** parameters. These values describe the linear response curve of the analyzer, separately for NO and NO_x. The values for these terms, both individually and relative to each other, indicate the quality of the calibration.

Set up the Data Logger with a Periodic trigger to record the values of the following parameters (see Section 2.5.1).

- NO Norm Offset
- NO Slope
- NO_x Norm Offset
- NO_x Slope

Ensure that these parameters are within the limits listed in Table 4-4 and frequently compare them to those values on the *Final Test and Validation Data Sheet* that came with

your instrument, which should not be significantly different. Otherwise, refer to the troubleshooting Section 5.5.7.

Table 4-4. Calibration Data Quality Evaluation

FUNCTION	MINIMUM VALUE	OPTIMUM VALUE	MAXIMUM VALUE
NO SLOPE	-0.700	1.000	1.300
NO _x SLOPE	-0.700	1.000	1.300
NO Norm Offset	-20.0 mV	0.0 mV	150.0 mV
NO _x Norm Offset	-20.0 mV	0.0 mV	150.0 mV

4.5. CONVERSION EFFICIENCY (CE) CALIBRATION

The analyzer automatically calculates the current NO₂ conversion efficiency, for either point A or B, by comparing the known concentration of NO₂ span gas, which is entered under the CE calibration menu, to the measured NO₂ reading. Gas Phase Titration (GPT) is the recommended method (Section 4.5.1) for NO₂ delivery. If GPT is not available then a NIST traceable bottle of NO₂ may be used. (Section 4.5.2).

Important

The first step in calibrating the CE is to Zero the instrument with dry instrument grade air and then perform a Span calibration with NO calibration gas balanced in Nitrogen (Sections 4.2.1.1 and 4.2.1.2).

4.5.1. CALIBRATING CE: GAS PHASE TITRATION (GPT) METHOD

Note

For greatest accuracy, use Gas Phase Titration to calibrate the CE A & B values. Note that the actual NO₂ value entered should represent the “NO before” minus the “NO remaining” value. It is best to calibrate the B point first, as it allows the pneumatics to stabilize faster with higher NO₂ concentration.

This section describes how to determine the converter’s efficiency using a GPT method. It is important to note that the actual concentration of ozone is not a critical factor in the accuracy of the calculation.

- In the following example CE values will be calibrated assuming a sample range of 0-500 ppb. This is only an example other reference points within the measurement range of the instrument may be used.
- For this procedure use a calibrated T700/T700U containing an O₃ generator.

Note

There must be a minimum of 20 ppb NO in excess of the O₃ produced during the GPT.

1. Zero the analyzer using clean dry zero air.
2. Calibrate the instrument at the appropriate span level, typically 80% to 90% of the expected sampling range, using NO span gas.
 - For this example: 450 ppb NO span gas.

3. CE B Point calibration (NO₂ setting of approximately 80% expected range).
 - a. Conduct a 450 ppb NO GPTZ using a Teledyne API calibrator. Note the analyzer concentrations once stabilized.
 - b. Conduct a 450 ppb NO and 430 ppb O₃ GPTS using a Teledyne API calibrator.
 - c. Conduct a 450 ppb NO and 430 ppb O₃ GPT using a Teledyne API calibrator. Note the analyzer concentrations once stabilized.
 - d. Calculate the actual NO₂ concentration delivered and enter this value into the Target Point B menu.

Note the actual NO₂ delivered is equal to the NO concentration measured during GPTZ minus the NO concentration remaining during GPT.
4. CE A Point calibration (NO₂ setting of approximately 20% expected range).
 - a. Repeat prior GPTZ, GPTS, and GPT steps at 100 ppb NO and 80 ppb O₃.
 - b. Calculate the actual NO₂ concentration delivered and enter this value into the Target Point A menu.
5. The conversion efficiency values are displayed on the Dashboard. Typically the CE A value is 90% or higher and CE B value is 85% or higher.

If the CE values are well below those values, consider cleaning the converter lamp (Section 5.4.7).

4.5.2. CALIBRATING CE: BOTTLED NO₂ METHOD

1. Make the pneumatic connections as shown in Figure 4-4.
2. Supply known concentrations of NO₂ gas to the analyzer.

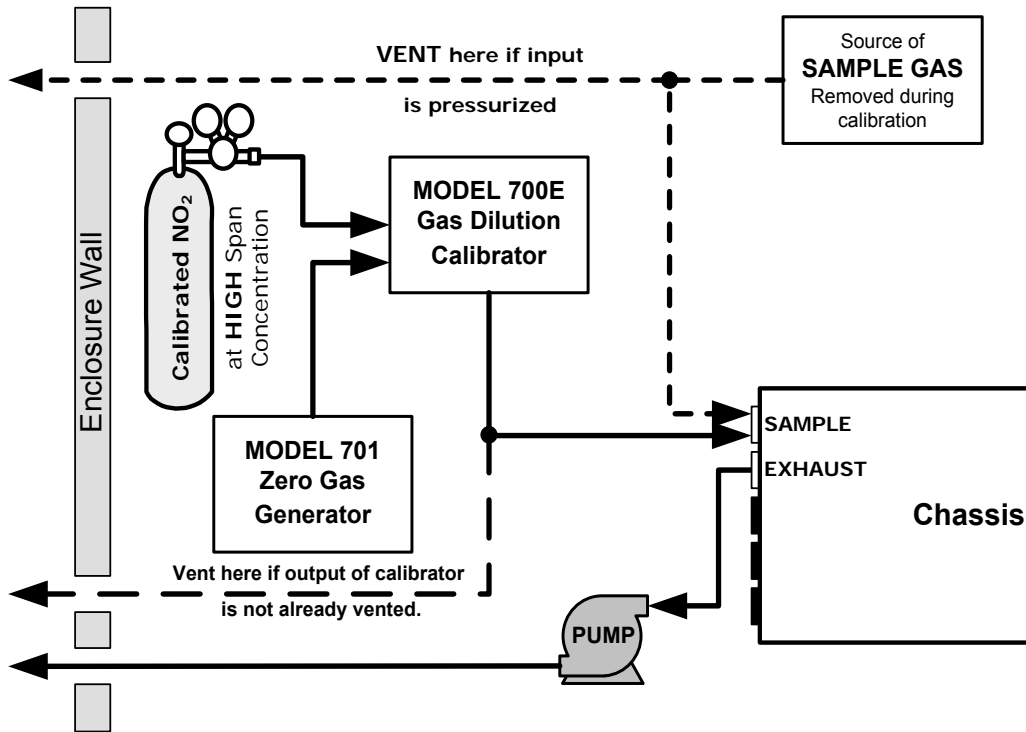


Figure 4-4. Setup for Determining Conversion Efficiency

① Home>Calibration (Perform zero and span cal with NO gas prior to CE Cal).

② Start with Point B first.

③ Start with Point B first.

④ NO2 Target B 100.00 PPB

⑤ Use keypad to edit.

⑥

⑦ Done

⑧ CAL B

⑨ Cal Result SUCCESS

⑩ Repeat steps 3 thru 9 for Point A, then press Stop in CE Cal page.

Figure 4-5. Conversion Efficiency Calibration Menu

Figure 4-5 illustrates the following steps:

1. In the Calibration>CE Cal menu, press Start.
2. Press Set NO₂ Target B.
3. Edit the NO₂ Target B value as necessary, pressing the ENTER button when complete.
4. In the Target Point B window press Done.
5. Press CAL B, when the analyzer has stabilized.
6. When the Cal Result window shows SUCCESS, press OK.
7. Adjust the calibrator to deliver a lower NO₂ concentration.
8. Press Set NO₂ Target A.
9. Edit the NO₂ Target A value as necessary, pressing the ENTER button when complete.
10. In the Target Point A window press Done.
11. Press CAL A, when the analyzer has stabilized.
12. When the Cal Result window shows SUCCESS, press OK.
13. Press Stop.

4.6. EPA PROTOCOL CALIBRATION

When running this instrument for U.S. EPA compliance, always calibrate prior to use, adhering to the EPA designation requirements for this instrument. (The official List of Designated Reference and Equivalent Methods is published in the U.S. Federal Register: <http://www3.epa.gov/ttn/amtic/criteria.html>). Pay strict attention to the built-in warning features, periodic inspection, regular zero/span checks, regular test parameter evaluation for predictive diagnostics and data analysis, and routine maintenance. Any instrument(s) supplying the zero air and span calibration gasses used must themselves be calibrated, and that calibration must be traceable to an EPA/NIST primary standard.

Comply with Code of Federal Regulations, Title 40 (downloadable from the U.S. Government Publishing Office at <http://www.gpo.gov/fdsys/>) and with Quality Assurance Guidance documents (available on the EPA website: <http://www3.epa.gov/ttn/amtic/qalist.html>). Give special attention to specific regulations regarding the use and operation of ambient NO_x analyzers (chemiluminescence).

5. MAINTENANCE AND SERVICE

Follow the maintenance schedule set forth in Section 5.1. Service and troubleshooting are covered in Section 5.5.

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY
Avoid spraying anything directly onto any part of the analyzer.

5.1. MAINTENANCE SCHEDULE

Table 5-1 shows a typical maintenance schedule.

In certain environments (e.g., dusty, very high ambient pollutant levels) some maintenance procedures may need to be performed more often than shown.



WARNING – ELECTRICAL SHOCK HAZARD

Disconnect power before performing any of the following operations that require entry into the interior of the analyzer.



CAUTION – QUALIFIED PERSONNEL

These maintenance procedures must be performed by qualified technicians only.

Important

IMPACT ON READINGS OR DATA

A span and zero calibration check (see CAL CHECK REQ'D Column of Table 5-1) must be performed following some of the maintenance procedures listed herein. To perform a CHECK of the instrument's Zero or Span Calibration, refer to Sections 4.2.1.1 and 4.2.1.2, respectively.

DO NOT press the Zero or Span buttons at the end of each operation (actual calibration), as this will reset the stored values for OFFSET and SLOPE and alter the instrument's calibration.

Alternatively, use the Auto Cal feature described in Section 4.3 with the CALIBRATE attribute set to OFF (not enabled).

Table 5-1. Maintenance Schedule

ITEM	ACTION	FREQ	CAL CHECK REQ'D	DATE PERFORMED													
Dashboard functions	Review and evaluate	Weekly	No														
Particulate filter	Change	Monthly or as necessary	No														
Zero/span check	Evaluate offset and slope	Weekly	No														
Zero/span calibration	Zero and span calibration	Every 3 months	Yes														
External zero air scrubber option	Exchange chemical	Every 3 months	No														
Software/ Firmware	Check for updates	Every 6 months or whenever serviced	Yes														
Ozone cleanser	Change chemical	Annually	Yes														
Reaction cell window ("optical filter")	Clean	Annually or as necessary	Yes														
DFU filters	Change	Annually (or as needed for highly polluted sample air)	No														
Pneumatic sub-system	Check for leaks in gas flow paths	Annually or after repairs involving pneumatics	Yes if a leak is repaired														
Reaction cell O-rings & sintered filters	Replace	Annually	Yes														
PMT Sensor Hardware Calibration	Low-level hardware calibration	When PMT/ preamp changes or if slope is outside of 1.0±0.3	Yes														
Pump	Rebuild head	when Rx Cell pressure exceeds 10 in-Hg-A (at sea level)	Yes														
Inline Exhaust Scrubber	Replace	Annually	No														
NO ₂ converter	Clean or Replace Lamps	When the CE value drops suddenly	Yes														
Desiccant bags	Replace	Any time PMT housing is opened for maintenance	n/a														

5.2. PREDICTIVE DIAGNOSTICS

Predictive diagnostic functions, including failure warnings and alarms built into the analyzer's firmware, aid in determining whether and when repairs are necessary.

The Dashboard Functions can also be used to predict failures by looking at how their values change over time, compared to the values recorded on the printed record of the *Final Test and Validation Data Sheet*. The internal data logger is a convenient way to record and track these changes (set up through the Data Logger, Section 2.5.1). Use NumaView™ Remote to download and review this data from a remote location.

The following table, checked weekly, can be used as a basis for taking action as these values change with time.

Table 5-2. Predictive Uses for Dashboard Functions

FUNCTION	EXPECTED	ACTUAL	INTERPRETATION & ACTION
Rx Cell Press (pressure)	Constant to within ± 0.5 in-Hg-A	Fluctuating	Developing leak in pneumatic system. Check for leaks.
		Slowly increasing	Pump performance is degrading. Rebuild pump when pressure is above 10 in-Hg-A.
Sample Press (pressure)	Constant within atmospheric changes	Fluctuating	Developing leak in pneumatic system. Check for leaks.
		Slowly increasing	Flow path is clogging up. Replace orifice filters.
		Slowly decreasing	Developing leak in pneumatic system to vacuum (developing valve failure). Check for leaks.
O3 Flow	Constant to within ± 15	Slowly decreasing	Flow path is clogging up. Replace orifice filters.
Auto Zero	Constant within ± 20 of check-out value	Significantly increasing	Developing AUTO ZERO valve failure. Replace valve.
			PMT cooler failure. Check cooler, circuit, and power supplies.
			Developing light leak.
			O ₃ air filter cartridge is exhausted. Change chemical.
NO2 Conc (Concentration)	Constant for constant concentrations	Slowly decreasing signal for same concentration	Converter efficiency may be degrading. Clean or replace converter components.
NO2 Conc with IZS Option installed (Concentration)	Constant response from day to day	Decreasing over time	Change in instrument response. Low level (hardware): calibrate the sensor. Degradation of IZS permeation tube. Change permeation tube.
		Heavily fluctuating day to day	Ambient changes in moisture are affecting the performance. Add a dryer to the zero air inlet.
NO Conc (Concentration)	Constant for constant concentration	Decreasing over time	Drift of instrument response; clean RCEL window. Check for flow leaks or irregularities.

5.3. SOFTWARE/FIRMWARE UPDATES

There are two ways to check for and acquire updates: either remotely or manually.

5.3.1. REMOTE UPDATES

The instrument must be connected to a network that is connected to the Internet. In the Setup>Instrument menu, select the Remote Update menu and the Check for Updates button. If an update is available, it can be downloaded through this page.

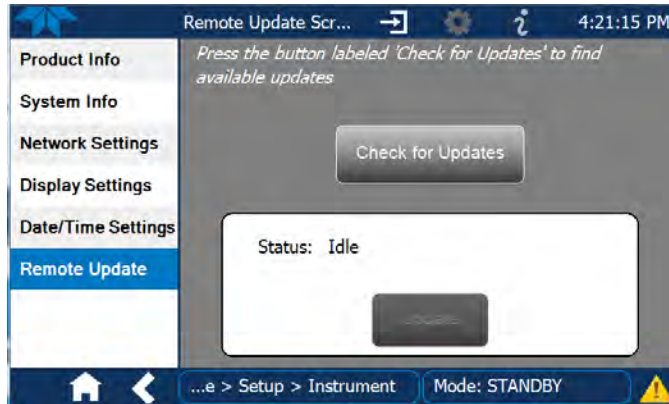


Figure 5-1. Remote Update Page

5.3.2. MANUAL RELOAD/UPDATE PROCEDURES

To reload or update firmware, first contact Technical Support to obtain the applicable file(s): sda_techsupport@teledyne.com / 800-324-5190.

1. Follow Technical Support’s instructions for copying the firmware files to a flash drive.
2. Go to the Utilities>USB Utilities menu.

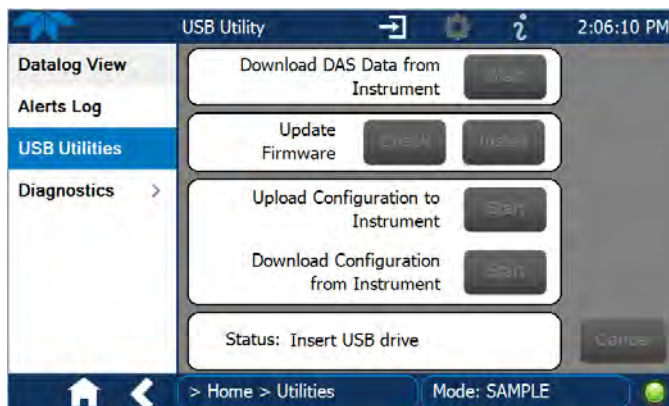


Figure 5-2. Manual Update Page (and other utilities)

3. Insert a flash drive into a front panel USB port and wait for the Status field to indicate that the drive has been detected.

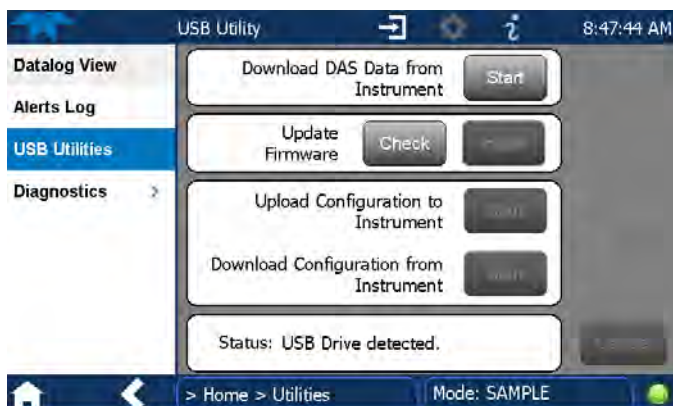


Figure 5-3. Manual Update, USB Drive Detected Page

4. In the Update Firmware field, press the Check button for the instrument to determine whether the firmware on the flash drive is more recent than what is currently installed. Once it's been determined that the firmware is new, the Install button will be enabled; if the firmware version on the flash drive is the same as or older than the current firmware of the instrument, the Install button will not be enabled.



Figure 5-4. Manual Update Install Page

5. Press the Install button, and note the messages in the Status field at the bottom of the page. Use the Cancel button if necessary.
6. When complete, as indicated in the Status field, press the Done button, which replaces the Cancel button, and remove the flash drive.
7. Power off and restart the instrument to complete the new firmware installation.

5.3.3. ADJUSTING THE INSTRUMENT DISPLAY SETTINGS

Although unlikely, if ever the touchscreen appears unresponsive or responds incorrectly, the screen can be calibrated via the Setup>Instrument>Display Settings menu.

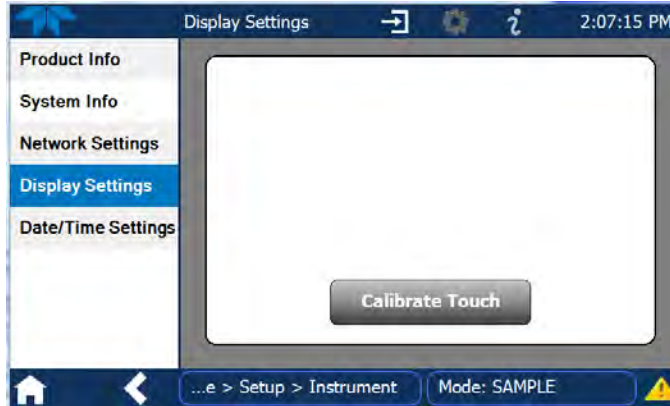


Figure 5-5. Touchscreen Calibration Page

1. Connect a mouse to either of the front panel USB ports.
2. Navigate with the pointer to Setup>Instrument>Display Settings.
3. Click on “Calibrate Touch” and a crosshair appears in the center of the display screen.

Note

A timer function is enabled, allowing only 15 seconds to start the calibration process. If the timer expires, the instrument will exit the calibration screen and return to normal operation.

4. Click the very center of the crosshair.
5. When a new crosshair appears in the upper left corner of the screen, carefully and accurately click and hold the very center of that crosshair until it finishes shrinking, then release.
6. Repeat Step 5 for each of the corners.
7. Once the process is completed, a CANCEL and an ACCEPT button appear in the lower left corner: Test the accuracy of the calibration by touching parts of the screen and see that the mouse pointer follows your touches.
8. If you press the CANCEL button, the calibration won't be altered. Otherwise, press the ACCEPT button.

If any difficulties persist, contact TAPI Technical Support:

sda_techsupport@teledyne.com / 800-324-5190

5.4. HARDWARE MAINTENANCE PROCEDURES

Perform the following procedures as standard maintenance per Table 5-1.

5.4.1. REPLACING THE SAMPLE PARTICULATE FILTER

Inspect the particulate filter often for signs of plugging or contamination. Do not touch any part of the housing, filter element, PTFE retaining ring, glass cover and the o-ring with your bare hands: use gloves or PTFE coated tweezers or similar handling to avoid contamination of the sample filter assembly.

To change the filter:

1. Turn OFF the analyzer to prevent drawing debris into the instrument.
2. Open the hinged front panel and unscrew the retaining ring on the filter assembly.

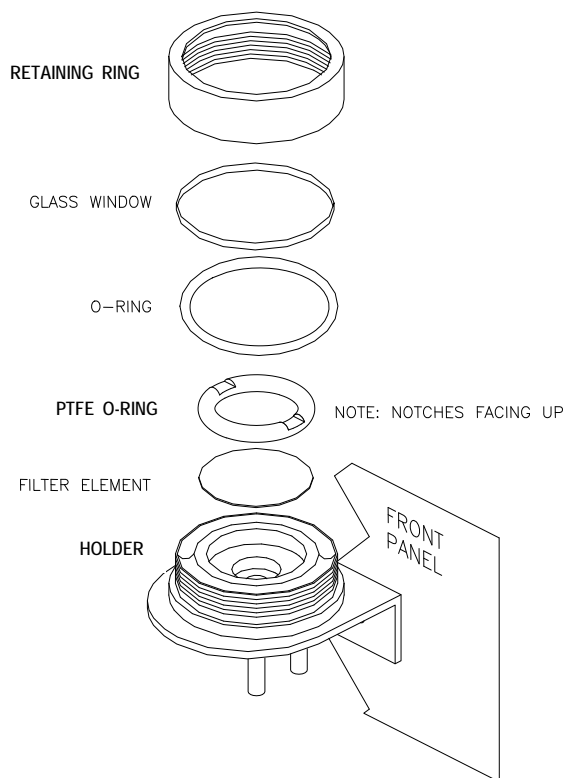


Figure 5-6. Replacing the Particulate Filter

3. Carefully remove the retaining ring, PTFE o-ring, glass window and filter element.
4. Replace the filter, being careful that the element is fully seated and centered in the bottom of the holder.
5. Reinstall the PTFE o-ring with the notches up; the glass window, then screw on the retaining ring and hand tighten. Inspect the seal between the edge of filter and the o-ring to assure a proper seal.
6. Close the panel and restart the analyzer.

5.4.2. CHANGING THE O₃ DRYER PARTICULATE FILTER

The air for the O₃ generator passes through a dryer equipped with a small particulate filter at its inlet, which prevents dust from entering the ozone dryer and degrading the dryer's performance over time. Change the filter as follows:

1. Before starting the procedure, check and record the average Rx Cell Press and the O₃ Flow values in the Dashboard. (If not visible, see Section 2.5.3 to configure).
2. Turn off the analyzer, unplug the power cord and remove the cover.
3. Unscrew the nut around the port of the filter using two 5/8" wrenches.

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Ensure to use proper wrenches.

Hold the main dryer fitting with a 5/8" wrench to ensure that it does not turn against the dryer.

Performing this procedure improperly or with incorrect tools creates the risk of causing a significant leak.

4. Take off the old filter element and replace it with a suitable equivalent (Teledyne API P/N FL-3).

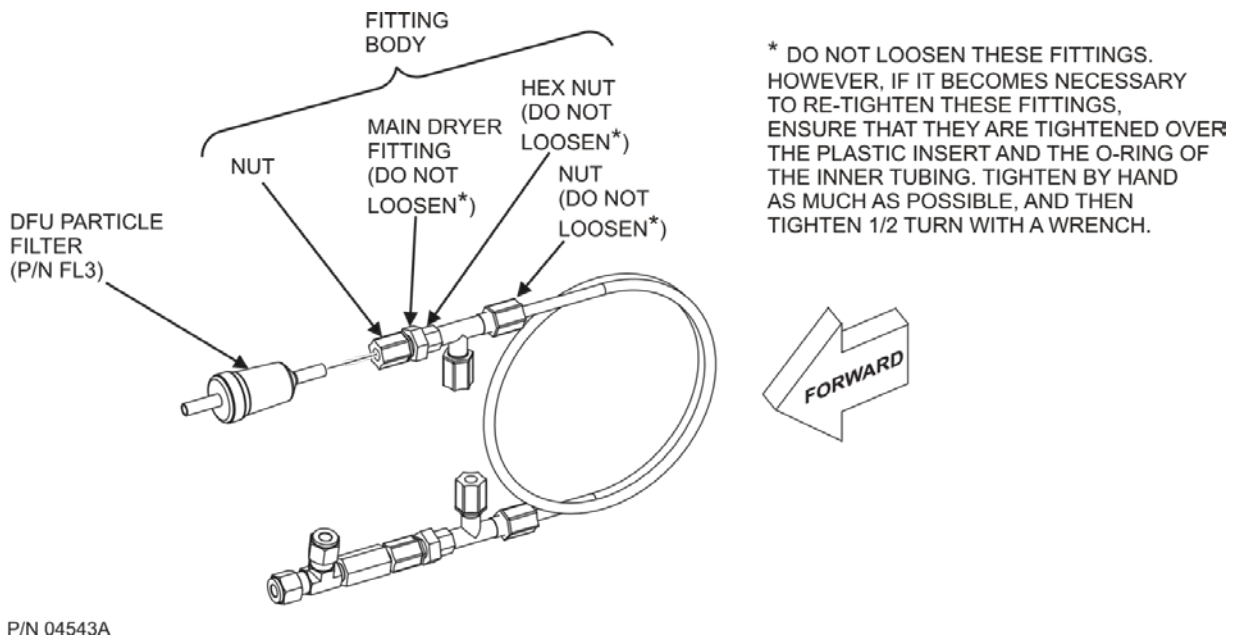


Figure 5-7. Particle Filter on O₃ Supply Air Dryer

5. Hold the main dryer fitting steady with a 5/8" wrench and tighten the nut with your hands.
6. If necessary use a second wrench but do not over-tighten the nut.
7. Replace the cover, plug in the power cord and restart the analyzer.
8. Check the O₃ flow (O₃ Flow) rate; it should be around 80 cc/min ± 15.
8. Check the Rx Cell Press; it should be the same value as before.
9. Refer to Section 5.4.11 to perform a leak check after installing the new DFU particle filter.

5.4.3. CHANGING THE OZONE CLEANSER CHEMICAL

The ozone (O₃) cleanser (Figure 5-8) is located next to the O₃ generator (see Figure 2-3 for location) and cleans the O₃ stream from solid and liquid contaminants that are created inside the O₃ generator. The content of the ozone cleanser needs periodical exchange according to Table 5-1. A rebuild kit is available from the factory (see Appendix B of this manual lists the part numbers).

To change the ozone cleanser chemical, follow these steps:

1. Turn off power to the analyzer and pump.
2. Remove the analyzer cover and locate the O₃ filter in the front of the analyzer next to the O₃ generator.
3. Use a 7/16" wrench to remove both pieces of 1/8" male nut with tubing from the NPT fittings.

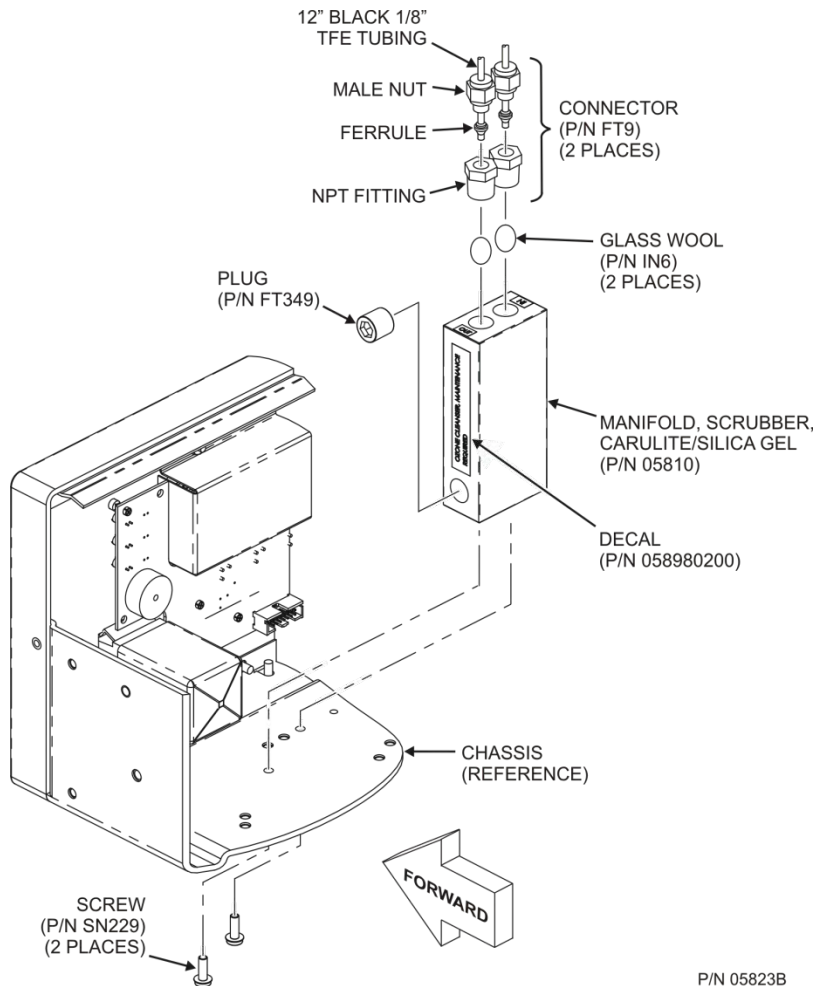


Figure 5-8. Ozone Cleanser Assembly

4. Remove the integrated screws with a Phillips screw driver and remove the scrubber manifold from the chassis.
5. Using a 9/16" wrench, remove both fittings from the cartridge.
6. Discard the glass wool.

7. Pour the contents of the scrubber manifold onto a sheet of white paper. If necessary, remove the plug to ensure that all the contents are poured out.
 - Notice any discoloration of the contents, which is usually white and slightly transparent.
 - The amount of discolored chemical (usually with yellow tint) may give you an indication of the lifetime of the chemical in your application.
 - The maintenance cycle of this item is dependent on ambient moisture, sub-micron particle load and other factors and may differ from that shown in Table 5-1.
8. Discard the used silica gel desiccant without touching it. It may contain nitric acid, which is a corrosive and highly irritating substance.



CAUTION – GENERAL SAFETY HAZARD

Immediately wash your hands after contact with the silica gel desiccant.

9. Using a small powder funnel, fill the cartridge with about 10 g new silica gel desiccant (Teledyne API P/N CH43) so that it is level on both legs of the cartridge.
 - Slight vibration is required to settle the chemical into the cartridge and achieve tightest packing, which increases performance and lifetime of the filter.
 - Ensure that the level of the chemical does not protrude farther than the first two threads of the NPT fitting.

Important

IMPACT ON READINGS OR DATA

Use only genuine, pre-conditioned Teledyne API's refill kits for this procedure. Teledyne API's refill kits have been properly conditioned to prevent a significant increase of the Auto Zero value which can cause large negative offsets, which may take 2-3 weeks to disappear.

Do not leave this material uncovered for more than a few seconds, as it will absorb contaminants from ambient air. Always store unused, well-covered refill material in a cool dry place.

10. Seal the silica gel desiccant with 1 cm³ of glass wool on each well.
 - Ensure that the plug is large enough and compressed into the cartridge so that the chemical is securely held in place.
11. Add new Teflon tape (P/N HN000036) to the NPT fittings.
12. Screw the NPT fittings back into the scrubber manifold.
13. Screw the cartridge back onto the chassis; orientation is not important.
14. Evaluate the ferrules on the tubing.
 - If the ferrules are too old, we recommend replacing them with new ferrules.

15. Reconnect the tubing using 7/16" and 9/16" wrenches.
 - Do not over-tighten the fittings.
16. If the service interval for this item has been exceeded, it may also be necessary to clean the reaction cell as described in Section 5.4.8.
17. Leak check the system using the pressurized approach described in Section 5.4.11.2.
 - If necessary, tighten the fittings some more but do not over-tighten.
18. Restart the analyzer and pump and continue operation.
19. Recalibrate the analyzer after one hour (Section 4).
 - If Auto Zero is high or is changing/not constant, you may have to wait a day until the silica gel is conditioned before recalibrating the instrument.

5.4.4. MAINTAINING THE EXTERNAL SAMPLE PUMP (PUMP PACK)

5.4.4.1. REBUILDING THE PUMP

The sample pump head periodically wears out and must be replaced when the **Rx Cell Press** exceeds 10 in-Hg-A (at sea level, adjust this value accordingly for elevated locations).

- A pump rebuild kit is available from the factory. Refer to the label on the pump for the part number. Instructions and diagrams are included in the kit.
- A flow and leak check after rebuilding the sample pump is recommended.
- A span check and re-calibration after this procedure is necessary as the response of the analyzer changes with the **Rx Cell Press**.

5.4.4.2. REPLACING THE SCRUBBER



CAUTION!

Do NOT attempt to change the contents of the inline exhaust scrubber cartridge; change the entire cartridge.

1. Through the Utilities>Diagnostics menu turn OFF the O3 Gen Override. Wait 10 minutes to allow pump to pull room air through scrubber before proceeding to the next step.
2. Disconnect exhaust line from analyzer.
3. Turn off (unplug) analyzer sample pump.
4. Disconnect tubing from (NOx or charcoal) scrubber cartridge.
5. Remove scrubber from system.
6. Dispose of according to local laws.
7. Install new scrubber into system.
8. Reconnect tubing to scrubber and analyzer.

9. Turn on pump.
10. Through the Utilities>Diagnostics menu (per Step 1 above) turn ON the O3 Gen Override.

5.4.5. CHANGING THE INTERNAL SPAN GAS GENERATOR PERMEATION TUBE

1. Turn off the analyzer, unplug the power cord and remove the cover.
2. Locate the permeation tube (Sample Gas Conditioner, see Figure 2-4) oven in the rear left of the analyzer.
3. Remove the top layer of insulation if necessary.
4. Unscrew the black aluminum cover of the oven (3 screws) using a medium Phillips-head screw driver.
 - Leave the fittings and tubing connected to the cover.
5. Remove the old permeation tube and replace it with the new tube (or store the permeation tube in its original container if the instrument will not be operated for several or more hours).
 - Ensure that the tube is placed into the larger of two holes and that the open permeation end of the tube (plastic) is facing up.
6. Re-attach the cover with three screws.
 - Ensure that the three screws are tightened evenly.
7. Replace the analyzer cover, plug the power cord back in and turn on the analyzer.
8. Carry out a span check to see if the new permeation device works properly (see Section 4).
9. The permeation rate may need several days to stabilize.

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Do not leave instrument turned off for more than 8 hours without removing the permeation tube. Do not ship the instrument without removing the permeation tube. The tube continues to emit NO₂, even at room temperature and will contaminate the entire instrument.

5.4.6. CHANGING THE EXTERNAL ZERO AIR SCRUBBER (OPT 86C)

The external zero air scrubber that is included with several of the analyzer's optional calibration valve packages contains two chemicals:

- Pink Purafil[®] (P/N CH 9) that converts NO in the ambient air to NO₂, and;
- Black, charcoal (P/N CH 1) that absorbs the NO₂ thereby creating zero air.

These chemicals need to be replaced periodically (see Table 5-1) or as needed.



CAUTION!

The following procedures apply only to the External Zero Air Scrubber and NOT to the inline exhaust scrubber cartridge that is part of the pump pack assembly.

Important

IMPACT ON READINGS OR DATA

This procedure can be carried out while the instrument is running, however ensure that the analyzer is not in ZERO calibration mode.

1. Locate the scrubber on the outside rear panel; Figure 5-9 shows the exploded assembly.
2. Remove the old scrubber by disconnecting the 1/4" plastic tubing from the DFU particle filter using 9/16" and 1/2" wrenches.
3. Remove the DFU particle filter from the cartridge using 9/16" wrenches.
4. Unscrew the top of the scrubber canister and discard the Purafil[®] and charcoal contents.
 - Ensure to abide to local laws about discarding these chemicals.
 - The rebuild kit (listed in Appendix B) comes with a Material and Safety Data Sheet, which contains more information on these chemicals.
5. It is not necessary to remove the insert from the barrel, but if removed, perform the following procedure:
 - Coat the threads of the insert with epoxy (Teledyne API P/N CH32).
 - Hand tighten the insert to the barrel.
6. It is not necessary to remove the nylon tube fitting from the insert, but if removed, apply Teflon tape (Teledyne API P/N HW36) to the threads of the nylon tube fitting before installing on the insert.
7. Refill the scrubber with charcoal at the bottom and the Purafil[®] chemical at the top.
 - Use three, white retainer pads to separate the chemicals as shown Figure 5-9.
8. Replace the screw-top cap and tighten the cap; hand-tighten only.

9. If necessary, replace the filter with a new unit and discard the old..
 - The bottom retainer pad should catch most of the dust; the filter should not be visibly dirty (on the inside).
10. Replace the scrubber assembly into its clips on the rear panel.
11. Reconnect the plastic tubing to the fitting of the DFU particle filter.
12. Adjust the scrubber cartridge such that it does not protrude above or below the analyzer in case the instrument is mounted in a rack.
 - If necessary, squeeze the clips for a tighter grip on the cartridge.

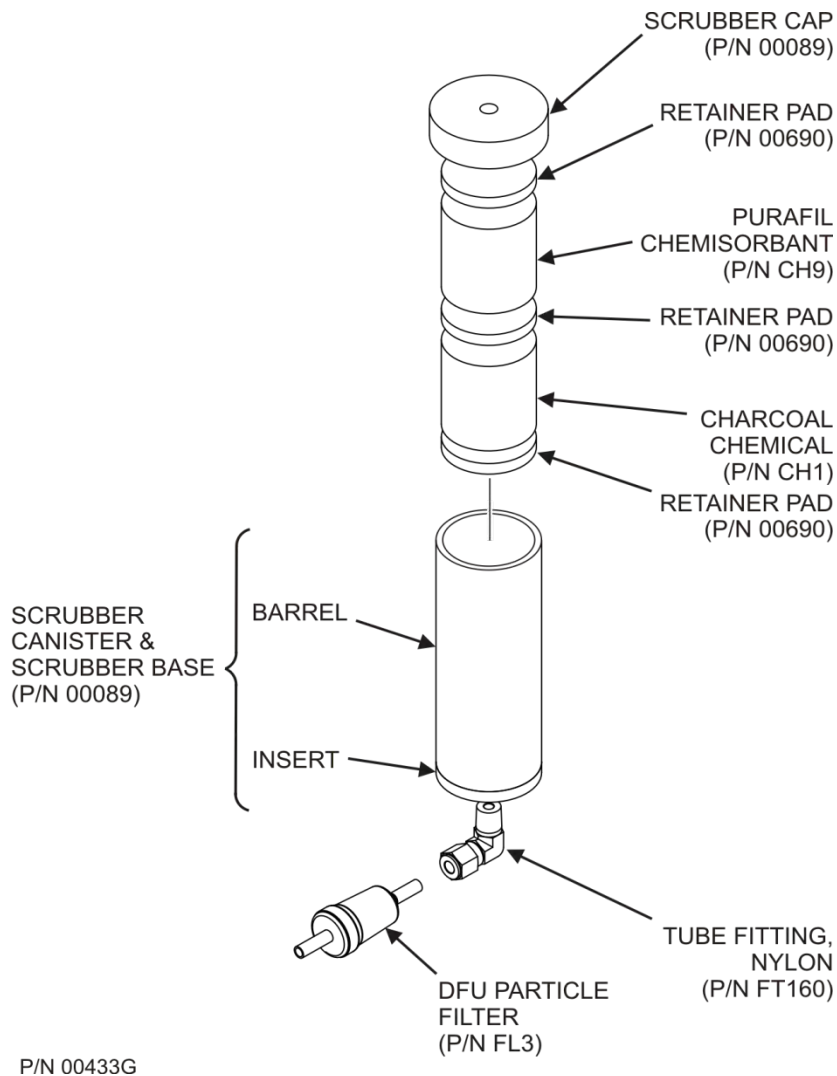


Figure 5-9. Zero Air Scrubber Assembly

5.4.7. CHANGING OR CLEANING A NO₂ CONVERTER LAMP

The NO₂ converter (Blue Light Converter) is located in the center of the instrument; see Figure 2-3 for the location, and Figure 5-10 for the assembly.

The converter is designed for replacement of both lamp assemblies, located at either end of the converter.



CAUTION! PERSONAL SAFETY HAZARD: HIGH INTENSITY LIGHT

Never open the photolytic converter while power is ON. The LEDs emit high intensity light.

1. Power OFF the instrument.
2. Remove the setscrew located in the top, center of the front panel and remove the top cover of the instrument, sliding the cover backward until it clears the front bezel, and lifting straight up.
3. Locate the Photolytic Converter assembly (Figure 2-3) and remove both lamp assemblies as follows:

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY
Handle electrical connectors gently – they are delicate.

- a. Gently disconnect the electrical connectors (they are delicate) between the housing and each lamp assembly (Figure 5-10).
 - b. Remove the four screws holding the body of the converter to the base plate. Remove the Photolytic Converter assembly from the analyzer.
 - c. Remove the four screws that secure the lamp assembly at either end of the housing.
4. Either clean or replace as follows, then continue to Step 7.
 - For cleaning, wipe the LEDs and the surfaces within the quartz sleeve chamber.
 - For replacement, remove each lamp assembly and install the replacement lamps.
 5. Reassemble in reverse order (screws, electrical connection).

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY
Do not use force during reconnection: the arrows on the molded connectors should face inward so that they point toward each other.

6. Conduct a leak check per instructions in this manual's Maintenance section.
7. Calibrate per the procedures in Section 4.2 and check the converter efficiency per Section 4.5.

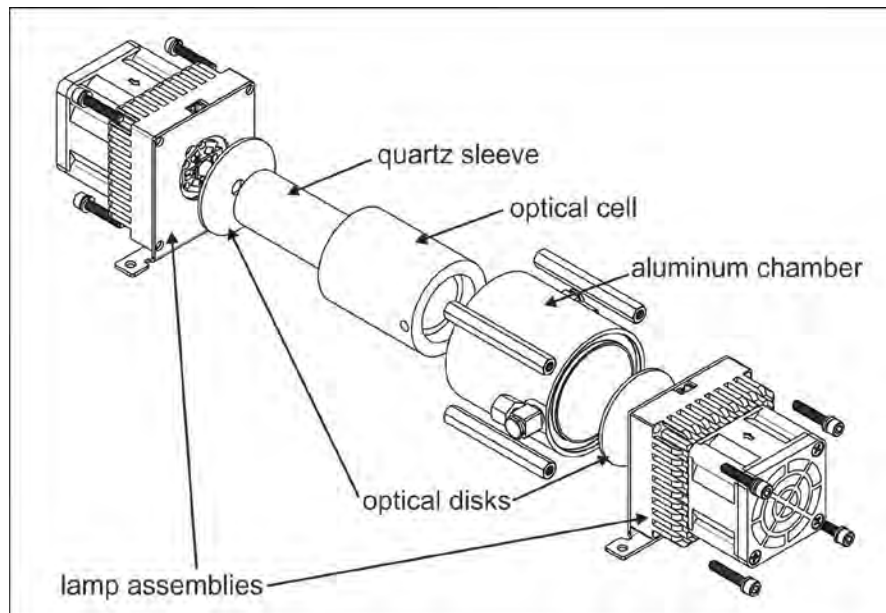


Figure 5-10. Photolytic Lamp Assembly Replacement

During regular maintenance, check the four hex head screws on each lamp assembly and tighten if necessary.

5.4.8. CLEANING THE REACTION CELL

A dirty reaction cell will cause excessive noise, drifting zero or span values, low response or a combination of all.

To clean the reaction cell, it is necessary to remove it from the sensor housing. Refer to Figure 5-11 for the following procedure.

1. Turn off the instrument power and vacuum pump.
2. Disconnect the black 1/4" exhaust tube and the 1/8" sample and ozone air tubes from the reaction cell. Disconnect the heater/thermistor cable.
3. Remove two screws (Teledyne API P/N SN144) and two washers holding the reaction cell to the PMT housing and lift the cell and manifold out.

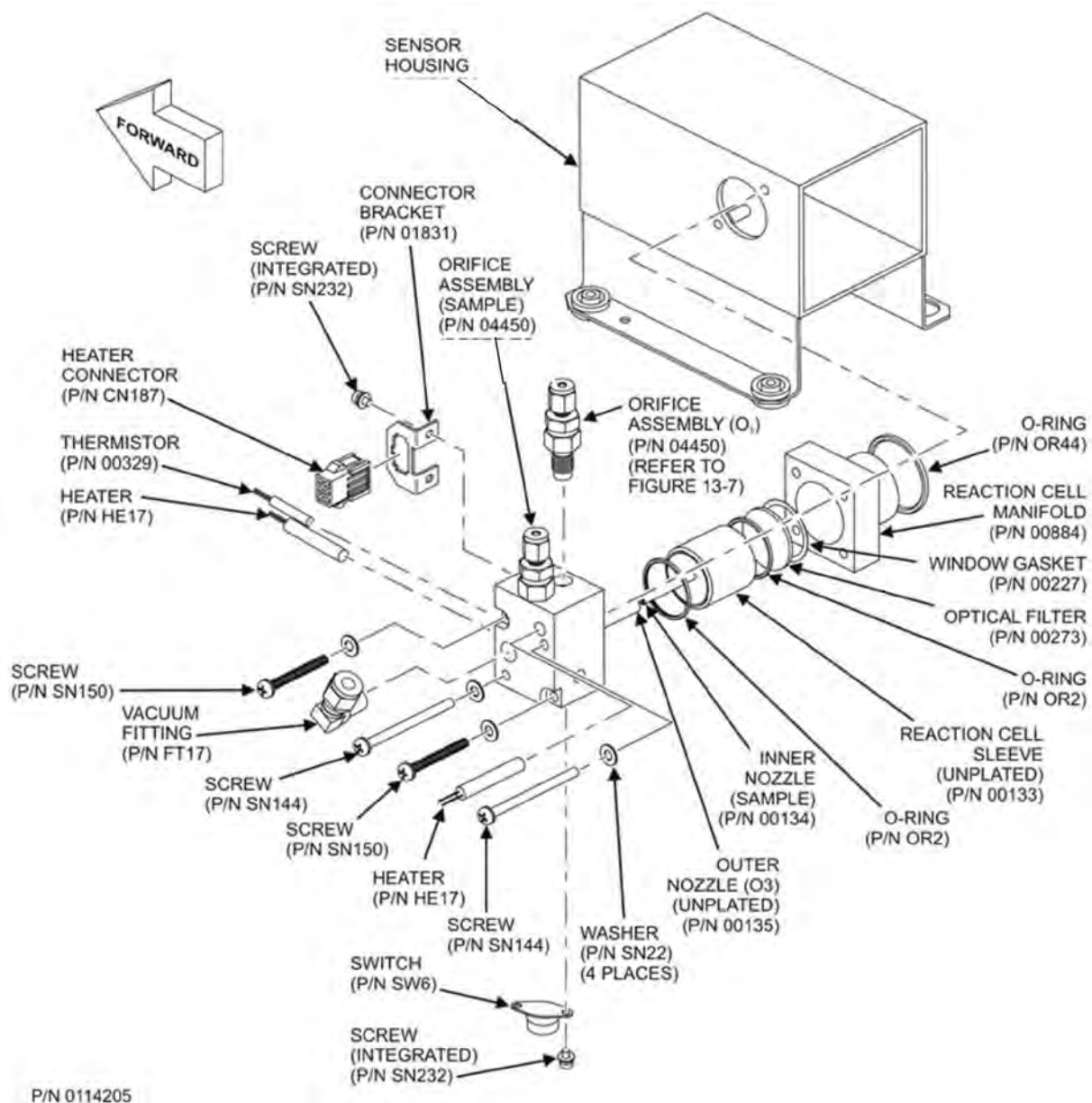


Figure 5-11. Reaction Cell Assembly

4. Remove two screws (Teledyne API P/N SN150) and two washers.
5. The reaction cell will separate into two halves, the stainless steel manifold assembly and the black plastic reaction cell with window gasket, stainless steel reaction cell sleeve, optical filter and O-rings.
6. The reaction cell (both plastic part and stainless steel sleeve) and optical filter should be cleaned with Distilled Water (DI - Water) and a clean tissue, and dried thereafter.
7. Usually it is not necessary to clean the sample and ozone flow orifices since they are protected by sintered filters.
 - If tests show that cleaning is necessary, refer to Section 5.4.9 on how to clean the critical flow orifice.

8. Do not remove the sample and ozone nozzles. They are Teflon threaded and require a special tool for reassembly. If necessary, the manifold with nozzles attached can be cleaned in an ultrasonic bath.
9. Reassemble in proper order and re-attach the reaction cell to the sensor housing. Reconnect pneumatics and heater connections, then re-attach the pneumatic sensor assembly and the cleaning procedure is complete.
10. After cleaning the reaction cell, it is also recommended to exchange the ozone supply air filter chemical as described in Section 5.4.3.
11. After cleaning, the analyzer span response may drop 10 - 15% in the first 10 days as the reaction cell window conditions. This is normal and does not require another cleaning.

5.4.9. SERVICING CRITICAL FLOW ORIFICES

There are several critical flow orifices installed in the analyzer (see Figure 6-8 for a pneumatic location of each orifice). Despite the fact that these flow restrictors are protected by sintered stainless steel filters, they can, on occasion, clog up, particularly if the instrument is operated without sample filter or in an environment with very fine, sub-micron particle-size dust.

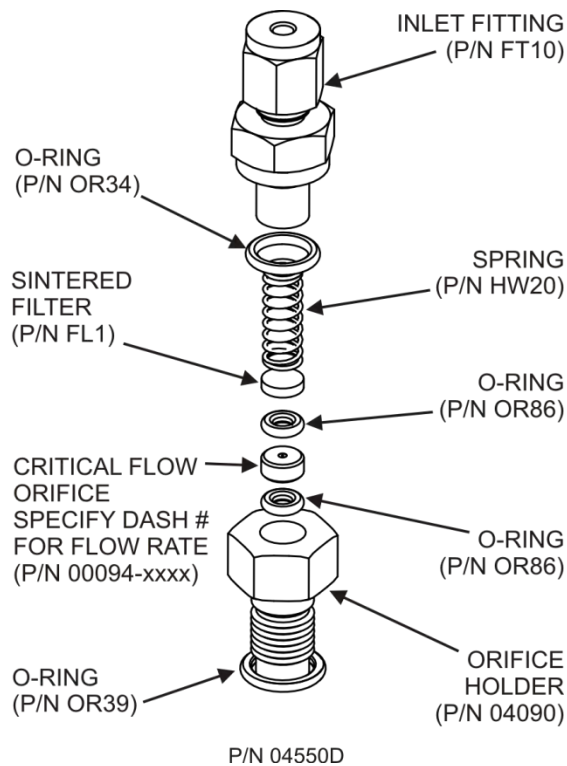


Figure 5-12. Critical Flow Orifice Assembly

To clean or replace a critical flow orifice:

1. Turn off power to the instrument and vacuum pump.
2. Remove the analyzer cover and locate the reaction cell assembly (refer to Figure 2-3 and Figure 5-11).
3. Unscrew the 1/8" sample and ozone air tubes from the reaction cell.

For orifices on the reaction cell:

4. Unscrew the orifice holder with a 9/16" wrench.
 - This part holds all components of the critical flow assembly as shown in Figure 5-12.

For orifices in the vacuum manifold: the assembly is similar to the one shown in Figure 5-12, except:

- Without the orifice holder, P/N 04090, and bottom O-ring, P/N OR34 and;
 - With an NPT fitting in place of the FT 10 fitting.
5. After taking off the connecting tube, unscrew the NPT fitting.
 6. Take out the components of the assembly:
 - spring
 - sintered filter
 - two O-rings
 - the orifice

Note

For the vacuum manifold only, you may need to use a scribe or pressure from the vacuum port to get the parts out of the manifold.

7. Discard the two O-rings and the sintered filter and install new ones.
8. Reassemble the parts as shown in Figure 5-12.
9. Reinstall the critical flow orifice assembly into the reaction cell manifold or the vacuum manifold.
10. Reconnect all tubing, power up the analyzer and pump. After a warm-up period of 30 minutes, carry out a leak test as described in Section 5.4.11.

5.4.10. CHECKING FOR LIGHT LEAKS

When re-assembled or operated improperly, the PMT assembly can develop small gaps, which let stray light from the analyzer surrounding into the PMT housing. To find such light leaks, follow the procedures below.



CAUTION – QUALIFIED PERSONNEL ONLY

This procedure is carried out with the analyzer running and its cover removed.

1. In the Dashboard view the **PMT Signal** (if not visible, configure the Dashboard to add; see Section 2.5.3).

2. Supply zero gas to the analyzer.
3. With the instrument still running, carefully remove the analyzer cover.



WARNING – ELECTRICAL SHOCK HAZARD

Do NOT touch any of the inside wiring with the metal cover or with your body.

Do NOT drop screws or tools into a running analyzer.

4. Shine a powerful flashlight or portable incandescent light at the inlet and outlet fitting and at all of the joints of the reaction cell as well as around the PMT housing.
 - The PMT value should not respond to the light, the PMT signal should remain steady within its usual noise floor.
5. If there is a PMT response to the external light, symmetrically tighten the reaction cell mounting screws or replace the 1/4" vacuum tubing with new, black PTFE tubing (this tubing will fade with time and become transparent).

Note

Often, light leaks are also caused by O-rings being left out of the assembly.

6. If, during this procedure, the black PMT housing end plate for the Sensor Assembly is removed, ensure to replace the 5 desiccant bags inside the housing.
7. Carefully replace the analyzer cover. If tubing was changed, carry out a pneumatic leak check (Section 5.4.11).

5.4.11. CHECKING FOR PNEUMATIC LEAKS



CAUTION - TECHNICAL INFORMATION

Do not exceed 15 psi when pressurizing the system during either Simple or Detailed checks.

5.4.11.1. SIMPLE VACUUM LEAK AND PUMP CHECK

Leaks are the most common cause of analyzer malfunction. This section presents a simple leak check, whereas the next section details a more thorough procedure. The method described here is easy, fast and detects, but does not locate, most leaks. It also verifies the sample pump condition.

1. Turn the analyzer ON, and allow at least 30 minutes for flows to stabilize.
2. Cap the sample inlet port (cap must be wrench-tight).
3. After several minutes, when the pressures have stabilized, note the Sample Press (sample pressure) and the Rx Cell Press (vacuum pressure) readings.
 - If both readings are equal to within 10% and less than 10 in-Hg-A, the instrument is free of large leaks.
 - It is still possible that the instrument has minor leaks.

- If both readings are < 10 in-Hg-A, the pump is in good condition.
 - A new pump will create a pressure reading of about 4 in-Hg-A (at sea level).
4. When done switch off the pump and open the cap to the sample inlet port slowly to minimize inrush flow.

5.4.11.2. DETAILED PRESSURE LEAK CHECK

If a leak cannot be located by the above procedure, obtain a leak checker that contains a small pump, shut-off valve, and pressure gauge to create both over-pressure and vacuum. Alternatively, a tank of pressurized gas, with the two-stage regulator adjusted to ≤ 15 psi, a shutoff valve and a pressure gauge may be used.

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Once tube fittings have been wetted with soap solution under a pressurized system, do not apply or reapply vacuum as this will cause soap solution to be sucked into the instrument, contaminating inside surfaces.

1. Turn OFF power to the instrument and remove the instrument cover.
2. Install a leak checker or a tank of gas (compressed, oil-free air or nitrogen) as described above on the sample inlet at the rear panel.
3. Disconnect the pump tubing on the outside rear panel and cap the pump port.
 - If IZS or zero/span valves are installed, disconnect the tubing from the zero and span gas ports and plug the ports.
 - Cap the DFU particle filter on the dryer.
4. Pressurize the instrument with the leak checker or tank gas, allowing enough time to fully pressurize the instrument through the critical flow orifice.
 - Check each tube connection (fittings, hose clamps) with soap bubble solution, looking for fine bubbles.
 - Once the fittings have been wetted with soap solution, do not reapply vacuum as it will draw soap solution into the instrument and contaminate it.
 - Do not exceed 15 psi pressure.
5. If the instrument has the zero and span valve option, the normally closed ports on each valve should also be separately checked.
 - Connect the leak checker to the normally closed ports and check with soap bubble solution.
6. If the analyzer is equipped with an IZS Option, connect the leak checker to the Dry Air inlet and check with soap bubble solution.
7. Once the leak has been located and repaired, the leak-down rate of the indicated pressure should be less than 1 in-Hg-A (0.4 psi) in 5 minutes after the pressure is turned off.
8. Clean surfaces from soap solution, reconnect the sample and pump lines and replace the instrument cover.
9. Restart the analyzer.

5.4.11.3. PERFORMING FLOW CHECKS/CALIBRATIONS

Important

IMPACT ON READINGS OR DATA

Use a separate, calibrated flow meter capable of measuring the flow specifications for the instrument being checked/calibrated in order to get accurate measurements. Do not use the built in flow measurement viewable in the Dashboard. This value is only calculated, not measured.

The rates of sample gas flow and O₃ flow through the analyzer are a key part of the NO_x, NO and NO₂ concentration readings, but the readings are only calculated values derived by the CPU. The Flow Cal and Ozone Flow Cal features under the Utilities>Diagnostics menu are used to check and to calibrate/adjust these calculations.

Such checks are useful for monitoring the actual flow of the instrument, using an external flow meter. A decreasing, actual sample flow may point to slowly clogging pneumatic paths, most likely critical flow orifices or sintered filters (Section 5.4.9).

FLOW CHECK

Low flows indicate blockage somewhere in the pneumatic pathway.

To check the Sample flow with the external flow meter:

1. Disconnect the sample inlet tubing from the rear panel SAMPLE port.
2. Attach the outlet port of a suitable flow meter to the rear panel SAMPLE port.
 - Ensure that the inlet to the flow meter is at atmospheric pressure.
3. The sample flow measured with the external flow meter should be within $\pm 10\%$ of the analyzer's Flow specification (Table 1-1).
 - If a combined sample/ozone air dryer is installed (optional equipment), the flow will be an additional 80 cc/min for the ozone generator supply air and 60 cc/min for the purge flow).

To check the Ozone flow with the external flow meter:

1. Open the analyzer to gain access to the reaction cell.
2. Disconnect the tube going to the reaction cell's 4 mil fitting.
3. Connect the flow meter to the reaction cell's 4 mil fitting.
4. The ozone flow measured with the external flow meter should be 80 cc/min.

FLOW CALIBRATION

To calibrate the Sample flow (Flow Cal) or the O₃ flow (Ozone Flow Cal):

1. In the Utilities>Diagnostics>Flow Cal or Ozone Flow Cal menu (Figure 5-13), edit the Actual Flow value by inputting the reading from the external flow meter obtained in the corresponding check of the flow to be calibrated.
2. Press the Calibrate button.

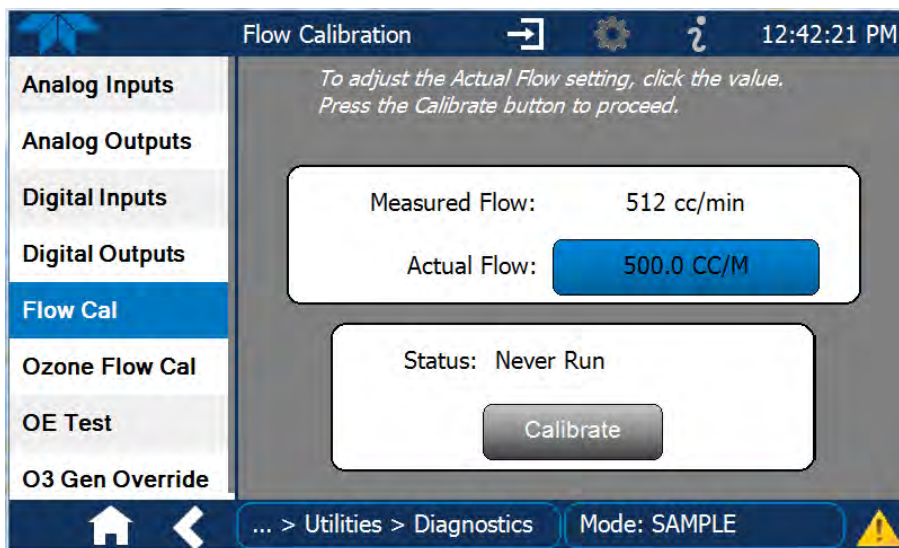


Figure 5-13. Flow Calibration Menu

5.5. SERVICE AND TROUBLESHOOTING

This section contains methods to identify the source of performance problems with the analyzer and procedures to service the instrument.

Note

Section 6, Principles of Operation, provides information about how the instrument works, to support your understanding of the technical details of maintenance.



CAUTION

The operations outlined in this section must be performed by qualified maintenance personnel only.



WARNING – RISK OF ELECTRICAL SHOCK

Some operations need to be carried out with the analyzer open and running.

Exercise caution to avoid electrical shocks and electrostatic or mechanical damage to the analyzer.

Do not drop tools into the analyzer or leave them after your procedures.

Do not short or touch electric connections with metallic tools while operating inside the analyzer.

Use common sense when operating inside a running analyzer.

The analyzer has been designed so that problems can be rapidly detected, evaluated and repaired. During operation, it continuously performs diagnostic tests and provides the ability to evaluate its key operating parameters without disturbing monitoring operations.

A systematic approach to troubleshooting will generally consist of the following five steps:

1. Note any Alerts and take corrective action as necessary (see Table 5-3).
2. Examine the values of all basic functions in the Dashboard and compare them to factory values. Note any major deviations from the factory values and take corrective action.
3. Use the internal electronic status LEDs to determine whether the electronic communication channels are operating properly.
 - Verify that the DC power supplies are operating properly by checking the voltage test points on the relay PCA.
 - Note that the analyzer's DC power wiring is color-coded and these colors match the color of the corresponding test points on the relay PCA.
4. Suspect a leak first!
 - Customer service data indicate that the majority of all problems are eventually traced to leaks in the internal pneumatics of the analyzer or the diluent gas and source gases delivery systems.
 - Check for gas flow problems such as clogged or blocked internal/external gas lines, damaged seals, punctured gas lines, damaged / malfunctioning pumps, etc.
5. Follow the procedures defined in Section 2.3.4.3 to confirm that the analyzer's vital functions are working (power supplies, CPU, relay PCA, touchscreen, PMT cooler, etc.).

5.5.1. FAULT DIAGNOSIS WITH ALERTS

Table 5-3 lists brief descriptions of warning Alerts that may occur during start up and describes their possible causes for diagnosis and troubleshooting..

It should be noted that if more than two or three warning Alerts occur at the same time, it is often an indication that some fundamental sub-system (power supply, relay PCA, motherboard) has failed rather than an indication of the specific failures referenced by the warnings.

Table 5-3. Warning Alerts, Fault Conditions and Possible Causes

WARNING	FAULT CONDITION	POSSIBLE CAUSES
AUTO ZERO WARN XXX.X MV	AutoZero reading too high. (Auto-zero reading above 200 mV). Value shown in message indicates auto-zero reading at time warning was displayed.	AUTO ZERO valve not working Valve control driver failed Bad Relay PCA Failed +12 VDC power supply Gas leak across AUTO ZERO Valve ports Dirty Reaction Cell O ₃ flow problem to RCELL

WARNING	FAULT CONDITION	POSSIBLE CAUSES
BOX TEMP WARNING	Temperature of chassis is outside specified limits. (typically < 7°C or > 48°C)	Box Temperature typically runs ~7°C warmer than ambient temperature Poor/blocked ventilation to the analyzer Stopped Exhaust-Fan Ambient Temperature outside of specified range
CANNOT DYN SPAN ²	Dynamic Span operation failed. (Contact closure span calibration failed while <i>DYN_SPAN</i> was set to ON).	Measured concentration value is too high or low Concentration Slope value to high or too low
CANNOT DYN ZERO ³	Dynamic Zero operation failed. (Contact closure zero calibration failed while <i>DYN_ZERO</i> was set to ON).	Measured concentration value is too high Concentration Offset value to high
CONFIG INITIALIZED	Configuration and Calibration data reset to original Factory state or erased.	Failed Disk on Module User erased data
O3 DESTRUCT TEMP WARNING	O ₃ Destruct temperature out of range	Heater configured for wrong voltage type Failed O ₃ Destruct Temperature Sensor Relay controlling the Heater is not working Failed Relay Board
DATA INITIALIZED	Data Storage in DAS was erased before the last power up occurred.	Failed Disk-on-Module User cleared data.
HVPS WARNING	High voltage power supply output is too high or too low for proper operation of the PMT. (Outside of warning limits).	No +15 VDC power supply to Preamplifier PCA Drive voltage not adjusted properly Failed PMT Preamplifier PCA Dirty reaction cell Bad pneumatic flow
OZONE FLOW WARNING	Ozone gas flow is too high or too low for accurate NO _x , NO and NO ₂ readings. (O ₃ flow rate < 50 cc/min or > 150 cc/min).	Failed Sample Pump Blocked O ₃ dryer Blocked inlet/outlet to O ₃ purifier Dirty O ₃ dryer DFU Leak downstream of RCELL Failed O ₃ Flow Sensor
OZONE GEN OFF ⁴	Ozone generator is off. This is the only warning message that automatically clears itself. It clears itself when the ozone generator is turned on. Upon power up the Ozone generator will remain off for 30 minutes, which allows the ozone dryer to reach its working dew point.	O ₃ generator override is turned ON. Electrical connection between motherboard and generator is faulty. Bad +15VDC power supply
IZS TEMP WARNING ⁵	IZS temperature is too high or too low for efficient O ₃ production. (Permeation tube oven temperature is < 45°C or > 55°C).	Heater configured for wrong voltage type Failed permeation tube Temperature Sensor Relay controlling the Heater is not working Failed Relay Board

WARNING	FAULT CONDITION	POSSIBLE CAUSES
PMT TEMP WARNING	PMT temperature outside of warning limits. (Sample temperature is < 5°C or > 12°C).	PMT fan not operating Failed PMT Temperature Sensor TEC not functioning Failed PMT Preamp PCA
RCELL PRESS WARN	Reaction cell pressure is too high or too low for accurate NO _x , NO and NO ₂ readings. (Sample Pressure is <15 in-Hg or > 35 in-Hg). Normally 29.92 in-Hg at sea level decreasing at 1 in-Hg per 1000 ft of altitude (with no flow – pump disconnected).	If Sample Pressure is < 15 in-Hg: •Blocked Particulate Filter •Blocked Sample Inlet/Gas Line •Failed Pressure Sensor/circuitry If Sample Pressure is > 35 in-Hg: •Bad Pressure Sensor/circuitry •Pressure too high at Sample Inlet.
RCELL TEMP WARN	Reaction cell temperature is too high or too low for accurate NO _x , NO and NO ₂ readings. (RCELL temperature is < 45°C or > 55°C).	Heater configured for wrong voltage type Failed RCELL Temperature Sensor Relay controlling the heater is not working Failed Relay Board I ² C Bus
REAR BOARD NOT DET	Motherboard not detected on power up. (CPU unable to communicate with motherboard).	This warning only appears on Serial I/O COM Port(s). Front panel display will be frozen, blank or will not respond. Failure of motherboard
RELAY BOARD WARN	The CPU unable to communicate with the Relay PCA.	I ² C Bus failure Failed Relay Board Loose connectors/wiring
SAMPLE FLOW WARN	The flow rate of the sample gas is outside the specified limits. (Sample flow rate is < 350 cc/min or > 600 cc/min).	Failed Sample Pump Blocked Sample Inlet/Gas Line Dirty Particulate Filter Leak downstream of RCELL Critical Flow Orifice Failed Sample Pressure Sensor Failed Vacuum Pressure Sensor
SYSTEM RESET	The computer has rebooted.	This message occurs at power on. If it is confirmed that power has not been interrupted: Failed +5 VDC power Fatal Error caused software to restart Loose connector/wiring

- ¹ Clears 45 minutes after power up.
- ² Clears the next time successful zero calibration is performed.
- ³ Clears the next time successful span calibration is performed.
- ⁴ Clears 30 minutes after power up.
- ⁵ Only appears if the IZS option is installed.

5.5.2. FAULT DIAGNOSIS WITH DASHBOARD FUNCTIONS

In addition to being useful as predictive diagnostic tools, the functions viewable in the Dashboard can be used to isolate and identify many operational problems when combined with a thorough understanding of the analyzer's principles of operation (see Section 6).

The acceptable ranges for these functions are listed in the "Nominal Range" column of the analyzer *Final Test and Validation Data Sheet* shipped with the instrument. Values outside these acceptable ranges indicate a failure of one or more of the analyzer's subsystems. Functions whose values are still within acceptable ranges but have significantly changed from the measurement recorded on the factory data sheet may also indicate a failure.

Make note of these values for reference in troubleshooting.

Note

A value of "XXXX" displayed for any of these Dashboard functions indicates an OUT OF RANGE reading.

Note

Sample Pressure measurements are represented in terms of "Absolute Atmospheric Pressure" because this is the least ambiguous method for reporting gas pressure.

Absolute atmospheric pressure is about 29.92 in-Hg-A at sea level. It decreases about 1 in-Hg per 1000 ft gain in altitude. A variety of factors such as air conditioning systems, passing storms, and air temperature, can also cause changes in the absolute atmospheric pressure.

Table 5-4. Dashboard Functions - Indicated Failures

DASHBOARD FUNCTION	INDICATED FAILURE(S)
Stability	Unstable concentrations; leaks
Sample Flow	Leaks; clogged critical flow orifice
O3 Flow	Leaks; clogged critical flow orifice
PMT	Calibration off; HVPS problem; no flow (leaks)
Norm PMT	Auto Zero too high
Auto Zero	Leaks; malfunctioning NO, NO _x or Auto Zero valve; O ₃ air filter cartridge exhausted
HVPS	Calibration off; preamp board circuit problems
Rx Cell Temp	Malfunctioning heater; relay board communication (I ² C bus); relay burnt out
BOX TEMP	Environment out of temperature operating range; broken thermistor
PMT TEMP	TEC cooling circuit broken; relay board communication (I ² C bus); 12 V power supply
IZS TEMP (option)	Malfunctioning heater; relay board communication (I ² C bus); relay burnt out
O3 Destruct Assy Temp	Malfunctioning heater; disconnected or broken thermocouple; relay board communication (I ² C bus); relay burnt out; incorrect AC voltage configuration
Rx Cell Pressure	Leak; malfunctioning valve; malfunctioning pump; clogged flow orifices
Sample Pressure	Leak; malfunctioning valve; malfunctioning pump; clogged flow orifices; sample inlet overpressure
NO_x Slope	HVPS out of range; low-level (hardware) calibration needs adjustment; span gas concentration incorrect; leaks
NO_x Norm Offset	Incorrect span gas concentration; low-level calibration off
NO Slope	HVPS out of range; low-level calibration off; span gas concentration incorrect; leaks
NO Norm Offset	Incorrect span gas concentration; low-level calibration off

5.5.3. USING THE DIAGNOSTIC SIGNAL I/O FUNCTIONS

The signal I/O functions in the Utilities>Diagnostics menu allows access to the digital and analog I/O in the analyzer. Some of the digital signals can be controlled through the Setup menu. These signals, combined with a thorough understanding of the instrument's principles of operation (Section 6), are useful for troubleshooting in three ways:

- The technician can view the raw, unprocessed signal level of the analyzer's critical inputs and outputs.
- Many of the components and functions that are normally under algorithmic control of the CPU can be manually exercised.
- The technician can directly control the signal level Analog and Digital Output signals.

This allows the technician to observe systematically the effect of directly controlling these signals on the operation of the analyzer. Use the Utilities>Diagnostics menu to view the raw voltage of an input signal or the Setup menu to control the state of an output voltage or control signal.

5.5.4. USING THE ANALOG OUTPUT CHANNEL

The signals available for output over the analyzer's analog output channel (configured in the Setup>Analog Outputs menu; see Section 2.5.8) can also be used as diagnostic tools through the Utilities>Diagnostics menu.

Table 5-5. Channel Outputs as Diagnostic Tools

TEST CHANNEL	DESCRIPTION	ZERO	FULL SCALE	CAUSES OF EXTREMELY HIGH / LOW READINGS
PMT DETECTOR	The output of the PMT detector converted to a 0 to 5 VDC scale.	0 mV	5000 mV	Failed PMT PMT Temperature too High/Low Bad PMT Preamp PCA Failed HVPS Misadjusted HVPS drive Voltage Light Leak in reaction cell
O3 Flow	The flow rate of O ₃ through the analyzer as measured by the O ₃ flow sensor	0 cm ³ /min	1000 cm ³ /min	Check for Gas Flow problems in the O ₃ gas lines.
Sample Flow	The calculated flow rate for sample gas through the analyzer.	0 cm ³ /min	1000 cm ³ /min	Check for Gas Flow problems in the sample gas lines.
Sample Press	The pressure of the sample gas measured upstream of the Auto Zero Valve	0 In-Hg-A	40 In-Hg-A	Check for Gas Flow problems in the sample gas lines.
Rx Cell Press	The pressure of gas inside the reaction cell of the sensor module	0 In-Hg-A	40 In-Hg-A	Check for Gas Flow problems in all gas lines.
Rx Cell Temp	The temperature of gas inside the reaction cell of the sensor module	0 °C	70 °C	Same as RCELL TEMP WARNING in Table 5-3.
IZS Temp (with IZS option)	The temperature of the permeation tube oven of the optional internal span gas generator.	0 °C	70 °C	Same as IZS TEMP WARNING in Table 5-3.
PMT DETECTOR	The output of the PMT detector converted to a 0 to 5 VDC scale.	0 mV	5000 mV	Failed PMT PMT Temperature too High/Low Bad PMT Preamp PCA Failed HVPS Misadjusted HVPS drive Voltage Light Leak in reaction cell
PMT Temp	The temperature inside PMT	0 °C	50 °C	Same as PMT TEMP WARNING in Table 5-3.
Box Temp	The temperature inside the T200's chassis	0 °C	70 °C	Same as BOX TEMP WARNING in Table 5-3.
HVPS VOLTAGE	Represents the output voltage of the PMT's high voltage power supply	0 mV	5000 mV	Same as HVPS WARNING in Table 5-3.

5.5.5. USING THE INTERNAL ELECTRONIC STATUS LEDs

Several LEDs are located inside the instrument to assist in determining if the analyzer's CPU, I²C bus and Relay PCA are functioning properly.

5.5.5.1. CPU STATUS INDICATOR

DS5, a red LED located on the motherboard (Figure 5-14), flashes when the CPU is running the main program loop. After power-up, approximately 30 – 60 seconds, DS5 should flash on and off. If the front panel displays properly but DS5 does not flash, then the program files have become corrupted, contact Teledyne API's Technical Support Department (see Section 5.7) because it may be possible to recover operation of the analyzer. If after 30 – 60 seconds, neither DS5 is flashing nor does the front panel display properly then the CPU is bad and must be replaced.

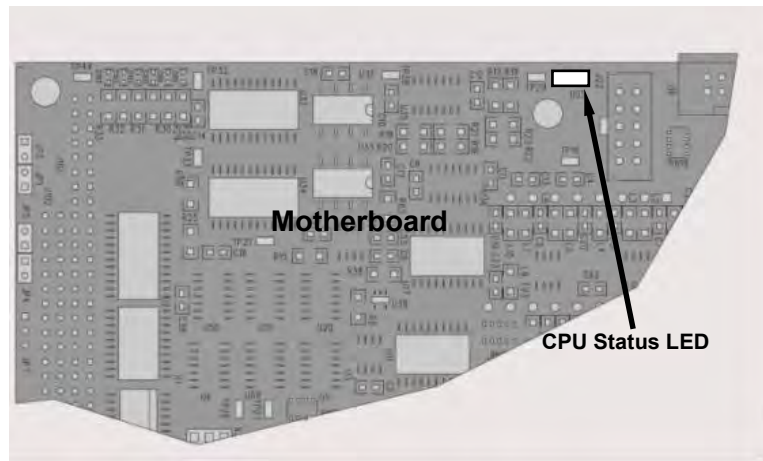


Figure 5-14. CPU Status Indicator

5.5.5.2. RELAY PCA WATCHDOG AND STATUS LEDs

There are sixteen LEDs located on the Relay PCA (some are not used on this model). The most important of the LEDs is D1 (see Figure 5-15), which indicates the health of the I²C bus.

RELAY PCA STATUS LEDs

LEDs that remain continuously on or off (not blinking) indicate a default state for their respective components as described in Table 5-6

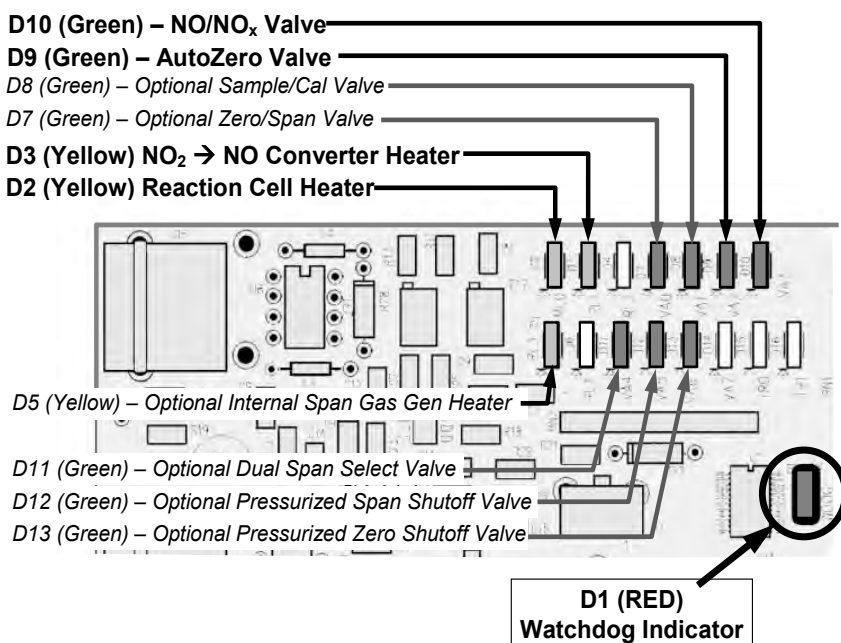


Figure 5-15.T200P Relay PCA Status LEDS Used for Troubleshooting

Table 5-6.T200P Relay PCA Watchdog and Status LED Failure Indications

LED	COLOR	FUNCTION	INDICATED FAILURE(S)
D1	Red	I2C bus Health (Watchdog Circuit)	Failed/Halted CPU. Faulty Motherboard, Touchscreen or Relay PCA. Faulty Connectors/Wiring between Motherboard, Touchscreen or Relay PCA. Failed/Faulty +5 VDC Power Supply (PS1).
LED ROW 1			
D2	Yellow	Reaction Cell heater	Heater broken, thermistor broken
D3	Yellow	O ₃ Destruct heater	Heater broken, thermocouple broken
D7	Green	Zero/Span valve status	Valve broken or stuck, valve driver chip broken
D8	Green	Sample/Cal valve status	Valve broken or stuck, valve driver chip broken
D9	Green	Auto-zero valve status	Valve broken or stuck, valve driver chip broken
D10	Green	NO/NO _x valve status	Valve broken or stuck, valve driver chip broken
LED ROW 2			
D5 ¹	Yellow	Internal span gas generator perm tube heater	Heater broken, thermistor broken
D11 ²	Green	Dual span select valve	Valve broken or stuck, valve driver chip broken
D12 ³	Green	Pressurized Span shutoff valve	Valve broken or stuck, valve driver chip broken
D13 ⁴	Green	Pressurized Zero shutoff valve	Valve broken or stuck, valve driver chip broken

¹ Only active when the optional internal span gas generator is installed.

² Only active when the dual pressurized span option is installed.

³ Only active when one of the pressurized span gas options is installed.

⁴ Only active when one of the pressurized zero gas options is installed.

Note: D4, D6, and D14-16 are not indicated as they are not used.

5.5.6. FLOW PROBLEMS

The analyzer has two main flow paths, the sample flow and the flow of the ozone supply air. With IZS or zero/span valve option installed, there is a third (zero air) and a fourth (span gas) flow path, but either one of those is only controlled by critical flow orifices and not displayed on the front panel or stored to the DAS.

- Flow is too high
- Flow is greater than zero, but is too low, and/or unstable
- Flow is zero (no flow)

When troubleshooting flow problems, it is essential to confirm the actual flow rate without relying on the analyzer's flow display. The use of an independent, external flow meter to perform a flow check as described in Section 5.4.11.3 is essential. Refer to the pneumatic flow diagrams as needed for reference.

5.5.6.1. SAMPLE FLOW IS ZERO OR LOW

The analyzer does not actually measure the sample flow but rather calculates it from a differential pressure between sample and vacuum manifold. On flow failure, the unit will display a SAMPLE FLOW WARNING in the Active Alerts page and the respective function reports nothing instead of a numerical value. This message applies to both a flow rate of zero as well as a flow that is outside the standard range (350-600 cc/min).

If the analyzer displays nothing for the sample flow, confirm that the external sample pump is operating and configured for the proper AC voltage.

- Whereas the analyzer can be internally configured for two different power regimes (100-120 V and 220-240 V, either 50 or 60 Hz), the external pump is physically different for each of three power regimes (100 V / 50 Hz, 115 V / 60 Hz and 230 V / 50 Hz).
- If the pump is not running, use an AC Voltmeter to ensure that the pump is supplied with the proper AC power. If AC power is supplied properly, but the pump is not running, replace the pump.

Note

Sample and vacuum pressures mentioned in this chapter refer to operation of the analyzer at sea level. Pressure values need to be adjusted for elevated locations, as the ambient pressure decreases by about 1 in-Hg per 300 m / 1000 ft.

If the pump is operating but the unit is not reporting gas flow value, take the following three steps:

1. Check for actual sample flow.
 - To check the actual sample flow, disconnect the sample tube from the sample inlet on the rear panel of the instrument.
 - Ensure that the unit is in basic SAMPLE mode.

- Place a finger over the inlet and feel for suction by the vacuum or, more properly, use a flow meter to measure the actual flow.
 - If there is proper flow of around 450-550 cc/min, contact Technical Support.
 - If there is no flow or low flow, continue with the next step.
2. Check pressures.
- Check that the sample pressure is at or around 28 in-Hg-A at sea level (adjust as necessary when in elevated location, the pressure should be about 1" below ambient atmospheric pressure) and that the Rx Cell pressure is below 10 in-Hg-A.
 - The analyzer will calculate a sample flow up to about 14 in-Hg-A RCEL pressure but a good pump should always provide less than 10 in-Hg-A.
 - If both pressures are the same and around atmospheric pressure, the pump does not operate properly or is not connected properly. The instrument does not get any vacuum.
 - If both pressures are about the same and low (probably under 10 in-Hg-A, or ~20" on sample and 15" on vacuum), there is a cross-leak between sample flow path and vacuum, most likely through the dryer flow paths. See troubleshooting the dryer later in this chapter.
 - If the sample and vacuum pressures are around their nominal values (28 and <10 in-Hg-A, respectively) and the flow still displays no numerical value, carry out a leak check as described in Section 5.4.11.
 - If gas flows through the instrument during the above tests but goes to zero or is low when it is connected to zero air or span gas, the flow problem is not internal to the analyzer but likely caused by the gas source such as calibrators/generators, empty gas tanks, clogged valves, regulators and gas lines.
 - If an IZS or Zero/Span valve option is installed in the instrument, press Start in the Calibration>Zero and Span menus. If the sample flow increases, suspect a bad Sample/Cal valve.
3. If none of these suggestions help, carry out a detailed leak check of the analyzer as described in Section 5.4.11.2.

5.5.6.2. OZONE FLOW IS ZERO OR LOW

If there is zero or a low (<50 cc/min) ozone flow, the unit displays an OZONE FLOW WARNING message in the Alerts page and a value between 0.0 and 50 cc/min for the actual ozone flow as measured by the internal mass flow meter. In this case, carry out the following steps:

1. Check the actual flow rate through the ozone dryer by using an external flow meter to the inlet port of the dryer.
 - This inlet port is inside the analyzer at the end of the plastic particle filter (Section 5.4.2 for illustration).
 - If there is nominal flow (about 160 cc/min from 80 cc/min O₃ flow and 80 cc/min purge flow), consult customer service as there is a problem with the firmware or electronics.

2. If the actual flow is low or zero, check if the pump operates properly. The RCEL pressure should be below 10 in-Hg-A at sea level.
3. If it is above 10", rebuild the pump (Section 5.4.4.1). Check the spare parts list in Appendix B on how to order pump rebuild kits.
4. Check if the particle filter is clogged.
 - Briefly remove the particle filter to see if this improves the flow.
 - Be very cautious when handling the dryer fittings (see Section 5.4.2 on proper handling instructions).
 - If the filter is clogged, replace it with a new unit.
 - If taking off this filter does not solve the problem, continue to the next step.
 - Do not leave the dryer without filter for more than a few seconds, as you may draw in dust, which will reduce the performance of the dryer.
5. A leak between the flow meter and the reaction cell (where the flow-determining critical orifice is located) may cause a low flow (the system draws in ambient air through a leak after the flow meter).
 - Check for leaks as described in Section 5.4.11.
 - Repair the leaking fitting, line or valve and re-check.
6. The most likely cause for zero or low ozone flow is a clogged critical flow orifice or sintered filter within the orifice assembly.
 - The orifice that sets the ozone flow is located on the reaction cell.
 - Check the actual ozone flow by disconnecting the tube from the reaction cell and measuring the flow going into the cell.
 - If this flow is correct (~80 cc/min), the orifice works properly.
 - If this flow is low, replace the sintered filter.
 - The orifice holder assembly allows a quick and easy replacement of the filter.
 - Appendix B lists a spare part kit with a complete orifice assembly that allows a quick replacement with minimum instrument down-time.

5.5.6.3. HIGH FLOW

Flow readings that are significantly higher than the allowed operating range (typically $\pm 10-11\%$ of the nominal flow) should not occur in the analyzer unless a pressurized sample, zero or span gas is supplied to the inlet ports.

- Ensure to vent excess pressure and flow just before the analyzer inlet ports.
- When supplying sample, zero or span gas at ambient pressure, a high flow could indicate a broken critical flow orifice (very unlikely case), allowing more than nominal flow, or were replaced with an orifice of wrong specifications.
- If the flows are within 15% above normal, we recommend measuring and recalibrating the flow electronically (Section 5.4.11.3), followed by a regular review of these flows over time to see if the new setting is retained properly.
- Also, check the flow assembly o-rings and replace as needed.

5.5.6.4. SAMPLE FLOW IS ZERO OR LOW BUT ANALYZER REPORTS CORRECT FLOW

The analyzer can report a correct flow rate even if there is no or a low actual sample flow through the reaction cell.

- The sample flow is only calculated from the sample pressure and critical flow condition is verified from the difference between sample pressure and vacuum pressure.
- If the critical flow orifice assembly is partially or completely clogged, both the sample and vacuum pressures are still within their nominal ranges (the pump keeps pumping, the sample port is open to the atmosphere), but there is no flow possible through the reaction cell.

Although measuring the actual flow is the best method, in most cases, this fault can also be diagnosed by evaluating the two pressure values.

- Since there is no longer any flow, the sample pressure should be equal to ambient pressure, which is about 1 in-Hg-A higher than the sample pressure under normal operation.
- The reaction cell pressure, on the other hand, is significantly lower than under normal operation, because the pump no longer has to remove 500 cc/min of sample gas and evacuates the reaction cell much better.
- Those two indicators, taken together with a zero or low actual flow, indicate a clogged sample orifice.

The analyzer features a new orifice holder, which makes switching sample and ozone flow orifices very easy; refer to Section 5.4.9 on how to change the sample orifices and to Appendix B for part numbers of these assemblies.

Again, monitoring the pressures and flows regularly will reveal such problems, because the pressures would slowly or suddenly change from their nominal, mean values. Teledyne API recommends reviewing all test data once per week and to do an exhaustive data analysis for test and concentration values once per month, paying particular attention to sudden or gradual changes in all parameters that are supposed to remain constant, such as the flow rates.

5.5.7. CALIBRATION PROBLEMS

This section describes possible causes of calibration problems.

5.5.7.1. NEGATIVE CONCENTRATIONS

Negative concentration values can be caused for several reasons:

- A slight, negative signal is normal when the analyzer is operating under zero gas and the signal is drifting around the zero calibration point.
- This is caused by the analyzer's zero noise and may cause reported concentrations to be negative for a few seconds at a time down to -20 ppb, but should randomly alternate with similarly high, positive values.

- The analyzer has a built-in Auto Zero function, which should take care of most of these deviations from zero, but may yield a small, residual, negative value.
- If larger, negative values persist continuously, check if the Auto Zero feature is functioning.
- In this case, the sensitivity of the analyzer may be drifting negative.
- A corruption of the Auto Zero filter may also cause negative concentrations.
- If a short, high noise value was detected during the Auto Zero cycle, that higher reading will alter the Auto Zero filter value.
- As the value of the Auto Zero filter is subtracted from the current PMT response, it will produce a negative concentration reading.
- High Auto Zero readings can be caused by
 - a leaking or stuck Auto Zero valve (replace the valve),
 - by an electronic fault in the preamplifier causing it to have a voltage on the PMT output pin during the Auto Zero cycle (replace the preamplifier),
 - by a reaction cell contamination causing high background (>40 mV) PMT readings (clean the reaction cell),
 - by a broken PMT temperature control circuit, allowing high zero offset (repair the faulty PMT cooler). After fixing the cause of a high Auto Zero filter reading, allow 15 minutes for the filter to clear itself, or
 - by an exhausted chemical in the ozone cleanser (see Section 5.4.3).
- Calibration error is the most likely explanation for negative concentration values.
- If the zero air contained some NO or NO₂ gas (contaminated zero air or a worn-out zero air scrubber) and the analyzer was calibrated to that concentration as “zero”, the analyzer may report negative values when measuring air that contains little or no NO_x.
- The same problem occurs, if the analyzer was zero-calibrated using zero gas that is contaminated with ambient air or span gas (cross-port leaks or leaks in supply tubing or user not waiting long enough to flush pneumatic systems).
- If the response offset test functions for NO (NO OFFS) or NO_x (NOX OFFS) are greater than 150 mV, a reaction cell contamination is indicated.
- Clean the reaction cell as described in Section 5.4.8.

5.5.7.2. NO RESPONSE

If the instrument shows no response (display value is near zero) even though sample gas is supplied properly and the instrument seems to perform correctly.

1. Carry out an electrical test with the ELECTRICAL TEST procedure (Run ETest) in the Utilities>Diagnostics>OE Test menu. See Electrical Test (ETest) in Section 5.5.9.11.
 - If this test produces a concentration reading, the analyzer’s electronic signal path is correct.
2. Carry out an optical test using the OPTIC TEST procedure (Run OTest) in the Utilities>Diagnostics>OE Test menu. See Optic Test (OTest) in Section 5.5.9.11.

- If this test results in a concentration signal, then the PMT sensor and the electronic signal path are operating properly.
 - If the analyzer passes both ETest and OTest, it is capable of detecting light and processing the signal to produce a reading.
 - Therefore, the problem must be in the pneumatics or the ozone generator.
3. Check if the ozone generator is turned on.
 - Usually, the analyzer issues a warning whenever the ozone generator is turned off.
 - Go to Utilities>Diagnostics>O3 Gen Override and see if it shows ON.
 - If it shows OFF, turn it ON and check the O3 Flow reading in the Dashboard menu.
 - If this is done and the ozone flow is correct, the analyzer should be properly supplied with ozone unless the generator itself is broken.
 4. Confirm the lack of response by supplying NO or NO₂ span gas of about 80% of the range value to the analyzer.
 5. Check the sample flow and ozone flow rates for proper values.
 6. Check for disconnected cables to the sensor module.
 7. If NO₂ signal is zero while NO signal is correct, check the NO/NO_x valve and the NO₂ converter for proper operation.

5.5.7.3. UNSTABLE ZERO AND SPAN

Leaks in the external gas supply and vacuum systems are the most common source of unstable and non-repeatable concentration readings.

1. Check for leaks in the pneumatic systems as described in Section 5.4.11.
2. Consider pneumatic components in the gas delivery system outside the analyzer such as a change in zero air source (ambient air leaking into zero air line or a worn-out zero air scrubber) or a change in the span gas concentration due to zero air or ambient air leaking into the span gas line.
3. Once the instrument passes a leak check, do a flow check (this chapter) to ensure that the instrument is supplied with adequate sample and ozone air.
4. Confirm the sample pressure, sample temperature, and sample flow readings are correct and steady.
5. Verify that the sample filter element is clean and does not need to be replaced.

5.5.7.4. INABILITY TO SPAN - DEACTIVATED SPAN BUTTON

In general, the analyzer will deactivate certain buttons whenever the actual value of a parameter is outside of the expected range for that parameter. If the Span is grayed out, the actual concentration must be outside of the range of the expected span gas concentration, which can have several reasons.

1. Verify that the expected concentration is set properly to the actual span gas concentration in the CONC sub-menu.

2. Confirm that the NO_x span gas source is accurate.
 - This can be done by comparing the source with another calibrated analyzer, or by having the NO_x source verified by an independent traceable photometer.
3. Check for leaks in the pneumatic systems as described in Section 5.4.11.
 - Leaks can dilute the span gas and, hence, the concentration that the analyzer measures may fall short of the expected concentration defined in the CONC sub-menu.
4. If the low-level, hardware calibration has drifted (changed PMT response) or was accidentally altered by the user, a low-level calibration may be necessary to get the analyzer back into its proper range of expected values.
 - One possible indicator of this scenario is a slope or offset value that is outside of its allowed range (0.7-1.3 for slope, -20 to 150 for offsets). See Section 5.5.10.4 on how to carry out a low-level hardware calibration.

5.5.7.5. INABILITY TO ZERO - DEACTIVATED ZERO BUTTON

In general, the analyzer will deactivate certain buttons whenever the actual value of a parameter is outside of the expected range for that parameter. If the Zero button is grayed out, the actual gas concentration must be significantly different from the actual zero point (as per last calibration), which may be for any of several reasons.

1. Confirm that there is a good source of zero air. If the IZS option is installed, compare the zero reading from the IZS zero air source to a zero air source using NO_x-free air. Check any zero air scrubber for performance. It may need to be replaced (Section 5.4.4.2).
2. Check to ensure that there is no ambient air leaking into zero air line. Check for leaks in the pneumatic systems as described in Section 5.4.11.

5.5.7.6. NON-LINEAR RESPONSE

The analyzer was factory calibrated to a high level of NO and should be linear to within 1% of full scale. Common causes for non-linearity are:

- Leaks in the pneumatic system:
 - Leaks can add a constant of ambient air, zero air or span gas to the current sample gas stream, which may be changing in concentrations as the linearity test is performed.
 - Check for leaks as described in Section 5.4.11.
- The calibration device is in error:
 - Check flow rates and concentrations, particularly when using low concentrations.
 - If a mass flow calibrator is used and the flow is less than 10% of the full scale flow on either flow controller, you may need to purchase lower concentration standards.
- The standard gases may be mislabeled as to type or concentration.

- Labeled concentrations may be outside the certified tolerance.
- The sample delivery system may be contaminated.
 - Check for dirt in the sample lines or reaction cell.
- Calibration gas source may be contaminated (NO₂ in NO gas is common).
- Dilution air contains sample or span gas.
- Ozone concentration too low because of wet air in the generator.
 - Generator system needs to be cleaned and dried with dry supply air.
 - Check the dryer for leaks.
 - This mostly affects linearity at the low end.
- Ozone stream may be contaminated with impurities.
 - An exhausted ozone cleanser chemical will let compounds such as HNO₃ and ammonia derivatives break through to the reaction cell.
 - Check the contents of the ozone cleanser and replace as necessary (Section 5.4.3).
 - This also will affect linearity mostly at the low level.
- Sample inlet may be contaminated with NO_x exhaust from this or other analyzers.
 - Verify proper venting of the pump exhaust.
- Span gas overflow is not properly vented and creates a back-pressure on the sample inlet port.
 - Also, if the span gas is not vented at all and does not supply enough sample gas, the analyzer may be evacuating the sample line.
 - Ensure to create and properly vent excess span gas.
- Diffusion of oxygen into Teflon-type tubing over long distances.
 - PTFE or related materials can act as permeation devices. In fact, the permeable membrane of NO₂ permeation tubes is made of PTFE.
 - When using very long supply lines (> 1 m) between high concentration span gases and the dilution system, oxygen from ambient air can diffuse into the line and react with NO to form NO₂.
 - This reaction is dependent on NO concentration and accelerates with increasing NO concentration, hence, affects linearity only at high NO levels.
 - Using stainless steel for long span gas supply lines avoids this problem.

5.5.7.7. DISCREPANCY BETWEEN ANALOG OUTPUT AND DISPLAY

If the concentration reported through the analog outputs does not agree with the value reported on the front panel, you may need to recalibrate the analog outputs.

- This becomes more likely when using a low concentration or low analog output range.
- Analog outputs running at 0.1 V full scale should always be calibrated manually.
- See Section 2.5.8.1 for a detailed description of this procedure.

5.5.7.8. DISCREPANCY BETWEEN NO AND NO_x SLOPES

If the slopes for NO and NO_x are significantly different after software calibration (more than 1%), consider the following three problems:

- NO₂ impurities in the NO calibration gas. NO gases often exhibit NO₂ on the order of 1-2% of the NO value.
- This will cause differences in the calibration slopes. If the NO₂ impurity in NO is known, it can easily be accounted for by setting the expected values for NO and NO₂ accordingly to different values, e.g., 448 ppb NO and 450 ppb NO_x.
- This problem is worse if NO gas is stored in a cylinder with balance air instead of balance gas nitrogen or large amounts of nitrous oxide (N₂O).
- The oxygen in the air slowly reacts with NO to yield NO₂, increasing over time.
- The expected concentrations for NO and NO_x in the calibration menu are set to different values.
- If a gas with 100% pure NO is used, this would cause a bias.
- See Section 4.2 on how to set expected concentration values.

An instrument calibration with the IZS option (and expected concentrations set to the same amount) will always yield identical slopes for NO and NO_x, as the instrument measures only NO_x and assumes NO to be the same (with NO₂ being zero).

5.5.8. OTHER PERFORMANCE PROBLEMS

Dynamic problems (i.e. problems that only manifest themselves when the analyzer is monitoring sample gas) can be the most difficult and time consuming to isolate and resolve. The following section provides an itemized list of the most common dynamic problems with recommended troubleshooting checks and corrective actions.

5.5.8.1. EXCESSIVE NOISE

Excessive noise levels under normal operation usually indicate leaks in the sample supply or the analyzer itself.

- Ensure that the sample or span gas supply is leak-free and carry out a detailed leak check as described earlier in this chapter.

Another possibility of excessive signal noise may be the preamplifier board, the high voltage power supply and/or the PMT detector itself.

- Contact the factory on troubleshooting these components.

5.5.8.2. SLOW RESPONSE

If the analyzer starts responding too slow to any changes in sample, zero or span gas, check for the following:

- Dirty or plugged sample filter or sample lines.
- Sample inlet line is too long.

- Leaking NO/NO_x valve. Carry out a leak check.
- Dirty or plugged critical flow orifices. Check flows, pressures and, if necessary, change orifices (Section 5.4.9).
- Wrong materials in contact with sample - use glass, stainless steel or Teflon materials only. Porous materials, in particular, will cause memory effects and slow changes in response.
- Dirty reaction cell. Clean the reaction cell.
- Insufficient time allowed for purging of lines upstream of the analyzer. Wait until stability is low.
- Insufficient time allowed for NO or NO₂ calibration gas source to become stable. Wait until stability is low.
- O₃ Destruct temperature is too low. Check for proper temperature.

5.5.8.3. AUTO ZERO WARNINGS

Auto Zero warnings occur if the signal measured during an Auto Zero cycle is higher than 200 mV.

Note

The Auto-Zero warning displays the value of the Auto Zero reading when the warning occurs.

- If this value is higher than 150 mV, check that the Auto Zero valve is operating properly.
- To do so, use the Utilities>Diagnostics>Digital Outputs menu to toggle the valve on and off.
- Listen if the valve is switching, see if the respective LED on the relay board is indicating functionality.
- Alternatively, navigate to the Dashboard and observe the PMT value change between the two valve states.
- If the valve is operating properly, you should be able to hear it switch (once a minute under normal operation or when manually activated from the Utilities>Diagnostics>Digital Outputs menu):
 - the PMT value should drop from span gas reading (e.g., 800-900 mV at 400 ppb NO) to less than 150 mV and;
 - the LED on the relay board should light up when the valve is activated.
- If the PMT value drops significantly but not to less than 150 mV, the valve is probably leaking across its ports.
 - In this case, replace the valve.
- If the PMT value does not change at all, the valve is probably not switching at all.
 - Check the power supply to the valve (12 V to the valve should turn on and off when measured with a voltmeter).

Note

It takes only a small leak across the ports of the valve to show excessive Auto Zero values when supplying high concentrations of span gas.

Another reason for high (although not necessarily out-of-range) values for Auto Zero could be the ozone air filter cartridge, if its contents have been exhausted and must be replaced.

- This filter cartridge chemicals that can cause chemiluminescence and, if saturated, these chemicals can break through to the reaction cell, causing an erroneously high Auto Zero value (background noise).

A dirty reaction cell can cause high Auto Zero values.

- Clean the reaction cell according to Section 5.4.8.

Finally, a high HVPS voltage value may cause excess background noise and a high Auto Zero value.

- The HVPS value changes from analyzer to analyzer and could show nominal values between 450 and 800 V.
- Check the low-level hardware calibration of the preamplifier board and, if necessary, recalibrate exactly as described in Section 5.5.10.4 in order to minimize the HVPS.

5.5.9. SUBSYSTEM CHECK FOR TROUBLESHOOTING

The preceding sections of this manual discussed a variety of methods for identifying possible sources of failures or performance problems within the analyzer. In most cases this included a list of possible causes and, in some cases, quick solutions or at least a pointer to the appropriate sections describing them. This section describes how to determine if a certain component or subsystem is actually the cause of the problem being investigated.

5.5.9.1. AC MAIN POWER

The analyzer's electronic systems will operate with any of the specified power regimes. As long as system is connected to 100-120 VAC or 220-240 VAC at either 50 or 60 Hz it will turn on and after about 30 seconds show a front panel display.

- Internally, the status LEDs located on the Relay PCA, Motherboard and CPU should turn on as soon as the power is supplied.
- If they do not, check the circuit breaker built into the ON/OFF switch on the instrument's front panel.
- If the configuration plug is set for 115 or 100 VAC and the unit is plugged into a 230 VAC circuit, the circuit breaker built into the ON/OFF Switch on the front panel will trip to the OFF position immediately after power is switched on.



WARNING – ELECTRICAL SHOCK HAZARD

Should the AC power circuit breaker trip, investigate and correct the condition causing this situation before turning the analyzer back on.

5.5.9.2. DC POWER SUPPLY

If the analyzer’s AC mains power is working, check the DC output with a voltmeter at the test points described in Table 5-7 and shown in Figure 5-16. Refer to Table 5-8 for acceptable values.

Check for excessive noise (> 100 mV p-p), using an oscilloscope in AC mode with band limiting turned on.

Table 5-7. DC Power Test Point and Wiring Color Codes

NAME	TEST POINT#	COLOR	DEFINITION
DGND	1	Black	Digital ground
+5V	2	Red	
AGND	3	Green	Analog ground
+15V	4	Blue	
-15V	5	Yellow	
+12R	6	Purple	12 V return (ground) line
+12V	7	Orange	

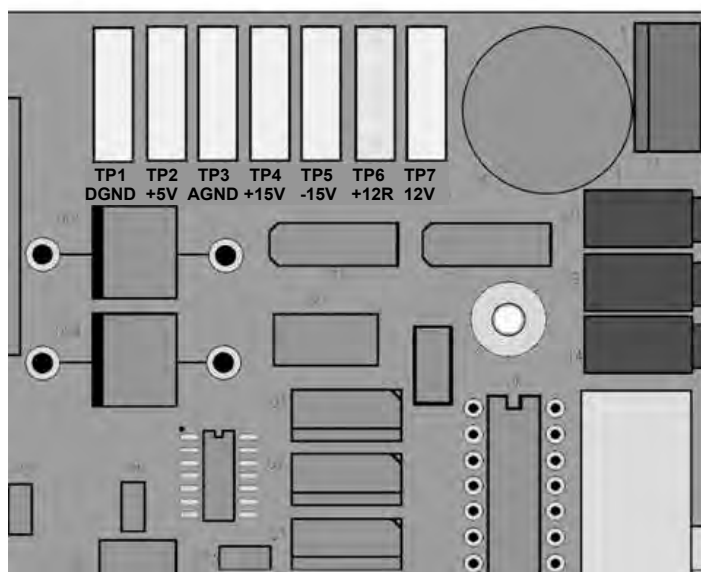


Figure 5-16. Location of DC Power Test Points on Relay PCA

Table 5-8. DC Power Supply Acceptable Levels

POWER SUPPLY	VOLTAGE	CHECK RELAY BOARD TEST POINTS				MIN V	MAX V
		FROM Test Point		TO Test Point			
		NAME	#	NAME	#		
PS1	+5	DGND	1	+5	2	+4.98	+5.02
PS1	+15	AGND	3	+15	4	+13.5	+16.5
PS1	-15	AGND	3	-15V	5	-14	-16.0
PS1	AGND	AGND	3	DGND	1	-0.05	+0.05
PS1	Chassis	DGND	1	Chassis	N/A	-0.05	+0.05
PS2	+12	+12V Ret	6	+12V	7	+11.5	+12.5
PS2	DGND	+12V Ret	6	DGND	1	-0.03	+0.03
Note: 24 V supply is dedicated to powering only the photolytic converter and has an independent source.							
PS3	+24V	PWR	n/a	n/a	n/a	+23.0	+25.0

5.5.9.3. I²C BUS

Verify operation of the I²C bus by checking whether the LEDs are flashing at the Relay PCA's D1 and the Valve Driver PCA's D2. If both are solid lit or are not on, and the DC power supplies are operating properly, there is a problem with the I²C bus.

5.5.9.4. LCD/DISPLAY MODULE

Assuming that there are no wiring problems and that the DC power supplies are operating properly, the display screen should light and show the splash screen and other indications of its state as the CPU goes through its initialization process.

5.5.9.5. RELAY PCA

The Relay PCA can be most easily checked by observing the condition of its status LEDs (see Section 5.5.5.2), and using the Utilities>Diagnostics>Digital Outputs menu (see Section 5.5.3) to toggle each LED ON or OFF.

If D1 on the Relay PCA is flashing and the status indicator for the output in question (Heater power, Valve Drive, etc.) toggles properly using the Signal I/O function, then the associated control device on the Relay PCA is bad.

Several of the control devices are in sockets and can be easily replaced. The following table lists the control device associated with a particular function:

Table 5-9. Relay PCA Control Devices

FUNCTION	CONTROL DEVICE	SOCKETED
All valves	U5	Yes
Reaction Cell Heater	K1	Yes
O ₃ Destruct Heater	K2	Yes
Permeation Tube Heater for Optional Internal Span Gas Generator	K4	Yes

5.5.9.6. MOTHERBOARD

A/D FUNCTIONS

The simplest method to check the operation of the A-to-D converter on the motherboard is to navigate to the Dashboard and check the two A/D reference voltages and input signals that can be easily measured with a voltmeter (configure the Dashboard to show the necessary parameters).

1. Navigate to the Dashboard to view the value of Ref 4096mV and Ref Ground.
 - If both are within 3 mV of nominal (4096 and 0), and are stable, ± 0.2 mV then the basic A/D is functioning properly. If not then the motherboard is bad.
2. Choose a parameter in the Dashboard function list such as O3FLOW.
 - Compare the voltage at its origin (see the interconnect drawing and interconnect list in Appendix C) with the voltage displayed through the signal I/O function.
 - If the wiring is intact but there is a large difference between the measured and displayed voltage (± 10 mV) then the motherboard is bad.

STATUS OUTPUTS

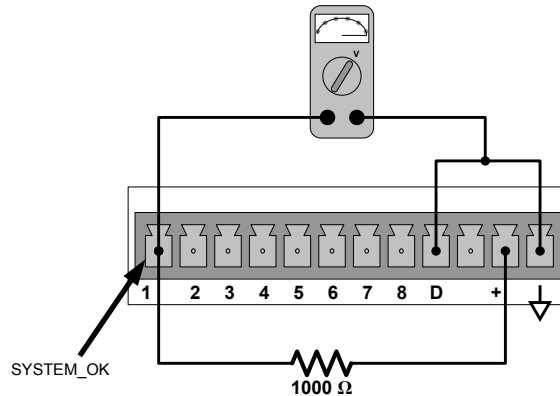


Figure 5-17. Typical Set Up of Status Output Test

To test the status output electronics:

1. Connect a jumper between the “D” pin and the “▽” pin on the status output connector.
2. Connect a 1000 ohm resistor between the “+” pin and the pin for the status output that is being tested.
3. Connect a voltmeter between the “▽” pin and the pin of the output being tested.
4. In the Utilities>Diagnostics>Digital Outputs menu (see Section 5.5.3), scroll through the outputs until you get to the output in question.
5. Alternately, turn on and off the output noting the voltage on the voltmeter.
 - It should vary between 0 volts for ON and 5 volts for OFF.

CONTROL INPUTS

The control input bits can be tested by applying a trigger voltage to an input and watching changes in the status of the associated function in the Utilities>Diagnostics menu:

EXAMPLE: to test the “A” and “B” control inputs:

1. Under the Utilities>Diagnostics>Digital Inputs menu, scroll through the signals to find EXTERNAL_ZERO_CAL.
2. Connect a jumper from the “+” pin on the appropriate connector to the “U” on the same connector.
3. Connect a second jumper from the “▽” pin on the connector to the “A” pin.
4. The status of EXTERNAL_ZERO_CAL should change to read “ON”.
5. Connect a second jumper from the “▽” pin on the connector to the “B” pin.
6. The status of EXTERNAL_HIGHSPAN_CAL should change to read “ON.”

Table 5-10. Control Input Pin Assignments and Corresponding Signal I/O Functions

INPUT	CORRESPONDING I/O SIGNAL
A	EXT_ZERO_CAL
B	EXT_HIGHSPAN_CAL
C, D, E & F	NOT USED

5.5.9.7. PRESSURE / FLOW SENSOR ASSEMBLY

The flow and pressure sensors are located on a PCA just behind the PMT sensor (see Figure 2-3) can be checked with a voltmeter.

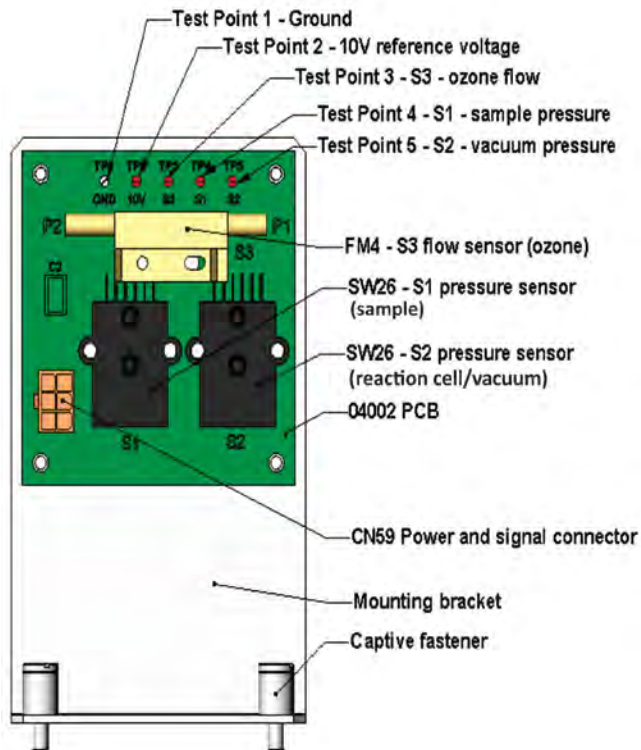


Figure 5-18. Pressure / Flow Sensor Assembly

The following procedure assumes that the wiring is intact and that the motherboard and power supplies are operating properly:

BASIC PCA OPERATION CHECK

- Measure the voltage between TP2 and TP1. It should be 10 VDC \pm 0.25 VDC. If not then the board is bad. Replace the PCA.

SAMPLE PRESSURE SENSOR CHECK

1. Measure the pressure on the inlet side of S1 with an external pressure meter.
2. Measure the voltage across TP4 and TP1.
 - The expected value for this signal should be:

$$\text{Expected mVDC} = \left(\frac{\text{Pressure}}{30.0_{\text{Hg-in-A}}} \times 4660_{\text{mVDC}} \right) + 250_{\text{mVDC}} \quad \pm 10\%_{\text{rdg}}$$

EXAMPLE: If the measured pressure is 20 Hg-in-A, the expected voltage level between TP4 and TP1 would be between 2870 mVDC and 3510 mVDC.

EXAMPLE: If the measured pressure is 25 Hg-in-A, the expected voltage level between TP4 and TP1 would be between 3533 mVDC and 4318 mVDC.

- If this voltage is out of range, then either pressure transducer S1 is bad, the board is bad or there is a pneumatic failure preventing the pressure transducer from sensing the absorption cell pressure properly. Replace the PCA.

VACUUM PRESSURE SENSOR CHECK

1. Measure the pressure on the inlet side of S2 with an external pressure meter.
2. Measure the voltage across TP5 and TP1.
3. Evaluate the reading in the same manner as for the sample pressure sensor.

O₃ FLOW SENSOR CHECK

- Measure the voltage across TP3 and TP1.
- With proper flow (80 cc³/min through the O₃ generator), this should be approximately 2V ± 0.25 (this voltage will vary with altitude).
- With flow stopped (photometer inlet disconnected or pump turned OFF) the voltage should be approximately 1V.
- If the voltage is incorrect, the flow sensor S3 is bad, or the board is bad (replace the PCA) or there is a leak upstream of the sensor.

5.5.9.8. CPU

There are two major types of CPU board failures, a complete failure and a failure associated with the Disk on Module (DOM). If either of these failures occurs, contact the factory.

For complete failures, assuming that the power supplies are operating properly and the wiring is intact, the CPU is faulty if on power-on, the watchdog LED on the motherboard is not flashing.

- In some rare circumstances, this failure may be caused by a bad IC on the motherboard, specifically U57, the large, 44 pin device on the lower right hand side of the board. If this is true, removing U57 from its socket will allow the instrument to start up but the measurements will be invalid.
- If the analyzer stops during initialization (the front panel display shows a fault or warning message), it is likely that the DOM, the firmware or the configuration and data files have been corrupted.

5.5.9.9. RS-232 COMMUNICATIONS

GENERAL RS-232 TROUBLESHOOTING

Teledyne API's analyzers use the RS-232 communications protocol to allow the instrument to be connected to a variety of computer-based equipment. Problems with RS-232 connections usually center around 4 general areas:

- Incorrect cabling and connectors. See Section 2.3.1.8 under RS-232 Connection for connector and pin-out information.
- The BAUD rate and protocol are incorrectly configured. See Section 2.3.1.8 under RS-232 Connection.
- If a modem is being used, additional configuration and wiring rules must be observed. See Sections 3.1 and 3.2.
- Incorrect setting of the DTE – DCE Switch. See Section 3.1 to set correctly.
- Verify that cable (P/N 03596) that connects the serial COM ports of the CPU to J12 of the motherboard is properly seated.

TROUBLESHOOTING ANALYZER/MODEM OR TERMINAL OPERATION

These are the general steps for troubleshooting problems with a modem connected to a Teledyne API's analyzer.

1. Check cables for proper connection to the modem, terminal or computer.
2. Check to ensure that the DTE-DCE is in the correct position as described in Section 3.1.
3. Check to ensure that the set up command is correct.
4. Verify that the Ready to Send (RTS) signal is at logic high. The analyzer sets pin 7 (RTS) to greater than 3 volts to enable modem transmission.
5. Ensure that the BAUD rate, word length, and stop bit settings between modem and analyzer match.
6. Use the RS-232 test function to send "w" characters to the modem, terminal or computer.
7. Get your terminal, modem or computer to transmit data to the analyzer (holding down the space bar is one way); the green LED should flicker as the instrument is receiving data.
8. Ensure that the communications software or terminal emulation software is functioning properly.

5.5.9.10. NO₂ → NO CONVERTER

The converter could become less efficient over time, due to LED degradation or contamination building up inside the chamber. The converter assembly can fail if the blue light converter lamps fail, thus lowering the conversion efficiency (CE); they would need to be cleaned or replaced if a CE Cal does not fix the problem.

First, conduct a CE Cal as instructed in Section 4.5. If necessary clean or replace the lamps as instructed in Section 5.4.7.

5.5.9.11. PHOTOMULTIPLIER TUBE (PMT) SENSOR MODULE

The PMT detects the light emitted by the reaction of NO with ozone. It has a gain of about 500,000 to 1,000,000. It is not possible to test the detector outside of the instrument in the field. The basic method to diagnose a PMT fault is to eliminate the other components using ETEST, OTEST and specific tests for other sub-assemblies.

OPTIC TEST (OTEST)

The optic test function tests the response of the PMT sensor by turning on an LED located in the cooling block of the PMT (see Figure 5-20). The analyzer uses the light emitted from the LED to test its photo-electronic subsystem, including the PMT and the current to voltage converter on the pre-amplifier board.

- To ensure that the analyzer measures only the light coming from the LED, the analyzer should be supplied with zero air.
- The optic test should produce a PMT signal of about 2000 ± 1000 mV.

To activate the optics test, go to the Utilities>Diagnostics>OE Test menu and press the Run OTest button.

Note

This is a coarse test for functionality and not an accurate calibration tool. The resulting PMT signal can vary significantly over time and also changes with low-level calibration.

ELECTRICAL TEST (ETEST)

The electrical test function creates a current, which is substituted for the PMT signal and feeds it into the preamplifier board.

- This signal is generated by circuitry on the pre-amplifier board itself and tests the filtering and amplification functions of that assembly along with the A/D converter on the motherboard.
- It does not test the PMT itself.
- The electrical test should produce a PMT signal of about 2000 ± 1000 mV.

To activate the electrical test, go to the Utilities>Diagnostics>OETest menu and press the Run ETest button.

5.5.9.12. PMT PREAMPLIFIER BOARD

To check the correct operation of the preamplifier board, perform an optics test (Utilities>Diagnostics>OE Test>Run OTest) and an electrical test (Utilities>Diagnostics>OE Test>Run ETest) described in Section 5.5.9.11 above.

- If the instrument passes the OTEST but fails the ETEST, the preamplifier board may be faulty or need a hardware calibration.

HIGH VOLTAGE POWER SUPPLY (HVPS)

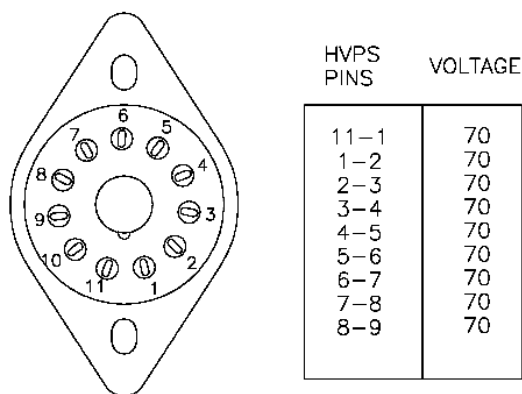
The HVPS is located in the interior of the sensor module and is plugged into the PMT tube. It requires 2 voltage inputs.

- The first is +15 V, which powers the supply.
- The second is the programming voltage which is generated on the preamplifier board.
- Adjustment of the HVPS is covered in the factory calibration procedure in Section 5.5.10.4.

This power supply has 10 independent power supply steps, one to each pin of the PMT. The following test procedure below allows you to test each step.

1. Turn off the instrument.
2. Remove the cover and disconnect the 2 connectors at the front of the NOX sensor module.
3. Remove the end cap from the sensor (4 screws).
4. Remove the HVPS/PMT assembly from the cold block inside the sensor (2 plastic screws).
5. Disconnect the PMT from the HVPS.
6. Re-connect the 7 pin connector to the sensor end cap, and power-up the instrument.
7. Navigate to the HVPS parameter in the Dashboard (if not shown, configure the Dashboard to display HVPS, Section 2.5.3).
8. Divide the displayed HVPS voltage by 10 and test the pairs of connector points as shown in the figure below.
9. Check the overall voltage (should be equal to the HVPS value displayed in the Dashboard and the voltages between each pair of pins of the supply

EXAMPLE: if the HVPS signal is 700 V the pin-to-pin voltages should be 70 V.



10. Turn off the instrument power, and reconnect the PMT, and then reassemble the sensor.
 - If any faults are found in the test, you must obtain a new HVPS as there are no user serviceable parts inside the supply.

5.5.9.13. PMT TEMPERATURE CONTROL PCA

The temperature control PCA is located on the sensor housing assembly, under the slanted shroud, next to the cooling fins and directly above the cooling fan.

If the red LED located on the top edge of this assembly is not glowing the control circuit is not receiving power. Check the analyzer's power supply, the relay board's power distribution circuitry and the wiring connecting them to the PMT temperature control PCA.

TEC CONTROL TEST POINTS

Four test points are also located at the top of this assembly they are numbered left to right start with the T1 point immediately to the right of the power status LED. These test points provide information regarding the functioning of the control circuit.

- To determine the current running through the control circuit, measure the voltage between T1 and T2. Multiply that voltage by 10.
- To determine the drive voltage being supplied by the control circuit to the TEC, measure the voltage between T2 and T3.
 - If this voltage is zero, the TEC circuitry is most likely open.

or,

- If the voltage between T2 and T3 = 0 VDC and the voltage measured between T1 and T2 = 0 VDC there is most likely an open circuit or failed op amp on control PCA itself.
- If the voltage between T2 and T3 = 0 VDC and the voltage measured between T1 to T2 is some voltage other than 0 VDC, the TEC is most likely shorted.
- T4 is tied directly to ground. To determine the absolute voltage on any one of the other test points make a measurement between that test point and T4.

5.5.9.14. O₃ GENERATOR

The ozone generator can fail in two ways, electronically (printed circuit board) and functionally (internal generator components). Assuming that air is supplied properly to the generator, the generator should automatically turn on 30 minutes after the instrument is powered up or if the instrument is still warm. See Section 6.3.3 for ozone generator functionality. Accurate performance of the generator can only be determined with an ozone analyzer connected to the outlet of the generator. However, if the generator appears to be working properly but the sensitivity or calibration of the instrument is reduced, suspect a leak in the ozone generator supply air.

A leak in the dryer or between the dryer and the generator can reduce sensitivity and cause performance drift. Carry out a leak check (Section 5.4.11).

O₃ GENERATOR OVERRIDE

This feature in the Utilities>Diagnostics menu is used to manually turn the ozone generator off and on. This should be done before disconnecting the generator, to prevent ozone from leaking out, or after a system restart if the user does not want to wait for 30 minutes during warm-up time.

Note

The ozone generator does not turn on if the ozone flow conditions are out of specification, e.g., if there is no flow through the system or the pump is broken.

5.5.9.15. INTERNAL SPAN GAS GENERATOR AND VALVE OPTIONS

The zero/span valves and internal span gas generator options need to be enabled in the software (contact the factory on how to do this).

The semi-permeable PTFE membrane of the permeation tube is severely affected by humidity. Variations in humidity between day and night are usually enough to yield very variable output results. If the instrument is installed in an air-conditioned shelter, the air is usually dry enough to produce good results. If the instrument is installed in an environment with variable or high humidity, variations in the permeation tube output will be significant. In this case, a dryer for the supply air is recommended (dewpoint should be -20°C or less).

The permeation tube of the internal span gas generator option is heated with a proportional heater circuit and the temperature is maintained at $50^{\circ}\text{C} \pm 1^{\circ}\text{C}$. Check the IZS Temp in the Dashboard or the IZS Temp Raw signal in the Utilities>Diagnostics>Analog Inputs menu. At 50°C , the temperature signal from the IZS thermistor should be around 2500 mV.

5.5.9.16. TEMPERATURE SENSOR

BOX TEMPERATURE SENSOR

The box temperature sensor (thermistor) is mounted on the motherboard below the bottom edge of the CPU board when looking at it from the front. It cannot be disconnected to check its resistance.

- Box temperature will vary with, but will usually read about 5°C higher than, ambient (room) temperature because of the internal heating zones from the NO_2 converter, reaction cell and other devices.
- To check the box temperature functionality, we recommend checking the Box Temp signal voltage in the Utilities>Diagnostics>Analog Inputs menu (Section 5.5.3).
- At about 30°C , the signal should be around 1500 mV.
- To check the accuracy of the sensor, use a calibrated external thermometer / temperature sensor to verify the accuracy of the box temperature by:
- Placing it inside the chassis, next to the thermistor labeled XT1 (above connector J108) on the motherboard.
- Compare its reading to the value of the PMT TEMP.

PMT TEMPERATURE SENSOR CONTROL

The temperature of the PMT should be low and constant. It is more important that this temperature is maintained at a constant level than it is to be a specific temperature.

The PMT cooler uses a Peltier, thermo-electric cooler element supplied with 12 V DC power from the switching power supply PS2. The temperature is controlled by a proportional temperature controller located on the preamplifier board.

- Voltages applied to the cooler element vary from 0.1 to 12 VDC.
- The temperature set point (hard-wired into the preamplifier board) will vary by ± 2 .
- The actual temperature will be maintained to within 0.1° C around that set point.

To check the operation of the PMT temperature control system:

1. Turn off the analyzer and let its internal components cool / heat to ambient temperature.
2. Turn on the analyzer.
3. Set the front panel to show the PMT TEMP test function (Setup>Dashboard).
 - The temperature should fall steadily to 6-10° C.
 - If the temperature fails to reach this point after 60 minutes, there is a problem in the cooler circuit.
 - If the control circuit on the preamplifier board is faulty, a temperature of -1° C will be reported.

5.5.10. SERVICE PROCEDURES

This section contains some procedures that may need to be performed when a major component of the analyzer requires repair or replacement.

Note

Regular maintenance procedures are discussed in Section 5.4 and are not listed here).

Also, there may be more detailed service notes for some of the below procedures. Contact Teledyne API's Technical Support Department.



WARNING – ELECTRICAL SHOCK HAZARD

Unless the procedure being performed requires the instrument to be operating, turn it off and disconnect power before opening the analyzer and removing, adjusting or repairing any of its components or subsystems.



CAUTION – QUALIFIED TECHNICIAN

The operations outlined in this chapter are to be performed by qualified maintenance personnel only.

5.5.10.1. DISK-ON-MODULE REPLACEMENT PROCEDURE

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Service of circuit components requires electrostatic discharge protection, i.e. ESD grounding straps, mats and containers. Failure to use ESD protection when working with electronic assemblies will void the instrument warranty. For information on preventing ESD damage, refer to the manual, Fundamentals of ESD, PN 04786, which can be downloaded from our website at <http://www.teledyne-api.com> under Help Center > Product Manuals in the Special Manuals section.

Replacing the Disk-on-Module (DOM) will cause loss of all DAS data; it may also cause loss of some instrument configuration parameters unless the replacement DOM carries the exact same firmware version. Whenever changing the version of installed software, the memory must be reset. Failure to ensure that memory is reset can cause the analyzer to malfunction, and invalidate measurements. After the memory is reset, the A/D converter must be re-calibrated, and all information collected in Step 1 below must be re-entered before the instrument will function correctly. Also, zero and span calibration should be performed.

1. Document all analyzer parameters that may have been changed, such as range, auto-cal, analog output, serial port and other settings before replacing the DOM.
2. Turn off power to the instrument, fold down the rear panel by loosening the mounting screws.
3. While looking at the electronic circuits from the back of the analyzer, locate the Disk-on-Module in the right-most socket of the CPU board.
4. The DOM should carry a label with firmware revision, date and initials of the programmer.
5. Remove the nylon standoff clip that mounts the DOM over the CPU board, and lift the DOM off the CPU. Do not bend the connector pins.
6. Install the new Disk-on-Module, making sure the notch at the end of the chip matches the notch in the socket.
7. It may be necessary to straighten the pins somewhat to fit them into the socket. Press the chip all the way in.
8. Close the rear panel and turn on power to the machine.
9. If the replacement DOM carries a firmware revision, re-enter all of the setup information.

5.5.10.2. O₃ GENERATOR REPLACEMENT

The ozone generator is a black, brick-shaped device with a printed circuit board attached to its rear and two tubes extending out the right side in the front of the analyzer (see Figure 2-3). The board has a red LED that, when lit, indicates ozone is being generated.

To replace the ozone generator:

1. Turn off the analyzer power; remove the power cord and the analyzer cover.
2. Disconnect the 1/8" black tube from the ozone cleanser and the 1/4" clear tube from the plastic extension tube at the brass fitting nearest to the ozone generator.
3. Unplug the electrical connection on the rear side of the brick.
4. Unscrew the two mounting screws that attach the ozone generator to the chassis and take out the entire assembly.
5. If you received a complete replacement generator with circuit board and mounting bracket attached, simply reverse the above steps to replace the current generator.

Note

Ensure to carry out a leak check (Section 5.4.11) and a recalibration after the analyzer has warmed up for about 60 minutes.

5.5.10.3. SAMPLE AND OZONE DRYER REPLACEMENT

The analyzer's standard configuration is equipped with a dryer for the ozone supply air. An optional dryer is available for the sample stream, and a combined dryer for both gas streams can also be purchased. To change one or both of these dryers:

1. Turn off power to the analyzer and pump, and remove the power cord and the analyzer cover.
2. Locate the dryer(s), and *gently* disconnect all tubing that extends out of the dryer assembly.

Note

Do not twist any of the white plastic fittings on the dryer: they connect the inner drying tube to the outer purge tube and are delicate. See Section 5.4.2.

3. Make note of the dryer's orientation on the bracket in order to correctly position the replacement dryer.
4. Cut the tie wraps that hold the dryer to the mounting bracket and take out the old dryer.
 - If necessary, unscrew the two mounting screws on the bracket and take out the entire assembly.
5. Attach the replacement dryer to the mounting bracket in the same orientation as the old dryer.
6. Fix the dryer to the bracket using new tie wraps.

7. Cut off excess length of the wraps.
8. Put the assembly back into the chassis and tighten the mounting screws.
9. Use at least two wrenches to carefully re-attach the tubes to vacuum manifold, flow meter and/or NO/NO_x valve using at least two wrenches.

Note

Avoid twisting the dryer's white plastic fittings, as this will result in large leaks, which are difficult to trouble-shoot or fix.

10. Carry out a detailed leak check (see Section 5.4.11.2),
11. Close the analyzer and reconnect the power cord.
12. Power up pump and analyzer and re-calibrate the instrument after it stabilizes.

5.5.10.4. PMT SENSOR HARDWARE CALIBRATION

The sensor module hardware calibration is used in the factory to adjust the slope and offset of the PMT output and to optimize the signal output and HVPS.

- If the instrument's slope and offset values are outside the acceptable range and all other more obvious causes for this problem have been eliminated, the hardware calibration can be used to adjust the sensor as was done in the factory.
- This procedure is also recommended after replacing the PMT or the preamplifier board.

To calibrate the PMT preamplifier PCA:

1. Perform a full zero point calibration using zero air (see Section 4.2.1.1).
2. Display the NO_x STB value on the NO_x plot (or if configured in the Home page meter or in the Dashboard ()).
3. Locate the preamplifier board (PMT Preamp PCA) (see Figure 2-3).
4. Locate the following components on the preamplifier board (Figure 5-19):
 - HVPS coarse adjustment switch (Range 0-9, then A-F).
 - HVPS fine adjustment switch (Range 0-9, then A-F).
 - Gain adjustment potentiometer (Full scale is 10 turns).
5. Turn the gain adjustment potentiometer 12 turns clockwise or to its maximum setting.
6. Feed NO gas into the analyzer.
 - This should be 90% of the upper limit setting for the T200's reporting range:

EXAMPLE: if the reporting range is set at 500 ppb, use 450 ppb NO.

7. Wait until the Stability is below 0.5 ppb

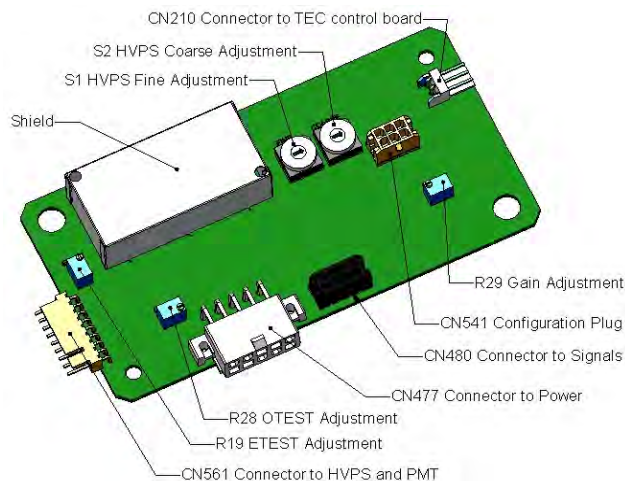


Figure 5-19. Pre-Amplifier Board Layout

8. Scroll to the NORM PMT test function on the analyzer's front panel.
9. With the NO gas concentrations mentioned in Step 5 above, the norm pmt value should be 900 mV.
10. Set the HVPS coarse adjustment to its minimum setting (0).
11. Set the HVPS fine adjustment switch to its maximum setting (F).
 - Set the HVPS coarse adjustment switch to the lowest setting that will give you just above the target value for NORM PMT signal.
12. Adjust the HVPS fine adjustment such that the NORM PMT value is close to the target value.
 - It may be necessary to go back and forth between coarse and fine adjustments if the proper value is at the threshold of the min/max coarse setting.

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Do not overload the PMT by accidentally setting both adjustment switches to their maximum setting. Start at the lowest setting and increment slowly: no sooner than every 10 seconds between adjustments.

Note

During these adjustments, the NORM PMT value will fluctuate as the analyzer continues to switch between NO and NO_x streams as well as between measure and Auto Zero modes.

13. Perform a span point calibration (Section 4.2.1.2) to normalize the sensor response to its new PMT sensitivity.
14. Review the slope and offset values:
 - The slope values should be 1.000 ± 0.300 .
 - The offset values should be approximately 0.0 (-20 to +150 mV is allowed).

5.5.10.5. REPLACING THE PMT, HVPS OR TEC

The photo multiplier tube (PMT) should last for the lifetime of the analyzer, however, the high voltage power supply (HVPS) or the thermo-electric cooler (TEC) components may fail. Replacing any of these components requires opening the sensor module. This is a delicate assembly and it is recommend that you ensure the PMT, HVPS or TEC modules are, indeed, faulty before unnecessarily opening of the module.

CAUTION – QUALIFIED PERSONNEL



While the PMT or HVPS can be removed through the front panel without un-mounting the entire sensor module, we recommend turning off the instrument, opening its top cover and removing the entire assembly so that further repairs can be carried out at an anti-ESD workstation.

Follow the guidelines for preventing electrostatic damage to electronic components, defined in the manual, Fundamentals of ESD, PN 04786, which can be downloaded from our website at <http://www.teledyne-api.com> under Help Center > Product Manuals in the Special Manuals section..

1. Turn OFF the analyzer and disconnect the power cord.
2. Remove the cover.
3. Disconnect all pneumatic and electrical connections from the sensor assembly.
4. Remove the sensor assembly.
5. If the TEC is to be replaced, remove the reaction cell assembly at this point by unscrewing two holding screws.
 - This is necessary only if the repair being performed involves removing the PMT cold block.

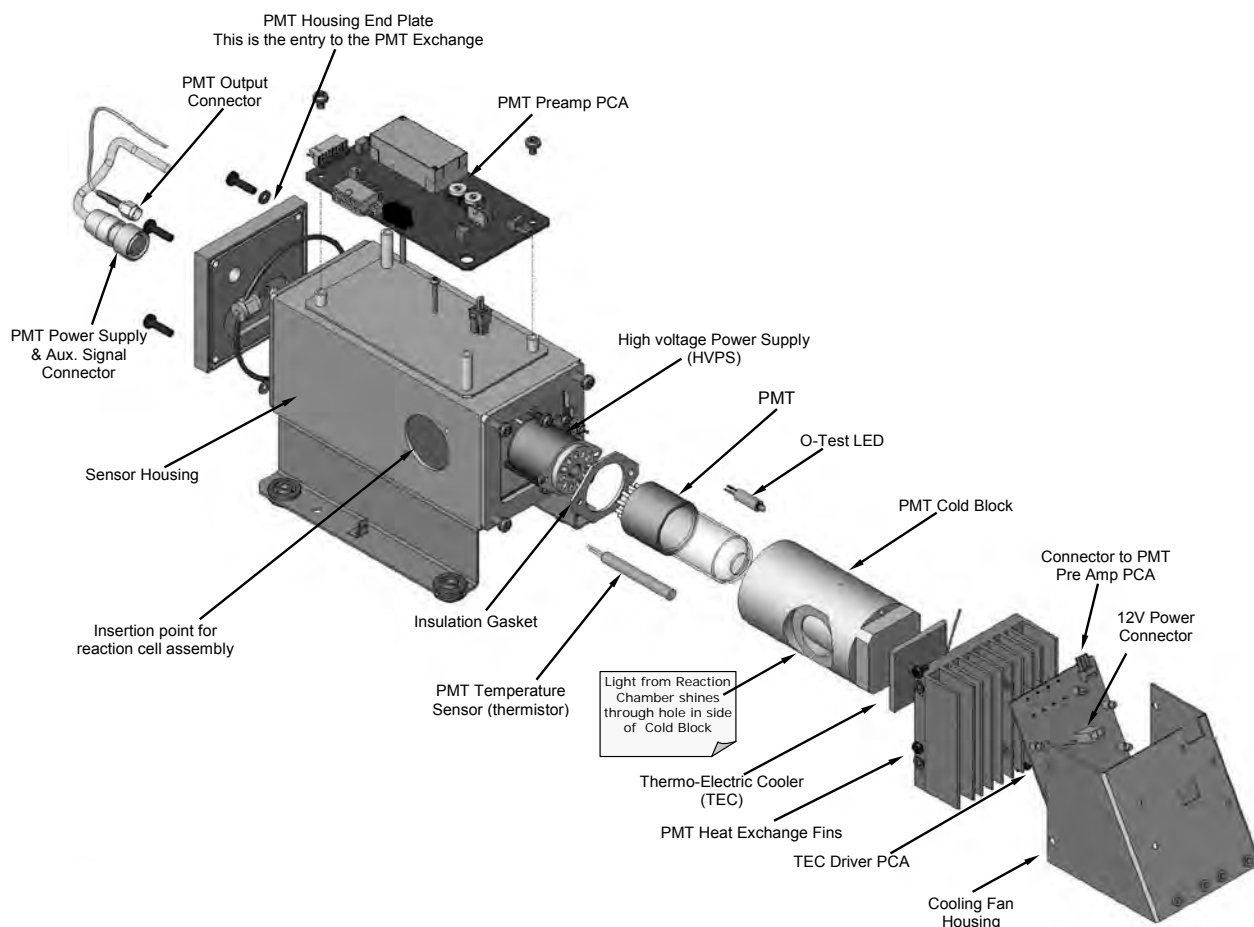


Figure 5-20. Sensor Assembly

6. Remove the two connectors on the PMT housing end plate facing towards the front panel.
7. Remove the end plate itself (4 screws with plastic washers).

Note

Any time the black PMT housing end plate for the Sensor Assembly is removed, replace the five desiccant bags inside the housing.

8. Remove the desiccant bags from the PMT housing.
9. Unscrew the PMT assembly, which is held to the cold block by two plastic screws.
10. Discard the plastic screws and replace with new screws at the end of this procedure (the threads get stripped easily and it is recommended to use new screws).
11. Along with the plate, slide out the optic test (O-Test) LED and the thermistor that measures the PMT temperature.
 - Thermistor will be coated with a white, thermal conducting paste.
 - Do not contaminate the inside of the housing with this grease, as it may contaminate the PMT glass tube on re-assembly.

12. Carefully take out the assembly consisting of the HVPS, the insulation gasket and the PMT.
13. Change the PMT or the HVPS or both, clean the PMT glass tube with a clean, anti-static wipe and do not touch it after cleaning.
14. If the cold block or TEC is to be changed:
 - Disconnect the TEC driver board from the preamplifier board, remove the cooler fan duct (4 screws on its side) including the driver board.
 - Disconnect the driver board from the TEC and set the sub-assembly aside.
15. Remove the end plate with the cooling fins (4 screws) and slide out the PMT cold block assembly, which contains the TEC.
16. Unscrew the TEC from the cooling fins and the cold block and replace it with a new unit.
17. Reassemble this TEC subassembly in reverse order.
 - Ensure to use thermal grease between TEC and cooling fins as well as between TEC and cold block and that the side opening in the cold block will face the reaction cell when assembled.
 - Evenly tighten the long mounting screws for good thermal conductivity.

CAUTION – QUALIFIED PERSONNEL



The thermo-electric cooler needs to be mounted flat to the heat sink.

If there is any significant gap, the TEC might burn out. Ensure to apply heat sink paste before mounting it and tighten the screws evenly and cross-wise.

18. Reinsert the TEC subassembly in reverse order.
 - Ensure that the O-ring is seated properly and the assembly is tightened evenly.
19. Insert the O-Test LED and thermistor into the cold block, insert new desiccant bags and carefully replace the end plate by making sure that the O-ring is properly in place.
 - Improperly placed O-rings will cause leaks, which – in turn – cause moisture to condense on the inside of the cooler and likely cause a short in the HVPS.
20. Reinsert the PMT/HVPS subassembly in reverse order.
 - Don't forget the insulation gasket between HVPS and PMT.
 - Use new plastic screws to mount the PMT assembly on the PMT cold block.
21. Install new silica gel packets (desiccant bags).
22. Reconnect the cables and the reaction cell (evenly tighten these screws).
23. Replace the sensor assembly into the chassis and fasten with four screws and washers.

24. Reconnect all electrical and pneumatic connections.
25. Leak check the system (see Section 5.4.11).
26. Turn ON the analyzer.
27. Verify the basic operation of the analyzer using the ETEST and OTEST features (Section 5.5.9.11) or zero and span gases, then carry out a hardware calibration of the analyzer followed by a zero/span point calibration Section 4.2.1).

5.5.10.6. REMOVING / REPLACING THE RELAY PCA FROM THE INSTRUMENT

This is the most commonly used version of the Relay PCA. It includes a bank of solid state AC relays. This version is installed in analyzers where components such as AC powered heaters must be turned ON & OFF.

A retainer plate is installed over the relay to keep them securely seated in their sockets.

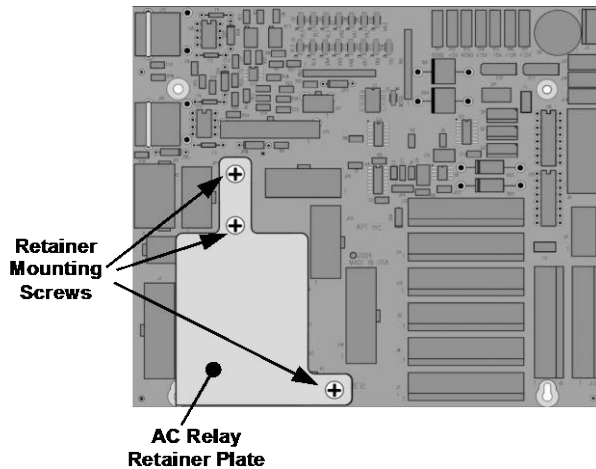


Figure 5-21. Relay PCA with AC Relay Retainer In Place

The Relay retainer plate installed on the relay PCA covers the lower right mounting screw of the relay PCA. Therefore, when removing the relay PCA, the retainer plate must be removed first.

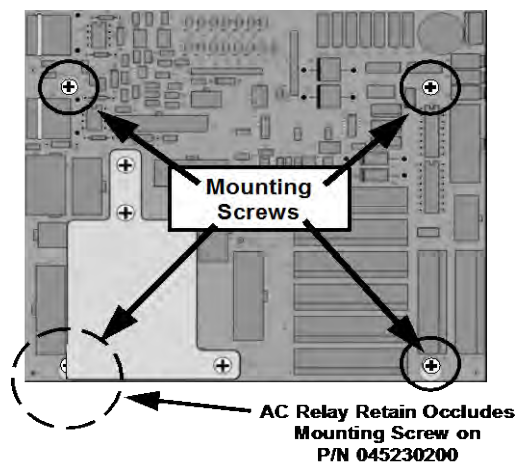


Figure 5-22. Relay PCA Mounting Screw Locations

5.6. FREQUENTLY ASKED QUESTIONS

The following list was compiled from the Teledyne API's Technical Support Department's ten most commonly asked questions relating to the analyzer.

QUESTION	ANSWER
Why does the ENTR button sometimes disappear on the front panel display?	Sometimes the ENTR button will disappear if you select a setting that is invalid or out of the allowable range for that parameter, such as trying to set the 24-hour clock to 25:00:00 or a range to less than 1 or more than 20000 ppb. Once you adjust the setting to an allowable value, the ENTR button will re-appear.
Why is the ZERO or SPAN button deactivated during calibration?	This happens when the measured gas concentration differs significantly from the span or zero gas concentration value entered by the user. This prevents accidental recalibration of the analyzer to an out-of-range response curve. EXAMPLE: The span set point is 400 ppb but gas concentration being measured is only 50 ppb.
How do I enter or change the value of my Span Gas?	See Section 4.2.1.2.
Can I automate the calibration of my analyzer?	Any analyzer with zero/span valve or IZS option can be automatically calibrated using the instrument's AutoCal feature (Section 4.3).
Can I use the IZS option to calibrate the analyzer?	Yes. However, the accuracy of the IZS option's permeation tube is only $\pm 5\%$. To achieve highest accuracy, it is recommended to use cylinders of calibrated span gases in combination with a zero air source.
How do I measure the sample flow?	For accurate measurement, attach a calibrated flow meter to the sample inlet port, and get a reading while the instrument is operating. The sample flow should be as specified in Table 1-1. (To calibrate, use the Utilities>Diagnostics menu; refer to Section 5.4.11.3).
How often do I need to change the particulate filter?	Refer to the Maintenance Schedule in Table 5-1. Keep in mind that highly polluted sample air may require more frequent changes.
How long does the sample pump last?	The sample pump should last one to two years and the pump head should be replaced when necessary. If the reaction cell pressure value goes above 10 in-Hg-A, on average, the pump head needs to be rebuilt.
Why does my RS-232 serial connection not work?	There are several possible reasons: <ul style="list-style-type: none"> • The wrong cable: please use the provided or a generic "straight-through" cable (do not use a "null-modem" type cable) and ensure the pin assignments are correct (Section 2.3.1.8 under RS-232 Connection). • The DCE/DTE switch on the back of the analyzer is not set properly; ensure that both green and red lights are on (Section 3.1). • The baud rate of the analyzer's COM port does not match that of the serial port of your computer/data logger (Table 2-16).
How do I make the instrument's display and my data logger agree?	This most commonly occurs when an independent metering device is used besides the data logger/recorder to determine gas concentration levels while calibrating the analyzer. These disagreements result from the analyzer, the metering device and the data logger having slightly different ground levels. Use the data logger itself as the metering device during calibration procedures.

QUESTION	ANSWER
Do the critical flow orifices of my analyzer require regular replacement?	No. The o-rings and the sintered filter associated with them require replacement once a year, but the critical flow orifices do not. See Section 5.4.9 for instructions.
How do I set up and use the contact closures (Control Inputs) on the rear panel of the analyzer?	See Section 2.3.1.6.

5.7. TECHNICAL ASSISTANCE

If this manual and its troubleshooting & service section do not solve your problems, technical assistance may be obtained from:

Teledyne API Technical Support
9970 Carroll Canyon Road
San Diego, California 92131-1106 USA

Toll-free Phone: 800-324-5190

Phone: +1 858-657-9800

Fax: +1 858-657-9816

Email: sda_techsupport@teledyne.com

Website: <http://www.teledyne-api.com/>

6. PRINCIPLES OF OPERATION

The T200P (and T200UP) NO/NO₂ Analyzer is a microprocessor-controlled instrument that uses a UV-based photolytic converter to provide “true” trace level measurements of NO₂. The patented technology allows for speciation of NO₂.

6.1. BLUE LIGHT CONVERTER (BLC) CONVERSION PRINCIPLE

The analyzer uses photolysis in its conversion process by flowing sample gas through the converter chamber where it is exposed to blue light from two high powered ultraviolet light-emitting diodes (LEDs) at very narrow wavelengths centered at ~ 395 nm (hashed bell curve region in graph). This blue spectral output includes the band where NO₂ is absorbed and where other interferences drop out (Figure 6-1), thereby selectively converting sample NO₂ to NO with negligible radiant heating or interference from other gases.

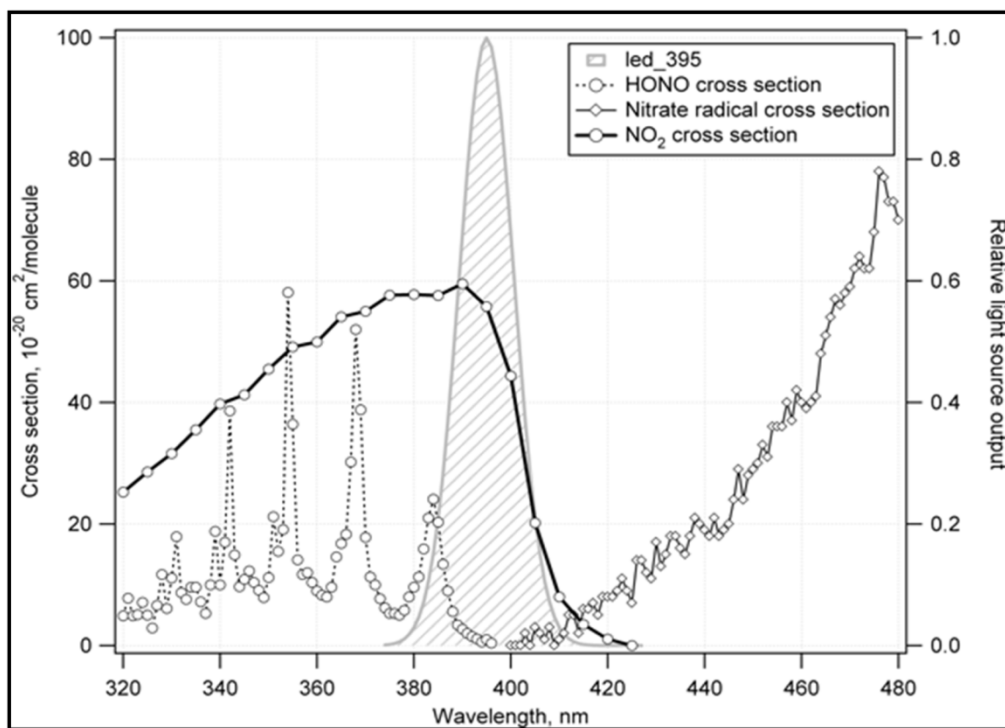


Figure 6-1. Blue Light Spectral Absorption Band

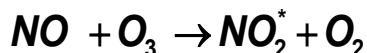
6.2. MEASUREMENT PRINCIPLE

6.2.1. CHEMILUMINESCENCE CREATION IN THE REACTION CELL

The analyzer measures the amount of NO present in a gas by detecting the chemiluminescence which occurs when nitrogen oxide (NO) is exposed to ozone (O₃). This reaction is a two-step process:

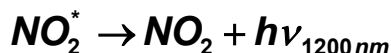
- In the first step, one molecule of NO and one molecule of O₃ collide and chemically react to produce one molecule of oxygen (O₂) and one molecule of nitrogen dioxide (NO₂). Some of the NO₂ molecules created by this reaction retain excess energy from the collision and exist in an excited state, where one of the electrons of the NO₂ molecule resides in a higher energy state than normal (denoted by an asterisk in the following equation).

Equation 6-1



- The second step occurs because the laws of thermodynamics require that systems seek the lowest stable energy state available, therefore the excited NO₂ molecule quickly returns to its ground state, releasing the excess energy. This release takes the form of a quantum of light ($h\nu$). The distribution of wavelengths for these quanta range between 600 and 3000 nm, with a peak at about 1200 nm.

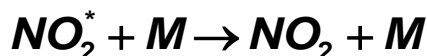
Equation 6-2



- All things being constant (temperature, pressure, amount of ozone present, etc.), the relationship between the amount of NO present in the reaction cell and the amount of light emitted from the reaction is very linear. If more NO is present, more IR light is produced. By measuring the amount of IR light produced with a sensor sensitive in the near-infrared spectrum (see Figure 6-3) the amount of NO present can be determined.

In addition, sometimes the excited NO₂ collides with other gaseous molecules in the reaction cell chamber or even the molecules of the reaction cell walls and transfers its excess energy to this collision partner (represented by M in Equation 6-3 below) without emitting any light at all. In fact, by far the largest portion of the excited NO₂ returns to the ground state this way, leaving only a few percent yield of usable chemiluminescence.

Equation 6-3



The probability of a collision between the NO₂* molecule and a collision partner M increases proportionally with the reaction cell pressure. This non-radiating collision with the NO₂* molecules is usually referred to as *third body quenching*, an unwanted process further described in Section 6.2.5.2.

Even under the best conditions only about 20% of the NO_2 that is formed by the reaction described in equation 12-1 is in the excited state. In order to maximize chemiluminescence, the reaction cell is maintained at reduced pressure (thereby reducing the amount of available collision partners) and is supplied with a large, constant excess of ozone (about 3000-5000 ppm) from the internal ozone generator.

6.2.2. CHEMILUMINESCENCE DETECTION IN THE REACTION CELL

6.2.2.1. THE PHOTO MULTIPLIER TUBE (PMT)

The analyzer uses a special kind of vacuum tube, called a photo-multiplier tube (PMT), to detect the amount of light created by the NO and O_3 reaction in the reaction cell.

Photons enter the PMT and strike a negatively charged photo cathode causing it to emit electrons. These electrons are accelerated by an applied high voltage and multiplied through a sequence of similar acceleration steps (dynodes) until a useable current signal is generated (see Section 6.6 for a more detailed description). The more light present (in this case photons given off by the chemiluminescent reaction described above), the more current is produced. Therefore the more NO present in the reaction cell the more current is produced by the PMT.

The current produced by the PMT is converted to a voltage and amplified by the preamplifier board and then communicated to the analyzer's CPU via the A \rightarrow D converter circuitry on the analyzer.

6.2.2.2. OPTICAL FILTER

A high pass optical filter, only transparent to wavelengths of light above 645nm, placed between the reaction cell and the PMT (see Figure 6-2) in conjunction with the response characteristics of the PMT creates a very narrow window of wavelengths of light to which the analyzer will respond.

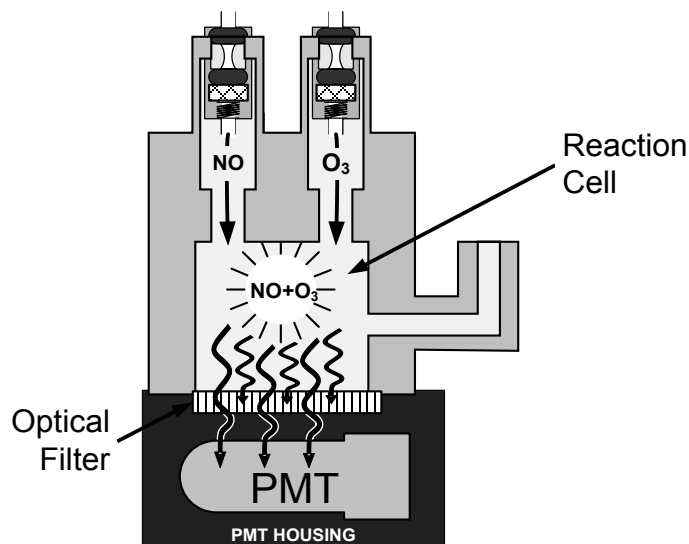


Figure 6-2. Reaction Cell with PMT Tube and Optical Filter

The narrowness of this band of sensitivity allows the analyzer to ignore extraneous light and radiation that might interfere with the analyzer's measurement (more on interferences in Section 6.2.5). For instance, some oxides of sulfur can also be chemiluminescent emitters when in contact with O₃ but give off light at much shorter wavelengths (usually around 260nm to 480nm).

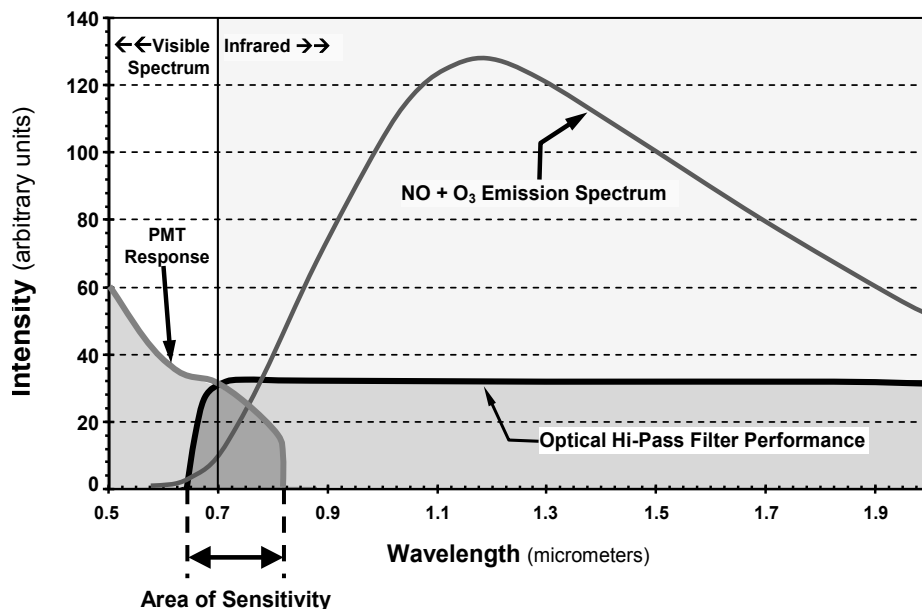


Figure 6-3. Sensitivity Spectrum

6.2.3. AUTO ZERO IN THE T200P

Inherent in the operation of any PMT is a certain amount of noise. This is due to a variety of factors such as black body infrared radiation given off by the metal components of the reaction cell, unit to unit variations in the PMT units and even the constant universal background radiation that surrounds us at all times. In order to reduce this amount of noise and offset, the PMT is kept at a constant 7° C (45° F) by a Thermo-Electric Cooler (TEC).

While this intrinsic noise and offset is significantly reduced by cooling the PMT, it is not eradicated. To determine how much noise remains, once every minute for a short period the analyzer diverts the sample gas flow directly to the vacuum manifold, bypassing the reaction cell. During this period, only O₃ is present in the reaction cell, effectively turning off the chemiluminescence reaction. Once the cell is completely dark (“zero” light), the analyzer records the output of the PMT and keeps a running average of these Auto Zero (Azero) values. This average offset value is subtracted from the raw PMT readings while the instrument is measuring NO and NO_x to arrive at an Auto Zero corrected reading.

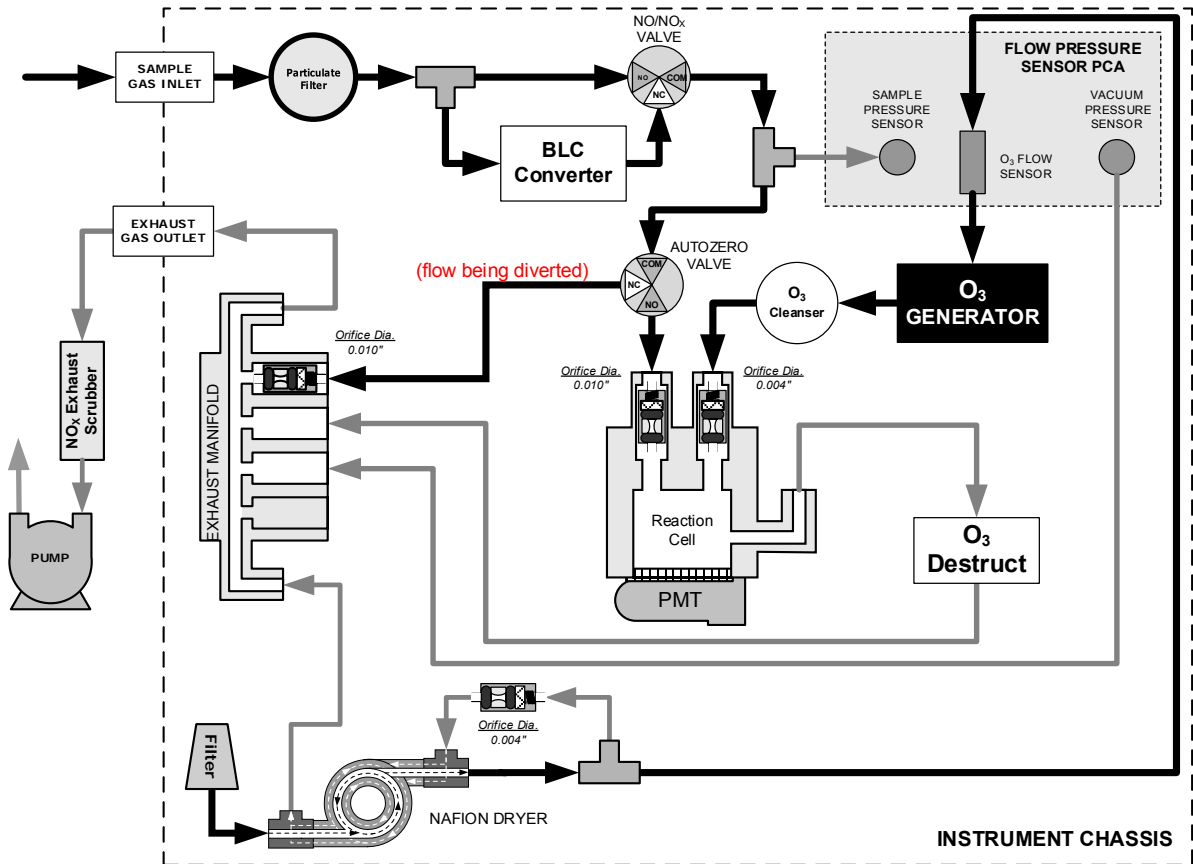


Figure 6-4. T200P Pneumatic Flow during the Auto Zero Cycle

6.2.4. AUTO ZERO IN THE T200UP

Different from using a “dark” period in the reaction cell as in the T200P (Section 6.2.3), Auto Zero in the T200UP accounts for hydrocarbons interference by rerouting the sample flow to the Prereactor (Figure 6-5), a chamber upstream of the Reaction cell, where the NO interacts with the O₃ and is chemiluminesced off, then the remaining sample gas with the hydrocarbons and O₃ enters the Reaction cell. This is accomplished because of the difference in the rate of reaction between the gas types with Ozone. Hydrocarbons have a slower rate of reaction. The analyzer records the output of the PMT and keeps a running average of these Auto Zero (Azero) values. This average offset value is subtracted from the raw PMT readings while the instrument is measuring NO and NO_x to arrive at an Auto Zero corrected reading.

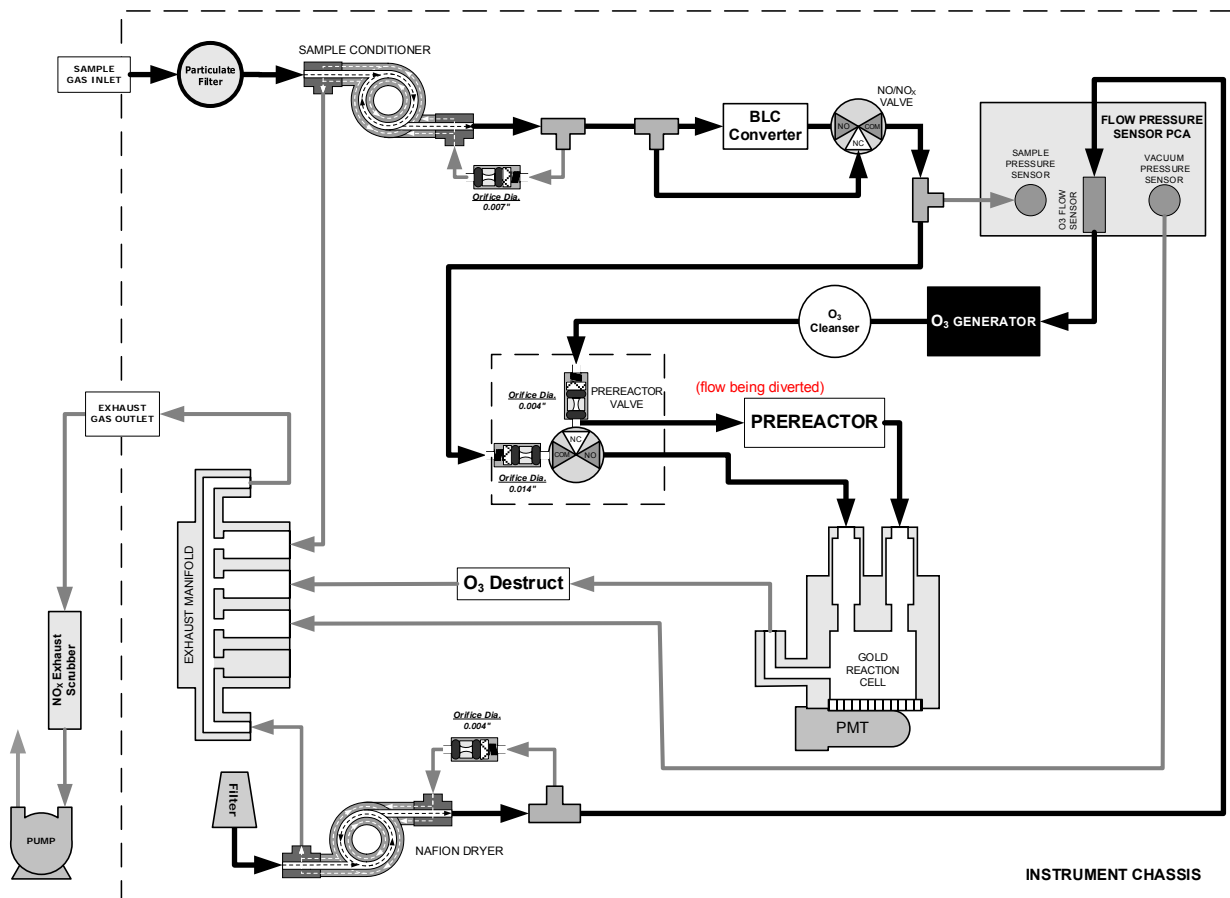


Figure 6-5.T200UP Pneumatic Flow during the Auto Zero Cycle

6.2.5. MEASUREMENT INTERFERENCES

Interferences in the chemiluminescence method come from a number of sources. The analyzer has been successfully tested for its ability to reject interference from most of these sources. Table 6-1 lists the most common types of interferences that could affect the analyzer's performance.

Table 6-1. List of Interferences

GAS	INTERFERENCE TYPE	REJECTION METHOD
CO ₂	Dilution: Viscosity of CO ₂ molecules causes them to collect in aperture of Critical Flow Orifice altering flow rate of NO.	If high concentrations of CO ₂ are suspected, special calibration methods must be performed to account for the effects of the CO ₂ . Contact Teledyne API's Technical Support Department (Section 5.7) for details.
	3 rd Body Quenching: CO ₂ molecules collide with NO ₂ * molecules absorbing excess energy kinetically and preventing emission of photons.	

GAS	INTERFERENCE TYPE	REJECTION METHOD
SO _x	Some SO _x variants can also initiate a chemiluminescence reaction upon exposure to O ₃ producing excess light.	Wavelengths of light produced by chemiluminescence of SO _x are screened out by the Optical Filter.
	Chemically reacts with NH ₃ , O ₂ and H ₂ O in O ₃ generator to create (NH ₃) ₂ SO ₄ (ammonium sulfate) and NH ₃ NO ₂ (ammonium nitrate) which form opaque white deposits on optical filter window. Also forms highly corrosive HNO ₃ (Nitric Acid)	Most of the ammonium sulfate and ammonium nitrate produced is removed from the sample gas by the Ozone cleanser located between the O ₃ Generator and the reaction cell.
	3 rd Body quenching: SO _x molecules collide with NO ₂ * molecules absorbing excess energy kinetically and preventing emission of photons.	If high concentrations of SO _x are suspected, special calibration methods must be performed to account for the affects of the SO ₂ . Contact Teledyne API's Technical Support Department (Section 5.7) for details.
H ₂ O	3 rd Body quenching: H ₂ O molecules collide with NO ₂ * molecules absorbing excess energy kinetically and preventing emission of light.	Analyzer's operating in high humidity areas must have some drying applied to the sample gas (see Section 2.3.2.6 for more details).
	Water also reacts with NH ₃ and SO _x in the O ₃ generator to create (NH ₃) ₂ SO ₄ (ammonium sulfate) and NH ₃ NO ₂ (ammonium nitrate) which form opaque white deposits on the optical filter window. This also forms highly corrosive HNO ₃ (nitric acid)	Water is effectively removed from the O ₃ gas stream by the Nafion Dryer (Section 6.3.3.2 for more details). We offer several Sample dryers for the sample stream (see Section 2.3.2.6 for more details).
NH ₃	NH ₃ also reacts with H ₂ O, O ₂ and SO _x in the O ₃ generator to create (NH ₃) ₂ SO ₄ (ammonium sulfate) and NH ₃ NO ₂ (ammonium nitrate) which form opaque white deposits on optical filter window. Also forms highly corrosive HNO ₃ (nitric acid).	The Sample dryer option, which is built into the T200UP analyzer, is sufficient for removing typical ambient concentration levels of NH ₃ .

6.2.5.1. DIRECT INTERFERENCE

Some gases can directly alter the amount of light detected by the PMT due to chemiluminescence in the reaction cell. This can either be a gas that undergoes chemiluminescence by reacting with O₃ in the reaction cell or a gas that reacts with other compounds and produces excess NO upstream of the reaction cell.

6.2.5.2. THIRD BODY QUENCHING

As described by Equation 6-3, other molecules in the reaction cell can collide with the excited NO₂^{*}, causing the excited NO₂^{*} to return to its ground state without releasing a photon of light. This is known as third party quenching.

Quenching is an unwanted phenomenon and the extent to which it occurs depends on the properties of the collision partner.

- Larger, more polarized molecules such as H₂O and CO₂ are the most significant quenching interferents of NO chemiluminescence.
- The influence of water vapor on the analyzer's measurement can be eliminated with an optional, internal sample gas dryer (see Section 2.3.2.6).
- The interference of varying CO₂ amounts at low concentrations (less than 0.5%) is negligible.

- In cases with excessively high CO₂ concentrations (larger than 0.5%), the effect can be calibrated out by using calibration gases with a CO₂ content equal to the measured air.
- Only very high and highly variable CO₂ concentrations will then cause a measurable interference. For those applications, it is recommended to use other analyzer models. Please consult Teledyne API's Sales Department or our website (front cover, this manual).
- Smaller less polar and electronically "harder" molecules such as N₂ and O₂ can cause interference of this type as well, however, the concentrations of N₂ and O₂ are virtually constant in ambient air measurements, hence provide a constant amount of quenching that is accounted for in the calibration of the instrument .

6.2.5.3. LIGHT LEAKS

The sensitivity curve includes a small portion of the visible light spectrum (see Figure 6-3), therefore it is important to ensure that the reaction cell is completely sealed with respect to light. To ensure this:

- All pneumatic tubing leading into the reaction cell is opaque in order to prevent light from entering the cell.
- Light penetration is prevented by stainless steel filters and orifices.

6.2.5.4. REACTION CELL TEMPERATURE CONTROL

The stability of the chemiluminescence reaction between NO and O₃ can be affected by changes in the temperature and pressure of the O₃ and sample gases in the reaction cell. In order to reduce temperature effects, the reaction cell is maintained at a constant 50° C, just above the high end of the instrument's operation temperature range.

Two AC heaters, one embedded into the bottom of the reaction cell, the other embedded directly above the chamber's exhaust fitting, provide the heat source. These heaters operate off of the instrument's main AC power and are controlled by the CPU through a power relay on the relay board (see Section 6.4.4.4).

A thermistor, also embedded in the bottom of the reaction cell, reports the cell's temperature to the CPU through the thermistor interface circuitry of the motherboard (see Section 6.4.3.3).

6.3. PNEUMATIC OPERATION

Important

IMPACT ON READINGS OR DATA

The sample gas is the most critical flow path in the analyzer. At any point before and in the reaction cell, the integrity of the sample gas must not be compromised. Therefore, it is important that the sample airflow system is both leak tight and not pressurized over ambient pressure.

Regular leak checks should be performed on the analyzer as presented in the maintenance schedule, Table 5-1. Procedures for correctly performing leak checks can be found in Section 5.4.11.

6.3.1. SAMPLE GAS FLOW

Note

In this section of the manual vacuum readings are given in inches of mercury absolute (In-Hg-A). This pressure value is referenced against zero (a perfect vacuum).

The sample gas flow is created by an external vacuum pump that is located pneumatically downstream from the rest of the instrument's components.

- The pump creates a vacuum of approximately 5 in-Hg-A which is distributed to various pneumatic components by a vacuum manifold, located just in front of the rear panel (see Figure 2-3).

Gas flow is created by keeping the analyzer's sample gas inlet near ambient pressure, usually by means of a small vent installed in the sample line at the inlet, in effect pulling the gas through the instrument's pneumatic systems.

By placing the pump downstream from the analyzer's reaction cell, several problems are avoided.

- First, the pumping process heats and compresses the sample air complicating the measurement process.
- Additionally, certain physical parts of the pump itself are made of materials that might chemically react with the sample gas.
- Finally, in certain applications where the concentration of the target gas might be high enough to be hazardous, maintaining a negative gas pressure relative to ambient means that should a minor leak occur, no sample gas would be pumped into the atmosphere surrounding the analyzer.

6.3.1.1. VACUUM MANIFOLD

The vacuum created by the analyzer's pump is supplied to all of the gas streams for the analyzer through the vacuum manifold (also called the exhaust manifold).

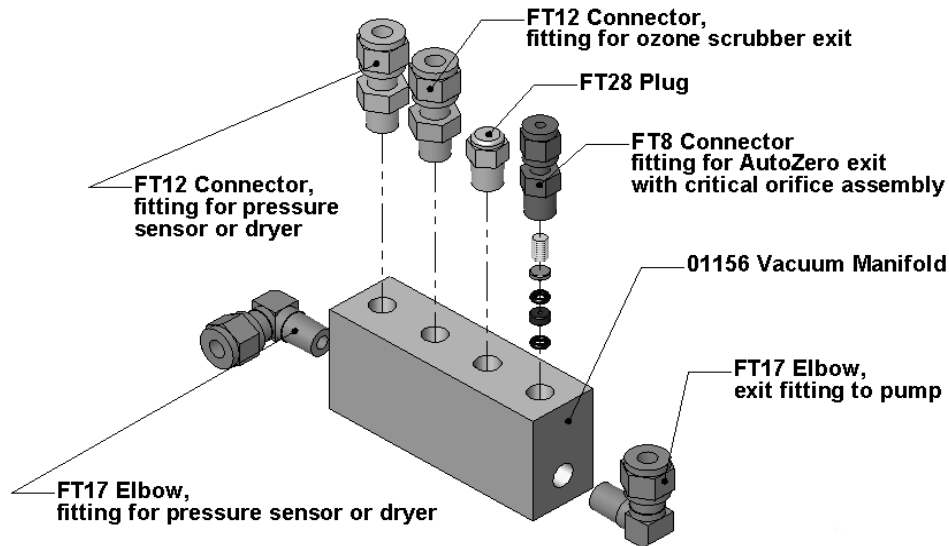


Figure 6-6. Vacuum Manifold, Standard Configuration

Configurations will vary depending on the optional equipment that is installed. For example:

- An optional internal span gas generator installed will add another FT8 connector and orifice assembly to the manifold where the FT28 fitting is shown in the above drawing.
- An optional sample gas dryer for the T200P will add a Tee-fitting so that two ¼" tubes can be connected to the same port.

6.3.2. FLOW RATE CONTROL - CRITICAL FLOW ORIFICES

Sample gas flow in the analyzer is created via the use of several flow control assemblies (see Figure 6-7 for an example) located in various places in the gas streams of the instrument. These assemblies consist of:

- a critical flow orifice
- two o-rings, Located just before and after the critical flow orifice, the o-rings seal the gap between the walls of assembly housing and the critical flow orifice
- a sintered filter
- a spring (applies mechanical force needed to form the seal between the o-rings, the critical flow orifice and the assembly housing)

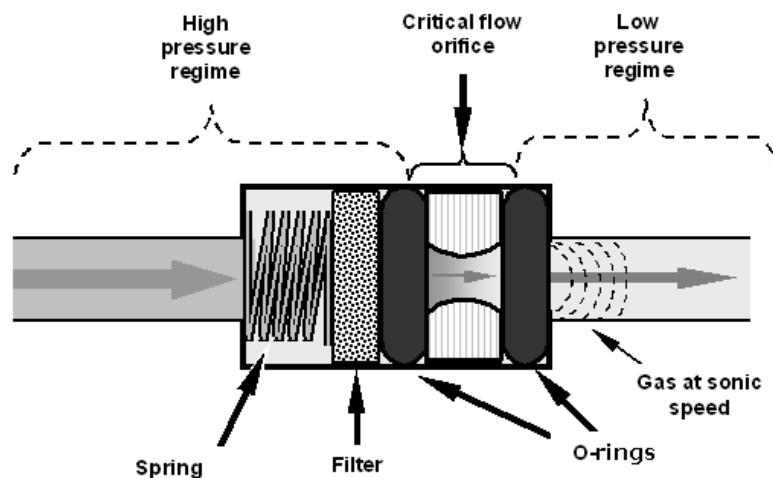


Figure 6-7. Flow Control Assembly & Critical Flow Orifice

6.3.2.1. CRITICAL FLOW ORIFICE

The most important component of each flow control assembly is the critical flow orifice. Critical flow orifices are a simple means to regulate stable gas flow rates. They operate without moving parts by taking advantage of the laws of fluid dynamics. By restricting the flow of gas through the orifice, a pressure differential is created. This pressure differential, created by the analyzer's external pump, draws the gas through the orifice.

As the pressure on the downstream side of the orifice (the pump side) continues to drop, the speed that the gas flows through the orifice continues to rise. Once the ratio of upstream pressure to downstream pressure is greater than 2:1, the velocity of the gas through the orifice reaches the speed of sound. As long as that ratio stays at least 2:1, the gas flow rate is unaffected by any fluctuations, surges, or changes in downstream pressure because such variations only travel at the speed of sound themselves and are therefore cancelled out by the sonic shockwave at the downstream exit of the critical flow orifice.

The actual flow rate of gas through the orifice (volume of gas per unit of time), depends on the size and shape of the aperture in the orifice. The larger the holes, the more gas molecules (moving at the speed of sound) pass through the orifice.

In addition to controlling the gas flow rates into the reaction cell, the two critical flow orifices at the inlets of the reaction cell also maintain an under-pressure inside it, effectively reducing the number of molecules in the chamber and the corresponding incidence of third body quenching (see Section 6.2.5.2), and thereby increasing the chemiluminescence yield.

- The analyzer reaches its peak sensitivity at about 2 in-Hg-A, below which the sensitivity drops due to there being too few molecules present and a corresponding decrease in chemiluminescence.

6.3.2.2. LOCATIONS AND DESCRIPTIONS OF CRITICAL FLOW

Several critical flow orifices (Figure 6-8) are used to create and maintain the proper flow rate of gas through its various components. (Please note that Figure 6-8 represents the standard configuration and is provided for reference).

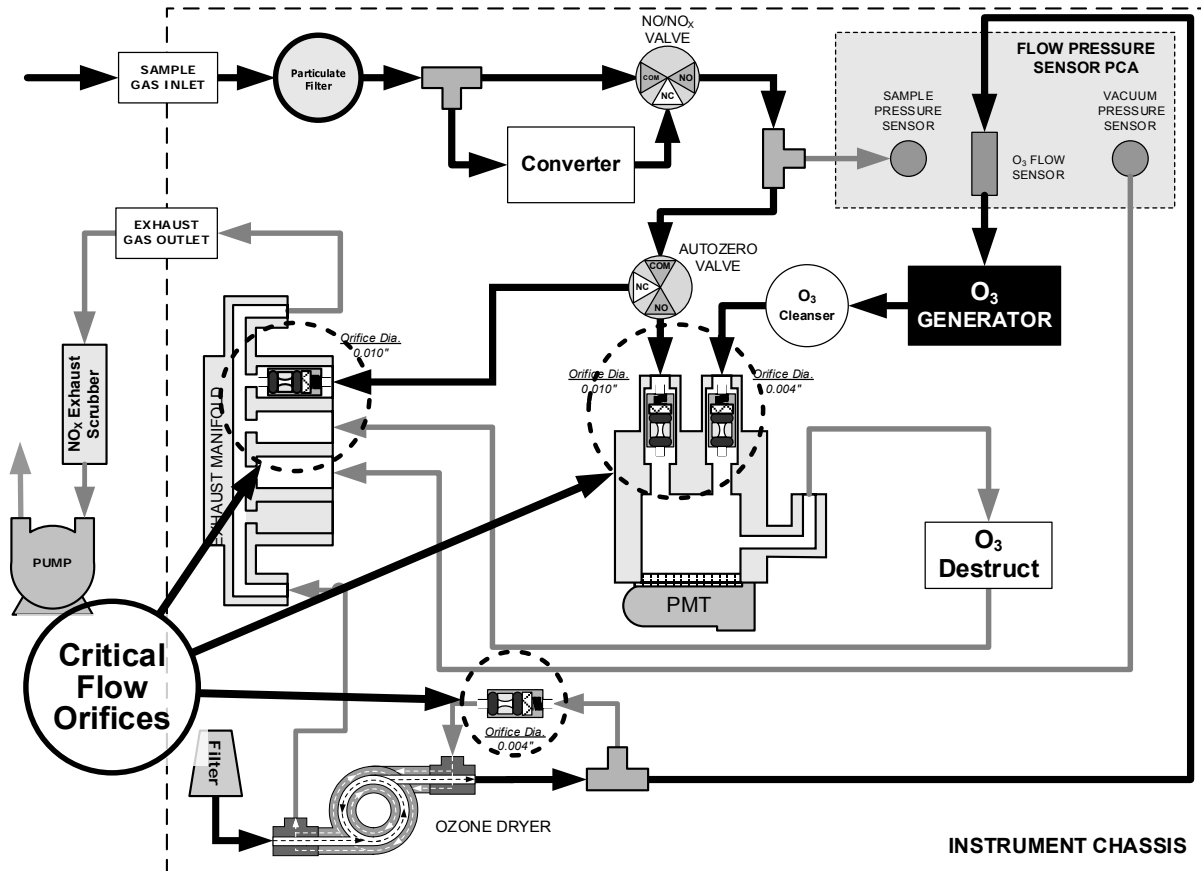


Figure 6-8. Location of Flow Control Assemblies & Critical Flow Orifices in T200P

Table 6-2. T200P Gas Flow Controls

LOCATION	PURPOSE	ORIFICE DIAMETER	FLOW RATE (NOMINAL)
Sample gas inlet of reaction cell	Controls rate of flow of sample gas into the reaction cell.	0.010" (0.25 mm)	500 cc/min
O ₃ supply inlet of reaction cell	Controls rate of flow of ozone gas into the reaction cell.	0.004" (0.10 mm)	80 cc/min
Dry air return of ozone dryer	Controls flow rate of dry air return / purge air of the dryer.	0.004" (0.10 mm)	80 cc/min
Vacuum manifold, Auto Zero connection.	Controls rate of sample gas flow when bypassing the reaction cell during the Auto Zero cycle.	0.010" (0.25 mm)	500 cc/min
Vacuum manifold, Internal span gas generator exhaust port (when optional IZS generator installed).	Controls rate of flow of zero purge gas through the optional Internal span gas generator when it is installed.	0.003" (0.08 mm)	60 cc/min

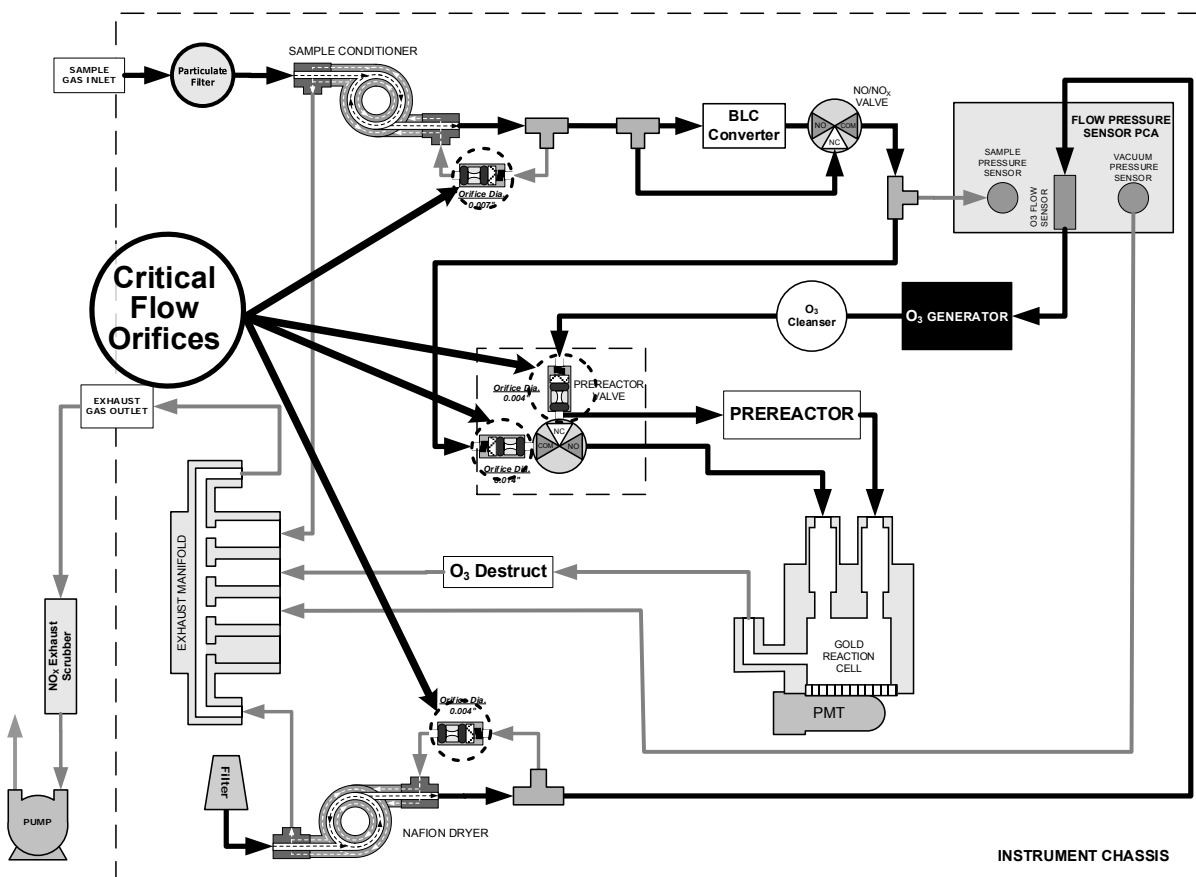


Figure 6-9. Location of Flow Control Assemblies & Critical Flow Orifices in T200UP

Table 6-3. T200UP Gas Flow Controls

LOCATION	PURPOSE	ORIFICE DIAMETER	FLOW RATE (NOMINAL)
Sample gas inlet of prereactor valve	Controls rate of flow of sample gas through the prereactor valve into the prereactor chamber or into the reaction cell.	0.014" (0.35 mm)	1100 cc/min
Dry air return of Sample dryer	Controls flow rate of dry air return / purge air of the dryer.	0.007" (0.18 mm)	250 cc/min
O ₃ supply inlet of prereactor valve	Controls rate of flow of ozone gas through the prereactor into the reaction cell.	0.004" (0.10 mm)	80 cc/min
Dry air return of ozone dryer	Controls flow rate of dry air return / purge air of the dryer.	0.004" (0.10 mm)	80 cc/min

The necessary 2:1 ratios across the critical flow orifices is largely exceeded by the pumps supplied with the analyzer which are designed to accommodate a wide range of possible variability in atmospheric pressure and age related degradation of the pump itself. Once the pump does degrade the ratio between sample and vacuum pressures may fall to less than 2:1. At this point, the instrument will display an invalid sample flow rate measurement.

Note

The diameter of a critical flow orifice may change with temperature because of expansion of the orifice material and, hence, the most crucial critical flow orifices (those controlling the sample gas and O₃ flow into the cell itself) are located in the reaction cell where they can be maintained at a constant temperature.

6.3.3. OZONE GAS GENERATION AND AIR FLOW

The excess ozone needed for reaction with NO in the reaction cell is generated inside the analyzer because of the instability and toxicity of ozone. Besides the ozone generator itself, this requires a dry air supply and filtering of the gas before it is introduced into the reaction cell.

Due to its toxicity and aggressive chemical behavior, O₃ must also be removed from the gas stream before it can be vented through the exhaust outlet.

CAUTION – GENERAL SAFETY HAZARD



Ozone (O₃) is a toxic gas.

Obtain a Material Safety Data Sheet (MSDS) for this gas. Read and rigorously follow the safety guidelines described there.

Always ensure that the plumbing of the O₃ generation and supply system is maintained and leak-free.

6.3.3.1. THE O₃ GENERATOR

The analyzer uses a dual-dielectric, Corona Discharge (CD) tube for creating its O₃, which is capable of producing high concentrations of ozone efficiently and with low excess heat (see Figure 6-10). The primary component of the generator is a glass tube with hollow walls of which the outermost and innermost surfaces are coated with electrically conductive material.

Air flows through the glass tube, between the two conductive coatings, in effect creating a capacitor with the air and glass acting as the dielectric. The layers of glass also separate the conductive surfaces from the air stream to prevent reaction with the O₃. As the capacitor charges and discharges, electrons are created and accelerated across the air gap and collide with the O₂ molecules in the air stream splitting them into elemental oxygen.

Some of these oxygen atoms recombine with O₂ to O₃. The quantity of ozone produced is dependent on factors such as the voltage and frequency of the alternating current applied to the CD cells. When enough high-energy electrons are produced to ionize the O₂ molecules, a light emitting, gaseous plasma is formed, which is commonly referred to as a corona, hence the name corona discharge generator.

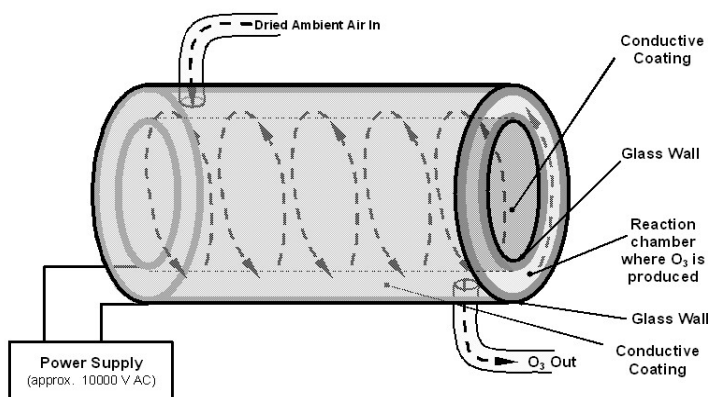


Figure 6-10. Ozone Generator Principle

6.3.3.2. OZONE GENERATOR DRY AIR SUPPLY

Ambient air usually contains enough water vapor to greatly diminish the yield of ozone produced by the ozone generator. Water also reacts with chemicals inside the O₃ Generator to produce caustic substances such as ammonium sulfate or highly corrosive nitric acid that will damage the optical filter located between the reaction cell and the PMT.

To prevent this, the air supply for the O₃ generator is dried using a special single tube permeation dryer. The dryer consists of a single tube of Nafion[®] that is mounted within an outer, flexible plastic tube. Nafion[®] is a co-polymer that absorbs water very well but not most other chemicals. As gas flows through the inner Nafion[®] tube, water vapor is absorbed into the membrane walls. The absorbed water is transported through the membrane wall and evaporated into the dry purge gas flowing through the outer tube, countercurrent to the gas in the inner tube.

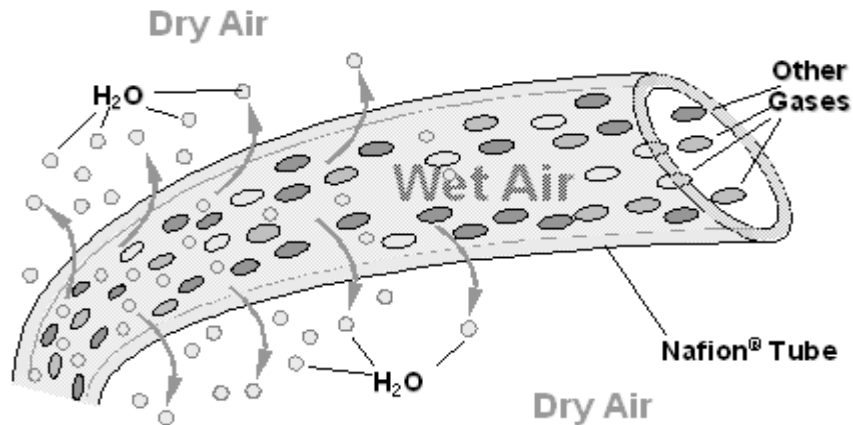


Figure 6-11. Semi-Permeable Membrane Drying Process

The process by which the water vapor molecules are collected and transported through Nafion[®] material is called per-evaporation and is driven by the humidity gradient between the inner and outer tubes as well as the flow rates and pressure difference between inner and outer tubing. Unlike micro-porous membrane permeation, which transfers water through a relatively slow diffusion process, per-evaporation is a simple kinetic reaction. Therefore, the drying process occurs quickly, typically within milliseconds.

Because this chemical reaction is based on hydrogen bonds between the water molecule and the Nafion[®] material most other chemical components of the gas to be dried are usually unaffected. Specifically, the gases of interest for the T200, NO and NO₂, do not get absorbed and pass the dryer unaltered.

On the other hand, other small polar gases that are capable of hydrogen bonds such as ammonia (NH₃) can be absorbed this way, too. This is an advantage since gases such as NH₃ can cause interference for the measurement of NO_x, NO and NO₂ (see Table 6-1).

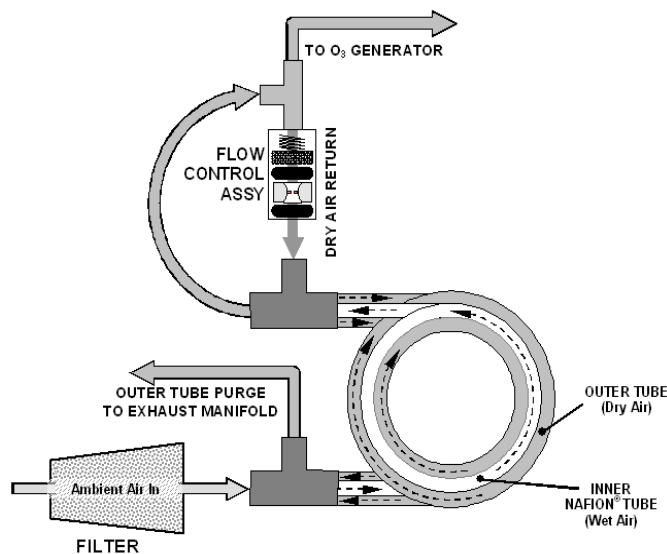


Figure 6-12. Sample Dryer

To provide a dry purge gas for the outer side of the Nafion[®] tube, the analyzer returns some of the dried air from the inner tube to the outer tube. This means that any time the analyzer is turned on after having been OFF for 30 minutes or more, the humidity gradient between the inner and outer tubes is not very large and the dryer's efficiency is low. It takes a certain amount of time for the humidity gradient to become large enough for the Sample Dryer operate efficiently, in such cold start cases the O₃ Generator is not turned on until 30 minutes has passed in order to ensure that it is not operating until its air supply is properly dry.

Note

When rebooting the instrument within less than 30 minutes of power-down, the generator is turned on immediately.

The Sample Dryer is capable of adequately drying ambient air to a dewpoint of $\leq -5^{\circ}\text{C}$ (~ 4000 ppm residual H₂O) at a flow rate of 1 standard liter per minute (slpm) or down to $\leq -15^{\circ}\text{C}$ (~ 1600 ppm residual H₂O) at 0.5 slpm. The Sample Dryer is also capable of removing ammonia from the sample gas up to concentrations of approximately 1 ppm.

6.3.3.3. OZONE SUPPLY AIR FILTER

The analyzer uses ambient air as the supply gas for the O₃ generator and may produce a variety of byproducts. Small amounts of water, ammonia and various sulfur oxides can combine to create ammonium sulfate, ammonium nitrate, nitric acid and other compounds. Whereas sulfates and nitrates can create powdery residues inside the reaction cell causing sensitivity drift, nitric acid is a very aggressive compound, which can deteriorate the analyzer's components. In order to remove these chemical byproducts from the O₃ gas stream, the output of the O₃ generator flows through a special filter between the generator and the reaction cell.

The small amount of NO_x produced in the generator (from the reaction of O₂ or O₃ and N₂ in the air) will not affect the analyzer's ability to measure NO_x, NO and NO₂ as it is accounted for and removed from the concentration calculations by the analyzer's Auto Zero feature (see Section 6.2.3).

6.3.3.4. OZONE DESTRUCT

Even though ozone is unstable and typically reacts to form O₂, the break-down is not quite fast enough to ensure that it is completely removed from the exhaust gas stream by the time the gas exits the analyzer. Due to the high toxicity and reactivity of O₃, a highly efficient catalytic converter scrubs or converts all of the O₃ from the gas exiting the reaction cell. The conversion process is very safe. It only converts ozone to oxygen and does not produce any toxic or hazardous gases.

The O₃ destruct is located just inside the NO₂ converter. As this is a true catalytic converter, there are no maintenance requirements as would be required for charcoal-based ozone destructs.

A certain amount of fine, black dust may exit the catalyst, particularly if the analyzer is subjected to sudden pressure drops (for example, when disconnecting the running pump without letting the analyzer properly and slowly equilibrate to ambient pressure). To

prevent the dust from entering the reaction cell or the pump, the ozone destruct is equipped with a quartz wool filter material.

6.3.4. PNEUMATIC SENSORS

Note

The analyzer displays all pressures in inches of mercury absolute (in-Hg-A), i.e. absolute pressure referenced against zero (a perfect vacuum).

Three pneumatic sensors verify the flow and pressure levels of the gas streams. They are located on a printed circuit assembly, called the pneumatic pressure/flow sensor board, located just behind the sensor assembly. The measurements made by these sensors are used for a variety of important calculations and diagnostics.

6.3.4.1. SAMPLE PRESSURE SENSOR

An absolute pressure transducer connected to the input of the NO/NO_x valve is used to measure the pressure of the sample gas before it enters the analyzer's reaction cell.

- In conjunction with the measurement made by the vacuum pressure sensor, this "upstream" measurement is used to compute the sample gas sample flow rate and to validate the critical flow condition (2:1 pressure ratio) through the sample gas critical flow orifice (Section 6.3.2).
- If the Temperature/Pressure Compensation (TPC) feature is turned on (Section 6.10.2), the output of this sensor is also used to supply pressure data for that calculation.

6.3.4.2. VACUUM PRESSURE SENSOR

An absolute pressure transducer connected to the exhaust manifold is used to measure the pressure downstream from and inside the instrument's reaction cell.

- The output of the sensor is used by the CPU to calculate the pressure differential between the gas upstream of the reaction cell and the gas downstream from it and is also used as the main diagnostic for proper pump operation.
- If the ratio between the upstream pressure and the downstream pressure falls below 2:1, an Alert is triggered, and the sample flow rate will not display an actual value.
- If this pressure exceeds 10 in-Hg-A, an RCELL Press Warn Alert is issued, even though the analyzer will continue to calculate a sample flow up to ~14 in Hg.
- If the Temperature/Pressure Compensation (TPC) feature is turned on (see Section 6.10.2), the output of this sensor is also used to supply pressure data for that calculation.
- This measurement is viewable in the Dashboard as Rx Cell.

6.3.4.3. SAMPLE GAS FLOW CALCULATION

Sample gas flow in the analyzer is not a directly measured value, but is rather calculated based on the measured pressure differential across the sample gas critical flow orifice. Specifically, the upstream reading of the sample pressure sensor is compared to the downstream pressure reading of the vacuum pressure sensor, and this differential is used by the analyzer's CPU to derive the gas flow rate through the reaction cell.

- The results of this calculation are viewable in the Dashboard and/or in the Home page meter if configured to display Sample Flow. (To configure, see Section 2.5.3 for Dashboard, and Section 2.5.6 for Home page).

6.3.4.4. O₃ SUPPLY AIR FLOW SENSOR

In contrast to the sample gas flow, the ozone flow is measured with a mass flow sensor, which is mounted on the flow/pressure sensor PCA just behind the PMT sensor assembly. Pneumatically, it lies between the Sample dryer and the O₃. This mass flow sensor has a full scale range of 0-1000 cc/min and can be calibrated through software to its span point (Section 4.5).

Since the flow value displayed on the front panel is an actual measurement (and not a calculated value), short term variability in the measurement may be higher than that of the sample flow, which is based on a calculation from (more stable) differential pressures. On the other hand, any sustained drift, i.e. long-term change, in the ozone flow rate may usually indicate a flow problem.

This information is used to validate the O₃ gas flow rate.

- If the flow rate exceeds $\pm 15\%$ of the nominal flow rate (80 cc/min), the Ozone FLOW WARNING appears in the Alerts page and the O₃ generator is turned off.
- A second warning, OZONE GEN OFF is also displayed.
- This flow measurement is viewable through instrument's front panel display as the test function OZONE FL and the SIGNAL I/O function OZONE_FLOW.

As with all other test parameters, we recommend to monitor the ozone flow over time for predictive diagnostics and maintenance evaluation.

6.4. ELECTRONIC OPERATION

6.4.1. OVERVIEW

Figure 6-13 shows a block diagram of the major electronic components of the analyzer.

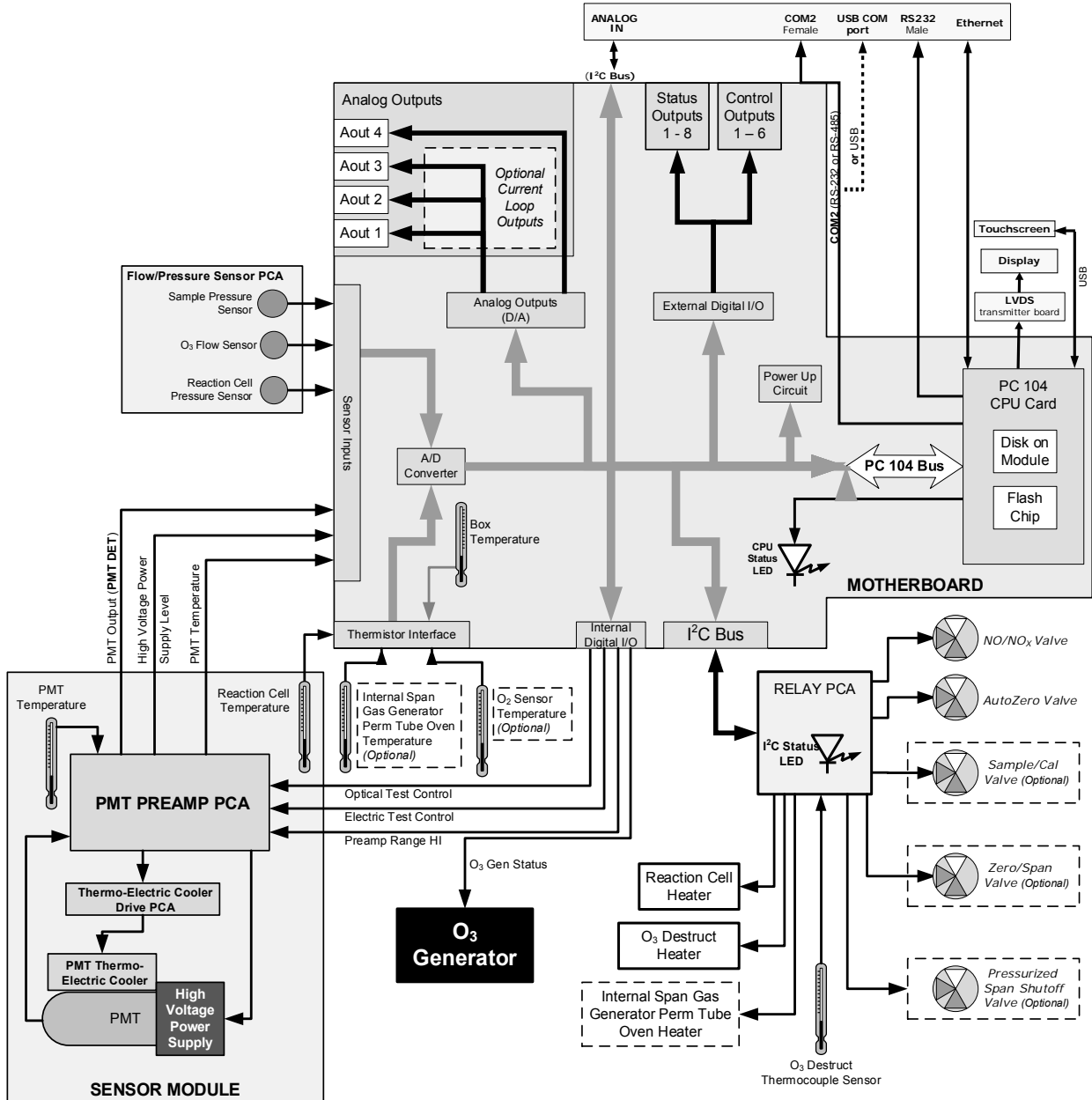


Figure 6-13. Electronic Block Diagram

The core of the analyzer is a microcomputer/central processing unit (CPU) that controls various internal processes, interprets data, makes calculations, and reports results using specialized firmware developed by Teledyne API. It communicates with the user as well as receives data from and issues commands to a variety of peripheral devices via a separate printed circuit assembly onto which the CPU is mounted: the motherboard.

The motherboard is directly mounted to the inside rear panel and collects data, performs signal conditioning duties and routes incoming and outgoing signals between the CPU and the analyzer's other major components.

Data are generated by the sensor module which outputs an analog signal corresponding to the amount of chemiluminescence present in the reaction cell. This signal is converted into digital data by a unipolar, analog-to-digital converter, located on the motherboard.

A variety of sensors report the physical and operational status of the analyzer's major components, again through the signal processing capabilities of the motherboard. These status reports are used as data for the various concentration calculations and as trigger events for certain warning messages and control commands issued by the CPU. This information is stored in memory by the CPU and in most cases can be viewed by the user via the front panel display.

The CPU issues commands via a series of relays and switches (also over the I²C bus) located on a separate printed circuit assembly, called the Relay PCA, to control the function of key electromechanical devices such as heaters and valves. It also issues some commands directly to the Sensor module (e.g. initiate Electric Test or Optical Test).

By controlling the state of various valves the CPU directs the flow of sample gas through the various gas paths of the analyzer (NO measurement path; NO_x measurement path; Auto Zero Path). Based on which path is active, the CPU interprets the sensor output to derive raw data representing concentrations for NO_x, NO and zero (dark condition), accesses the operational data stored in memory then calculates final concentrations for NO_x, NO and NO₂.

The CPU communicates with the user and the outside world in several ways:

- Through the analyzer's front panel LCD touch-screen interface
- Through the serial I/O channels
- Various analog voltage and current outputs
- Several sets of Digital I/O channels
- Ethernet

6.4.2. CPU

The unit's CPU card, installed on the motherboard located inside the rear panel, is a low power, high performance, 86-based PC 104 microcomputer running Windows CE. It includes two types of non-volatile data storage: a Disk-on-Module (DOM) and an embedded flash chip. The DOM is a 44-pin IDE flash drive with storage a 512 MB capacity. It is used to store the computer's operating system, the Teledyne API firmware, and most of the operational data generated by the analyzer's internal data acquisition system (DAS). The non-volatile, embedded flash chip includes 2MB of storage for calibration data as well as a backup of the analyzer configuration.

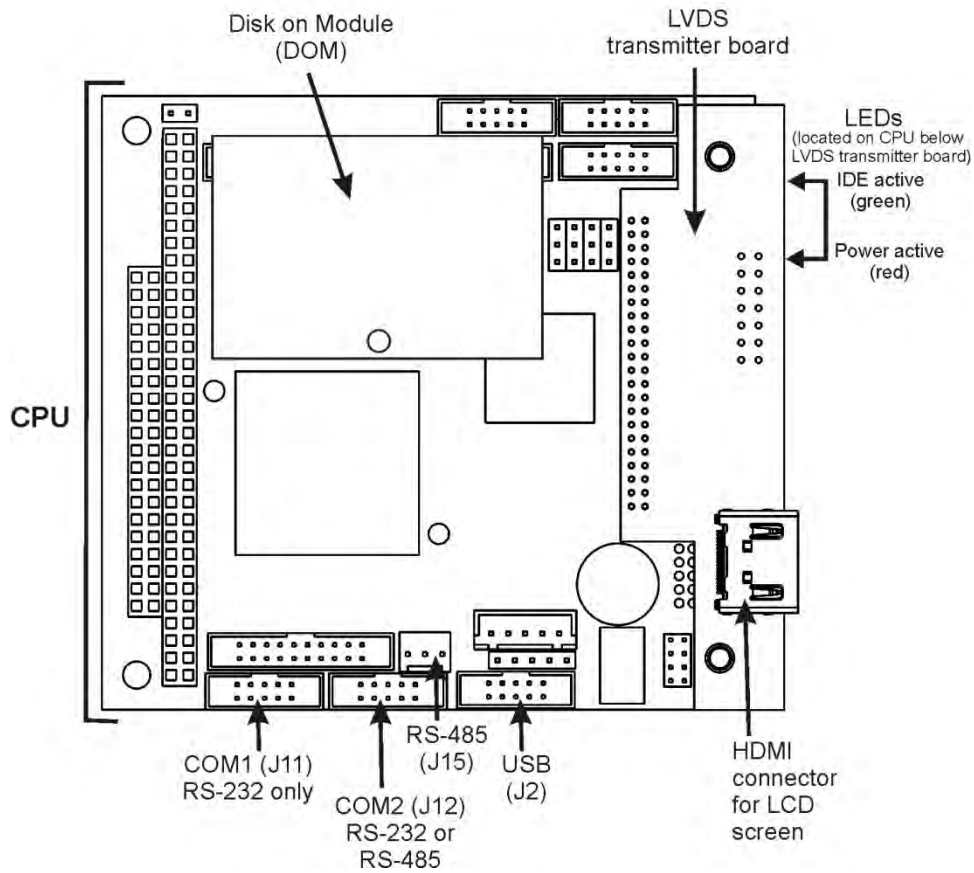


Figure 6-14. CPU Board

6.4.3. MOTHERBOARD

This PCA provides a multitude of functions including, A/D conversion, digital input/output, PC-104 to I²C translation, temperature sensor signal processing and is a pass through for the RS-232 and RS-485 signals.

6.4.3.1. A TO D CONVERSION

Analog signals, such as the voltages received from the analyzers various sensors, are converted into digital signals that the CPU can understand and manipulate by the analog to digital converter (A/D). Under the control of the CPU, this functional block selects a particular signal input and then converts the selected voltage into a digital word.

The A/D consists of a Voltage-to-Frequency (V-F) converter, a Programmable Logic Device (PLD), three multiplexers, several amplifiers and some other associated devices. The V-F converter produces a frequency proportional to its input voltage. The PLD counts the output of the V-F during a specified time, and sends the result of that count, in the form of a binary number, to the CPU.

The A/D can be configured for several different input modes and ranges, but in this analyzer it is used in unipolar mode with a +5V full scale. The converter includes a 1% over and under-range. This allows signals from -0.05V to +5.05V to be fully converted.

For calibration purposes, two reference voltages are supplied to the A/D converter: Reference ground and +4.096 VDC. During calibration, the device measures these two voltages, outputs their digital equivalent to the CPU. The CPU uses these values to compute the converter's offset and slope and uses these factors for subsequent conversions.

6.4.3.2. SENSOR INPUTS

The key analog sensor signals are coupled to the A/D through the master multiplexer from two connectors on the motherboard. 100K terminating resistors on each of the inputs prevent cross talk from appearing on the sensor signals.

PMT DETECTOR OUTPUT: The PMT detector output from the PMT preamplifier is used in the computation of the NO, NO_x and NO₂ concentrations.

HIGH VOLTAGE POWER SUPPLY (HVPS) LEVEL: The PMT high voltage is based on the drive voltage from the preamplifier board. It is digitized and sent to the CPU which then calculates the voltage setting of the HVPS.

PMT TEMPERATURE: The PMT temperature is measured with a thermistor inside the PMT cold block. Its signal is amplified by the PMT temperature feedback circuit on the preamplifier board and is digitized and sent to the CPU which calculates the current temperature of the PMT.

SAMPLE GAS PRESSURE SENSOR: Measures the sample chamber's gas pressure.

VACUUM PRESSURE SENSOR: Measures the pressure of the gas mixture inside the reaction cell.

O₃ FLOW SENSOR: Measures the flow rate of the O₃ gas stream as it is supplied to the reaction cell.

6.4.3.3. THERMISTOR INTERFACE

This circuit provides excitation, termination and signal selection for several negative coefficient, thermistor temperature sensors located inside the analyzer.

REACTION CELL TEMPERATURE SENSOR: A thermistor that measures the temperature inside the reaction cell manifold, which is used by the CPU to control the reaction cell heating circuit and as a parameter in the temperature/pressure compensation algorithm.

BOX TEMPERATURE SENSOR: A thermistor that measures the analyzer's inside temperature, which is then reported through the front panel display. It is also used as part of the NO, NO_x and NO₂ calculations when the instrument's Temperature/Pressure Compensation feature is enabled.

INTERNAL SPAN GAS GENERATOR OVEN_TEMPERATURE: This thermistor reports the temperature of the optional internal span gas generator's NO₂ permeation source to the CPU as part of a control loop that keeps the tube at a high constant temperature (necessary to ensure that the permeation rate of NO₂ is constant).

Note

There are two thermistors that monitor the temperature of the PMT assembly:

One is embedded in the cold block of the PMT's TEC. Its signal is conditioned by the PMT preamplifier PCA and reported to the CPU via the motherboard (see Section 6.4.3.2).

The second is located on the PMT Preamplifier PCA and is used only as a reference for the preamplifier circuitry. Its output is neither reported nor stored.

6.4.3.4. ANALOG OUTPUTS

The analyzer comes equipped with four configurable analog outputs on the instrument's rear panel analog connector, labeled A1, A2, A3 and A4. A variety of scaling measurement and electronic factors apply to these signals.

OUTPUT LOOP-BACK: All of the functioning analog outputs are connected back to the A/D converter through a Loop-back circuit. This permits the voltage outputs to be calibrated by the CPU without need for any additional tools or fixtures.

6.4.3.5. EXTERNAL DIGITAL I/O

The external digital I/O controls the Status Outputs and the Control Inputs.

6.4.3.6. INTERNAL DIGITAL I/O

The internal Digital I/O controls some subsystems, such as the electrical and optical tests, the PMT preamplifier range control, and the O₃ generator.

6.4.3.7. I²C DATA BUS

I²C is a two-way, clocked, bi-directional digital serial I/O bus that is used widely in commercial and consumer electronic systems. A transceiver on the Motherboard converts data and control signals from the PC-104 bus to I²C format. The data are then fed to the relay board, optional analog input board and valve driver board circuitry.

6.4.3.8. POWER-UP CIRCUIT

This circuit monitors the +5V power supply during start-up and sets the analog outputs, external digital I/O ports, and I²C circuitry to specific values until the CPU boots and the instrument software can establish control.

6.4.4. RELAY PCA

The CPU issues commands via a series of relays and switches located on a separate printed circuit assembly, called the Relay PCA (Figure 6-15), to control the function of key electromechanical devices such as heaters and valves. The Relay PCA receives instructions in the form of digital signals over the I²C bus, interprets these digital instructions and activates its various switches and relays appropriately.

The Relay PCA is located in the right-rear quadrant of the analyzer and is mounted vertically on the backside of the same bracket as the instrument's DC power supplies.

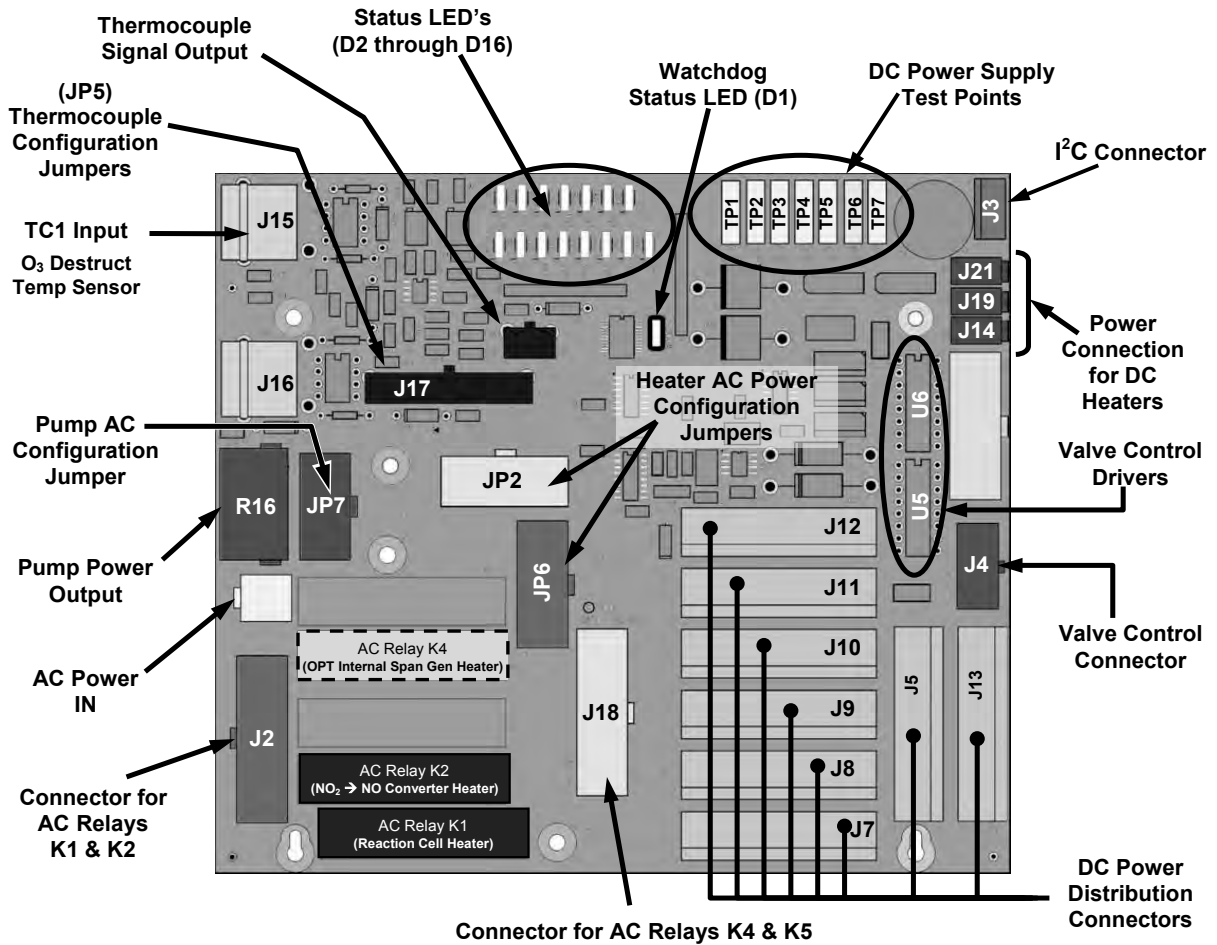


Figure 6-15. Relay PCA Layout (P/N 045230100)

WARNING – ELECTRICAL SHOCK HAZARD

Only those relays actually required by the configuration of the analyzer are populated.



A protective retainer plate is installed over the ac power relay to keep them securely seated in their sockets and prevent accidental contact with those sockets that are not populated see Figure 6-16).

Never remove this retainer while the instrument is plugged in and turned on. The contacts of the AC relay sockets beneath the shield carry high AC voltages even when no relays are present.

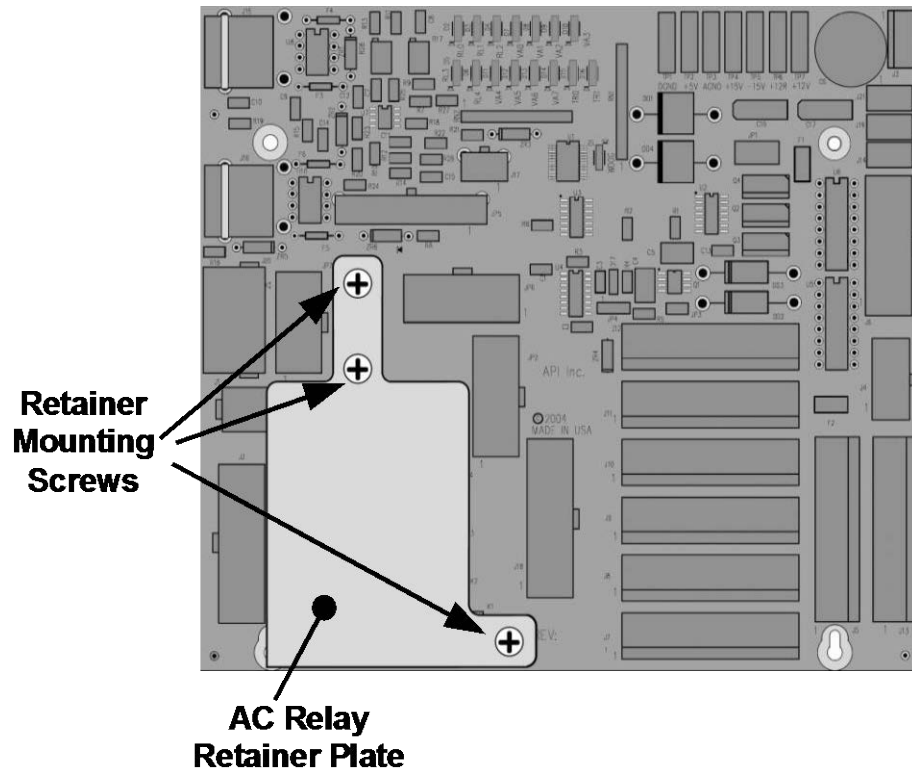


Figure 6-16. Relay PCA P/N 045230100 with AC Relay Retainer in Place

6.4.4.1. STATUS LED'S

Sixteen LEDs are located on the analyzer's Relay PCA to show the current status on the various control functions performed by the Relay PCA (see Figure 5-15). Their on/off states are described in Table 6-4; their functions and fault descriptions were presented in Table 5-6.

Table 6-4. Relay PCA Status LED's Table 5-6

LED	STATUS WHEN LIT (ENERGIZED STATE)	STATUS WHEN UNLIT (DEFAULT STATE)
D1	Cycles ON/OFF every 3 Seconds under direct control of the analyzer's CPU.	
D2	Reaction cell heater is heating	Not Heating
D3	Heating	Not Heating
D4		
D5 ¹	Converter heater is heating	Not Heating
D6		
D7	Z/S valve OPEN to span gas flow	Valve OPEN to zero gas flow
D8	Sample/Cal valve OPEN to calibration gas flow	Valve OPEN to sample gas flow
D9	A/Z valve: sample gas flow BYPASSES the reaction cell	Sample gas flow is routed THROUGH the reaction cell
D10	NO/NOx valve: gas flow routed THROUGH the converter	Gas Flow BYPASSES the converter
D11 ²	Dual span gas valve (1 or 2): OPEN to SPAN 1 gas inlet	OPEN to SPAN2 inlet
D12 ³	Pressurized span shutoff valve: Span gas flow SHUTOFF	Span gas flow OPEN
D13 ⁴	Pressurized zero shutoff valve: Zero gas flow SHUTOFF	Zero gas flow OPEN
D14 – 16	Spare	

¹ Only active when the optional internal span gas generator is installed.

² Only active when the dual pressurized span option is installed.

³ Only active when one of the pressurized span gas options is installed.

⁴ Only active when one of the pressurized zero gas options is installed.

6.4.4.2. WATCHDOG CIRCUITRY

The most important of the status LED's on the relay board is the red I²C bus watch-dog LED. It is controlled directly by the analyzer's CPU over the I²C bus. Special circuitry on the Relay PCA watches the status of D1. Should this LED ever stay ON or OFF for 30 seconds, indicating that the CPU or I²C bus has stopped functioning, this Watchdog Circuit automatically shuts all valves and turns off all heaters.

6.4.4.3. VALVE CONTROL

The relay board also hosts two valve driver chips, each of which can drive up four valves. The main valve assembly is the NO/NO_x - Auto-zero solenoid valve component mounted right in front of the NO₂ converter housing.

- These two valves are actuated with 12 V supplied from the relay board and under the control of the CPU through the I²C bus.

Additional valve set options also controlled by the CPU via the I²C bus, and the relay PCA can be included. (see Sections 2.3.2.3, 2.3.2.4, and 2.3.2.5 regarding these valve sets).

6.4.4.4. HEATER CONTROL

For a variety of reasons such as, efficiency of certain chemical reactions, stabilization of sample gas temperature and pressure, etc., various subcomponents are heated/cooled.

Two types of sensors are used to gather temperature data for the CPU:

- THERMISTORS: These are used in areas where the temperature control point is at or near ambient temperature (e.g. the reaction cell temperature, internal chassis temperate).
 - Thermistors change resistance as they heat up and cool down. A DC signal is sent from the Mother board of a sent voltage and current. As the thermistor changes resistance, the returning voltage rises and falls in direct relationship to the change in temperature.
 - The output signal from the thermistors is received by the motherboard, converted into digital data which is forwarded to the CPU.
- THERMOCOUPLES: These are used where the target temperature is high.
 - Thermocouples generate DC voltage that rises and falls as the thermocouple heats up and cools down.
 - This DC signal interpreted, conditioned and amplified by the Relay PCA then transmitted to the motherboard where it is also converted into digital data and forwarded to the CPU.

All of the heaters used are AC powered which are turned ON/OFF by AC relays located on the Relay PCA in response to commands issued by the CPU.

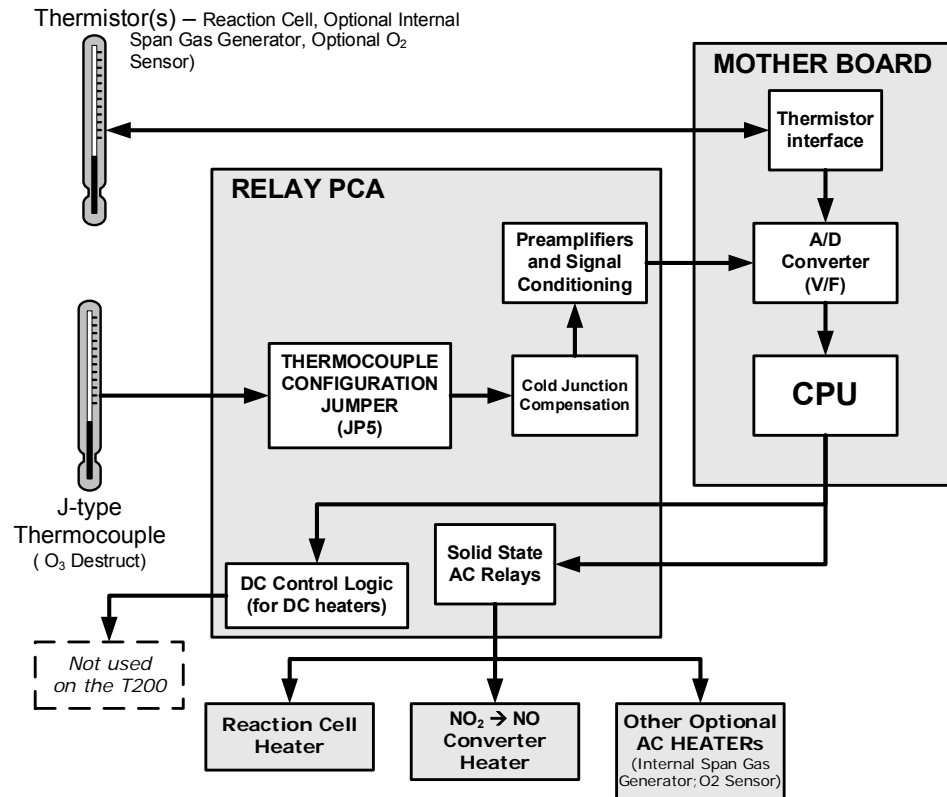


Figure 6-17. Heater Control Loop Block Diagram.

Note The PMT temperature is maintained by a separate control loop that does not involve the relay PCA (see Section 6.6.2).

6.4.4.5. THERMOCOUPLE INPUTS AND CONFIGURATION JUMPER (JP5)

Although the Relay PCA supports two thermocouple inputs, these analyzers only utilize one. It is used to sense the temperature of the Ozone Destruct.

- This single thermocouple input is plugged into the TC1 input (J15).
- TC2 (J16) is currently not used (see Figure 6-15 for location of J15 and J16).
- The type and operating parameters of this thermocouple are set using a jumper plug (JP5).

The default configuration for this thermocouple is:

- Type-K
- Temperature compensated for Type-K
- Isolated

Table 6-5. Thermocouple Configuration Jumper (JP5) Pin-Outs

TC INPUT	JUMPER PAIR	DESCRIPTION	FUNCTION
TC1	1 – 11	Gain Selector	Selects preamp gain factor for J or K TC OUT = K TC gain factor; IN = J TC gain factor
	2 – 12	Output Scale Selector	Selects preamp gain factor for J or K TC OUT = 10 mV / °C; IN = 5 mV / °C
	3 – 13	Type J Compensation	When present, sets Cold Junction Compensation for J type Thermocouple
	4 – 14	Type K Compensation	When present, sets Cold Junction Compensation for K type Thermocouple
	5 – 15	Termination Selector	Selects between Isolated and grounded TC IN = Isolate TC; OUT = Grounded TC
TC2	NOT USED		

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

The correct Thermocouple Type must be used if there is ever the need for replacement. If in doubt please consult Teledyne API Technical Support.

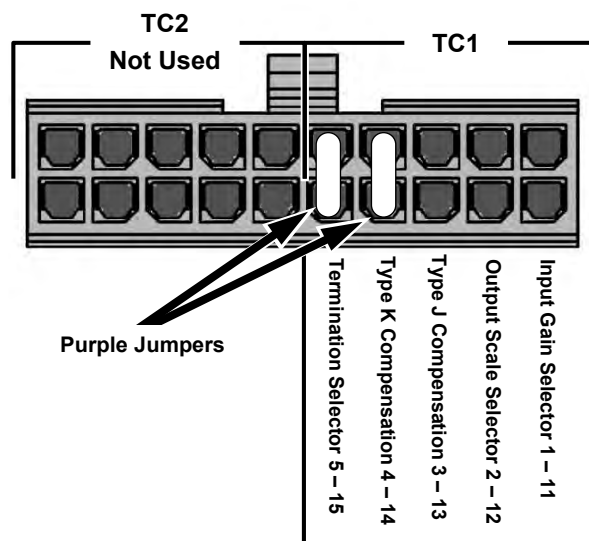


Figure 6-18. Thermocouple Configuration Jumper (JP5) Pin-Outs

6.5. SENSOR MODULE

The sensor assembly (Figure 5-20) consists of several subassemblies, each with different tasks:

- The Photo Multiplier Tube (PMT) detects the intensity of the light from the chemiluminescence reaction between NO and O₃ in the reaction cell. It outputs a current signal that varies in relationship with the amount of light in the reaction cell.
- The PMT Preamplifier PCA converts the current output by the PMT into a voltage and amplifies it to a signal strong enough to be usable by the motherboard's A → D converter. It also supplies the drive voltage and gain adjustment for the PMT's High Voltage Power Supply (HVPS)
- The Thermo-Electric Cooler (TEC) controls the temperature of the PMT to ensure the accuracy and stability of the measurements.

6.6. PHOTO MULTIPLIER TUBE (PMT)

The analyzers use a photo multiplier tube (Figure 5-20) to detect the amount of chemiluminescence created in the Reaction Cell.

A typical PMT is a vacuum tube containing a variety of specially designed electrodes. Photons from the reaction are filtered by an optical high-pass filter, enter the PMT and strike a negatively charged photo cathode causing it to emit electrons. A high voltage potential across these focusing electrodes directs the electrons toward an array of high voltage dynodes.

The dynodes in this electron multiplier array are designed so that each stage multiplies the number of emitted electrons by emitting multiple, new electrons. The greatly increased numbers of electrons emitted from one end of the electron multiplier are collected by a positively charged anode at the other end, which creates a useable current signal. This current signal is amplified by the preamplifier board and then reported to the motherboard.

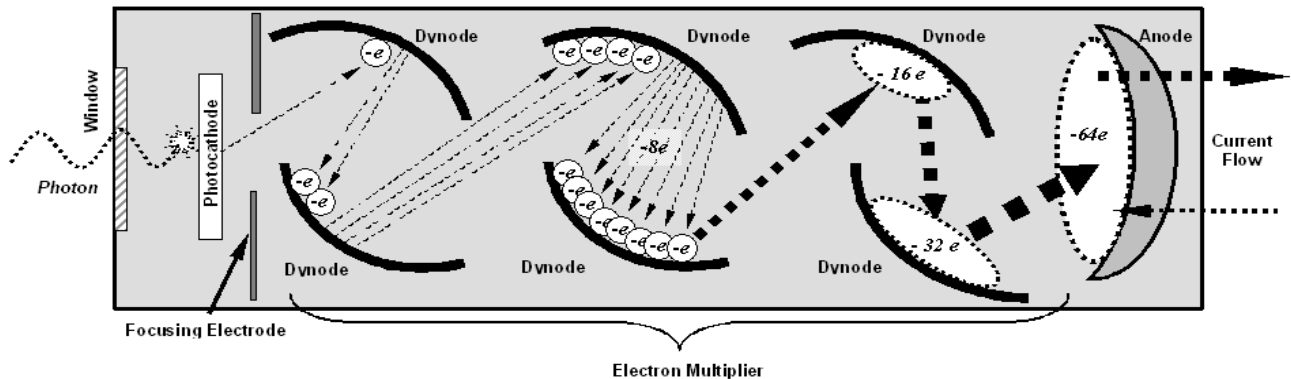


Figure 6-19. Basic PMT Design

A significant performance characteristic of the PMT is the voltage potential across the electron multiplier. The higher the voltage, the greater the number of electrons emitted from each dynode of the electron multiplier, in effect, making the PMT more sensitive and responsive to smaller variations in light intensity, but also more noisy (this is referred to as “dark noise”).

- The gain voltage of the PMT is usually set between 400 V and 800 V. The range is usually 400V to 600V for the T200UP.
- This parameter is viewable in the Dashboard as hvps.
- For information on when and how to set this voltage, see Section 5.5.10.4.

The PMT is housed inside the PMT module assembly (see Figure 5-20). This assembly also includes the high voltage power supply required to drive the PMT, an LED used by the instrument’s optical test function, a thermistor that measures the temperature of the PMT and various components of the PMT cooling system including the TEC.

6.6.1. PMT PREAMPLIFIER

The PMT preamplifier board provides a variety of functions:

- Amplifies the PMT Signal into a useable analog voltage that can be processed by the motherboard into a digital signal to be used by the CPU to calculate the NO, NO₂ and NO_x concentrations of the gas in the sample chamber.
- Supplies the drive voltage for the HVPS.
- Includes the circuitry for switching between the two physical ranges.
- Amplifies the signal output by the PMT Temperature sensor and feeds it back to the thermoelectric cooler driver PCA. This amplified signal is also sent to the Motherboard to be digitized and forwarded to the CPU.
- Provides the means for adjusting the electronic signal output from the PMT.

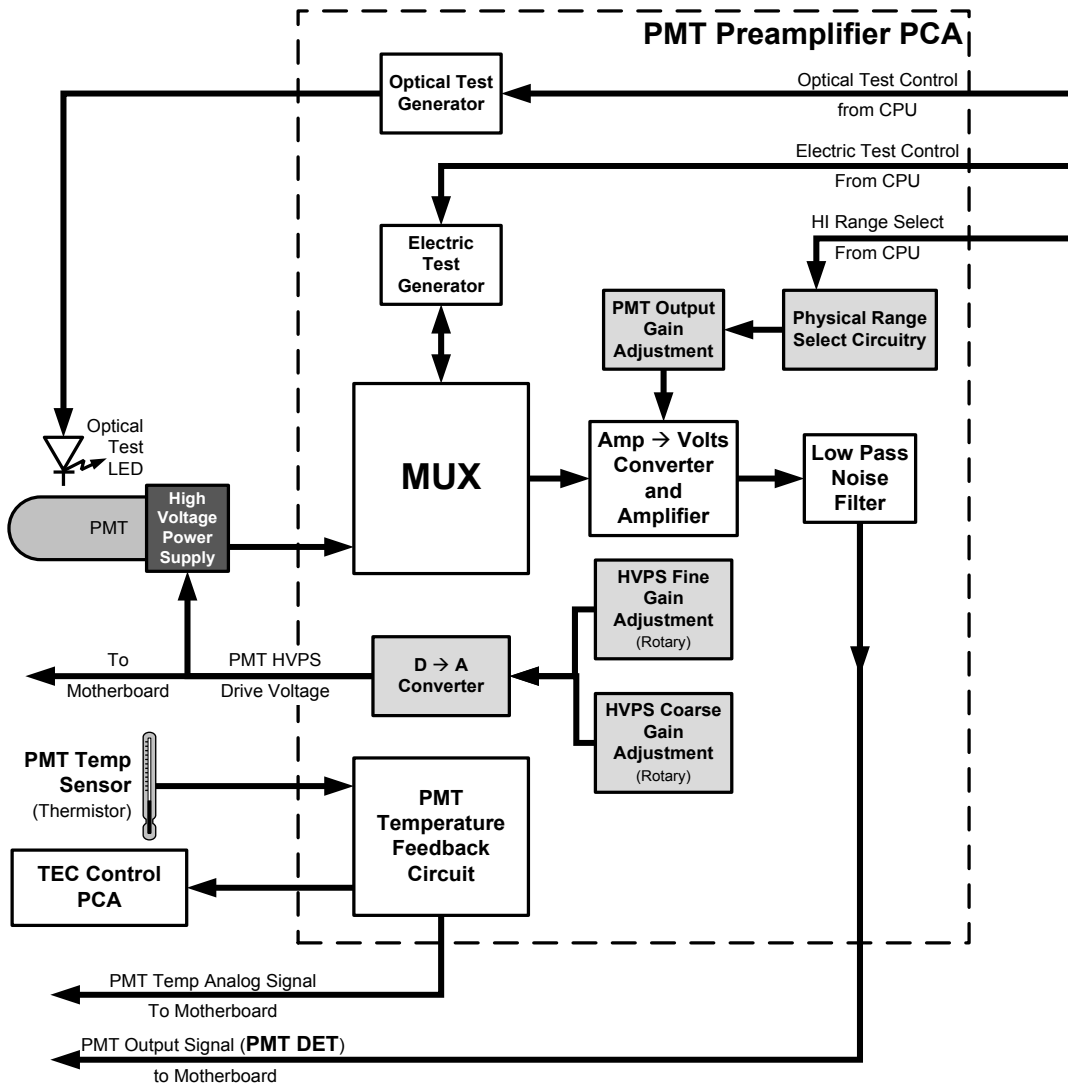


Figure 6-20. PMT Preamp Block Diagram

The PMT preamplifier PCA also operates two different tests used to calibrate and check the performance of the sensor module.

- The electrical test (Utilities>Diagnostics>OE Test, ETest) circuit generates a constant, electronic signal intended to simulate the output of the PMT (after conversion from current to voltage). By bypassing the detector's actual signal, it is possible to test most of the signal handling and conditioning circuitry on the PMT preamplifier board. See Section 5.5.9.11 for instructions on performing this test.
- The optical test (Utilities>Diagnostics>OE Test, OTest) feature causes an LED inside the PMT cold block to create a light signal that can be measured with the PMT. If zero air is supplied to the analyzer, the entire measurement capability of the sensor module can be tested including the PMT and the current to voltage conversion circuit on the PMT preamplifier board. See Section 5.5.9.11 for instructions on performing this test.

6.6.2. PMT COOLING SYSTEM

The performance of the analyzer's PMT is significantly affected by temperature. Variations in PMT temperature are directly reflected in the signal output of the PMT. Also the signal to noise ratio of the PMT output is radically influenced by temperature as well. The warmer the PMT is, the noisier its signal becomes until the noise renders the concentration signal useless.

To alleviate this problem, the instrument uses a special cooling system called a thermo-electric cooler (TEC), which is a solid-state active heat pump that transfers heat from a heat absorbing "cool" side to a heat releasing "hot" side via a series of DC powered semiconductor junctions. The effectiveness of the pump at moving heat away from the cold side is reliant on the amount of current flowing through the semiconductor junctions and how well the heat from the hot side can be removed.

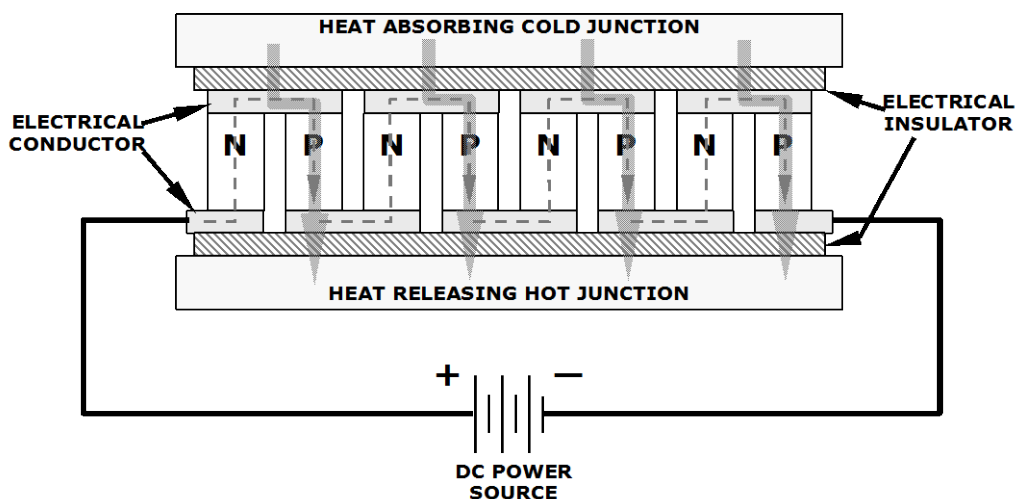


Figure 6-21. Typical Thermo-Electric Cooler

In this case, the current flow is controlled by the TEC Control PCA which adjusts the amount of current applied to the TEC based on the temperature sensed by a thermistor embedded in the PMT's cold block. The higher the temperature of the PMT, the more current is pumped through the TEC. The "hot" side of the TEC is cooled by a constant flow of ambient air that is directed across a set of heat sinks by a fan.

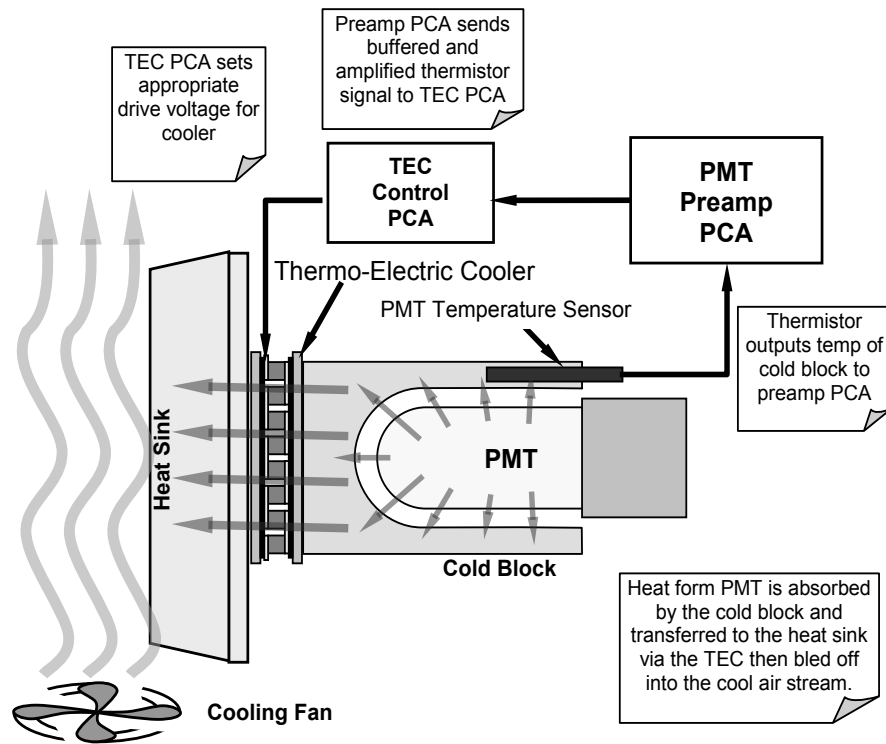


Figure 6-22. PMT Cooling System Block Diagram

The target temperature at which the TEC system keeps the PMT is approximately 8.0°C. Arriving at this temperature may take up to 30 minutes after the instrument is turned on.

The actual temperature of the PMT can be viewed in the Dashboard.

6.6.2.1. TEC CONTROL BOARD

The TEC control PCA is located on the sensor housing assembly, under the slanted shroud, next to the cooling fins and directly above the cooling fan. Using the amplified PMT temperature signal from the PMT preamplifier board (see Section 6.6.1), it sets the drive voltage for the thermoelectric cooler. The warmer the PMT gets, the more current is passed through the TEC causing it to pump more heat to the heat sink.

- A red LED located on the top edge of this circuit board indicates that the control circuit is receiving power.
- Four test points are also located at the top of this assembly.
- For the definitions and acceptable signal levels of these test points see Section 5.5.9.13.

6.7. PNEUMATIC SENSOR BOARD

The flow and pressure sensors of the analyzer are located on a printed circuit assembly just behind the PMT sensor. The signals of this board are supplied to the motherboard for further signal processing. All sensors are linearized in the firmware and can be span calibrated from the front panel.

6.8. POWER SUPPLY/CIRCUIT BREAKER

The analyzer operates on 100 VAC, 115 VAC or 230 VAC power at either 50 Hz or 60Hz. Individual instruments are set up at the factory to accept any combination of these five attributes. A 6.75 amp circuit breaker is built into the ON/OFF switch. In case of a wiring fault or incorrect supply power, the circuit breaker will automatically turn off the analyzer.

- Under normal operation, the analyzer draws about 1.5 A at 115 V and 2.0 A during start-up.



WARNING – ELECTRICAL SHOCK HAZARD

Should the AC power circuit breaker trip, investigate and correct the condition causing this situation before turning the analyzer back on.

Power enters the analyzer through a standard International Electrotechnical Commission (IEC) 320 power receptacle located on the rear panel of the instrument. From there it is routed through the ON/OFF Switch located in the lower right corner of the front panel. AC Line power is stepped down and converted to DC power by three DC power supplies (PS).

- One PS provides +5 VDC (3 A) and ± 15 VDC (1.5/0.5 A) for logic and analog circuitry as well as the power for the O₃ generator.
- A second PS provides +12 VDC (5 A), for the PMT's thermoelectric cooler, fans and as well as the various gas stream valves (both standard and optional).
- The third PS provides + 24 VDC to power the photolytic converter directly.

All AC and DC Voltages, except for the dedicated 24 VDC, are distributed via the relay PCA.

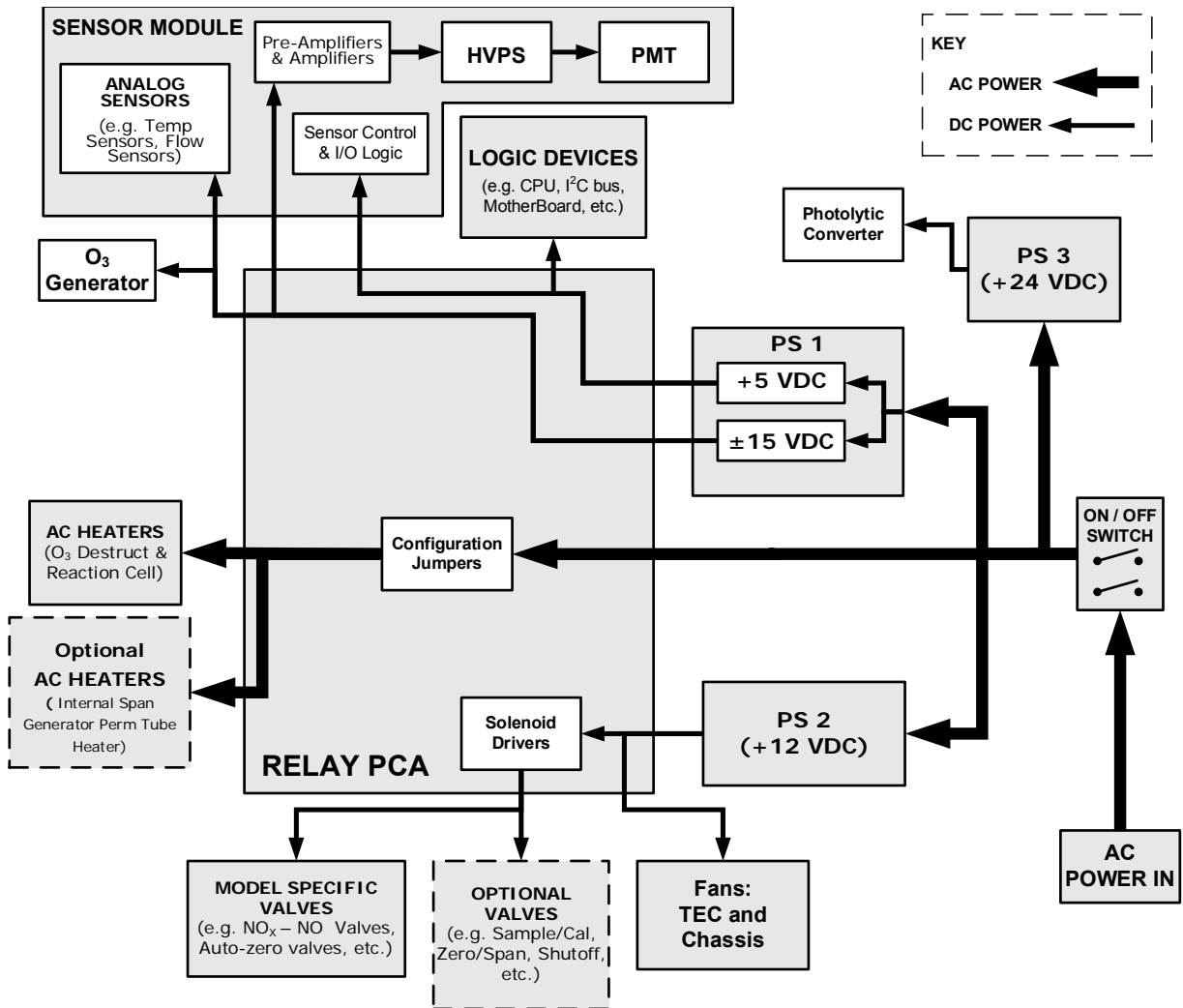


Figure 6-23. Power Distribution Block Diagram

6.8.1. AC POWER CONFIGURATION

The analyzer’s digital components will operate with any of the specified power regimes. As long as instrument is connected to 100-120 VAC or 220-240 VAC at either 50 or 60 Hz. Internally, the status LEDs located on the Relay PCA, Motherboard and CPU should turn on as soon as the power is supplied.

However, some of the analyzer’s non-digital components, such as the AC-powered heaters for the O₃ Destruct or the reaction cell, must be properly configured for the type of power being supplied to the instrument.

Configuration of the power circuits is set using several jumper sets located on the instrument’s Relay PCA.

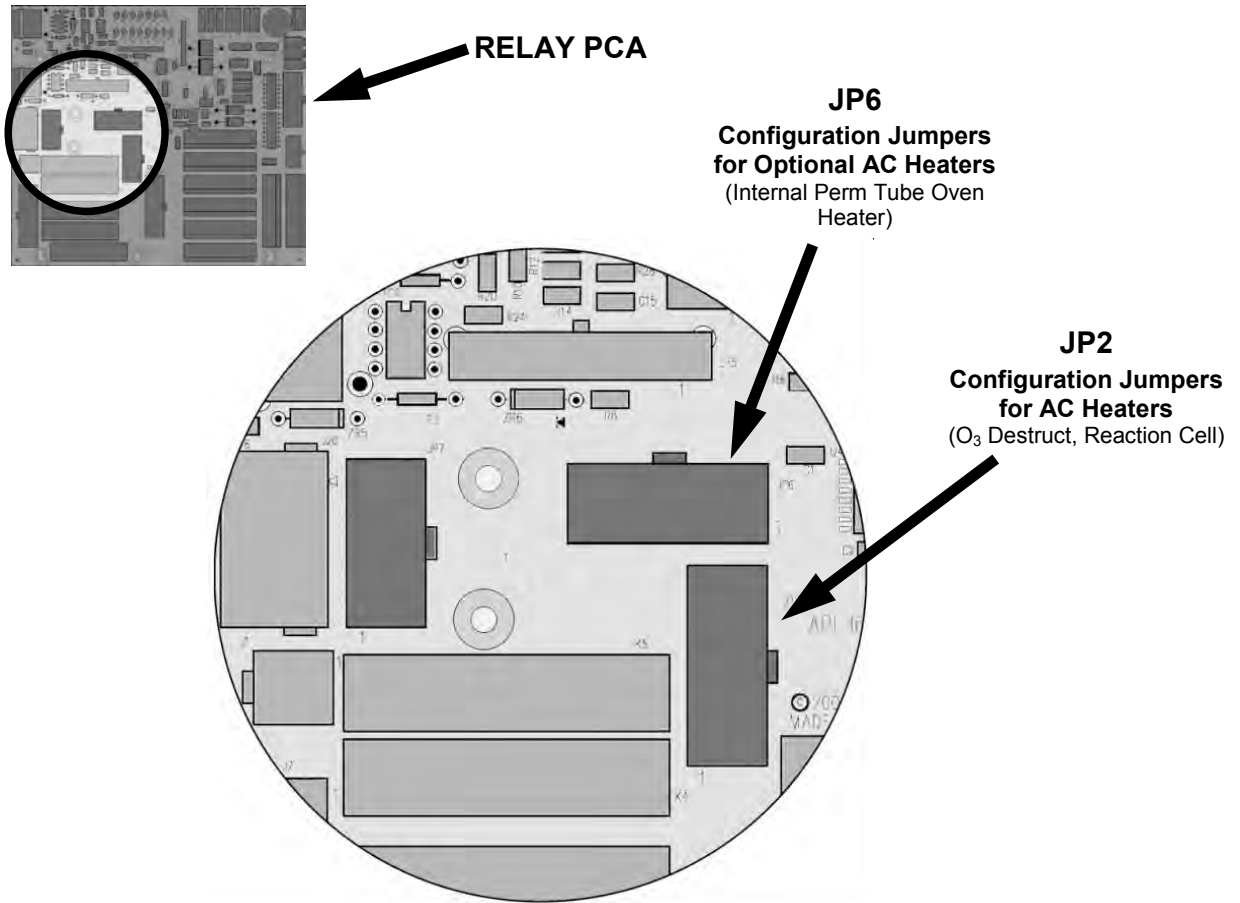


Figure 6-24. Location of AC power Configuration Jumpers

6.8.1.1. AC CONFIGURATION – STANDARD HEATERS (JP2)

Power configuration for the AC the standard heaters is set using Jumper set JP2 (see Figure 6-25 for the location of JP2).

Table 6-6. Power Configuration for Standard AC Heaters (JP2)

LINE VOLTAGE	JUMPER COLOR	HEATER(S)	JUMPER BETWEEN PINS	FUNCTION
110 VAC / 115 VAC 50Hz & 60 Hz	WHITE	Reaction Cell / Sample Chamber Heaters	1 to 8	Common
			2 to 7	Neutral to Load
			4 to 9	Neutral to Load
		O ₃ Destruct Heater	3 to 10	Common
			4 to 9	Neutral to Load
			6 to 11	Neutral to Load
220 VAC / 240 VAC 50Hz & 60 Hz	BLUE	Reaction Cell / Sample Chamber Heaters	1 to 7	Load
		O ₃ Destruct Heater	3 to 9	Load

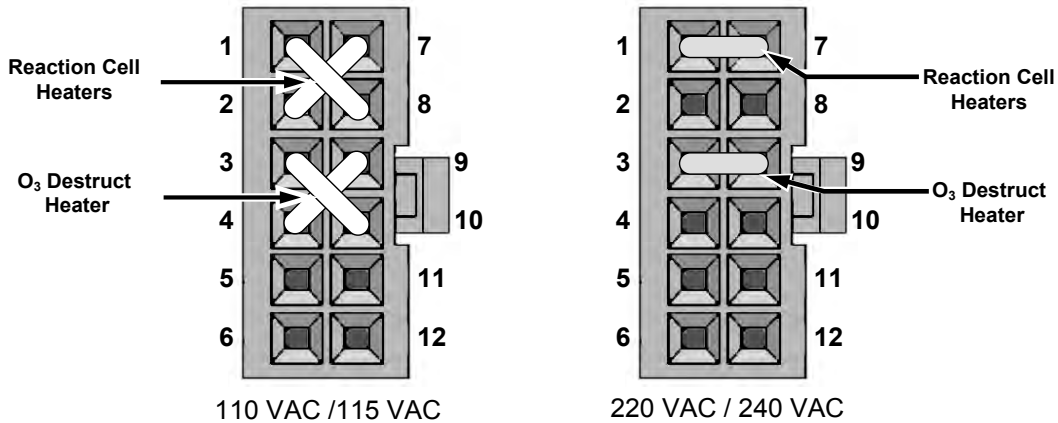


Figure 6-25. Typical Set Up of AC Heater Jumper Set (JP2)

6.8.1.2. AC CONFIGURATION – HEATERS FOR OPTION PACKAGES (JP6)

The IZS valve option includes an AC heater that maintains an optimum operating temperature for key components of those options. Jumper set JP6 is used to connect the heaters associated with those options to AC power. Since these heaters work with either 110/155 VAC or 220/240 VAC, there is only one jumper configuration.

Table 6-7. Power Configuration for Optional Heaters (JP6)

JUMPER COLOR	HEATER(S)	JUMPER BETWEEN PINS	FUNCTION
RED	Internal Permeation Tube Oven Heater	1 to 8	Common
		2 to 7	Neutral to Load

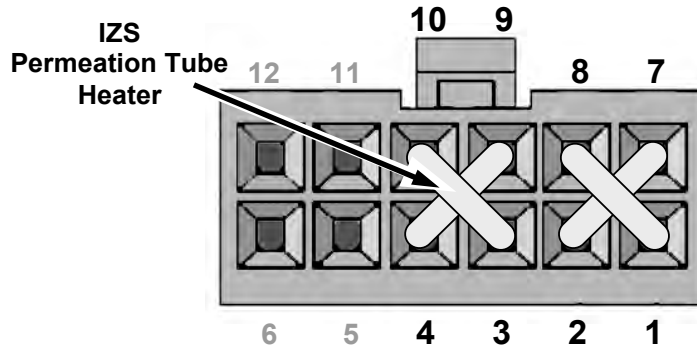


Figure 6-26. Typical Jumper Set (JP2) Set Up of Heaters

6.9. FRONT PANEL TOUCHSCREEN/DISPLAY INTERFACE

Users can input data and receive information directly through the front panel touchscreen display. The LCD display is controlled directly by the CPU board. The touchscreen is interfaced to the CPU by means of a touchscreen controller that connects to the CPU via the internal USB bus and emulates a computer mouse.

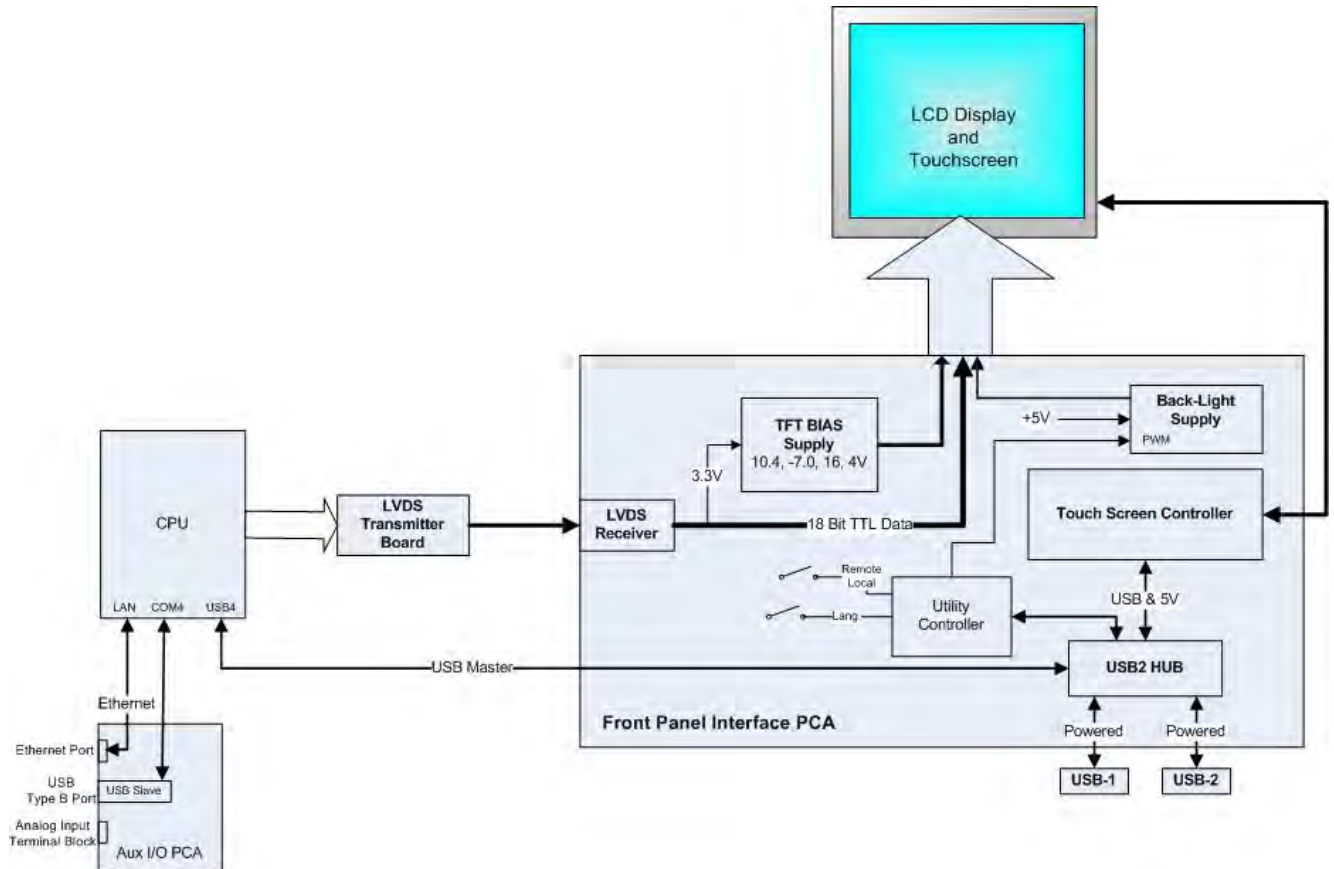


Figure 6-27. Front Panel and Display Interface Block Diagram

6.9.1. LVDS TRANSMITTER BOARD

The LVDS (low voltage differential signaling) transmitter board converts the parallel display bus to a serialized, low voltage, differential signal bus in order to transmit the video signal to the LCD interface PCA.

6.9.2. FRONT PANEL TOUCHSCREEN/DISPLAY INTERFACE PCA

The front panel interface PCA controls the various functions of the display and touchscreen. For driving the display it provides connection between the CPU video controller and the LCD display module. This PCA also contains:

- power supply circuitry for the LCD display module
- USB hub for communications with the touchscreen controller and the two front panel USB device ports
- circuitry for powering the display backlight

6.10. SOFTWARE OPERATION

The analyzer has a high performance, 86-based microcomputer running Windows CE. Inside the WINDOWS CE shell, special software developed by Teledyne API interprets user commands via the various interfaces, performs procedures and tasks, stores data in the CPU's various memory devices and calculates the concentration of the sample gas.

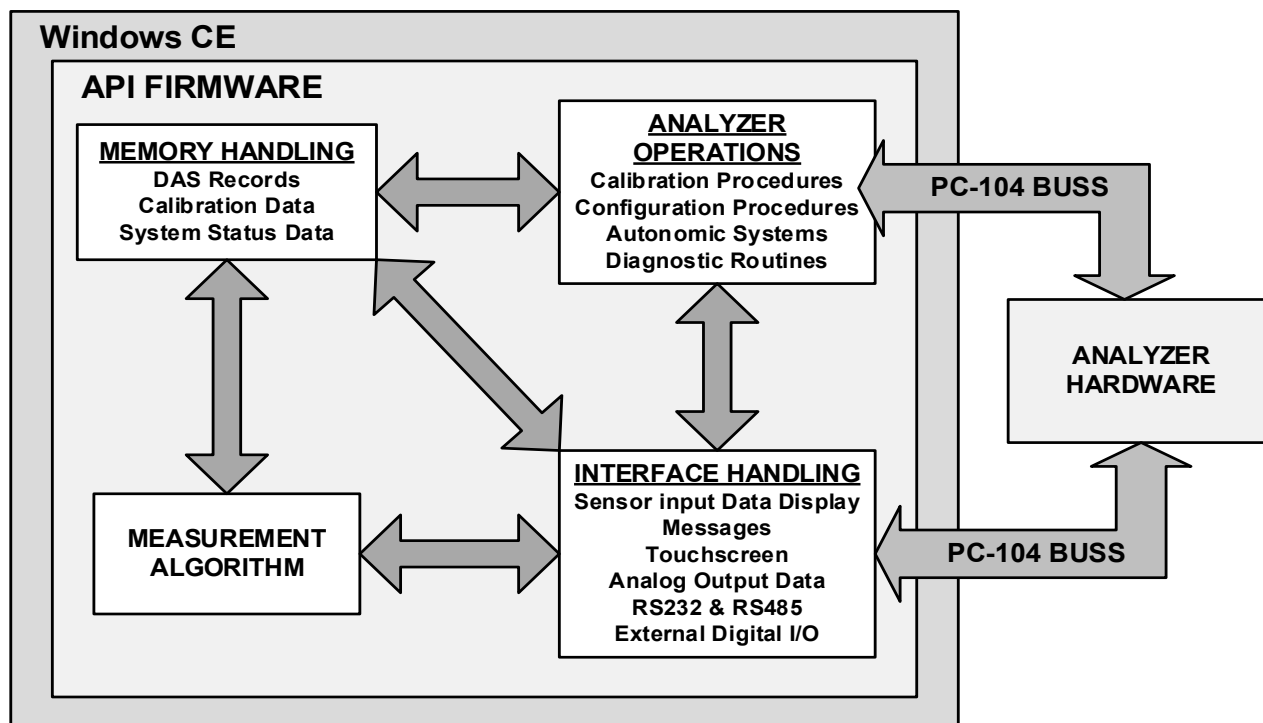


Figure 6-28. Basic Software Operation

6.10.1. ADAPTIVE FILTER

The analyzer software processes sample gas concentration data through a built-in adaptive filter. Unlike other analyzers that average the output signal over a fixed time period, these analyzers average over a defined number of samples. This technique is known as boxcar filtering. During operation, the software may automatically switch between two different filter lengths based on the conditions at hand.

During constant or nearly constant concentrations, the software, by default, computes an average sample value using the long filter. This provides smooth and stable readings and averages out a considerable amount of random noise for an overall less noisy concentration reading.

If the filter detects rapid changes in concentration, the filter reduces its size thus allowing the analyzer to respond more quickly. Two conditions must be simultaneously met to switch to the short filter. First, the instantaneous concentration must differ from the average in the long filter by an absolute amount. Second, the instantaneous concentration must differ from the average in the long filter by at least a set percentage of the average in the long filter.

6.10.2. TEMPERATURE/PRESSURE COMPENSATION (TPC)

The software includes a feature that compensates for some temperature and pressure changes that might affect measurement of NO and NO_x concentrations.

When the TPC feature is enabled (default setting), the analyzer divides the value of the PMT output signal (PMT Signal) by a value called TP_FACTOR, which is calculated using the following four parameters:

- Box Temp: The temperature inside the analyzer's case measured in K. This is typically about 5 K higher than room temperature.
- Rx Cell Temp: The temperature of the reaction cell, measured in K.
- Rx Cell Press: The pressure of the gas in the vacuum manifold, measured in in-Hg-A.
- Sample Press: The pressure of the sample gas before it reaches the reaction cell, measured in in-Hg-A. This measurement is ~1 in-Hg-A lower than atmospheric pressure.

As Rx Cell Temp, Box Temp, Rx Cell Press and Sample Press increase, the value of TP_FACTOR increases and, hence, the PMT Signal value decreases. These adjustments are meant to counter-act changes in the concentrations caused by these parameters.

- The current value of each of these measurements is viewable in the editable Dashboard (see Sections 2.4.2 and 2.5.3).
- The preset gain parameters are set at the factory and may vary from analyzer to analyzer. The TPC feature is enabled or disabled by setting the value of the variable TPC Enable in the Setup>Vars menu. (see Section 2.5.5).

6.10.3. CALIBRATION - SLOPE AND OFFSET

Calibration of the analyzer is performed exclusively in the software. During instrument calibration, (see Section 4) the user enters expected values for zero and span via the front panel touchscreen control and commands the instrument to make readings of calibrated sample gases for both levels.

- The readings taken are adjusted, linearized and compared to the expected values.
- With this information, the software computes values for instrument slope and offset and stores these values in memory for use in calculating the NO_x, NO and NO₂ concentrations of the sample gas.

The instrument slope and offset values recorded during the last calibration can be viewed in the Dashboard.

GLOSSARY

TERM	DESCRIPTION/DEFINITION
10BaseT	an Ethernet standard that uses twisted (“T”) pairs of copper wires to transmit at 10 megabits per second (Mbps)
100BaseT	same as 10BaseT except ten times faster (100 Mbps)
APICOM	name of a remote control program offered by Teledyne-API to its customers
ASSY	<i>Assembly</i>
CAS	<i>Code-Activated Switch</i>
CD	<i>Corona Discharge</i> , a frequently luminous discharge, at the surface of a conductor or between two conductors of the same transmission line, accompanied by ionization of the surrounding atmosphere and often by a power loss
CE	<i>Converter Efficiency</i> , the percentage of the total amount that is actually converted (e.g., light energy into electricity; NO ₂ into NO, etc.)
CEM	<i>Continuous Emission Monitoring</i>
Chemical elements that may be included in this document:	
CO ₂	carbon dioxide
C ₃ H ₈	propane
CH ₄	methane
H ₂ O	water vapor
HC	general abbreviation for hydrocarbon
HNO ₃	nitric acid
H ₂ S	hydrogen sulfide
NO	nitric oxide
NO ₂	nitrogen dioxide
NO _x	nitrogen oxides, here defined as the sum of NO and NO ₂
NO _y	nitrogen oxides, often called odd nitrogen: the sum of NO _x plus other compounds such as HNO ₃ (definitions vary widely and may include nitrate (NO ₃), PAN, N ₂ O and other compounds as well)
NH ₃	ammonia
O ₂	molecular oxygen
O ₃	ozone
SO ₂	sulfur dioxide
cm ³	metric abbreviation for <i>cubic centimeter</i> (replaces the obsolete abbreviation “cc”)
CPU	<i>Central Processing Unit</i>
DAC	<i>Digital-to-Analog Converter</i>
DAS	<i>Data Acquisition System</i>
DCE	<i>Data Communication Equipment</i>
DFU	<i>Disposable Filter Unit</i>
DHCP	<i>Dynamic Host Configuration Protocol</i> . A protocol used by LAN or Internet servers to automatically set up the interface protocols between themselves and any other addressable device connected to the network
DOM	<i>Disk On Module</i> , a 44-pin IDE flash drive with up to 128MB storage capacity for instrument’s firmware, configuration settings and data
DOS	<i>Disk Operating System</i>
DRAM	<i>Dynamic Random Access Memory</i>

TERM	DESCRIPTION/DEFINITION
DR-DOS	<i>Digital Research DOS</i>
DTE	<i>Data Terminal Equipment</i>
EEPROM	<i>Electrically Erasable Programmable Read-Only Memory</i> also referred to as a FLASH chip or drive
ESD	<i>Electro-Static Discharge</i>
ETEST	<i>Electrical Test</i>
Ethernet	a standardized (IEEE 802.3) computer networking technology for local area networks (LANs), facilitating communication and sharing resources
FEP	<i>Fluorinated Ethylene Propylene</i> polymer, one of the polymers that Du Pont markets as Teflon [®]
Flash	non-volatile, solid-state memory
FPI	<i>Fabry-Perot Interface</i> : a special light filter typically made of a transparent plate with two reflecting surfaces or two parallel, highly reflective mirrors
GFC	<i>Gas Filter Correlation</i>
I ² C bus	a clocked, bi-directional, serial bus for communication between individual analyzer components
IC	<i>Integrated Circuit</i> , a modern, semi-conductor circuit that can contain many basic components such as resistors, transistors, capacitors etc in a miniaturized package used in electronic assemblies
IP	<i>Internet Protocol</i>
IZS	<i>Internal Zero Span</i>
LAN	<i>Local Area Network</i>
LCD	<i>Liquid Crystal Display</i>
LED	<i>Light Emitting Diode</i>
LPM	<i>Liters Per Minute</i>
MFC	<i>Mass Flow Controller</i>
M/R	<i>Measure/Reference</i>
NDIR	<i>Non-Dispersive Infrared</i>
MOLAR MASS	<p>the mass, expressed in grams, of 1 mole of a specific substance. Conversely, one mole is the amount of the substance needed for the molar mass to be the same number in grams as the atomic mass of that substance.</p> <p>EXAMPLE: The atomic weight of Carbon is 12 therefore the molar mass of Carbon is 12 grams. Conversely, one mole of carbon equals the amount of carbon atoms that weighs 12 grams.</p> <p>Atomic weights can be found on any Periodic Table of Elements.</p>
NDIR	<i>Non-Dispersive Infrared</i>
NIST-SRM	<i>National Institute of Standards and Technology - Standard Reference Material</i>
PC	<i>Personal Computer</i>
PCA	<i>Printed Circuit Assembly</i> , the PCB with electronic components, ready to use
PC/AT	<i>Personal Computer / Advanced Technology</i>
PCB	<i>Printed Circuit Board</i> , the bare board without electronic component
PFA	<i>Per-Fluoro-Alkoxy</i> , an inert polymer; one of the polymers that Du Pont markets as Teflon [®]
PLC	<i>Programmable Logic Controller</i> , a device that is used to control instruments based on a logic level signal coming from the analyzer

TERM	DESCRIPTION/DEFINITION
PLD	<i>Programmable Logic Device</i>
PLL	<i>Phase Lock Loop</i>
PMT	<i>Photo Multiplier Tube</i> , a vacuum tube of electrodes that multiply electrons collected and charged to create a detectable current signal
P/N (or PN)	<i>Part Number</i>
PSD	<i>Prevention of Significant Deterioration</i>
PTFE	<i>Poly-Tetra-Fluoro-Ethylene</i> , a very inert polymer material used to handle gases that may react on other surfaces; one of the polymers that <i>Du Pont</i> markets as <i>Teflon</i> [®]
PVC	<i>Poly Vinyl Chloride</i> , a polymer used for downstream tubing
Rdg	Reading
RS-232	specification and standard describing a serial communication method between DTE (Data Terminal Equipment) and DCE (Data Circuit-terminating Equipment) devices, using a maximum cable-length of 50 feet
RS-485	specification and standard describing a binary serial communication method among multiple devices at a data rate faster than RS-232 with a much longer distance between the host and the furthest device
SAROAD	<i>Storage and Retrieval of Aerometric Data</i>
SLAMS	<i>State and Local Air Monitoring Network Plan</i>
SLPM	<i>Standard Liters Per Minute</i> of a gas at standard temperature and pressure
STP	<i>Standard Temperature and Pressure</i>
TCP/IP	<i>Transfer Control Protocol / Internet Protocol</i> , the standard communications protocol for Ethernet devices
TEC	<i>Thermal Electric Cooler</i>
TPC	<i>Temperature/Pressure Compensation</i>
USB	<i>Universal Serial Bus</i> : a standard connection method to establish communication between peripheral devices and a host controller, such as a mouse and/or keyboard and a personal computer or laptop
VARs	<i>Variables</i> , the variable settings of the instrument
V-F	<i>Voltage-to-Frequency</i>
Z/S	<i>Zero / Span</i>

APPENDIX A – MODBUS REGISTERS

MODBUS REGISTER

MODBUS REGISTER ADDRESS (DECIMAL, 0-BASED)	DESCRIPTION 10	UNITS
MODBUS Floating Point Input Registers		
(32-bit IEEE 754 format; read in high-word, low-word order; read-only)		
0	Instantaneous PMT detector reading	mV
2	NO _x slope for range #1	—
4	NO _x slope for range #2	—
6	NO slope for range #1	—
8	NO slope for range #2	mV
10	NO _x offset for range #1	mV
12	NO _x offset for range #2	mV
14	NO offset for range #1	mV
16	NO offset for range #2	mV
18	NO _x concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB
20	NO _x concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
22	NO concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB
24	NO concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
26	NO ₂ concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB
28	NO ₂ concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
30	NO _x concentration for range #1	PPB
32	NO _x concentration for range #2	PPB
34	NO concentration for range #1	PPB
36	NO concentration for range #2	PPB
38	NO ₂ concentration for range #1	PPB
40	NO ₂ concentration for range #2	PPB
42	Concentration stability	PPB
44	Auto zero offset (range de-normalized) Pre React ¹¹	mV
46	Ozone flow rate	cc/m
48	Reaction cell pressure	"Hg

MODBUS REGISTER ADDRESS (DECIMAL, 0-BASED)	DESCRIPTION 10	UNITS
50	Reaction cell temperature	°C
52	Manifold temperature	°C
54	Converter efficiency factor for range #1	—
56	Converter efficiency factor for range #2	—
58	Converter temperature	°C
60	PMT temperature	°C
62	Sample flow rate	cc/m
64	Sample pressure	"Hg
66	Internal box temperature	°C
68	High voltage power supply output	Volts
70	Ground reference (REF_GND)	mV
72	4096 mV reference (REF_4096_MV)	mV
74	Diagnostic test input (TEST_INPUT_13)	mV
76	Diagnostic temperature input (TEMP_INPUT_6)	°C
78	IZS temperature	°C
80 ⁹	Sample restrictor temperature	°C
82 ⁹	Remote box temperature	°C
80	Diagnostic test input (TEST_INPUT_11)	mV
82	Diagnostic temperature input (TEMP_INPUT_5)	°C
84 ¹	Raw PMT detector reading for NO _x	mV
86 ¹	Raw PMT detector reading for NO	mV
100 ³	NO _x slope for range #3	—
102 ³	NO slope for range #3	mV
104 ³	NO _x offset for range #3	mV
106 ³	NO offset for range #3	mV
108 ³	NO _x concentration for range #3 during zero/span calibration, just before computing new slope and offset	PPB
110 ³	NO concentration for range #3 during zero/span calibration, just before computing new slope and offset	PPB
112 ³	NO ₂ concentration for range #3 during zero/span calibration, just before computing new slope and offset	PPB
114 ³	NO _x concentration for range #3	PPB
116 ³	NO concentration for range #3	PPB
118 ³	NO ₂ concentration for range #3	PPB
120 ³	Converter efficiency factor for range #3	—
130 ¹²	External analog input 1 value	Volts
132 ¹²	External analog input 1 slope	eng unit /V
134 ¹²	External analog input 1 offset	eng unit

MODBUS REGISTER ADDRESS (DECIMAL, 0-BASED)	DESCRIPTION 10	UNITS
136 ¹²	External analog input 2 value	Volts
138 ¹²	External analog input 2 slope	eng unit /V
140 ¹²	External analog input 2 offset	eng unit
142 ¹²	External analog input 3 value	Volts
144 ¹²	External analog input 3 slope	eng unit /V
146 ¹²	External analog input 3 offset	eng unit
148 ¹²	External analog input 4 value	Volts
150 ¹²	External analog input 4 slope	eng unit /V
152 ¹²	External analog input 4 offset	eng unit
154 ¹²	External analog input 5 value	Volts
156 ¹²	External analog input 5 slope	eng unit /V
158 ¹²	External analog input 5 offset	eng unit
160 ¹²	External analog input 6 value	Volts
162 ¹²	External analog input 6 slope	eng unit /V
164 ¹²	External analog input 6 offset	eng unit
166 ¹²	External analog input 7 value	Volts
168 ¹²	External analog input 7 slope	eng unit /V
170 ¹²	External analog input 7 offset	eng unit
172 ¹²	External analog input 8 value	Volts
174 ¹²	External analog input 8 slope	eng unit /V
176 ¹²	External analog input 8 offset	eng unit
188 ¹³	Converter efficiency factor slope for range #1	—
190 ¹³	Converter efficiency factor offset for range #1	—
192 ¹³	Converter efficiency factor slope for range #2	—
194 ¹³	Converter efficiency factor offset for range #2	—
196 ^{13,3}	Converter efficiency factor slope for range #3	—
198 ^{13,3}	Converter efficiency factor offset for range #3	—
200 ⁵	O ₂ concentration	%
202 ⁵	O ₂ concentration during zero/span calibration, just before computing new slope and offset	%
204 ⁵	O ₂ slope	—
206 ⁵	O ₂ offset	%
208 ⁵	O ₂ sensor cell temperature	°C
300 ⁶	CO ₂ concentration	%
302 ⁶	CO ₂ concentration during zero/span calibration, just before computing new slope and offset	%
304 ⁶	CO ₂ slope	—
306 ⁶	CO ₂ offset	%

MODBUS REGISTER ADDRESS (DECIMAL, 0-BASED)	DESCRIPTION 10	UNITS
308 ⁶	CO ₂ sensor cell temperature	°C
400 ¹⁴	O ₃ concentration	PPB
402 ¹⁴	O ₃ concentration during zero/span calibration, just before computing new slope and offset	PPB
404 ¹⁴	O ₃ slope	—
406 ¹⁴	O ₃ offset	PPB
408 ¹⁴	O ₃ sensor cell temperature	°C
410 ¹⁴	O ₃ photometer reference potential	mV
412 ¹⁴	O ₃ photometer measurement potential	mV
414 ¹⁴	O ₃ cell pressure	PSIA
416 ¹⁴	O ₃ lamp temperature	°C
418 ^{14 + 15}	O ₃ bench serial number	—
420 ¹⁴	O ₃ bench firmware revision	—
MODBUS Floating Point Holding Registers		
(32-bit IEEE 754 format; read/write in high-word, low-word order; read/write)		
0	Maps to <i>NOX_SPAN1</i> variable; target conc. for range #1	Conc. units
2	Maps to <i>NO_SPAN1</i> variable; target conc. for range #1	Conc. units
4	Maps to <i>NOX_SPAN2</i> variable; target conc. for range #2	Conc. units
6	Maps to <i>NO_SPAN2</i> variable; target conc. for range #2	Conc. units
100 ³	Maps to <i>NOX_SPAN3</i> variable; target conc. for range #3	Conc. units
102 ³	Maps to <i>NO_SPAN3</i> variable; target conc. for range #3	Conc. units
200 ⁵	Maps to <i>O2_TARG_SPAN_CONC</i> variable; target conc. for range O ₂ gas	%
300 ⁶	Maps to <i>CO2_TARG_SPAN_CONC</i> variable; target conc. for range CO ₂ gas	%
400 ¹⁴	Maps to <i>ID_VAR_O3_TARG_SPAN_CONC</i> variable; O ₃ target span concentration	PPB
402 ¹⁴	Maps to <i>ID_VAR_O3_PRESSURE_OFFSET</i> variable; O ₃ cell pressure compensation offset	PSIA
404 ¹⁴	Maps to <i>ID_VAR_O3_PRESSURE_SLOPE</i> variable; O ₃ cell pressure slope compensation	—
406 ¹⁴	Maps to <i>ID_VAR_O3_TEMP_SET</i> variable; O ₃ temperature setpoint	°C
408 ¹⁴	Maps to <i>ID_VAR_O3_DWELL</i> variable; O ₃ dwell time	Seconds
410 ¹⁴	Maps to <i>ID_VAR_O3_RANGE</i> variable; O ₃ analog output range	PPB

MODBUS REGISTER ADDRESS (DECIMAL, 0-BASED)	DESCRIPTION 10	UNITS
MODBUS Discrete Input Registers		
(single-bit; read-only)		
0	Manifold temperature warning	
1	Converter temperature warning	
2	Auto-zero warning	
3	Box temperature warning	
4	PMT detector temperature warning	
5	Reaction cell temperature warning	
6	Sample flow warning	
7	Ozone flow warning	
8	Reaction cell pressure warning	
9	HVPS warning	
10	System reset warning	
11	Rear board communication warning	
12	Relay board communication warning	
13	Front panel communication warning	
14	Analog calibration warning	
15	Dynamic zero warning	
16	Dynamic span warning	
17	Invalid concentration	
18	In zero calibration mode	
19	In span calibration mode	
20	In multi-point calibration mode	
21	System is OK (same meaning as <i>SYSTEM_OK</i> I/O signal)	
22	Ozone generator warning	
23	IZS temperature warning	
24 ⁸	In low span calibration mode	
25 ⁷	NO concentration alarm limit #1 exceeded	
26 ⁷	NO concentration alarm limit #2 exceeded	
27 ⁷	NO ₂ concentration alarm limit #1 exceeded	
28 ⁷	NO ₂ concentration alarm limit #2 exceeded	
29 ⁷	NO _x concentration alarm limit #1 exceeded	
30 ⁷	NO _x concentration alarm limit #2 exceeded	
200 ⁵	Calibrating O ₂ gas	
201 ⁵	O ₂ sensor cell temperature warning	
202 ⁵⁺⁷	O ₂ concentration alarm limit #1 exceeded	
203 ⁵⁺⁷	O ₂ concentration alarm limit #2 exceeded	

MODBUS REGISTER ADDRESS (DECIMAL, 0-BASED)	DESCRIPTION 10	UNITS
300 ⁶	Calibrating CO ₂ gas	
301 ⁶	CO ₂ sensor cell temperature warning	
302 ⁶⁺⁷	CO ₂ concentration alarm limit #1 exceeded	
303 ⁶⁺⁷	CO ₂ concentration alarm limit #2 exceeded	
400 ¹⁴	Calibrating O ₃ gas	
401 ¹⁴	O ₃ cell temperature warning	
402 ¹⁴	O ₃ concentration alarm limit #1 exceeded	
403 ¹⁴	O ₃ concentration alarm limit #2 exceeded	
MODBUS Coil Registers		
(single-bit; read/write)		
0	Maps to relay output signal 36 (<i>MB_RELAY_36</i> in signal I/O list)	
1	Maps to relay output signal 37 (<i>MB_RELAY_37</i> in signal I/O list)	
2	Maps to relay output signal 38 (<i>MB_RELAY_38</i> in signal I/O list)	
3	Maps to relay output signal 39 (<i>MB_RELAY_39</i> in signal I/O list)	
20 ²	Triggers zero calibration of NO _x range #1 (on enters cal.; off exits cal.)	
21 ²	Triggers span calibration of NO _x range #1 (on enters cal.; off exits cal.)	
22 ²	Triggers zero calibration of NO _x range #2 (on enters cal.; off exits cal.)	
23 ²	Triggers span calibration of NO _x range #2 (on enters cal.; off exits cal.)	

¹ Engineering firmware only.

² Set *DYN_ZERO* or *DYN_SPAN* variables to *ON* to enable calculating new slope or offset. Otherwise a calibration check is performed.

³ Triple-range option.

⁴ Optional.

⁵ O₂ option.

⁶ CO₂ option.

⁷ Concentration alarm option.

⁸ Low span option.

⁹ M200EUP.

¹⁰ All NO_x references become NO_y for M200EU_NO_y.

¹¹ M200EU and M200EU_NO_y.

¹² External analog input option.

¹³ M200EU_PHOTO.

¹⁴ O₃ option.

¹⁵ 32-bit integer value stored in high/low word order (i.e. **not** a floating-point value).